DEPARTMENT OF THE ARMY TECHNICAL MANUAL

OPERATOR, ORGANIZATIONAL, DIRECT AND GENERAL SUPPORT AND DEPOT MAINTENANCE MANUAL ELECTRIC POWER PLANTS!

D.E.D., SKID MOUNTED,

1, 500 KW, 4160 VOLTS, AC.,

(ELECTROMOTIVE MODEL MP36A-60 HERTZ)

1250 KW, 4, 160 VOLTS, AC.,

(ELECTROMOTIVE MODEL MP36A-50 HERTZ)

FSN: NONE ASSIGNED

This copy is a reprint which includes current pages from Changes 1 through 4.

HEADQUARTERS, DEPARTMENTOF THE ARMY

OCTOBER 1968

SAFETY PRECAUTIONS

BEFORE OPERATION

The voltage produced by this power plant is dangerous to personnel coming in contact with any part of electrical system operation. Severe, possibly fatal shock may result.

Be extremely careful when unit or surrounding area is damp or wet.

When servicing any part of electrical system or making any connections, make sure main power switch is OFF. Clean or service power plant only when unit is OFF.

Be extremely careful when using a carbon tetrachloride fire extinguisher in an inclosed area. A poisonous gas is generated by contact of carbon tetrachloride with heated metallic surfaces.

DURING OPERATION

In case of accident from electrical shock, shut down unit at once. If unit cannot be shut down, free victim from contact with live conductor. Avoid direct contact with victim. Use a dry board, drp rope, or any nonconducting implement to free victim. If victim is unconscious, apply artificial respiration and get medical help.

AFTER OPERATION

If unit stops by operation of safety devices, do not attempt to operate until cause has been eliminated.

Do not open oil pan inspection covers if a crankcase pressure trip has occurred and there is evidence of an overheated engine. Hot oil vapors resulting from a hot bearing or other part can ignite with explosive force if air is admitted to oil pan.

CHANGE }
NO.4

HEADQUARTERS
DEPARTMENT OF THE ARMY
WASHINGTON, D. C., *15 April 1981*

Operator's, Organizational, Direct and General Support and Depot Maintenance Manual
ELECTRIC POWER PLANTS
D.E.D., SKID MOUNTED
4500 KW, 4, 160 VOLTS, A.C.,
(ELECTROMOTIVE MODEL MP36A-60 HERTZ)
NSN 6115-00-250-4402
3750 KW, 4, 160 VOLTS, A.C.,
(ELECTROMOTIVE MODEL MP36A-50 HERTZ)
NSN 6115-00-250-4403

TM 5-6115-456-15, 8 October 1968, is changed as follows:

Page 1-128. After the first sentence the following is added.

Refer to FO-1 thru FO-39 for reproductions of referenced drawings showing 50 cycle operation. FO-40 thru FO-74 are power plant drawings showing conversion to 60 cycle operation.

FO-1 thru FO-74 are added as follows:

By Order of the Secretary of the Army:

E. C. MEYER
General, United States Army
Chief of Staff

Official:

J. C. PENNINGTON
Major General, United States Army
The Adjutant General

DISTRIBUTION:
To be distributed in accordance with DA Form 12-25D, Operator Maintenance requirements for Generator Sets, Engine Driven.

CHANGE
NO. 3.

HEADQUARTERS
DEPARTMENT OFTHE ARMY,
WASHINGTON, D. C. (*26 April 1979)*

Operator's, Organizational, Direct and General Support and Depot Maintenance Manual

**ELECTRIC POWER PLANTS D. E. D., SKID MOUNTED
4500 KW, 4,160 VOLTS, A.C.,
(ELECTROMOTIVE MODEL MP36A-60 HERTZ)
NSN 6115-00-250-4402
(ELECTROMOTIVE MODEL MP36A-50 HERTZ)
NSN 6115-00-250-4403**

TM 5-6115-456-15, 8 October 1968, is changed as follows:

Page 2-65. Add after second line the following information:

Piston Rings.
Compression ring end-clearance 0.040 = 0.005
(new ring in 8-1/2 inch liner) 0.010

Page 3-81. Delete last paragraph and add the following:

The oil should be a heavy duty additive type having a high resistance to oxidation, a low tendency toward the formation of carbon deposits.

Page 3-82. Delete first paragraph.

By Order of the Secretary of the Army:

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General, United States Army
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J. C. PENNINGTON
Major General, United States Army
The Adjutant General

Distribution:
To be distributed in accordance with DA Form 12-25D, Operator maintenance requirements for Generator Sets, Engine Driven: Over 200 KW.

Changes in Form: C 1 and C 2

TM 5-6115-456-15
C2

CHANGE

NO. 2

HEADQUARTERS
DEPARTMENT OF THE ARLMY
WASHINGTON, D. C., *7 March 1975*

Operator's, Organizational, Direct and General Support and Depot Maintenance Manual
ELECTRIC POWER PLANTS
D.E.D., SKID MOUNTED
4500 KW, 4, 160 VOLTS, A.C.,
(ELECTROMOTIVE MODEL MP36A-60 HERTZ)
NSN 6115-0 -250-4402
3750 KW, 4, 160 VOLTS, A.C.,
(ELECTROMOTIVE MODEL MP36A-50 HERTZ)
NSN 6115-00-250-4403

TM 5-6115-456-15, 8 October 1968, is changed as follows:
The title is changed as shown above.
Page 2 of Cover. Add the following warnings:

WARNING

Dry Cleaning solvent P-D-680, or P-S-661, used to clean parts is potentially dangerous to personnel and property. Avoid repeated and prolonged skin contact. Do not use near open flame or excessive heat. Flash point of solvent is 100 degrees F. (38°C.) • 138'F. I60°C).

WARNING

Operation of this equipment presents a noise hazard to personnel in the area. The noise level exceeds the allowable limits for unprotected personnel. Wear ear muffs or ear plugs which were fitted by a trained professional

WARNING

Generator sets shall be grounded in order to prevent *shock* due to defective insulation, *or* external electrical faults. Poor grounding can endanger personnel, may damage equipment, and can create interference in communication or electronic circuits.

Page i. Table of Contents. In Part I. add Section O. Introduction.....Page 1-0.
Page ii. Following this page add new page "1-0.

Section O. INTRODUCTION

1-1. Scope

This manual contains information useful to personnel responsible for operating and maintaining the Electromotive Electric Power Plants, Model MP36A-60 Hertz and Model MP36A-50 Hertz. The power plants are capable of providing either 4500 KW (Model MP36A-60 Hertz) or 3750 KW (Model MP36A-50 Hertz) of power. Basically the power plants consists of generator sets and switching gears.

1.2. Forms and Records

Maintenance forms, records, and reports which are to be used by maintenance personnel at all maintenance levels are listed in and prescribed by TM 38-750.

1-3. Recommendation for Maintenance Publications Improvements

You can help to improve this manual by calling attention to errors and by recommending improvements.

This publication is a courtesy quick copy1 from the UNITED STATES ARMY PUBLICATIONS CENTER, ST. LOUIS, MISSOURI, to meet your needs while we are replenishing our regular stock.

Your letter, DA Form 2028 (Recommended Changes to Publications), and/or DA Form 2028-2 (Recommended Changes to Equipment Technical Manuals), may be used. Copies of DA Form 2028-2 are attached in the back of the manual for your use. Please mail your recommended changes direct to Commander, US Army Troop Support Command, ATTN: AMSTS-MPP, 4300 Goodfellow Blvd., St. Louis, MO 63120. A reply will be furnished direct to you.

1-4. Administrative Storage and Instructions for the Destruction of Material to Prevent Enemy Use

Refer to TM 740-90-1 for information on the administrative storage of this equipment. Refer to TM 750-244-3 for information on destruction of material to prevent enemy use. *Page 1-53, Installation.* Delete the fourth paragraph. "Ground connections should....customer system requirements.", and add the following:

WARNING

Generator wets shall be grounded in order to prevent shock due to defective insulation, or external electrical faults. Poor grounding can endanger personae. may damage equipment. and can create interference in communication or electronic circuits.

1. Install one of the following items as a grounding device:

a. Drive a ground rod to depth of at least 8 feet This is the preferred device which is available in the Army supply system.

b. Drive a ground pipe, 3/4 inch, copper or steel to depth of at least 8 feet. An existing under ground pipe may be used in an emergency.

c. Bury a 1/4 inch thick iron or steel plate. approximately 18 inch x 18 inch size, with ground cable attached, to a depth of at least 4 feet.

d. Bury a 1/16 inch thick aluminum or copper plate approximately 18 inch x 18 inch size. With ground cable attached, to a depth of at least 4 feet.

e. Position a 1/4 inch thick iron or steel plate, or 1/16 inch thick aluminum or copper plates. approximately 18 inch x 18 inch size, on the hard ground or bedrock beneath the trailer stand or roll the wheel of a trailor or truck until it comes to rest on top of the grounding plate.

f. Saturate the area around the grounding device with water to increase conductivity.

2. Ground cables should be copper. Braided cable is the best, but No. 6 AWG gauge (or larger copper wire will suffice.

3. Connect the ground cable from the grounding device to the generator set frame.

CAUTION

Do not rely on grounding or safety devices to prevent accidents. Electrical circuits and equipment are potentially hazardous. Personnel should always exercise caution to prevent injury or possible death due to electrical shock.

CHANGE
NO. 1

HEADQUARTERS
DEPARTMENT OF THE ARMY
WASHINGTON, D. C., *11 September 197*

Operator, Organizational, Direct and General Support, and Depot Maintenance Manual
ELECTRIC POWER PLANT, DED; SKID MOUNTED;
4500 KW, 4160 VOLTS, A.C.,
(ELECTROMOTIVE MODEL MP36A-60 HZ)
FSN 6115-250-4402
3750 KW, 4160 VOLTS, AC.,
(ELECTROMOTIVE MODEL MP36A-50 HERTZ)
FSN 6115-250-4403

TM 5-6115-456-15, dated 8 October 1968, is changed as follows:

The title is changed to read as shown above.
Page A-1. Appendix A is superseded.

APPENDIX A
BASIC ISSUE ITEMS LIST AND ITEMS TROOP INSTALLED OR AUTHORIZED
Section 1. INTRODUCTION

A-1. Scope

This appendix lists items required by the operator for operation of the power plant.

A-2. General

T
This list is divided into the following sections:

a. Basic Issue Items List - Section II. Not applicable.

b. Items Troop Installed or Authorized List - Section III. A list of items in alphabetical sequence, which at the discretion of the unit commander may accompany the power plant. These items are NOT SUBJECT TO TURN-IN with the power plant when evacuated.

A-3. Explanation of Columns

The following provides an explanation of columns in the tabular list of Basic Issue Items List, Section II, and Items Troop Installed or Authorized, Section III.

a. Source, Maintenance and Recoverability Code (SMR). Not applicable.

b. Federal Stock Number. This column indicates the Federal stock number assigned to the item and will be used for requisitioning purposes.

c. Description. This column indicates the Federal item name and any additional description of the item required.

d. Unit of Measure (U/M). A two character alphabetic abbreviation indicating the amount or quantity of the item upon which the allowances are based, e.g., ft, ea, pr, etc.

e. Quantity Furnished with Equipment (BIIL). Not applicable.

f. Quantity Authorized (Items Troop Installed or Authorized).
This column indicates the quantity of the item authorized to be used with the equipment.

Section III. ITEMS TROOP INSTALLED OR AUTHORIZED LIST

(1) SMR code	(2) Federal stock number	(3) Ref. No. & mfr code / Usable on code	(4) Unit of meas	(5) Qty auth
PO	7520-559-9618	CASE, Maintenance and Operation Manuals.	EA	1
PO	5975-878-3791	ROD, Ground	EA	1
PO	4210-555-8837	EXTINGUISHER, Fire	EA	1

By Order of the Secretary of the Army:

CREIGHTON W. ABRAMS
General, United States Army
Chief of Staff

Official:

VERNE L. BOWERS
Major General United States Army
The Adjutant General

Distribution:

To be distributed in accordance with DA Form 12-25D (qty rqr block No. 1102) Organizational Maintenance requirements for Generator Sets, Engine Driven, Over 200 KW.

TECHNICAL MANUAL
No. 5-6115-456-15

HEADQUARTERS
DEPARTMENT OF THE ARMY
WASHINGTON, D.C., *8 October 1968*

OPERATOR, ORGANIZATIONAL, DIRECT AND GENERAL SUPPORT AND DEPOT MAINTENANCE MANUAL ELECTRIC POWER PLANTS, D.E.D., SKID MOUNTED, 1, 500 KW, 4160 VOLTS, AC., (ELECTROMOTIVE MODEL MP36A-60 HERTZ) 1250 KW, 4,160 VOLTS, AC., (ELECTROMOTIVE MODEL MP36A-50 HERTZ) FSN: NONE ASSIGNED

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PART I

OPERATING MANUAL

MU POWER PLANT

1-1

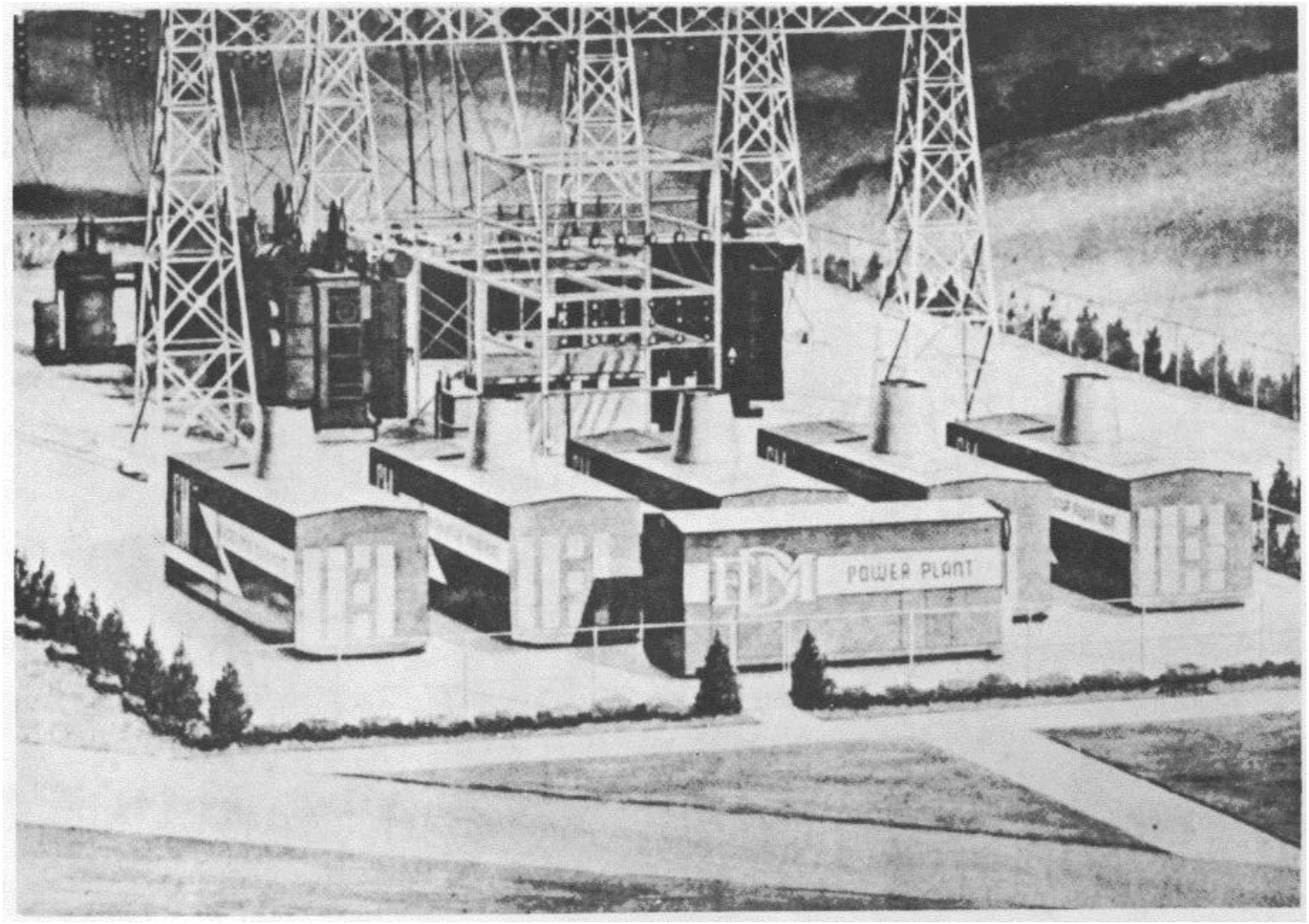


Fig. 0-1. Power Plant Installation

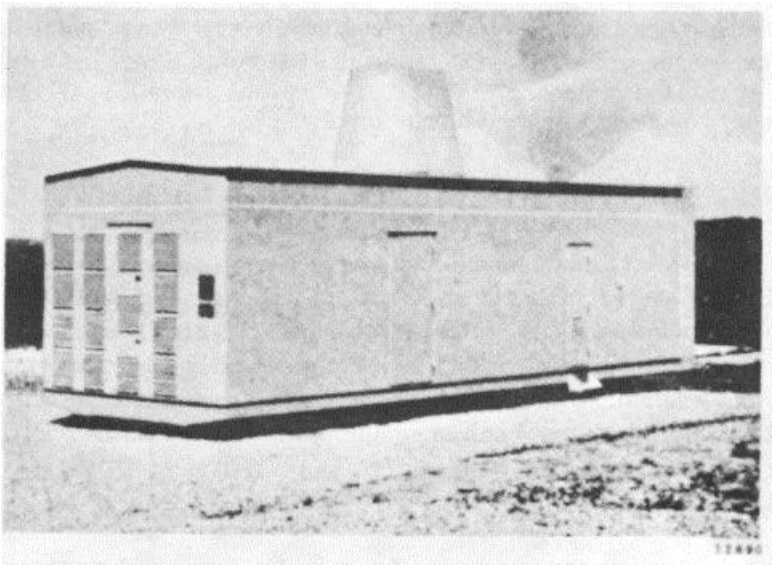


Fig. 1-1. Generating Unit

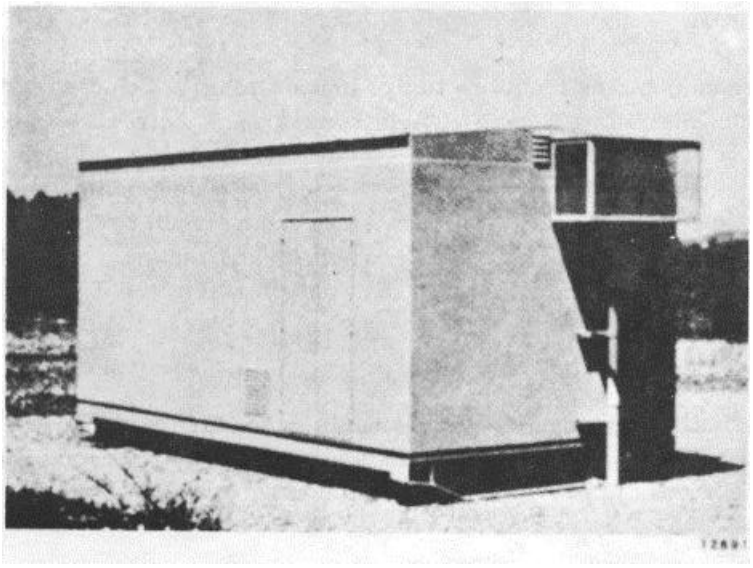


Fig. 1-2. Control Unit

SECTION 1
GENERAL DESCRIPTION

GENERAL

The General Motors Electro-Motive Division MU type power plant is designed for the specific purpose of providing AC power at 4160 volts, 3 phase, 50 or 60 cycle for base load operation. Control of the power plant manually is accomplished from the operator's panels in the control unit.

GENERATING UNIT, Fig. 1-1

Each MU type power plant consists of one or more diesel driven generating units. A unit consists of a skid mounted enclosure that houses a diesel engine that is directly coupled to a synchronous generator. The enclosure also houses accessory equipment for engine cooling and lubrication, for engine starting and control, and for generator excitation and control. The diesel engine may be operated from within the enclosure, but the primary power output control equipment is located in the control unit.

CONTROL Unit, Fig. 1-2

All of the control equipment necessary for completely manual or automatic operation of the MU type power plant is housed in a single control unit regardless of the number (from one to five) of generating units in an MU installation. The control unit is divided into a control room and a relay room.

CONTROL ROOM

The control room contains from one to five unit switchgear cubicles and a single transformer cubicle. Each switchgear cubicle houses an air circuit breaker located in the line between a generating unit and the power terminals located high on the end of the control unit housing. The door of each switchgear cubicle contains relays and switches related to the specific generating unit connected to the circuit breaker. The transformer cubicle contains transformers, relays, switches, and meters related to the power bus that is common to all generating units in the MU installation. The transformers in the cubicle provide power for operation of switchgear, relays, and lights; and they provide signals for metering and control.

A fault annunciator light panel and a manual engine start panel are located on the control room side of the relay room wall. Access to the relay room is from the control room. Outside access is provided only to the control room.

RELAY ROOM

The relay room walls consist of panels on which are mounted relays and related devices for control of the MU installation. The room contains a master control panel, an auxiliary master control panel, a fuse panel, and a battery charging panel. It also contains one speed sensing panel and one unit control panel for each generating unit in the installation.

A storage battery for engine starting power and deadline starting is located under the floor of the relay room. These batteries are shipped dry, therefore the proper level of electrolyte should be added and then placed on a 24 hour charge, see Section 3, Part I, Battery Charger article.

GENERAL OPERATING SEQUENCE

The following articles provide a brief description of MU plant operating sequence. Detailed operating sequences are provided later in this manual.

In normal operation, a start signal will cause the master control to sequence the starting of the generating units. When one unit has started, it sends a signal to the master control, which causes the next unit to start. The second unit when started sends a signal for the next unit. This cycle is repeated until all units are running. Each unit will idle a short time, then build up speed and voltage. The first unit up to synchronous speed becomes the master unit. Its generator is excited and its breaker closes on the MU bus. The next unit to build up voltage uses the synchronizer and holds off the other units from attempting to synchronize. When one unit has synchronized with the master unit and its breaker has closed, another unit uses the synchronizer. This cycle is continued until all units have been synchronized and put on the MU bus. A signal may then be given to close the load tie breaker and pick up the dead load.

All generating units can be stopped by a single stop signal. The master control receives the stop signal and sends the signal to each unit. The units will then unload, the breakers will open, and the engines will idle to cool and then stop.

The systems contain a number of protective circuits and have protective devices to handle abnormal conditions. For example, each unit is given five chances to mesh the starter motor pinion with the ring gear. If all five attempts fail the unit will be locked out. After the starter pinion meshes, the unit will be cranked for 10 seconds. If the unit fails to start within that time, the unit will be locked out.

A number of conditions, as shown on the master annunciator, will cause lockouts and either stop the engine or prevent it from starting.

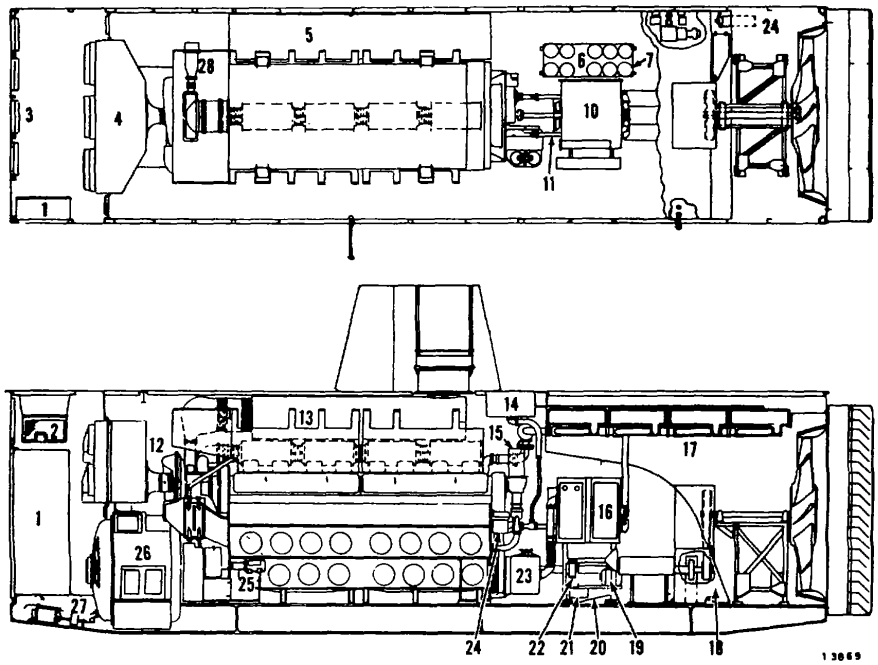
When a unit is stopped by certain faults relating directly to the engine, the cause will have to be corrected and the annunciator manually reset before the unit can be restarted.

SECTION 2

GENERATING UNIT EQUIPMENT AND SYSTEMS

GENERAL

The generating unit consists of a synchronous generator equipped with a regulated static type exciter, a 16-567E4 diesel engine that is directly coupled to the generator, and the required engine supporting auxiliaries, such as oil coolers and filters, an engine water cooling system, an engine exhaust snubber, a fuel oil system, and an engine control panel. The general arrangement of the equipment is shown in Figs. 2-1 and 2-2 and each of the more important equipment components is numbered and identified.



1. Generator Control Cabinet
2. Static Exciter
3. Outside Air Filters
4. Engine Air Intake Filter
5. Lube Oil Tank
6. Lube Oil Filters
7. Turbocharger Lube Oil Filter
8. Fuel Transfer System (When Applied)
9. Radiator Cooling Fan
10. Lube Oil Cooler
11. Temperature Switch Manifold
12. Turbocharger
13. Engine Exhaust Snubber
14. Engine Water Tank
15. Engine Governor
16. Engine Control Cabinet
17. Radiators
18. Fuel Oil Day Tank
19. Oil Circulating Pump
20. Immersion Heater
21. Emergency Fuel Cutoff
22. Fuel Oil Strainer
23. Lube Oil Strainer
24. Fuel Oil Filters
25. Engine Starter
26. Synchronous Generator
27. Current Transformers
28. Crankcase Ejector Assembly

Fig. 2-1. Generating Unit General Arrangement

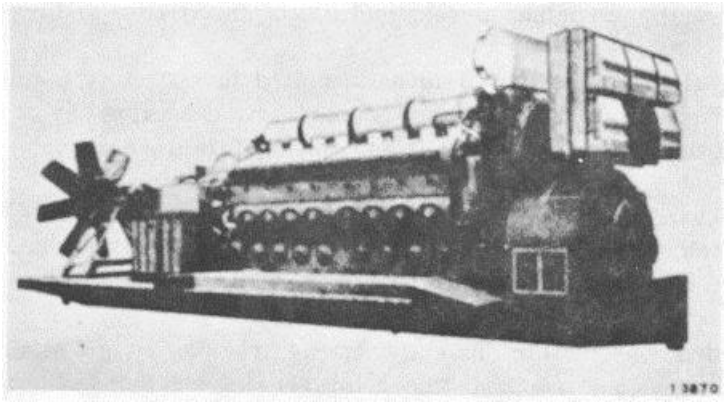


Fig. 2-2. Generating Unit Without Housing

AC SYNCHRONOUS GENERATOR

DESCRIPTION

This instruction applies to alternating current synchronous generator Model A15, shown in Fig. 2-3. It is designed to operate at 600 RPM and produces 3-phase, 50 cycle current at either 2400 or 4160 volts, or 720 RPM and produces 3-phase, 60 cycle current at either 2400 o4 4160 volts.

The generator is a single bearing type with the rotor directly connected to the engine crankshaft through a flexible coupling flywheel. It is supported at the outboard end by a

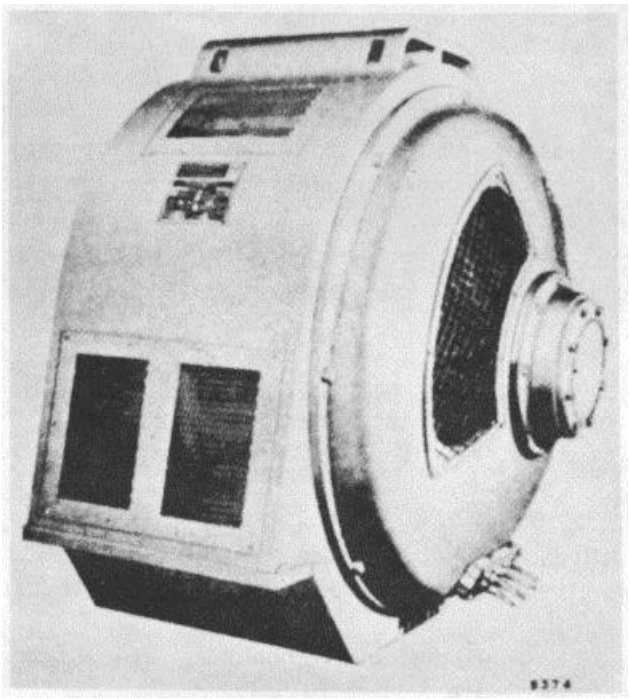


Fig. 2-3. Model A15 - Synchronous Generator

single sealed lubricated, self-aligning bearing assembled in an end bell housing which is bolted to the main frame of the alternator. The generator assembly rests on a common base with the engine, thereby facilitating installation and maintenance.

The rotating field consists of field coils bolted to a drum type spider supported by a shaft. Slip rings for excitation are mounted at the bearing end of the rotor shaft and leads connect the slip rings to the series connected field coils.

Amortisseur windings (damper windings) are located on the face of each pole piece. Baffles on each side of the field coil direct cooling air flow to obtain maximum cooling efficiency.

Utilizing welded construction, the stator frame provides a rigid structure which houses the stator windings and supports the rotor bearing end bell assembly. The Class "H" insulated stator coils are connected at the bearing end of the stator and both leads *of* each phase are brought out for external connection.

The highest quality insulation materials provide generous overload and reactive capacity. The continuous duty temperature rise is 400 C. The overload rating is 25% for a maximum of 2 hours at 80% power factor.

The continuous rating for the A15 machine is given below:

KW Rating	Power Factor	KVA	Amps Delta	Amps Wye	Volts Delta	Volts Wye	Cycles
1250	0.8	1560	375	217	2400	4160	50
1500	0.8	1875	451	260	2400	4160	60

MAINTENANCE

This synchronous generator is designed and manufactured to provide long life and satisfying performance with a minimum of maintenance. Like any machine, however, certain maintenance is required, the extent of which is largely determined by the operation and service to which the generator is subjected. Inspections and maintenance should be performed on the systematic basis outlined in the Scheduled Maintenance Program.

CLEANING

Both the interior and exterior of the generator should be kept clean and free of dust, dirt, oil and water which are likely to have a detrimental effect on insulation and performance.

As frequent as conditions warrant, the generator should be blown out with low pressure air. Avoid excessive air pressure which could cause damage to insulation.

Clean, bound edge, lintless wiping cloths should be used as necessary to remove oil, grease and accumulations of dirt.

COLLECTOR RINGS AND BRUSHES

Collector rings should be checked frequently while generator is in operation. Any sparking should be corrected immediately.

Sparking on collector rings may be due to the various causes listed below:

1. Collector rings not running concentric with shaft.
2. Collector ring surface rough or pitted.
3. Brushes tight in brush holders.
4. Oil on surface of collector ring.
5. Vibration of brush holder studs.

If the slip ring concentricity exceeds .001" total indicator reading and slip ring lateral run out exceeds 1/32", rings will have to be machined or stoned to bring them into tolerance.

A rough or pitted collector ring surface is usually due to prolonged sparking. Usually this condition can be corrected by grinding. The brush holder assembly should be re- moved and the slip ring grinder 8219264 and adapter 8219265 assembled to the tapped holes provided in the end housing just to the left of the brush holder mounting location.

Position the grinder so there will be 1/8" clearance between it and the rings to be stoned. Install grinding stones 8204167 in position on the grinder, making certain there will be enough travel to grind the rings.

Make the necessary preparation to start the engine and run at approximately 300 RPM.

CAUTION: Be sure the grinding stones do not contact the slip rings until the generator begins rotating. Then gradually bring the stones in contact with the rings.

When the stones are in contact with the rings, proceed to grind until the ring surface is smooth. After grinding, check the surface with a dial indicator. Runout should not exceed .001" total indicator reading (60 cycle unit) or .004" (50 cycle unit).

When the grinding operation is complete, remove the grinding equipment. Blow out all grinding dust and reassemble the brush holder assembly in its proper position. Replace brushes if necessary.

CAUTION: Never use emery cloth for polishing slip rings due to its continued abrasive action.

When installing new brushes, they should be sanded to fit the curvature of the slip ring. This can be done by putting a piece of sandpaper on the surface of the ring with the rough side against the brush. Then with the brush held down with pressure arm of the brush holder, move sandpaper in direction of rotation of the rings. Repeat motion until brush fits curvature of the rings.

BEARING

A sealed grease lubricated, double row, spherical, self-aligning bearing is used and is assembled into an insulated bearing housing to prevent damage to the bearing due to electrical arcing. No additional lubrication is required. Occasionally checking the bearing temperature during operation, by applying a pyrometer to the outside surface of the bearing cover, will give an indication of the bearing condition. The bearing temperature should not exceed a 25° C. rise. High bearing temperature may be caused by:

1. Contamination of grease.
2. Excessive thrust due to misalignment.
3. Pounding caused by bearing being loose on shaft or worn rollers.
4. Actual bearing failure caused by bearing fatigue or wear.

BR Mil-G-18709grease should be applied to the bearing at intervals recommended in the applicable Scheduled Maintenance Program. The bearing cover should be removed and a one ounce sample of the darkened part of the grease removed. The grease sample should be subjected to a laboratory analysis as follows:

Determination	Acceptable Limits
PH	10 or higher
1/4 scale worked micropenetration	190 to 250
% ash	2.0 or less
% iron	2.0 or less
% copper	2.0 or less
Acidity, as % oleic acid	0.50 or less

NOTE: All tests to be per latest ASTM standards.

Should the grease fail to pass only the PH test, clean out and repack the bearing cover as outlined later under Generator Assembly. While the cover is removed, visually inspect the exposed portion of the bearing for signs of distress such as overheating, abnormal wear and brass flakes.

If the visual inspection shows any defects or if the grease does not pass any of the remaining tests, the bearing will have to be removed and replaced with a new bearing or have the used bearing cleaned of the contaminated grease. If bearing and grease are satisfactory, repair grease contour in a cover with a clean putty knife or spatula, where it was deformed by the test sample removal. When grease contour has been restored, replace cover using a new gasket.

CAUTION: Take extreme care to ensure that no foreign material gets into the grease or bearing while the cover is removed.

Whenever it becomes necessary to remove the generator bearing, the generator will have to be removed from the unit.

GENERATOR DISASSEMBLY

Before the generator is removed from its location, place strips of fish paper 1/16" x 3" x 36" in the bottom air gap between the armature and field pole cores. The following steps should be used in disassembling the generator:

1. Mount the generator on a sturdy stand such as shown in Fig. 2-4, at a suitable height from the floor.
2. Remove the screens from the two openings at the bearing end of the generator.
3. Install an arbor fixture as shown in Fig. 2-4, which will be used to remove the rotor assembly from the stator assembly.
4. Remove the blocks from the bottom of the end housing that hold the six connectors to the stator windings.
5. Remove the eight bolts that hold the end housing to the stator.
6. Using two wire cable loops, attach one loop to the arbor fixture and attach the other loop to the end housing, Fig. 2-4. With the aid of a crane, raise the arbor fixture end and space the rotor air gap in the stator frame. Raise the cable attached to the end housing until the slack has been removed and the cable is taut.
7. Insert three jack bolts in the tapped holes provided in the end housing, and free the housing from the stator frame.
8. Ease the rotor assembly out of the stator frame. Care must be exercised not to injure the laminations or windings. Do not allow the rotor assembly to rub on the poles while it is being removed.

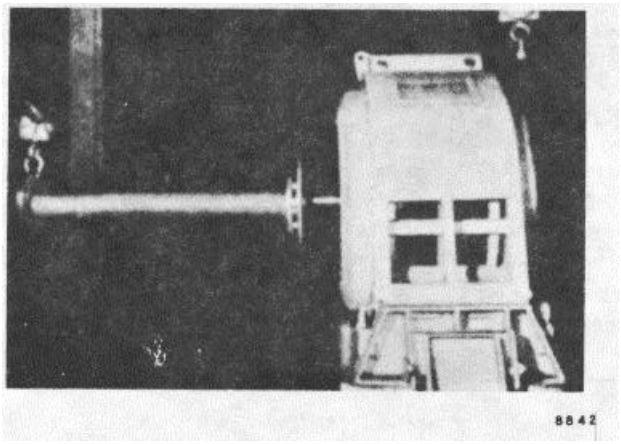


Fig. 2-4. Removing Rotor From Stator Assembly

9. Rest the rotor assembly in a cradle, Fig. 2-5, being sure to place strips of fish paper between the cradle and the rotor assembly.
10. Remove the brush holder assembly from the end housing.
11. Remove the end housing by first removing the eight bolts holding the bearing cover in place and removing the bearing cover. The cover may be removed by tapping with a rawhide mallet or soft metal hammer.

12. The end housing is now free and can be slid off the bearing, as shown in Fig. 2-5.

CAUTION: Be careful at all times not to damage the insulated bearing housing bore. Do not damage or lose the eight fiber tubes that are located in the bearing cover bolt holes.

13. To remove the bearing, first remove the four bolts that hold the retainer to the end of the shaft and remove the plate.
14. Use bearing puller 8178286, as shown in Fig. 2-6, to remove the bearing. Be sure the puller is pulling equally on all studs to prevent damage to the inside bearing cap and bearing. An optional method of removing the bearing is the float-off method.
15. Bearing and bearing parts can now be cleaned and inspected for reuse. Any defective parts should be replaced with new parts.

The insulated bearing bore in the bearing housing should be inspected for wear or dam- age. If found defective, replace it with a new bearing housing. Bearing housing bore should be thoroughly cleaned using Apco #42(or equal), then apply a thin coat of Molykote M88 (or equal) to the bore with a brush and allow to dry before assembly.

ELECTRICAL INSULATION TEST

Before the generator is assembled it is advisable to electrically qualify the stator and rotor. The following qualifications should be met before any attempt to give the stator

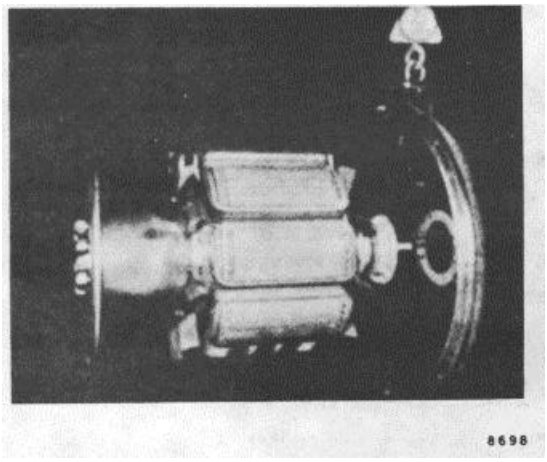


Fig. 2-5. End Housing Removal

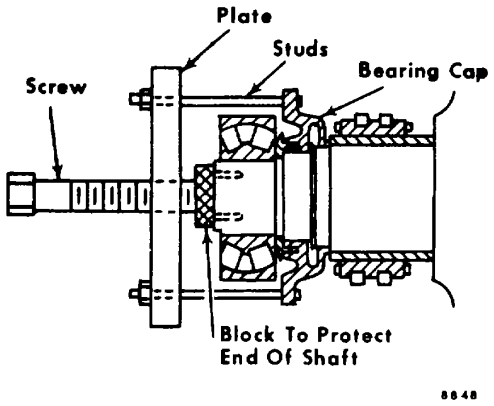


Fig. 2-6. Bearing Removal

or rotor a high potential test. This applies to any stator or rotor that has had an occasion for windings to accumulate moisture or dirt.

1. Stator and rotor must be clean.

2. They must show a steady insulation reading for at least three hours at any given temperature from 75° C. to 90° C.

3. The ratio of insulation resistance taken 5 minutes after starting the megger check should not be less than 1-1/2 times the reading taken 10 seconds after starting the check. The check should be taken with a stator temperature reading of 50° C.

4. The insulation resistance of the rotor must be not less than one megohm at any temperature up to 75° C.

Any stator or rotor which, although clean, shows low or erratic insulation resistance readings should be dried at 90° C. until a stabilized insulation resistance reading is obtained for a period of twenty-four hours. Before applying high potential test, all the other qualifications outlined must be met.

NOTE: Generators which have been stored for a considerable period of time should be given an insulation resistance check before being put into service.

HIGH POTENTIAL TEST

If the stator and rotor meet the listed qualifications, test should be taken at 50° C plus or minus 5° C. in the following manner.

1. For stators, check one phase at a time. Ground the four leads of the two phases not being tested.

2. Apply 4800 volts RMS for one minute to each phase separately.

3. For rotor, apply 500 volts for one minute.

GENERATOR ASSEMBLY

After the generator stator and rotor have been cleaned and checked, the inside of the stator and the outside of the rotor should be painted with red air drying enamel.

Now that the component parts have been cleaned, checked, inspected and painted, the generator is ready for assembly. Using the same facilities that were used to dismantle the generator, place the stator and rotor in position for assembly and proceed as follows:

1. Bearing assembly - make sure all bearing parts are free of grease and dirt.

2. Quantity by weight of BR Mil-G-19709, Grade 3 grease to be applied is as follows:

Cap	14 ounces
Bearing	13 ounces
Cover	19 ounces
	46 ounces total

3. Refer to Fig. 2-7 showing cross-section of cap and cover. Grease should be built up as shown to effect the following.

a. Height of grease to contact bearing cage.
b. Depth of grease to be sufficient to contact the roller bearing.

The arc of the grease application for the bearing cap and cover should include the lower 180° to 200° (60 cycle unit) or 240° to 270° (50 cycle unit) keeping the ungreased portion at the top of the cap and cover. Work grease into bearing cap and cover making sure that there will be no air pockets or voids in grease.

NOTE: Voids or pockets in the grease will cause the grease to lose its contour and pull away from the bearing during operation. This could result in a bearing failure.

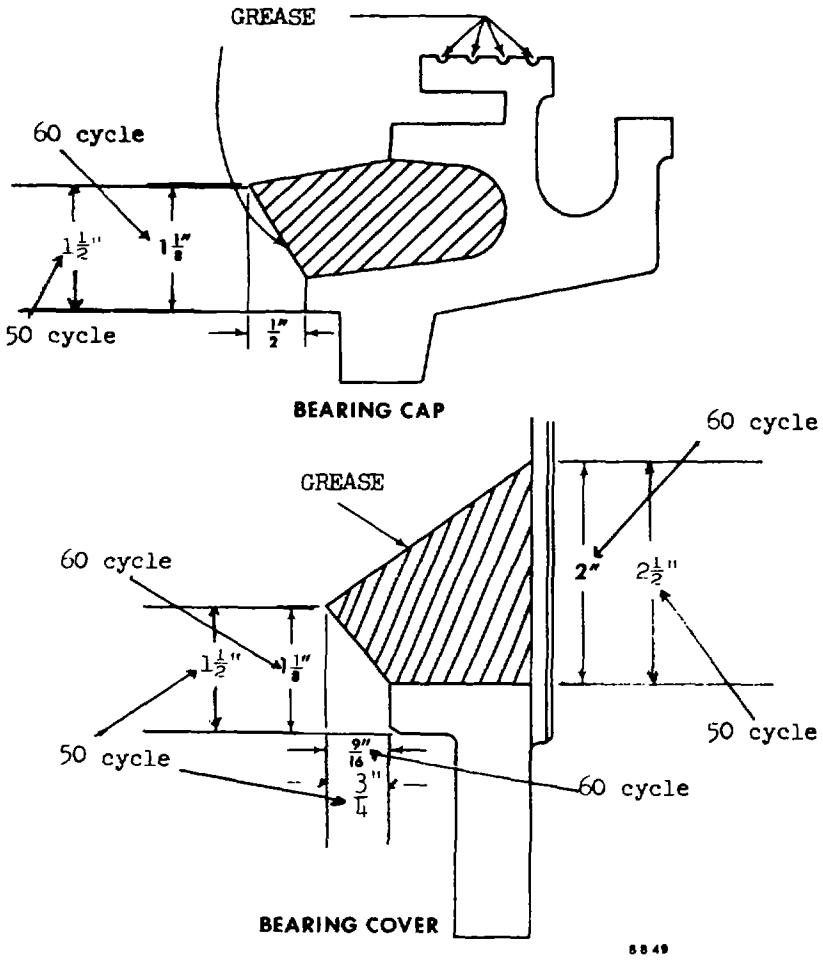


Fig. 2-7. Grease Application

The labyrinth grooves of the bearing cap, Fig. 2-7, are to be filled flush with BR Mil-G-18709, Grade 3 grease.

4. Clean rotor shaft, remove any burrs or gall marks that might have been caused by pulling the bearing.

5. Place the greased bearing cap on the shaft. Apply new gasket to cap.

6. Using induction heater 8041446, heat the inner oil thrower to a temperature of 248° F. or 120° C. The temperature can be checked with pyrometer, 8027937. When using an induction heater, pyrometer reading should be taken with the current off. After heating, place the oil thrower on the shaft, Fig. 2-8, and hold in place until it will not move.

CAUTION: When using an induction heater, care must be taken not to overheat the parts. Overheating may result in warping or metallurgically upsetting the parts, causing a failure in operation.

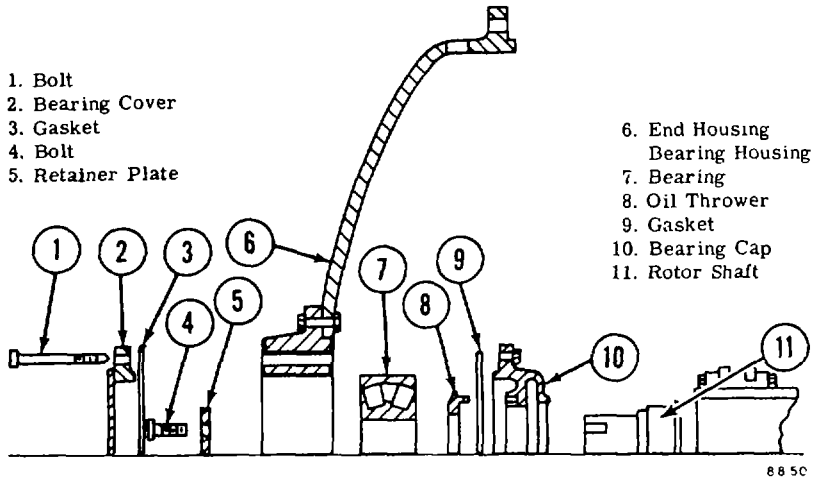


Fig. 2-8. Assembly Sequence

7. Fill the bearing with 13 oz. of BR Mil-G-]8700, Grade 3 grease. The outer race may be moved to any position. Fill the space between rollers and around the outside diameter of the cage with the full amount of grease specified. Work grease uniformly into bearing.
8. After the bearing has been properly greased, heat the bearing with the induction heater to 248° F. or 120° C. Take the pyrometer readings only at the outside face of the bearing inner race.

When the bearing has reached the correct temperature, remove it from the heater, taking care not to move the outer race out of position. Place the bearing on the shaft, being careful not to cock it on the shaft. Push the bearing on the shaft up against the inner oil thrower. If the bearing is heated to the proper temperature and not cocked as it is placed in position, the bearing will slide freely onto the shaft and into position. If the bearing should cock, when attempting to place it on the shaft, a brass pipe the size of the inner race should be used to straighten out the bearing by tapping it on the

inner race. Bearing will then slide into position. Bearing should be held in place until snug on shaft. Let bearing cool to room temperature before trying to assemble the end housing.

9. Apply two studs 1800 apart to the threaded nut inserts in the bearing cap, Fig. 2-9. The purpose of the studs is to line up the bearing cap with the end housing. The studs will be removed later.

10. Place new gasket over the studs and up against the face of the bearing cap making sure all stud holes line up.

11. Before assembling end housing to the bearing, a steel plate should be bolted to the end of the shaft, Fig. 2-10, using the tapped holes that hold the retaining plate. The purpose of this plate is to prevent the outer race of the bearing from cocking as the end housing is pushed over the outer race. In constructing the steel plate, its diameter should be made slightly smaller than the outside diameter of the bearing so it will not interfere with the bearing sliding into the housing bore.

12. With the end housing hanging in position and the bore of the housing level with the outside diameter of the bearing, position the bearing cap so the bottom of the cap lines up with the bottom of the housing.

13. Line up the two studs in the bearing cap with the proper holes in the end housing.

14. Bring the housing slowly up to the bearing, being careful not to cock the bearing in the housing bearing bore. If properly lined up, the bearing will slide freely into the bore and against the bearing cap.

15. Remove the temporary steel plate bolted to the end of the shaft, Fig. 2-10.

16. Check bearing clearance. With the bearing assembled to shaft and the end housing on bearing, the clearance should be .002" minimum.

17. Assemble retainer plate and four bolts to end of shaft. Torque bolts to 110-120 ft-lbs.

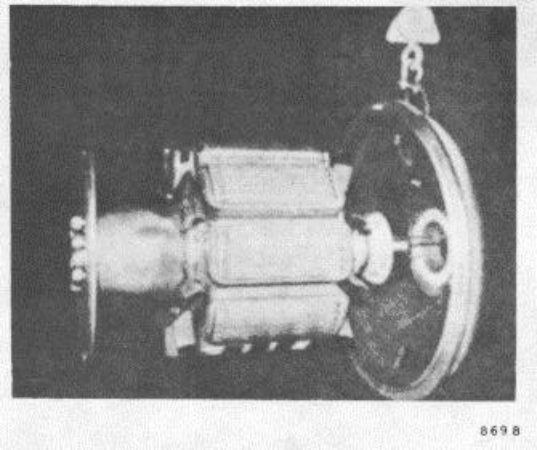


Fig. 2-9. End Housing Application

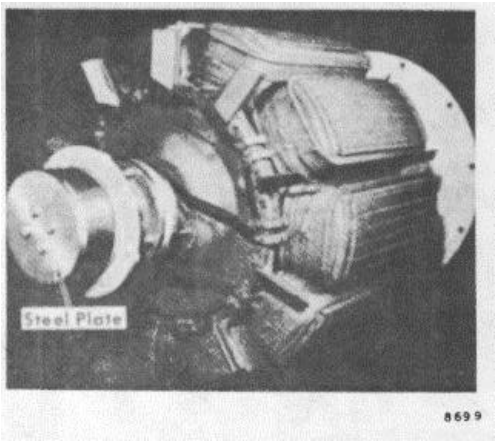


Fig. 2-10. Bearing Aligning Plate In Position

18. Apply 19 ounces(60 cycle) or 35 ounces(50 cycles) of grease to the bearing cover, Fig.2-11. The arc of the grease should include the lower 180°-200° (60 cycles) or 240°-270° (50 cycles) keeping the ungreased portion at the top of the cover when assembled to the end housing.

19. Position a new gasket on the cover and assemble cover to the end housing.

20. Before removing the two line-up studs from the bearing cap, that were used to line up housing with the bearing cap, install six bolts in the bearing cover bolt holes and tighten. Then remove the two studs and install the two remaining bolts. These bolts should be torqued to 50 - 55 ft-lbs.

21. To check the end play or the lateral movement of the bearing in the end housing, push the end housing all the way back towards the rotor, remove the brass plug in the bearing cover and measure the distance from the outside of the cover to the bearing outer race, Fig. 2-12. This distance should be approximately 1-1/2". Then pull the end housing away from the rotor and check the distance from the outside of the cover to the bearing again. The movement should be 15/64" ± 1/32".

NOTE: For information on generator alignment, see Maintenance Instruction 1753.

With the bearing and end housing assembled to the rotor, the assembly is now ready to place into the stator.

22. Assemble and adjust brush holder rigging using care not to damage the slip rings.

23. Install arbor fixture to the engine end of the rotor, as shown in Fig. 2-13.

24. Position stator and rotor assembly so that arbor fixture protrudes through stator assembly.

25. Lift both ends of the rotor and end housing assembly to clear the cradle that was used during end housing assembly. Then remove the cradle.

26. Push rotor and end housing assembly into stator being careful not to damage the six connector leads. They must line up with the opening near the bottom of the end housing.

CAUTION: To prevent damaging the winding or coils, rotor must be kept level, with equal clearance around the coils, while assembling it into the stator.

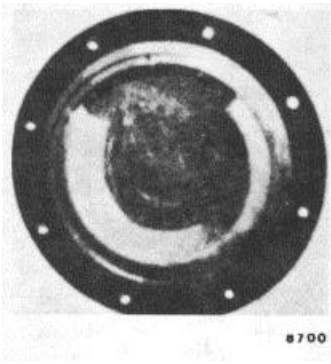


Fig. 2-11. - Grease Application To Cover



Fig. 2-12. - Checking End Play

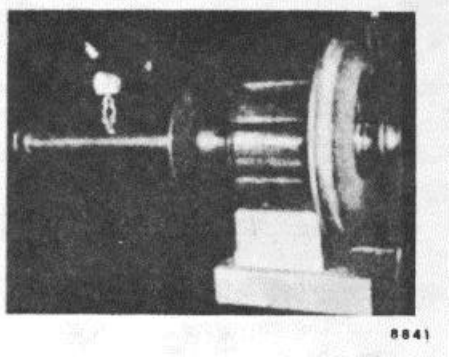


Fig. 2-13. - Installing Rotor In Stator

27. When end housing and stator frame are flush, install the eight mounting bolts and torque to 270 ft-lbs. Be sure the end housing is not cocked before tightening bolts.

28. Before setting the rotor assembly down on the stator, place strips of fish paper between the bottom of the rotor and the stator.

29. Remove the arbor fixture and replace the lead clamp block at the bottom of the generator.

MAINTENANCE DATA

The following maintenance data can be used as a guide to inspection and testing of an A15 synchronous generator.

Weights ..... 16,550 lbs.

Brushes
- Number of brushes 4
- Size of brush ..... 2" x 1-1/4" x 1/2"
- Wear limit ..... 1"
- Grade ..... AY

Brush Holder
- Number of brush arms 4
- Spring pressure ..... 3.29 ±.25 lbs.
  Constant Pressure Type (non-adjustable)

Slip Rings
- Maximum ring eccentricity ..... .001"
- Maximum lateral ring runout ..... 1/32"

Roller Bearing
- Outer diameter ..... 10.2362 + .0000"
  ..... -.0014"

Bearing Bore ..... 4.7244 + .0000"
..... - .0008"
- Width 3.386
  ..... +.000"
  ..... -.005"
- Internal clearance ..... .0041" to .0059"
  (before assembly)
- Internal clearance ..... .002" min.
  (after assembly)

Bearing Housing Bore Inside Diameter 10.2397
..... + .001"
..... - .000"

Lubricant Capacity		50 Cycles	60 Cycles
Bearing cap		17 ozs.	14 ozs.
Bearing		13 ozs.	13 ozs.
Outer bearing cover		35 ozs.	19 ozs.
	Total	65 ozs.	46 ozs.

Recommended Lubricant ..... BR Mil-G-18709, Grade 3

End Play Clearance
After assembly in generator housing..... 15/64" ± 1/32"

Rotor, Slip Ring to Slip Ring Resistance At 75° C.

Nom.	+ 4%	- 4%
1.459	1.516	1.400

Stator, Per Phase

Nom.	+ 2%	- 2%
.1573 (60c)	.1605 (60c)	.1541 (60c)
.0660 (50c)	.0673(50c)	.0647 (50c)

Hy-Pot Test
Rotor..... 500 volts RMS for 60 sec.
Stator..... 4800 volts RMS for 60 sec.
Check each phase separately

DIESEL ENGINE

The prime mover in the generating unit is the Model 16-567E4 turbocharged diesel engine. A complete description and maintenance procedures are contained in Part II of this publication.

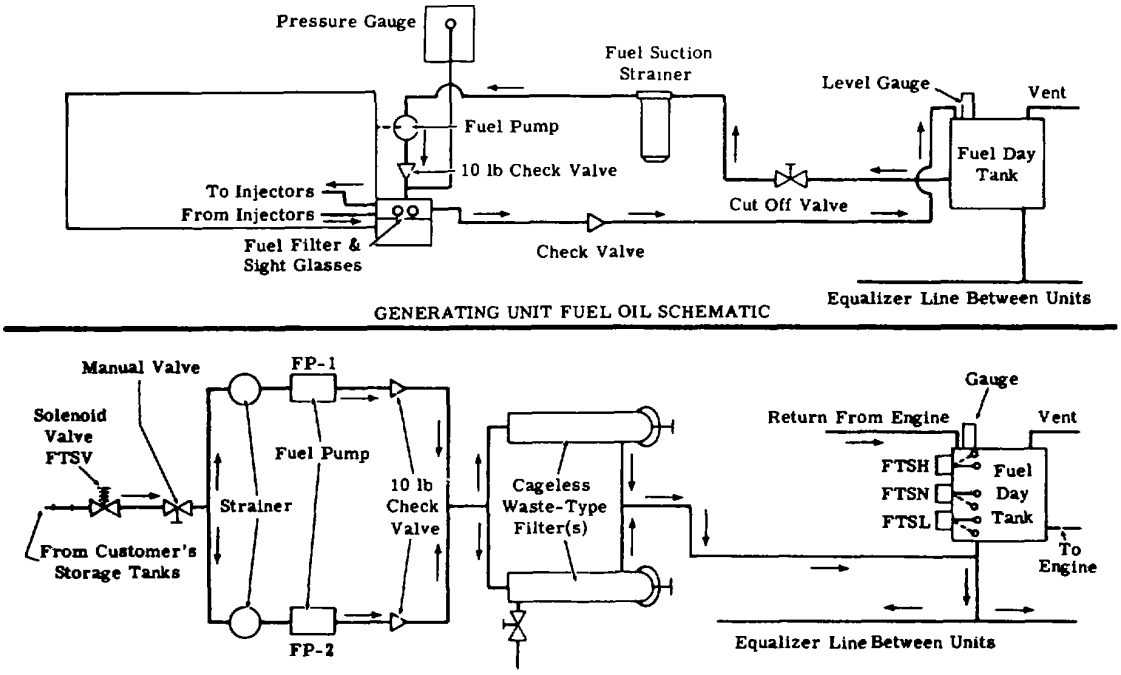
FUEL OIL SYSTEM, Fig. 2-14

The fuel oil system for each generating unit includes an auxiliary fuel tank located in the unit. This tank is called a day tank. It has a capacity of 120 gallons and acts as a reservoir for fuel suction and fuel return from the engine. Fuel is drawn from the day tank and through a suction strainer to the engine mounted fuel pump. Fuel from the pump is forced through a 10 pound relief valve to the double element engine mounted fuel filter. After passing through the engine mounted filter, fuel flows through manifolds that extend along both banks of the engine. These manifolds supply fuel to the injectors. The fuel pump delivers more fuel to the injectors than the engine can burn. The excess is used to cool and lubricate the fine working parts of the injectors. It is then returned to the fuel oil day tank through the return fuel sight glass.

FUEL SIGHT GLASSES, Fig. 2-15

Two sight glasses are located on the engine mounted filter housing to give visual indication of fuel system condition. During normal operation the glass nearest the engine should be full of fuel, clear, and free of bubbles. This is the return fuel sight glass. A 10 pound relief valve inside the glass causes a back pressure, thus maintaining a positive supply of fuel at the engine injectors. Fuel passes through the relief valve and back to the day tank.

The sight glass farthest from the engine is normally empty. When more than a trickle of fuel is seen in the glass it indicates that the 60 pound relief valve is open to bypass fuel around clogged fuel filters. If this condition is not remedied, it can become serious and cause engine failure from lack of fuel to the injectors.



FUEL TRANSFER SYSTEM SCHEMATIC ABOVE GROUND
(Applied To Only One Unit In An Installation)

13871

Fig. 2-14. - Fuel Oil Systems Simplified Schematic Diagram

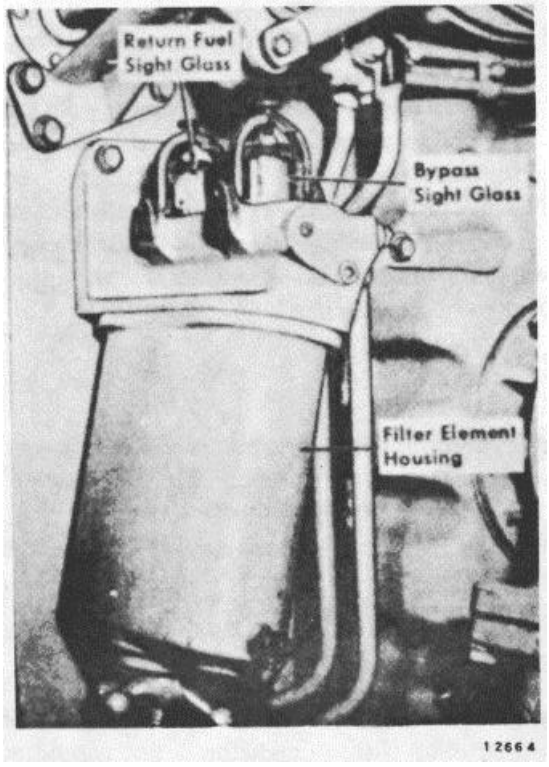


Fig. 2-15. - Fuel Oil Sit Glasses

ABOVE GROUND SYSTEM, Fig. 2-14

One generating unit in an installation is equipped to transfer fuel from the main storage tank to the day tanks of each generating unit in a multiple unit installation. The equipment consists of two fuel transfer pumps, a suction strainer for each pump, cotton waste type pump discharge filter(s), and float level gauges and switches. The fuel level is controlled by the float switches located in the day tank of this generating unit only. The fuel level in other generating units is maintained by equalizing piping.

If the fuel level in the day tank rises above the fuel transfer switch high level, both fuel pumps will be de-energized and the solenoid shut-off valve in the main supply line will be de-energized. The FUEL TRANSFER light on the control unit annunciator will come on; but operation will continue, using fuel from the day tanks. When fuel level in day tanks drops to a normal level, the switch drops out and the fuel transfer solenoid valve is again energized, but the fuel pump will not operate until fuel level drops below the normal level.

Referring to the lower portion of Fig. 2-14, the fuel transfer system functions as follows. As soon as any one of the diesel engines starts, the fuel transfer solenoid valve FTSV, located in the fuel line between the main storage tank and the fuel transfer pumps is energized, provided that the fuel level is not already higher than normal. As fuel is consumed and the fuel level drops, the fuel transfer switch/FTSN will activate the No. 1 fuel transfer pump to maintain fuel level in all the day ta1fks in an installation.

If the fuel level drops below the FTSN level, the fuel transfer switch low FTSL will activate fuel transfer pump No. 2, and the FUEL TRANSFER light on the control unit annunciator will come on to indicate a fuel transfer fault. The fault indication does not cause a shutdown; however, operation of the fuel transfer system should be checked.

LUBRICATING OIL SYSTEM

The schematic diagram, Fig. 2-16, and the following articles cover that part of the lube oil system that is external to the/engine. Refer to Part II of this publication for the engine lube oil system.

After performing engine lubrication and piston cooling, engine oil drains back to the engine oil sump. The scavenging oil pump draws oil from the sump and through the suction strainer compartment of the strainer housing. The pump then forces oil through nine cartridges in the ten cartridge filter assembly. From the filter the oil flows through the oil trap and the lube oil cooler to the main and piston cooling oil strainers and to the main and piston cooling oil pumps. Oil from the pumps flows to all working parts of the engine, including the turbocharger, and the turbocharger oil filter.

STANDBY HEATING - IMMERSION HEATER

An auxiliary lube oil system operates upon engine shutdown to maintain engine oil temperature and lubrication for fast starting. It also provides cooling oil to remove residual heat from the turbocharger bearing immediately after shutdown.

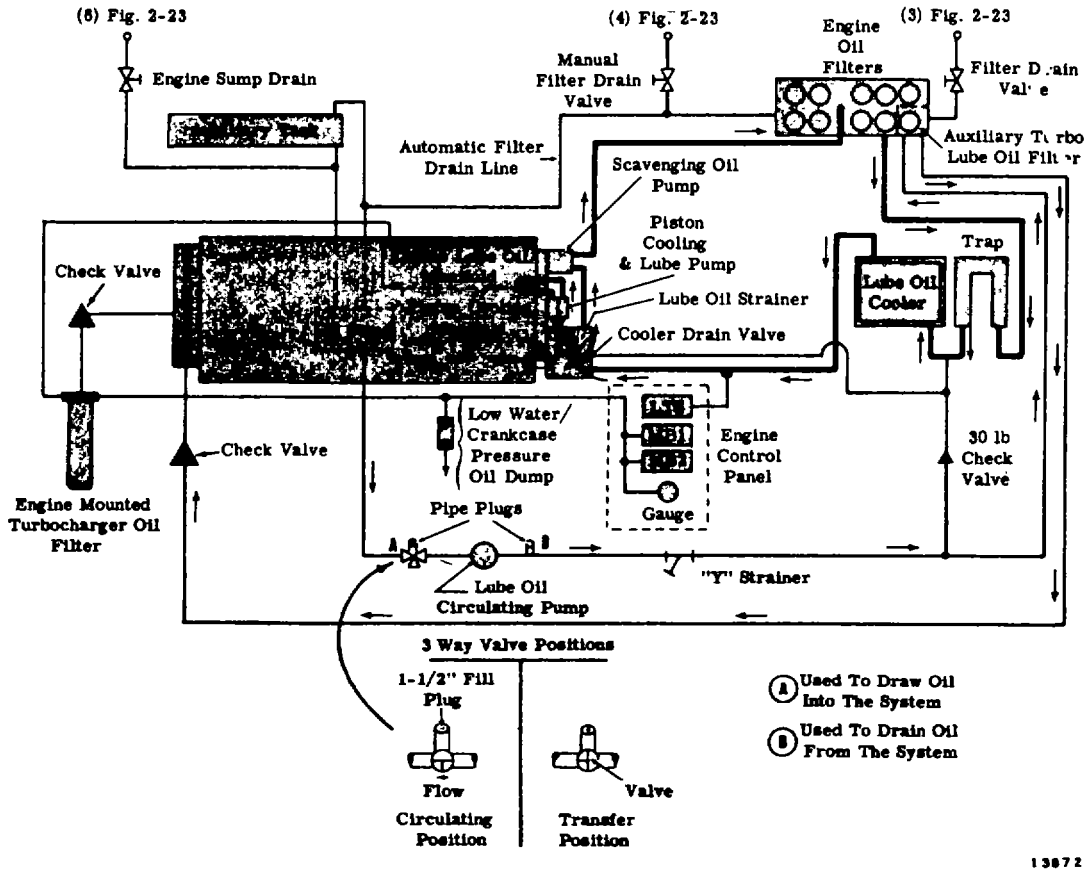


Fig. 2-16 - Lube Oil System Simplified Schematic Diagram

When the engine is shut down, water warmed by an immersion heater, Fig. 2-19, is moved through the lube oil cooler by thermo-siphon action. During shutdown the lube oil cooler actually operates as a lube oil heater, the heat first being applied to the water by the immersion heater and then transferred to the lube oil. This method utilizes the large surface area of the lube oil cooler and prevents carbonization that might occur if the oil were heated directly.

A circulating pump (soak back pump) draws oil from the engine sump and forces it partly through the lube oil cooler and partly through the auxiliary turbo lube oil filter. This filter is the tenth unit in the filter assembly. Oil from the filter passes to the turbocharger bearings, then drains back to the sump. Oil from the cooler (working as a heater at this time) drains back to the engine mounted strainer and from there to the sump. The sensing element of a lube oil temperature switch is located in the line between the cooler and the strainer.

AUTOMATIC COLD IDLE

If during extremely cold weather, the immersion heater is unable to maintain adequate oil temperature, or if a failure occurs in the immersion heating system, a low (oil) temperature switch LTS, with sensing element located in the piping between the oil cooler and oil strainer, trips to initiate an engine start. The engine will then idle until oil temperature increases to a level where LTS drops out.

ADDING OR DRAINING LUBE OIL

Engine oil level should be checked with the engine hot and running at idle speed, but, if necessary, oil level maybe checked with engine at operating speed. A dipstick, Fig. 2-17, is located at the right side of the engine. It should show a level between LOW and FULL when the engine is running. If the oil level is checked with the engine stopped, the reading on the dipstick will usually be above the FULL mark.

Oil may be added in small amounts with the engine running or stopped. When oil is added to the system, it should be poured into the strainer housing through the opening having the square cap as shown in Fig. 2-18. Should the round caps be removed while the engine is running, hot oil under pressure will come from the openings and possibly cause personal injury.

If local maintenance procedures require that oil be added in large amounts (the engine operating range between low and full is 150 gallons), a service boom can be used with the unit. The boom can be employed to hoist oil barrels into position to be emptied onto the engine top deck. This can be done only with the engine shut down, for oil will spray out of the top deck of an operating engine.

NOTE: Overfilling of the engine may cause foaming of the oil in the accessory drive and camshaft gear trains. The oil pan aspirator may become saturated and the engine may shut down due to positive crankcase (oil pan) pressure.

Oil may also be added or drained through use of the 3-way valve and circulating pump. An elbow and pipe plug are provided in the line adjacent to the 3-way valve to facilitate transfer of the lube oil from a drum to the system. With the valve in the transfer position, suction can be applied at opening (A) Fig. 2-16. The circulating pump can also be used to remove oil from the system. In such cases the 3-way valve is placed in the circulating position and drain pipe is fastened at (13). When draining the lube oil system, the filter drain valve should be opened and the oil cooler drain valve, Fig. 2-18, located in the lube oil strainer, should be open.

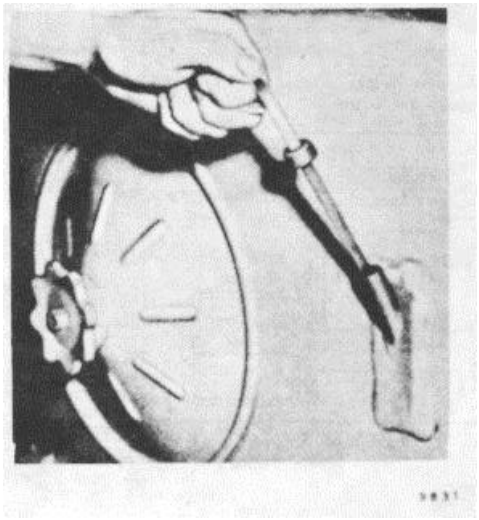


Fig. 2-17.-Checking Oil Level

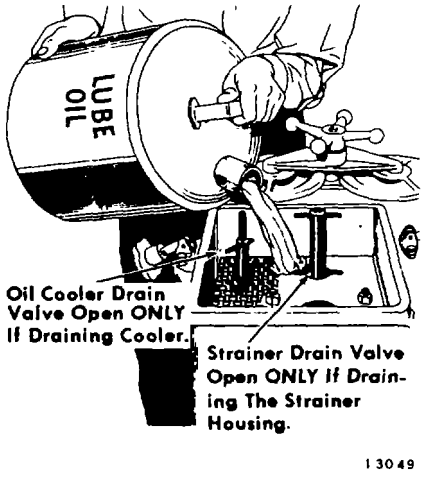


Fig. 2-18.-Adding Oil To Engine

If maintenance conditions require more rapid lube oil transfer, it is possible for the user to provide his own high volume pump and piping for transfer through the oil pan handholes.

Several devices sense oil pressure in a line connected at a point in the engine where the greatest pressure drop has occurred; that is, at a point farthest from the lube oil pumps. Pressure switch MB-1 prevents engine speed increase until satisfactory oil pressure is reached, and MB-2 will shut down the engine if satisfactory oil pressure is not obtained after load is applied to the engine. Lack of oil pressure at MB-1 and MB-2 can result from a true oil pressure failure or from oil being dumped by tripping of the crankcase pressure/low water detector. Whenever an ENGINE fault indication is given, all possible causes of engine shutdown should be checked.

COOLING SYSTEM

Detailed information on the diesel engine cooling system will be found in Part II of this publication.

A schematic flow diagram of the cooling system is shown in Fig. 2-19. Water is circulated through the engine by means of two centrifugal pumps mounted on the front of the engine. The pumps are driven from the front or accessory gear train of the engine.

Heated water from the discharge manifold leaves the engine and flows through the water outlet to a thermostatic valve. Elements in the valve respond to water temperature to divert water to bypass piping leading to the oil cooler or to direct it to the radiators. Valve action maintains engine cooling water at a constant temperature. The valve is

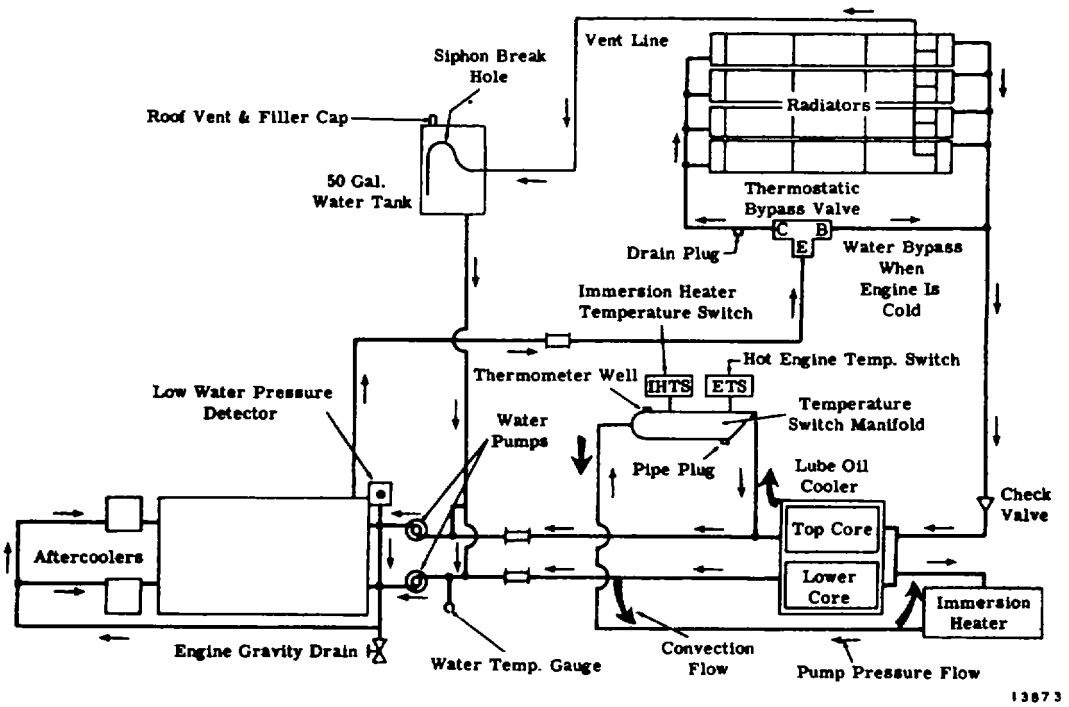


Fig. 2-19.-Cooling System Simplified Schematic Diagram

self-powered and self-contained. Non-adjustable thermostatic element assemblies hold valve sleeves in the bypass position when engine water is cool. As water temperature increases, the elements expand to open the valve outlet to the radiators.

Water from the radiators is piped to the lube oil cooler, and from there to the engine water pumps. A temperature switch manifold is mounted on the oil cooler and connected to the discharge piping from the cooler. An immersion heater temperature switch IHTS and an engine temperature switch ETS are mounted on the manifold. During shutdown, IHTS operates to turn the immersion heater elements on and off to maintain lubricating oil temperature. During operation, ETS trips if water temperature at the engine outlet approaches the boiling point; however, because heat loss occurs between the engine out-let and the temperature switch, the switch is calibrated to trip at a much lower temperature.

During engine shutdown the immersion heater is energized by IHTS, and heater water circulates by thermo-siphon action through the lube oil cooler, which at times functions as a heater. A check valve in the pipe between the cooler and radiators prevents heater water from flowing to the radiators, and a siphon break hole at the expansion tank pre-vents water flow from the expansion tank to the radiators.

FILLING THE COOLING SYSTEM

The coolant used in the engine cooling system should be made up and tested in accordance with the applicable Maintenance Instruction and the Engine Section in Part II of this publication.

The cooling system can be filled through the filler opening located on the roof of the generating unit housing, or through the drain opening located at the underframe approximately 15 feet from the fan end of the unit. A water level sight glass on the 50 gallon reserve water tank is visible from inside the housing. Coolant should be maintained at a level in the sight glass about 2/3 full. It is important that the water level at immersion heater temperature be marked on the sight glass. This provides a means of deter-mining possible water loss.

CAUTION: If the cooling system of a hot engine has been drained, do not refill until the engine cools. A sudden change in temperature can damage the engine.

After filling a dry or nearly dry system the low water reset button must be pressed.

ENGINE SPEED GOVERNOR, Fig. 2-20

The engine speed governor is the Woodward LSG-10. It is a mechanical-hydraulic speed sensing and electrical-hydraulic load sensing governor with steady state speed regulation (speed droop). The governor is designed for use on single or paralleled generator sets. The basic governor contains no control or adjustment devices on its outer case, except a knob attached to the speed setting gear train and the rack stop.

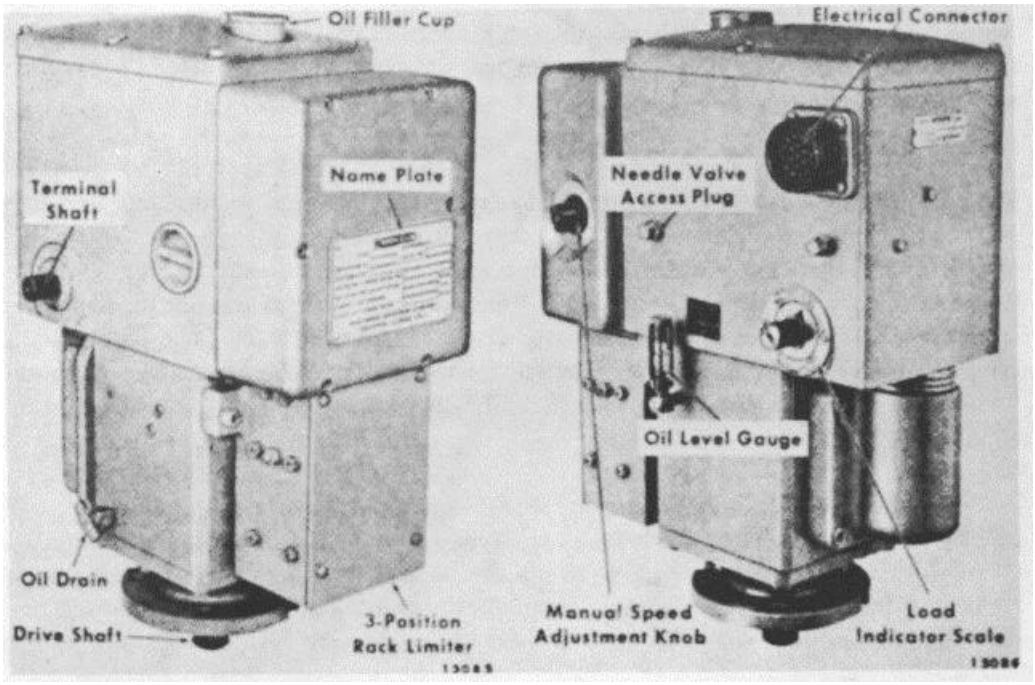


Fig. 2-20. - LSG-10 Engine Speed Governor

With the generating unit operating in deadload operation the load sensing will in effect parallel with zero speed droop and divide load proportionately between units. The load sensing portion of the governor effectively cancels speed droop.

Speed droop is the governor characteristic of maintaining a slower speed when greater load is applied and a higher speed when lesser load is applied. When a speed droop governor is operating in a synchronous system where speed cannot be altered, a change in the governor speed setting results not in a change of speed, but in change of load. Consequently, the governor mechanism normally used to control engine speed is used to control the load on the engine. The isochronous (zero speed droop) governor cannot operate in this manner because it attempts to maintain a constant speed regardless of load. Therefore, a generating unit equipped with an isochronous governor operating in a synchronous system would either take all the load it was capable of handling or it would drop all load. The engine would then be motored by the system and be shut down by reverse current relays.

The load sensing portion of the LSG-10 governor is used during deadload operation. It senses a change in load before that change has any effect upon the speed sensing portion of the governor. A load computer and trimmer put out a signal to a force motor and to other paralleled load computer s to keep all paralleled units at synchronous speed and equal load.

Refer to Part II of this publication for a more detailed explanation of governor operation.

LOAD COMPUTER

During MU operation to pick up a deadload, the first generating unit in a consist to start and come up to speed is selected as the master unit. The load computer of this unit

senses the load imposed on the master generating unit, and it puts out a signal that is in proportion to the load. The signal is directed to a transducer in the engine governor. This transducer (sometimes called a force motor) operates to move governor linkage to accomplish accurate and extremely rapid changes in fuel supplied to the engine. This ability to immediately sense load changes and immediately provide more or less fuel in response to the load changes, enables the generating unit to operate at constant speed.

GOVERNOR TRIMMER

When a change in generating unit load or a small frequency error results in repositioning of governor linkage, the speed sensing portion of the governor is affected and the governor flyballs would operate to position the speed setting mechanism at a new speed setting. When this occurs, the speed setting mechanism operates to close switches that short out windings in the shaded pole governor trimmer motor. The motor turns and changes a rheostat setting that controls electrical input to the load computer. The load computer output signal to the transducer (force motor) then results in a repositioning of the load governor power piston and the speed setting mechanism achieves a new balance, resulting in correct generator speed even though the load has changed.

THREE POSITION RACK STOP MECHANISM

This mechanism provides three rack limit positions during engine starting and operation. These are; rack travel limited to approximately 1/3 rated load; rack travel limited to rated load position; rack travel limited to maximum position. The purposes of these positions are as follows:

1. Rack Stop At 1/3 Rated Load

   During engine start the governor starting solenoid GSS is energized to limit rack travel to 1/3 rated load. The purpose of this stop is to modify the quick governor response resulting from accumulator booster pump oil pressure buildup. The engine, without the 1/3 rack stop, would overfuel at starting and heavy exhaust smoke would result until the engine came up to speed. At 200 RPM the GSS solenoid is de-energized to allow the racks to move toward the rack stop at full rated load.

   The 1/3 rack stop can also be employed during particular operating modes, such as spinning reserve, to limit load on the MU installation. Note in Fig. 2-24 that the generating units should not be run at synchronous speed and no load, except for short periods.

2. Maximum Rack During Deadload Pickup

   During deadload pickup, a delay inherent in the operating characteristics of the engine turbocharger would prevent the engine from immediately putting out full rated load when the rack has advanced to the full rack position. To prevent the delay, a governor loading solenoid LS is employed to nullify the full load rack stop and allow the racks to travel to maximum fuel position. LS is energized during deadload pickup and during deadload operation by a terminal-shaft-operated switch.

The switch is closed when the terminal shaft position is above 75% of rated load. LS pickup is timed by a relay that drops out after sufficient time has passed for the engine to sustain rated load without overfueling, or if LS pickup occurs during deadload operation its pickup provides added fuel to compensate for increased load. The timing in such cases prevents continued overloading of the generating unit. On base load installations LS may be used to permit overload (peaking) operations when required. The restrictions shown in Fig. 2-24 apply.

3. Normal Rack Stop Position

The normal rack stop is to limit generating unit output to full rated load for overload operation (peaking) or to a lesser load if the generating unit takes a base load. Note that setting of the overload rack stop should be done in accordance with ambient temperatures at the installation. Refer to the Engine Section Part II for setting information.

ENGINE PROTECTIVE DEVICES

LOW WATER AND CRANKCASE PRESSURE DETECTOR

A combination low water pressure/crankcase (oil pan) pressure detector, Fig. 2-21, is mounted on the engine accessory drive gear housing. When the device is tripped, it dumps oil from a line leading to oil pressure sensing switches MB-1 and MB-2 (see Fig. 2-16), energizing the ENGINE fault circuit and shutting the generating unit down.

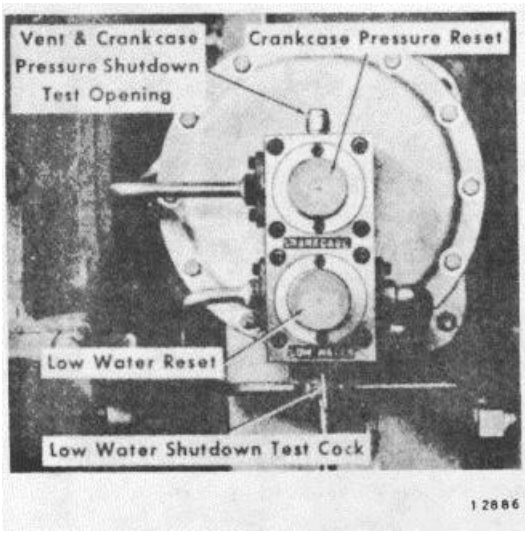


Fig. 2-21.-Low Water/Crankcase (Oil Pan) Pressure Detector

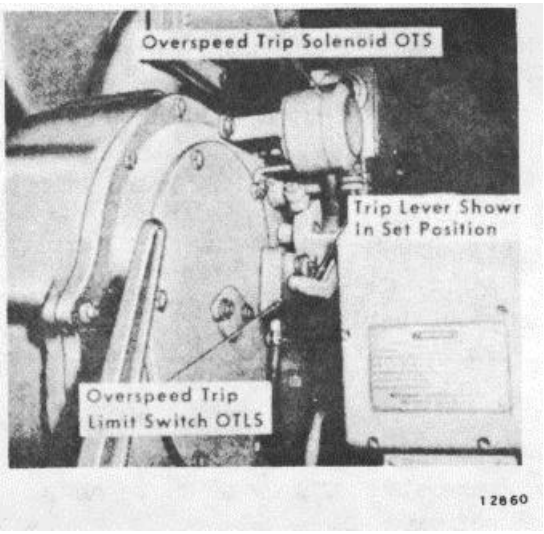


Fig. 2-22.-Engine Overspeed Tripping Device

Whenever an ENGINE fault occurs the low water and crankcase pressure detector should be checked. The lower button protrudes if the shutdown was due to low water pressure. The upper button protrudes if the shutdown was due to positive oil pan pressure.

The device is provided with a test cock to check operation of the low water trip. The low water reset button will pop out if the test cock is turned to the horizontal position.

A vent and test opening is provided for the crankcase pressure trip also. Crankcase pressure trip may be tested by placing a hydrometer bulb over the vent at the top of the device and allowing the suction to cause the crankcase pressure reset button to pop out.

NOTE: Low water and crankcase pressure shutdown should be verified periodically as indicated in the applicable Scheduled Maintenance Program.

ENGINE OVERSPEED PROTECTION

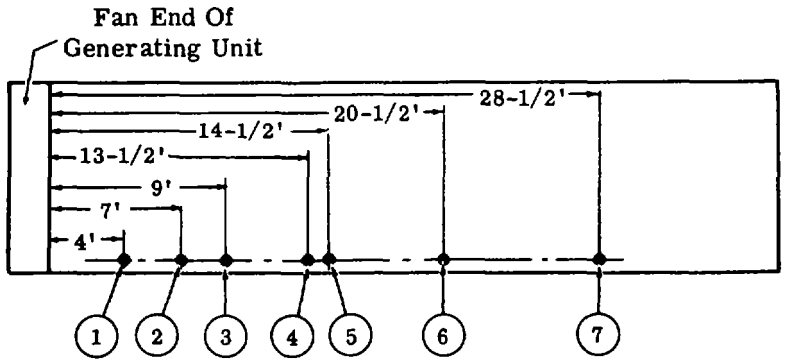
Engine overspeed protection, independent of the governor, is provided by a mechanical tripping device located in the camshaft counterweight housing at the upper front portion of the engine. A lever, Fig. 2-22, extends from this housing and is in the set position when it is inclined at approximately 9 o'clock. The overspeed trip device functions to stop the injection of fuel, which stops the diesel engine. When tripped, the lever is inclined toward the 11 o'clock position. It must be manually reset before the engine can be started.

The overspeed trip may also operate electrically when protective circuits actuate an overspeed trip solenoid OTS. When the device is tripped, an ENGINE OVERSPEED fault is registered on the control unit annunciator. To reset the overspeed trip, pull the handle in a counterclockwise direction until it latches in the set position.

SYSTEM DRAINS, Fig. 2-23

AIRBOX DRAINS

During normal operation, a small amount of engine oil will find its way into the airbox. This oil drains through tubes leading to a cast block at the base of the accessory end of the engine.



*1. Fuel Oil Filter Drain
*2. Fuel Oil Filter Drip Pan Drain
3. Turbocharger Filter Lube Oil Drain
4. Lube Oil Filter Drain
5. Cooling System Drain
6. Engine Lube Oil Drain
7. Manual Engine Air Box Drain

*Only on unit equipped with fuel transfer equipment.

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Fig. 2-23. -- Generating Unit Drain Connection Points - General Orientation

The cast block restricts air pressure through tubes from each side of the engine opposing each other in the block across a calibrated opening. A tee leads off the block of which one end leads to a tube which carries the excess oil to the engine exhaust system where it is dissipated. The other end of the tee is piped to the outside of the unit and is terminated with a hand controlled valve.

The tubes should be drained periodically, and a container employed to catch the draining matter for observation. Normally a small amount of black oil will be emitted, which is of no concern. But if water is present, the engine should be locked out and carefully inspected for water leaks. Fig. 2-23 illustrates the location of the airbox drain pipe and other drain pipes on the generating unit.

CAUTION: To prevent loss of airbox pressure and resulting faulty operation, always close the manual airbox drain valves after draining.

ENGINE LUBE OIL SUMP DRAIN

Normal draining procedure is performed after the engine has run to thoroughly warm and circulate the oil. The engine is then shut down, and oil can be pumped from the engine by connecting a drain line to the opening adjacent to the circulating oil pump (B) Fig. 2-16. After at least one barrel of oil has been pumped from the oil pan, the oil strainer drain valves, Fig. 2-18, are opened. Oil drains from the lube oil filters, from the cooler and trap, and from the strainer into the sump. After oil has been pumped out, complete draining of the engine sump may be accomplished by use of the engine sump drain valve, (6) Fig. 2-23.

LUBE OIL FILTER DRAIN

When the engine is shut down most of the lube oil automatically drains out of the filters, but the elevation of the drain piping prevents thorough draining. The filter drain valve, Fig. 2-16, and the drain opening (4) Fig. 2-23, are used to thoroughly drain the filter assembly.

AUXILIARY TURBO LUBE OIL FILTER DRAIN

This drain opening, (3) Fig. 2-23, and its related drain valve are employed to completely drain the auxiliary turbo lube oil filter housing, which is separate from the remaining lube oil filters in the assembly.

COOLING SYSTEM DRAIN

The cooling system drain (5), Fig. 2-23, and engine drain valve, Fig. 2-19, will completely drain the cooling system; but the thermostatic valve elements may trap water' in front of the valve and in the radiator header. For this reason, a drain plug, Fig. 2-19, is provided in the piping between the valve and the radiator header.

The right bank water pump appears to be positioned so that it will trap water, but a hole is drilled in the web to allow the pump housing to drain completely. No drain plug is needed.

FUEL OIL FILTER DRAINS

These drains are provided only on the unit equipped with fuel transfer equipment. The drains, (1 and 2) Fig. 2-23, are used when changing fuel oil filters.

DIESEL ENGINE SPEED AND LOAD RESTRICTIONS

Certain precautions must be observed regarding high speed, no-load operation. If the diesel engine is allowed to run at high speed and light load or no load for appreciable lengths of time, excess wear or failure of the turbocharger gear train can result, or objectionable oil "souping" or smoking can occur. To prevent undesirable operating conditions, observe speed-load restrictions shown in Fig. 2-24.

NOTE: The term "souping" is meant to indicate the accumulation of oily carbon in the exhaust system. The condition may occur during the full speed low load operation.

TABLE OF ENGINE SPEED AND LOAD RESTRICTIONS		
SPEED, RPM	LOAD, KW	TIME LIMIT OR OTHER CONSIDERATION
720 or 750 RPM - 1500 KW Base Load (60 cycle)		
Idle	0	No restriction
720 /600	0	1 Hour Maximum
720 /600	100	1 Hour Maximum
720 /600	200	Undesirable "souping" condition that should
720 /600	300	be held to a minimum
720 /600	375-1500	No restriction
720 /600	1650/1375 (10% overload)	Not to exceed 2 hours continuous out of any 24 hour period

NOTE: 50 cycle unit RPM speed is 600, 10% overload is 1375

Fig. 2-24.- Table Of Engine Speed And Load Restrictions

AIR INTAKE FILTERS

GENERATING UNIT FILTERS

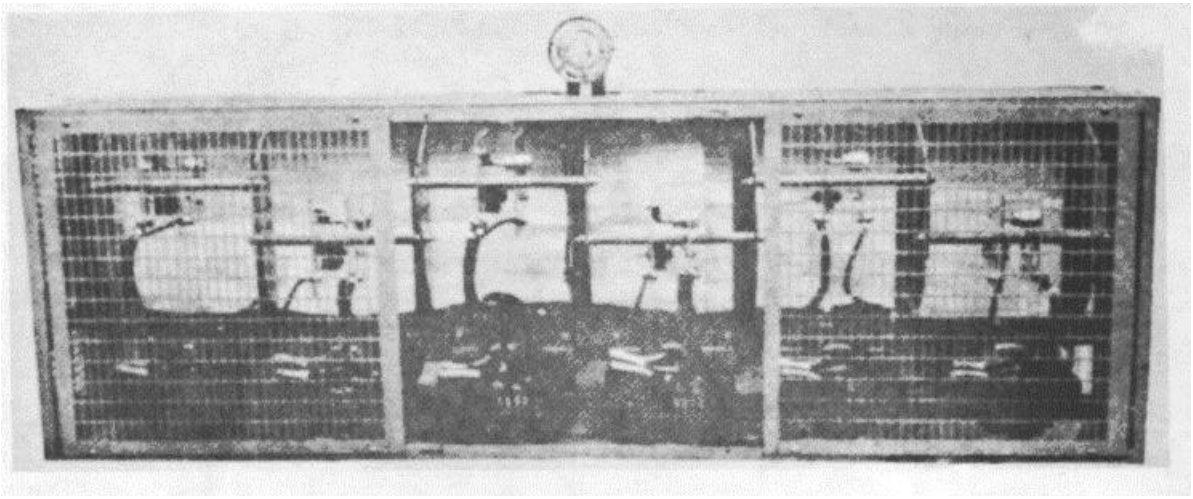
The air intake filter assemblies are built into the generator end of the unit. The filters are fitted with replaceable glass wool blankets, impregnated with a viscous fluid that does not dry out over a long period of service. Each pad is fitted inside a louvered air intake panel. Should the filters become plugged, the spring loaded mounting panels will pull open to admit air to the unit.

ENGINE FILTER ASSEMBLY

The filter assembly is composed of panel type oil bath filters. Oil level and cleanliness should be checked periodically in accord with the Scheduled Maintenance Program.

STATIC EXCITER, Fig. 2-25

The static exciter is mounted near the roof at the generator end of the unit and is located directly above the body intake air filters. The exciter incorporates rectifiers and re-actors in a magnetic-amplifier combination. The output of the magnetic amplifier is employed to excite the generator field. The exciter location provides for cooling of the rectifier elements by the engine intake air stream.



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Fig. 2-25. - Static Exciter

GENERATOR CONTROL CABINET

The generator control cabinet, Fig. 2-26, contains primarily heavy duty contactors related to generator excitation, engine starting, fuel transfer, and oil heating. The functions of these contactors are described in the electrical equipment description section of this manual.

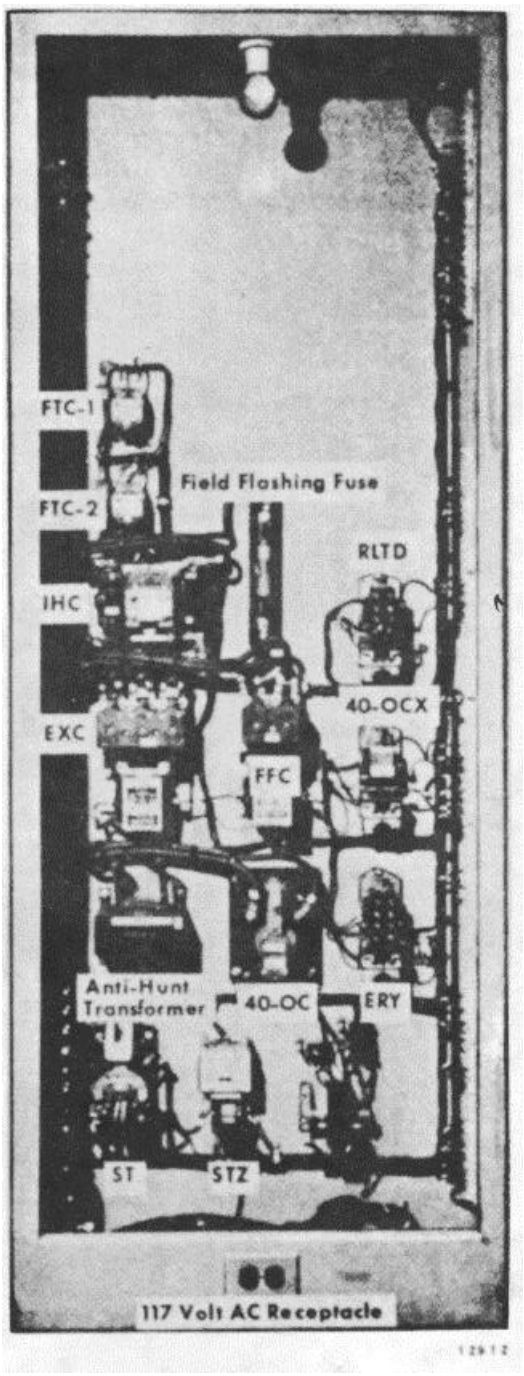


Fig. 2-26. - Generator Control Cabinet

ENGINE CONTROL CABINET

The engine control cabinet, Fig. 2-27, is mounted on the accessory rack located at the governor end of the engine. The following items are visible on the outside of the cabinet:

OIL PRESSURE GAUGE

Oil pressure as indicated on the gauge Is taken from a line supplying oil to the turbo-charger. This same pressure is sensed by MB-1 and MB-2 pressure switches.

HOT ENGINE LIGHT

This light comes on when the engine temperature switch ETS picks up. ETS picks up when water temperature at the engine water outlet is approaching the boiling point, but

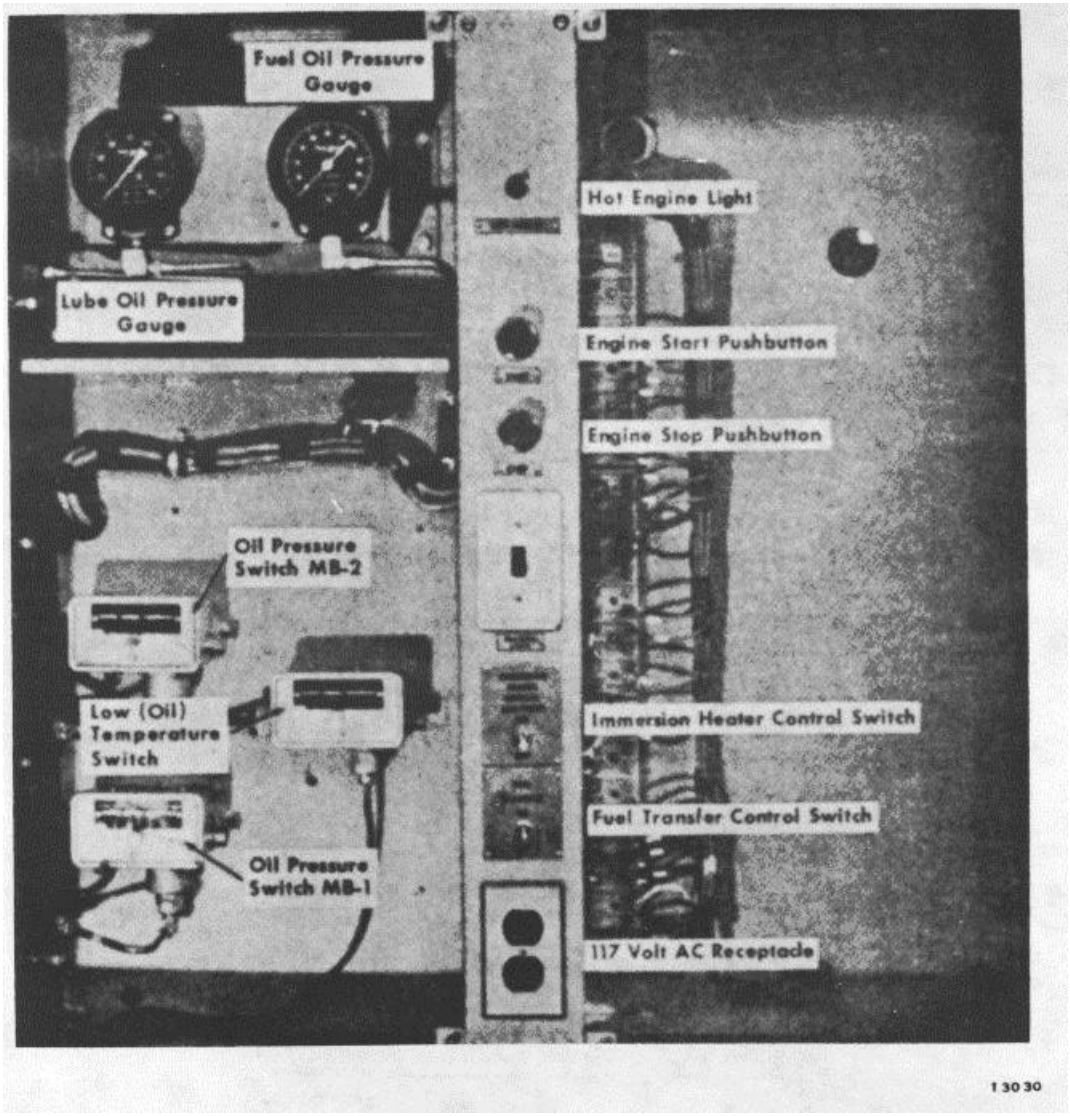


Fig. 2-27. -- Engine Control Cabinet

due to the heat loss between the engine and the switch location, the switch is calibrated to pick up at much less than 212 degrees F. The light goes off when engine temperature returns to normal.

ENGINE START PUSHBUTTON

This pushbutton can be used for operator controlled start of the diesel engine.

ENGINE STOP PUSHBUTTON

This pushbutton is provided for operator controlled stop of the generating unit from within the generating unit enclosure. The annunciator registers a fault when the engine is stopped in this manner.

IMMERSION HEATER CONTROL AND PUMP SWITCH

This toggle switch must be on before the lube oil circulating pump motor will run. The switch also provides a feed to the immersion heater contactor, the pickup of which is controlled by a temperature switch.

FUEL TRANSFER SWITCH

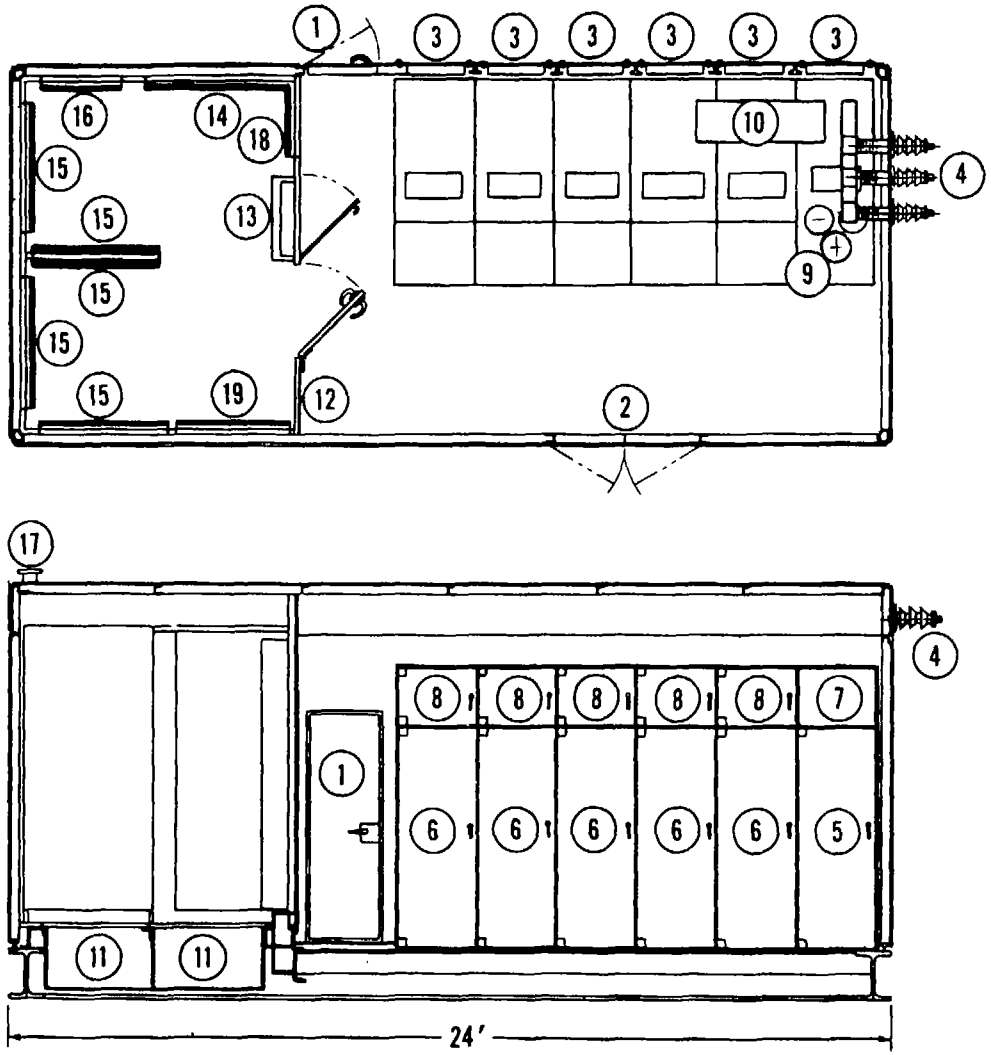
This switch appears only on the one unit that is equipped with fuel transfer pumps. The switch provides the feed to the fuel transfer contactors, the pickup of which is controlled by float switches.

ENGINE STARTING MOTOR

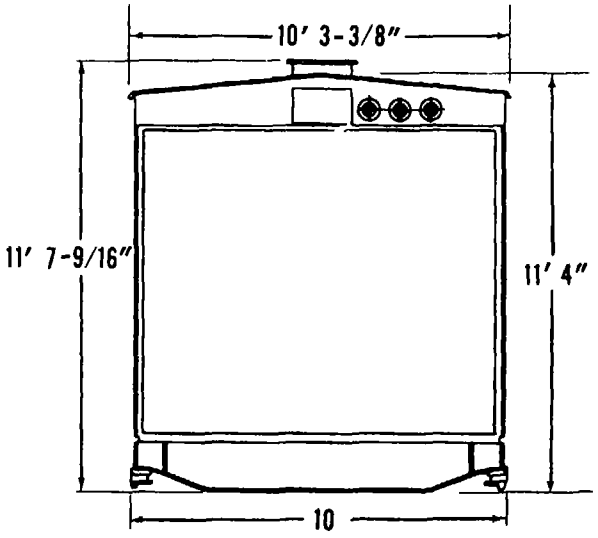
A single 120 V engine starting motor is used to crank the diesel engine during starting. A Dyer drive is used on the starter motor to mesh with the ring gear when attempting to crank the engine. A timing relay limits engagement attempts to five. A speed sensing device de-energizes the cranking circuit after the engine fires and is accelerating.

A heavy duty resistor is used to reduce voltage to the cranking motor during the first four seconds of cranking. This limits the cranking effort and prevents a build-up of momentum for the first revolution of the engine. Should a hydraulically locked piston be encountered, the engine will cease to rotate. Protective circuits will signal a starting fault and lock the engine out. If the engine is free to rotate, full cranking power is applied after four seconds and fuel is injected into the cylinders.

Refer to Part II of this publication for a more detailed description of the engine starting motor.



1. Access Door
2. Service Doors
3. Removable Panel
4. Power Terminals
5. Bus Metering Transformer Compartment
6. Circuit Breaker Compartment
7. Access Panel
8. Generator Metering Transformer Compartment
9. Surge Protective Equipment
10. Control Power Transformer
11. Battery Compartment
12. Annunciator And Control Panel
13. Fuse Panel
14. Master Control Panel
15. Unit Control Panel
16. Auxiliary Control Panel
17. Battery Box Vent
18. Control Cable Terminals
19. Battery Charging And Speed Sensing Panel



13874

Fig. 3-1. - Control Unit - Five Generating Unit Installation

SECTION 3

CONTROL UNIT

The electrical equipment for controlling the automatic operation of the generating units is contained in the master control unit (MC unit). The interior of the control unit is divided into two sections; a relay room and a control room as shown in Fig. 3-1.

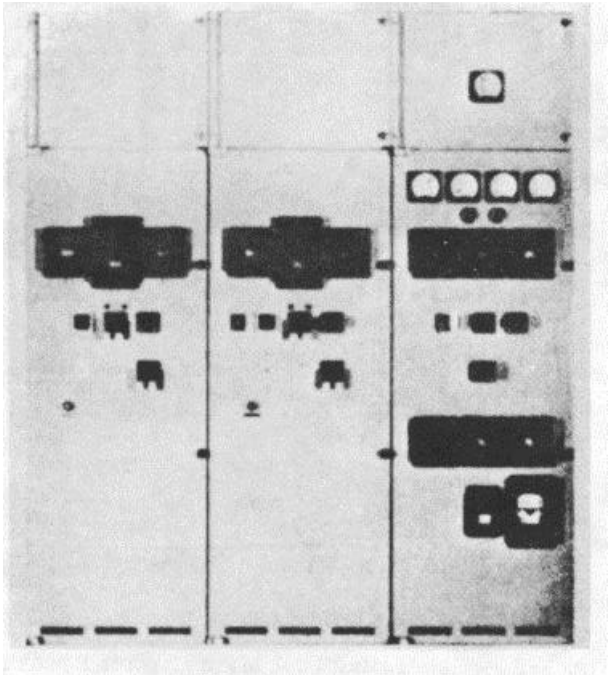
The control room contains switchgear and transformer compartments, Fig. 3-2. There is one main circuit breaker for each power unit controlled. Meters, protective relays, and manual controls are located on the compartment doors. Additional controls for manual operation, a fuse panel, and a fault annunciator are located on the wall that divides the control room from the relay room.

The relay room contains control panels as indicated in Fig. 3-1, with the quantity of unit control panels dependent upon the number of generating units to be controlled. Batteries for starting and control are located below lift-up sections in the relay room floor.

EQUIPMENT IN THE CONTROL ROOM

CIRCUIT BREAKER COMPARTMENT

The MU installation contains from one to five main circuit breaker compartments, each equipped with a roller-mounted air circuit breaker assembly, Fig. 3-3. Each breaker has a guide track and interlock mechanism, Fig. 3-4, and can be levered into the disconnect, test, or connect position by the tools provided. Controls necessary for manual operation of the breaker and generating unit are located on the face of the compartment door, Fig. 3-5.



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Fig. 3-2. - Switchgear And Transformer Compartments

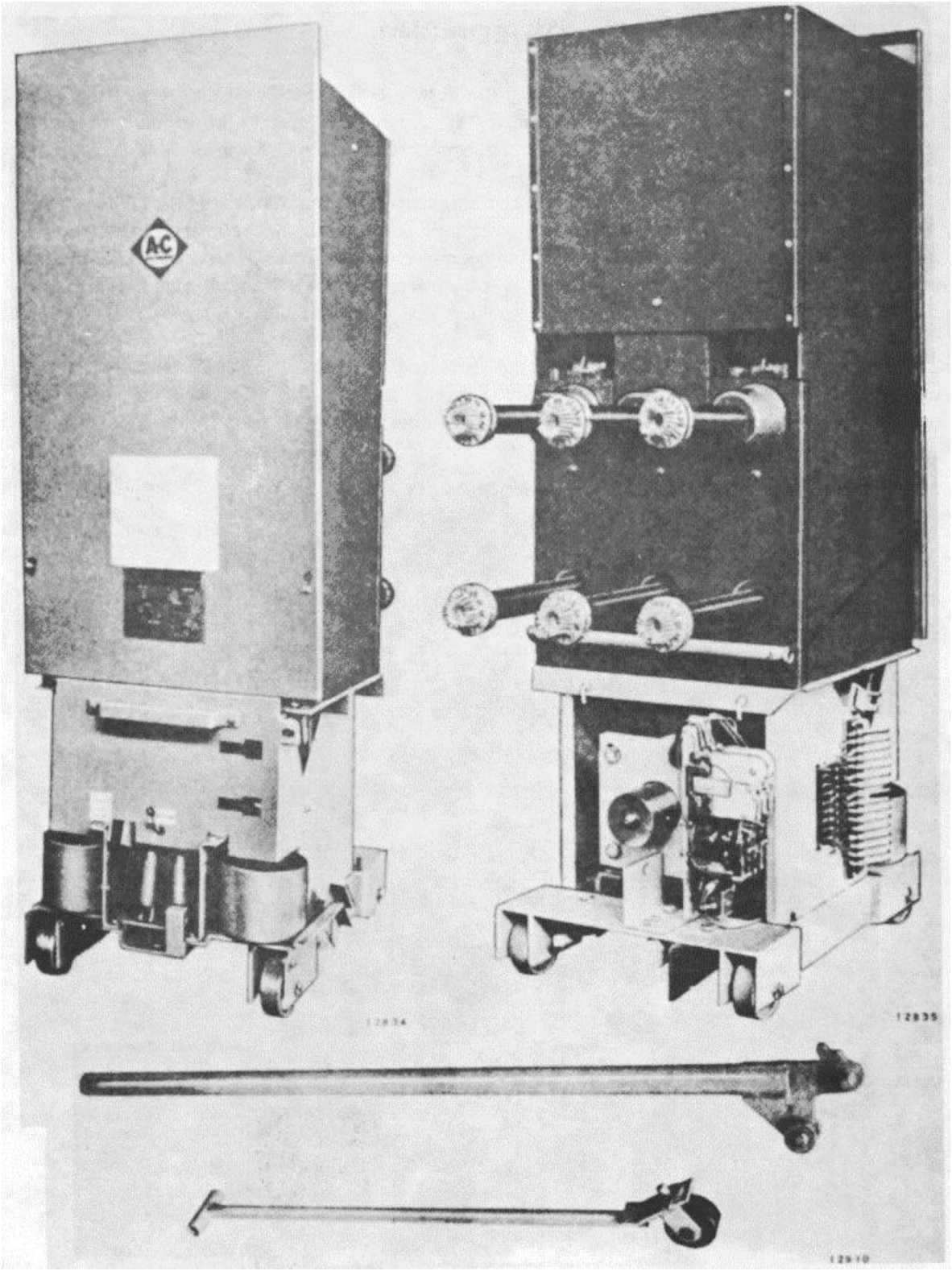


Fig. 3-3. - Generating Unit Main Circuit Breaker And Positioning Tools

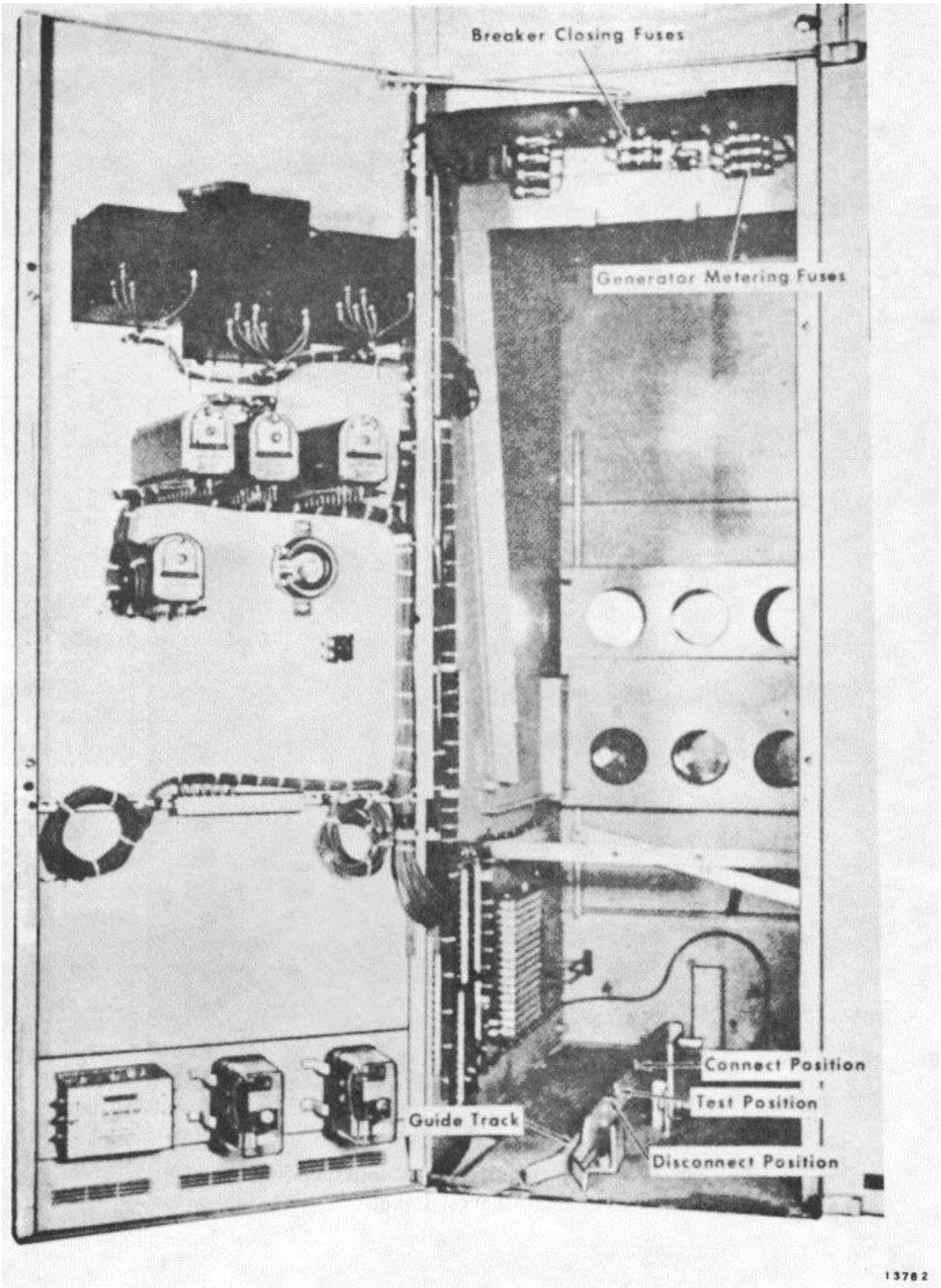


Fig. 3-4. -- Circuit Breaker Compartment

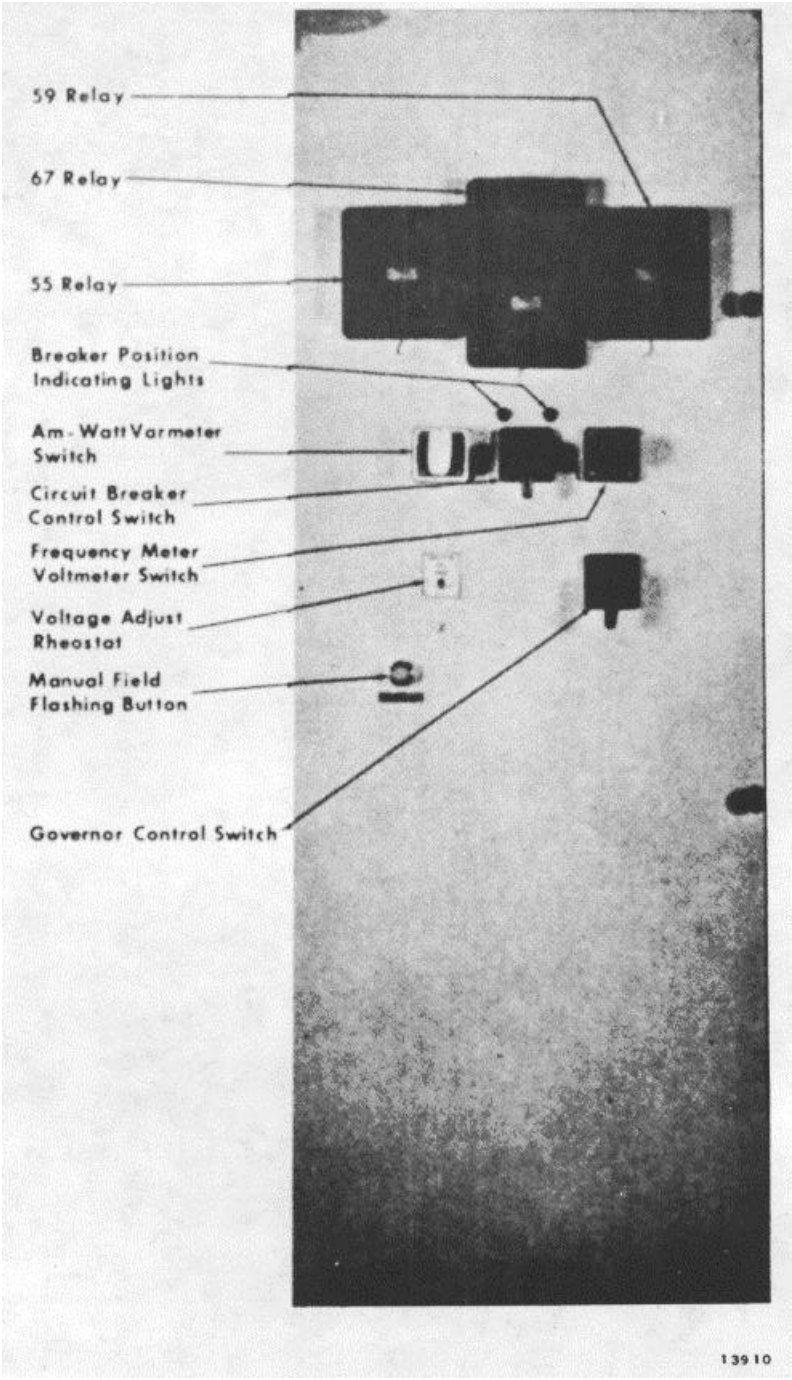


Fig. 3-5. -- Circuit Breaker Compartment Manual Control Panel

GENERATOR METERING TRANSFORMER COMPARTMENT, Fig. 3-6

This compartment is located above the circuit breaker compartment. It contains the generator metering transformers and the high voltage fuses. These components are accessible by opening a swing-out door and a pivoted carriage. When the carriage is pivoted downward, transformers and fuses are exposed and disconnected from the circuits. When the carriage is in normal position it is held in place by side latches. The inner carriage must be closed and latched and the swing out door must be closed and securely fastened during operation.

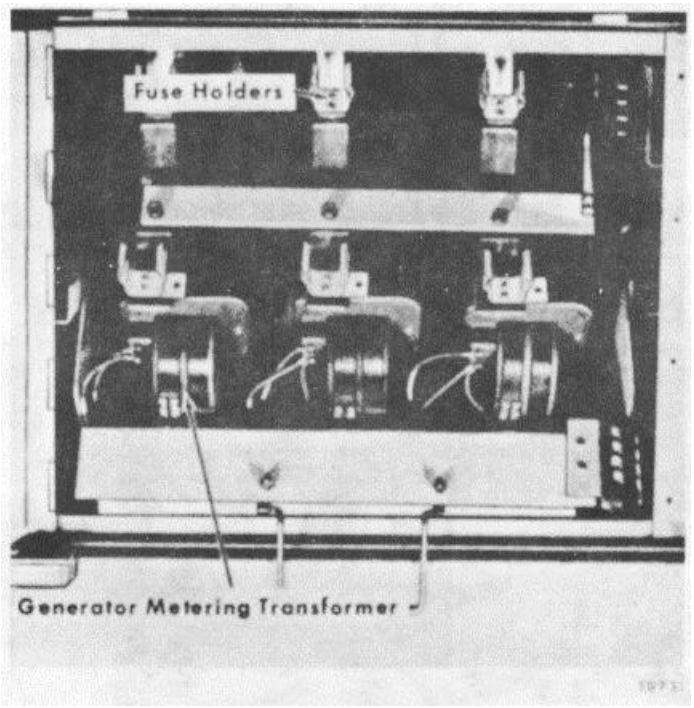


Fig. 3-6. - Generator Metering Transformer Compartment

BUS METERING TRANSFORMER COMPARTMENT, Figs. 3-7 and 3-8.

This compartment contains three sections as follows:

The top section contains a circuit breaker to protect the control power transformer, which is located above and behind the bus metering transformer compartment and the adjacent circuit breaker compartment. A metal plate containing a key and lock arrangement is located in front of the circuit breaker. The circuit breaker must be in the off position before the key can be removed. This locks the circuit breaker in the off position. The key can then be used to unlock the pivoted carriage that contains the control power transformer fuses.

The center section contains a pivoted carriage that is equipped with bus metering transformers and fuses. The carriage is held in place by side latches.

The lower section contains a pivoted carriage that is equipped with control power transformer fuses, The carriage is normally locked, and can be opened by use of a key that

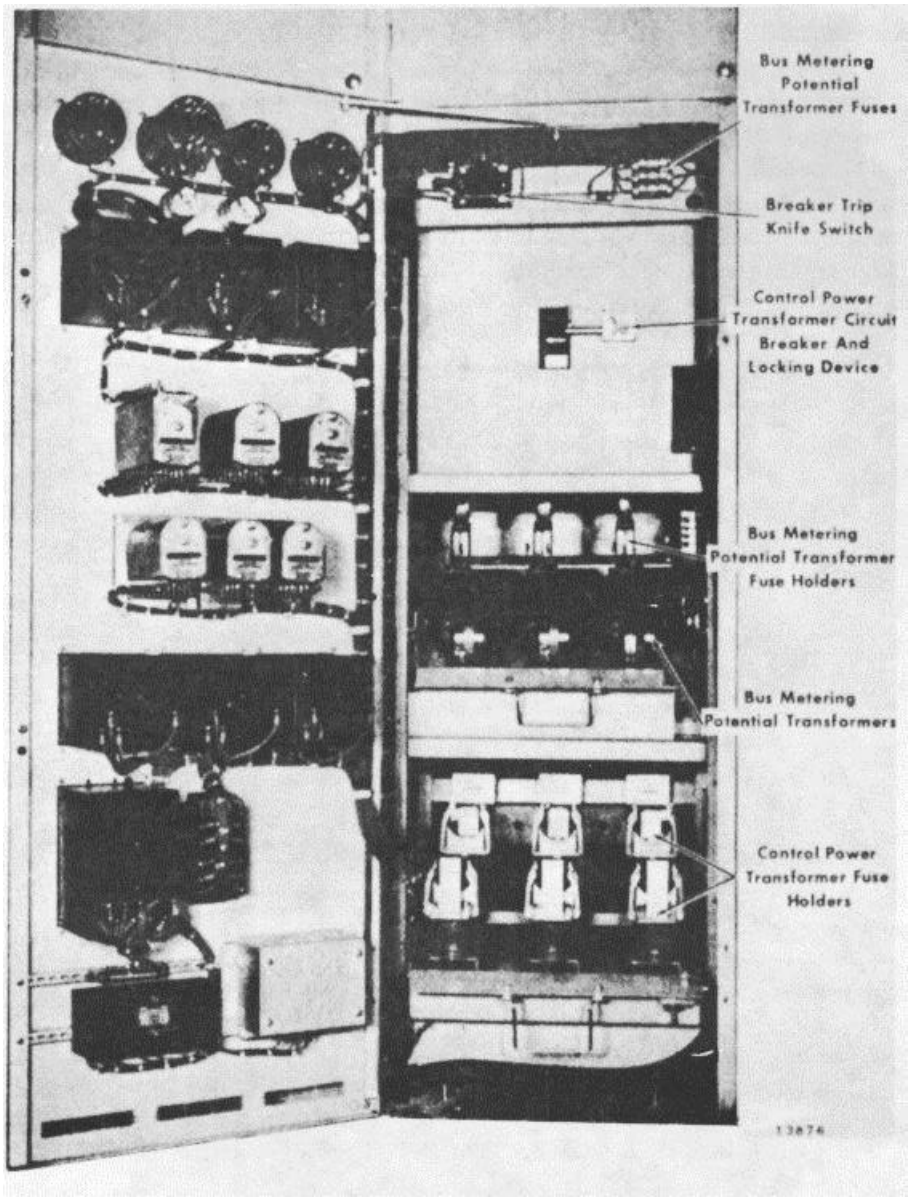


Fig. 3-7. - Bus Metering Transformer Compartment

is removed from the circuit breaker lock when the control power transformer circuit breaker is in the off position.

The front door panel of the transformer compartment, Fig. 3-8, contains meters for monitoring MU installation operation, and it also contains protective relays.

ANNUNCIATOR, Fig. 3-9

The annunciator, by neon light display, gives visual indication of abnormal operation. The red FAULT light comes on whenever a fault occurs in any generating unit in the MU installation or when a system fault occurs. System fault indications such as FUEL

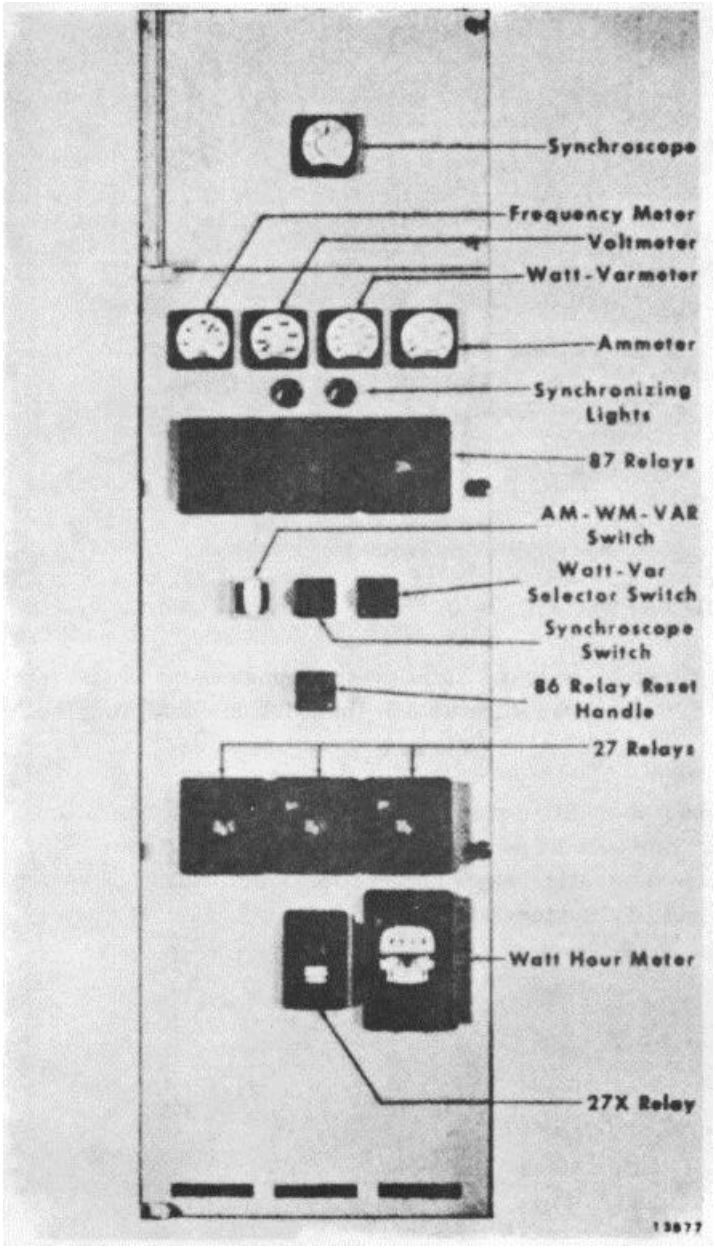


Fig. 3-8. - Bus Metering Transformer Compartment Instrument Panel

TRANSFER or EXTERNAL FAULT appear regardless of the UNIT selector switch position. Specific generating unit fault indications appear when the selector switch is positioned to the number of the generating unit in which the fault has occurred.

Certain faults result in engine shutdown; others provide only indication of the fault. Refer to Section 8 for a detailed description of annunciator operation.



12837

Fig. 3-9. - Annunciator Panel

OPERATING CONTROL PANEL, Fig. 3-10

The operating control panel is located just below the annunciator on the relay room wall. Fig. 3-10 illustrates a control panel for an MU installation containing the following.

1. Five generating units.
2. Equipment for automatic deadline operation (Isolated System Operation).
3. Equipment for operation as a base load or a peaking installation.
4. Equipment for semi-automatic resynchronization (restoration of system tie).
5. Equipment for control of a system tie breaker.

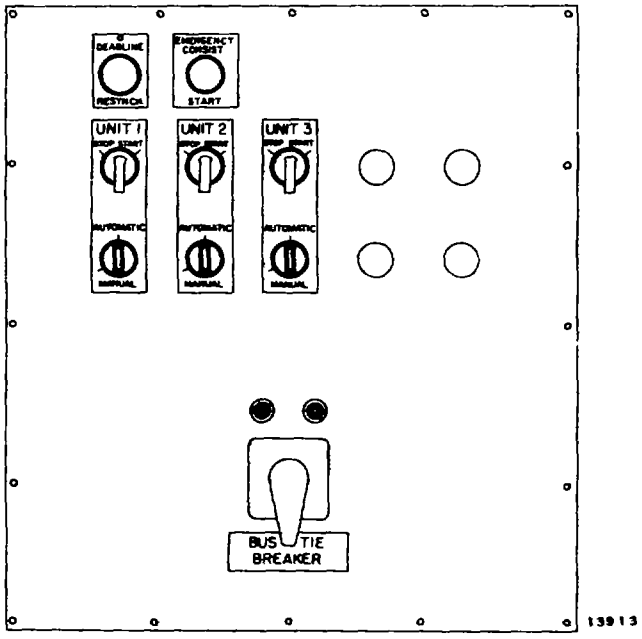
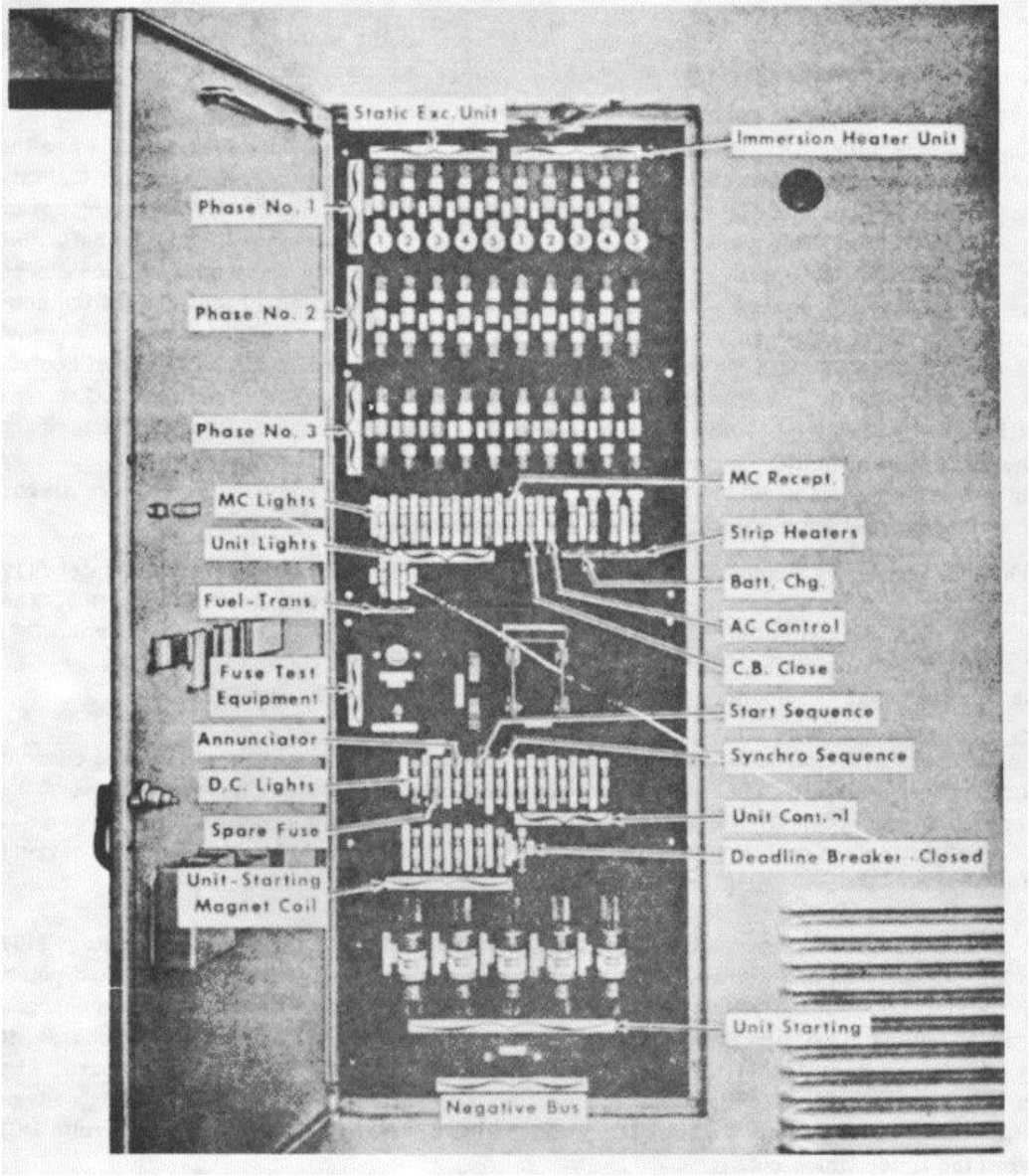


Fig. 3-10. - Operating Control Panel
(MU Installation With Three Generating Units)

MAIN FUSE PANEL, Fig. 3-11

The main fuse panel is located to the right of the entry to the relay room. It is divided into two sections; the upper section contains fuses for AC circuits, the lower section contains fuses for DC circuits. Equipment for testing fuses is centrally located on the panel. Always test a fuse before installing it.

Removable links on the back of the AC panel permit standby equipment such as battery charger, lights, and immersion heater to be supplied from an external source, if desired.



13734

Fig. 3-11. - Main Fuse Panel (Typical MU Installation With Five Generating Units)

With this external source, the control power transformer and the high voltage bus can be de-energized when the units are not operating.

EQUIPMENT IN THE RELAY ROOM

BATTERY CHARGING AND SPEED SENSING PANEL, Fig. 3-12

This panel is mounted just to the left as you enter the relay room. It contains the battery charger with associated relays, and engine speed sensing panels. The speed sensing panels are not related to the battery charging function, they merely make use of available space.

The battery charger is a completely automatic, solid state, constant voltage device having the following characteristics; A.C. voltage compensation, D.C. voltage regulation and current limiting, see Fig. 3-13.

The Transformer, Saturable Reactor, Silicon Rectifier Stacks, and Control Unit are the four basic components of the charger. The transformer changes the incoming A.C. voltage to the required level to charge the battery and also isolates the incoming power from the output. The saturable reactor regulates the power output of the transformer continuously over the charge cycle. The rectifier stacks are made up of silicon diodes to change the secondary A.C. power to D.C. power. The control unit senses the condition of the battery and controls the reactor which in turn regulates the power output of the transformer. Power for charger operation is taken from the MU bus and control power transformer, or from a separate station service supply. In case of an A.C. power failure a relay is provided to disconnect the automatic control from the battery and thereby eliminate any drain on the battery. One set of normally closed contacts from this relay is connected to terminals for connection to a remote power failure alarm. The charger will automatically resume charging upon return of A.C. power.

When a battery is discharged or standing idle its terminal voltage (approximately 112 volts DC) will be less than its on charge float or equalize voltage (131 volts DC). The charger will immediately begin to charge the battery at its rated output to 131 volts DC. When this voltage is reached the charge rate will begin to taper to a trickle charge of an amount necessary to maintain the battery voltage at 120 to 131 volts DC.

The charger will charge to its maximum current capacity (28 amps.) and begin to current limit if overloaded. The automatic current limiting feature limits the output of the charger to a maximum of 140% rated load, (chargers rated current capacity 20 amps.). The saturating current resistor is pre-set and factory adjusted to the required current limiting.

A potentiometer is provided to adjust the DC output so that the desired float voltage (127 volts DC) may be maintained. If the potentiometer does not give the required float point, the slider bands of the voltage divider located across the output terminals of the charger may be adjusted to give the required operating voltage. To give an equalizing charge, it is only necessary to set the timer control for any amount of time up to 24 hours. The rectifier will automatically hold the cell voltage (2.17 volts DC) at equalizing voltage (2,33 volts DC) for the pre-set time and will drop back to float voltage (127 volts DC) when the timer times out.

The A.C. input line is fused with a 45 Amp., 250 volt A.C. fuse and the D.C. output line is fused with a 35 Amp., 250 volt D.C. fuse.

The only maintenance required on the battery charger is an occasional blowing out of dust and tightening of connections.

One speed sensing panel, Fig. 3-14, for each generating unit in an installation is mounted above the battery charging control panel. A frequency generator mounted on the front end of the engine supplies a signal to the speed sensing panel. The signal initiates pickup of relays at various speeds to cause proper sequencing.

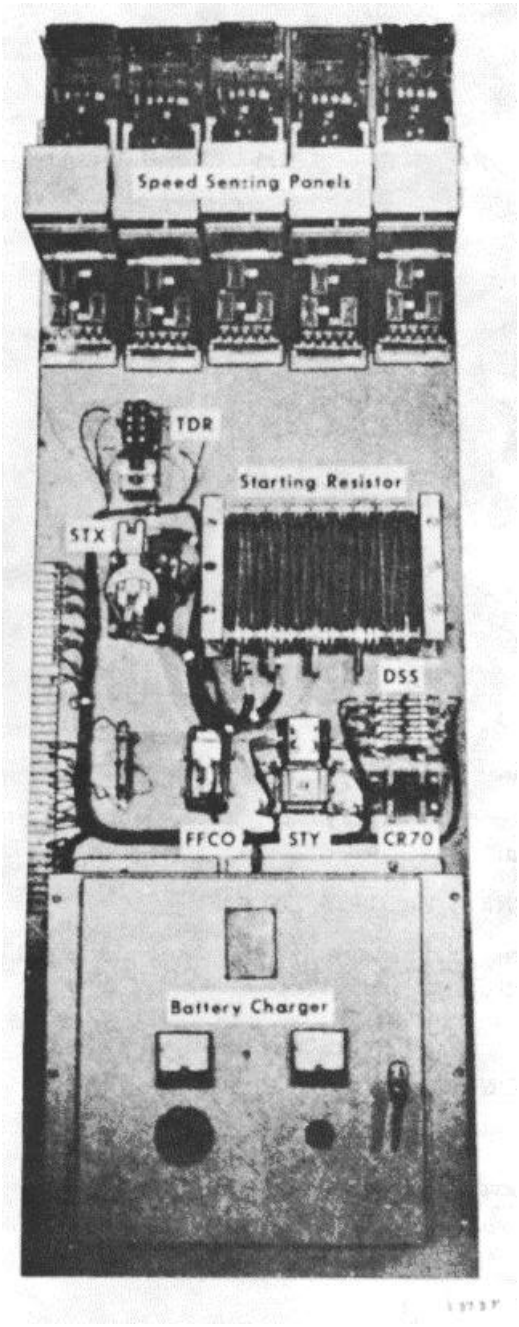


Fig 3-12. - Battery Charging And Speed Sensing Panel (MU Installation With Five Generating Units)

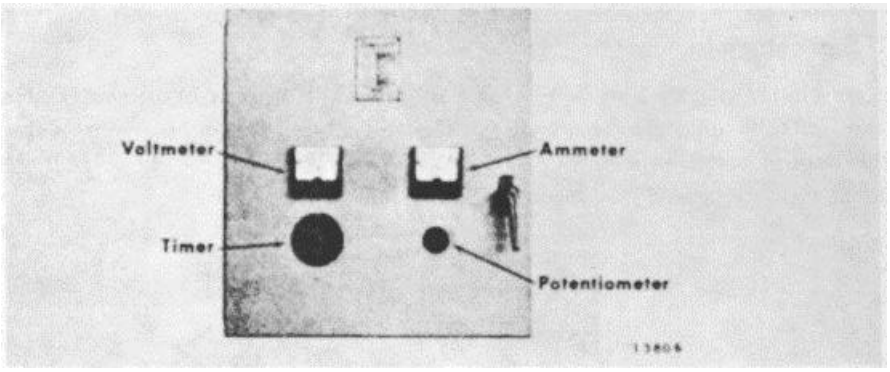


Fig. 3-13. - Battery Charging Controls

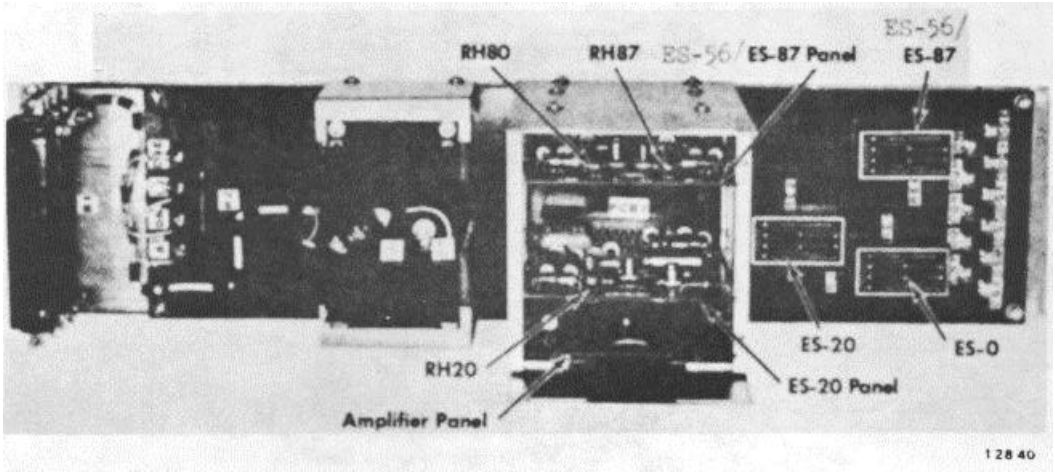


Fig. 3-14. - Speed Sensing Panel

UNIT CONTROL PANEL, Fig. 3-15

The unit control panel contains relays and other electrical devices related to operation of a single generating unit.

MASTER CONTROL PANEL, Fig. 3-16

The master control panel contains relays and other electrical devices related to operation of all generating units in an installation.

AUXILIARY MASTER CONTROL PANEL, Fig. 3-17

The auxiliary master control panel for the basic MU installation contains a KW limiter, a static synchronizer, and a governor amplifier. This equipment is employed at proper times in the operating sequence by each generating unit in an installation.

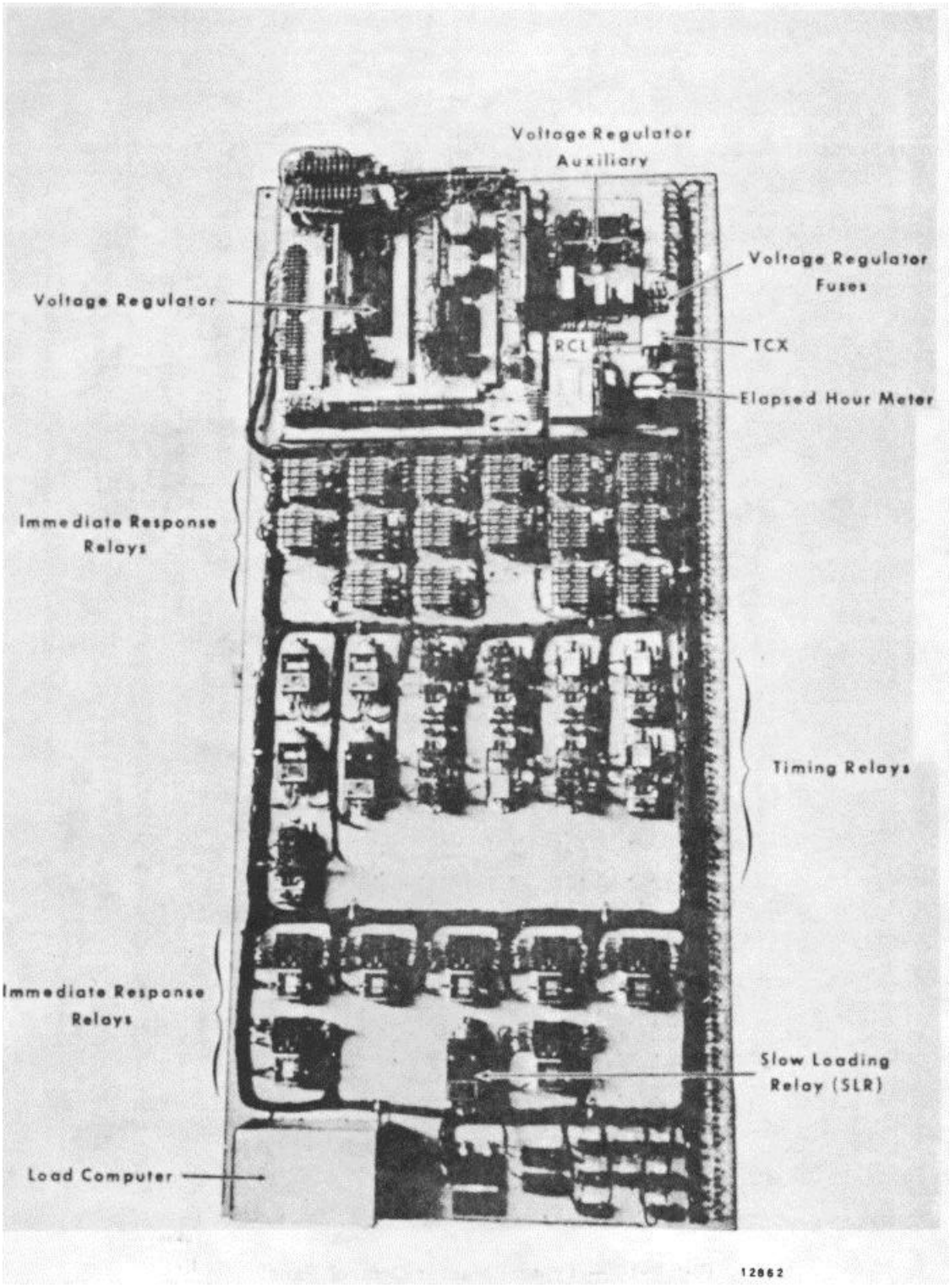


Fig. 3-15. - Unit Control Panel - Typical Installation

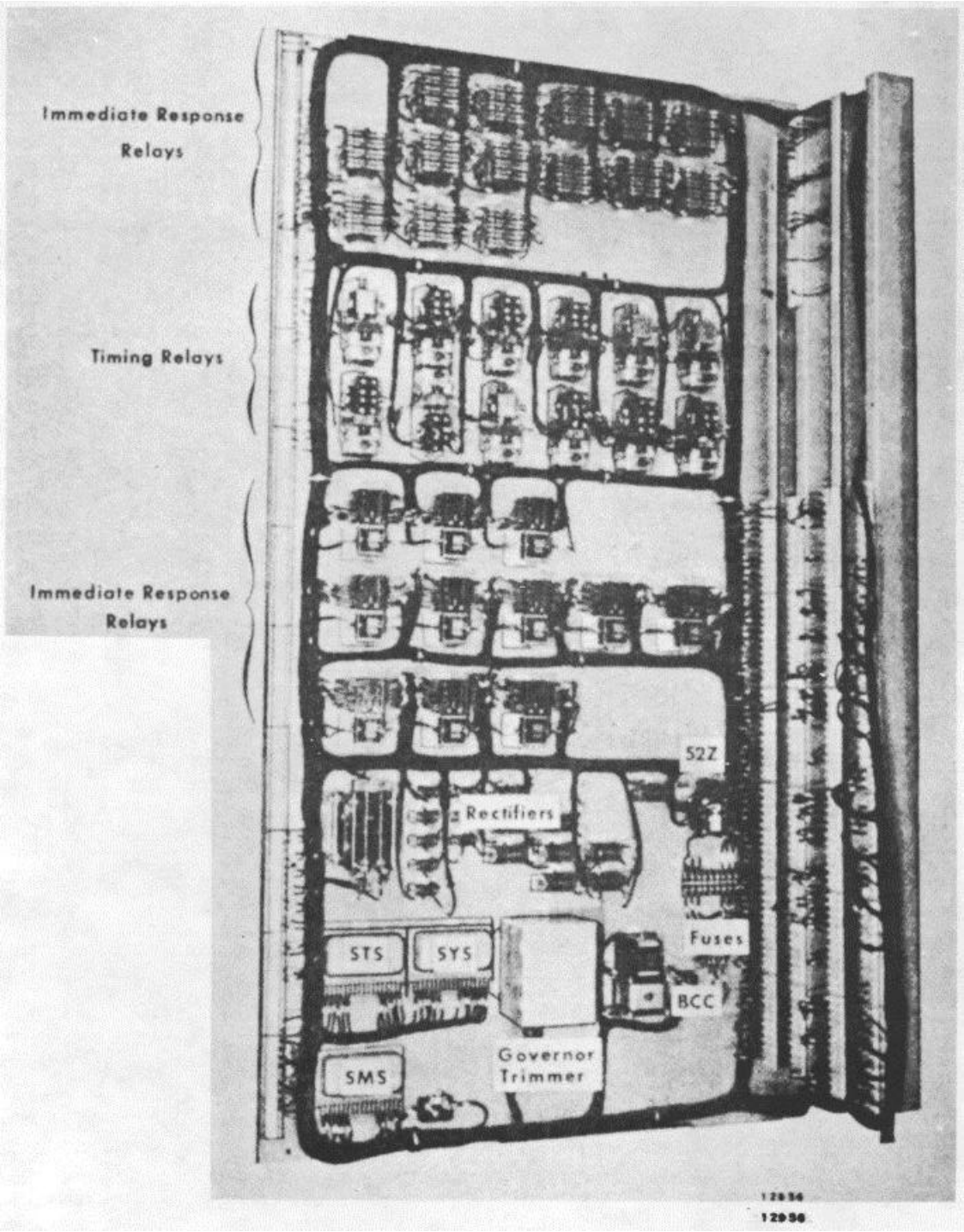


Fig. 3-16. - Typical Master Control Panel

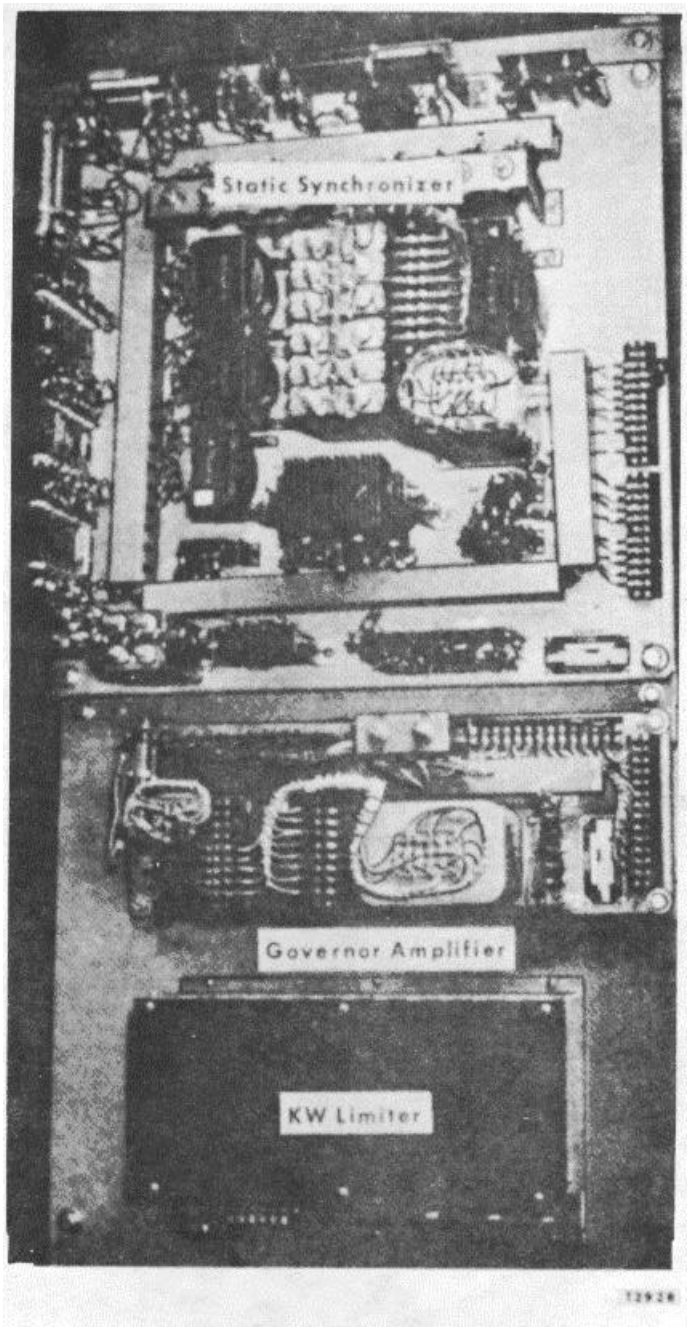


Fig. 3-17. - Auxiliary Master Control Panel

BUS TIE BREAKER

A load circuit breaker, Fig. 3-18, is provided to connect the MU installation bus to the load. This breaker is housed in a weatherproof steel shelter mounted on a concrete slab. A transfer truck is provided for handling the breaker in and out of the shelter.

A breaker operating switch identified as BUS TIE BREAKER is provided on the control panel in the MC control unit. This switch is used to connect the MU installation to a load or disconnect it from a load.

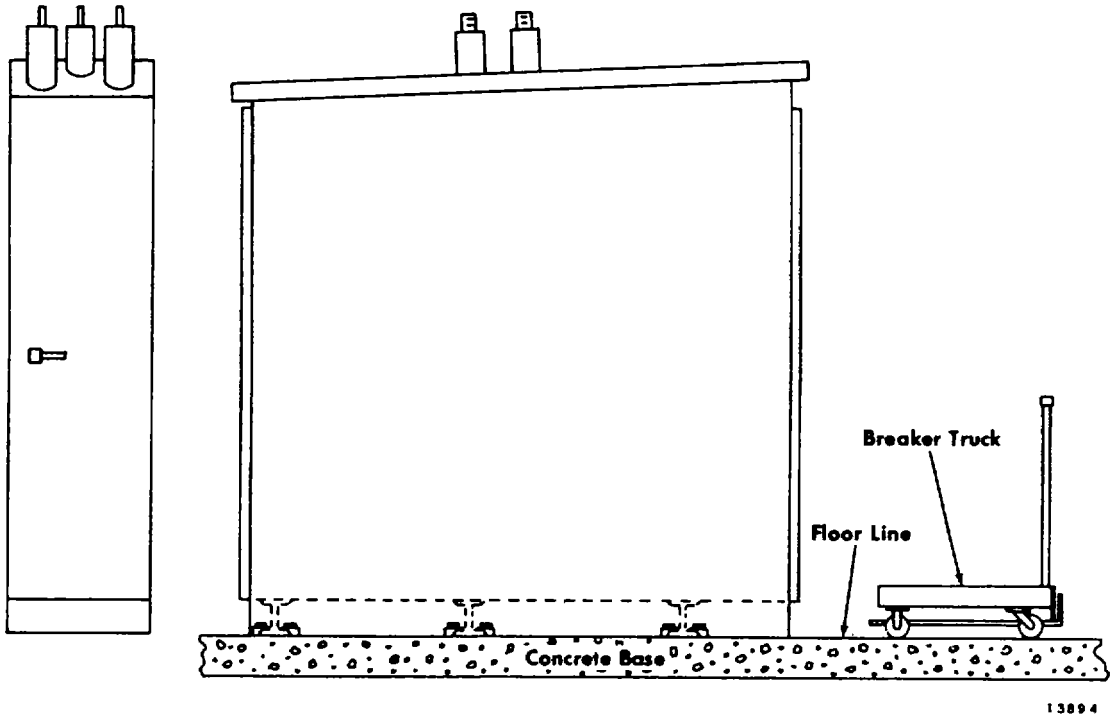


Fig. 3-18. - Bus Tie Breaker

SECTION 4

INSTALLATION AND PRE-SERVICE CHECK

GENERAL

The design and construction of the MU power plant is such that the control unit and generating unit can be transported to and positioned at a previously prepared power plant site and put into operation without major servicing or assembly procedures. All wiring within the individual units has been connected at the factory. The grounding connections, the power unit to control unit connections, and the control unit system connections are all that have to be made at the site.

Since the engines have been run and tested at the factory no break-in procedure is required. After these installation and pre-service checks have been made the units may be placed in commercial service.

Additional installation and pre-service information maybe found in applicable Maintenance Instructions.

WARNING: An MU installation is completely automatic and the diesel units will start by themselves when proper connections are complete. Therefore do not install the 400 ampere starting fuse until all preliminary checks have been made and the unit is ready to run.

INSTALLATION

Installation of the units consists of moving them into their proper location on the previously prepared site, adding the necessary supplies, and making the proper connections to them.

Most piping and wiring between generating units and the control unit is made underground. It is often desirable to install the underground portion of the piping and wiring while preparing the site.

Fuel oil equalizing lines must be installed between all power units, and a supply line must be installed from the user's fuel storage tank to the power unit with the fuel transfer equipment.

Grounding connections should be made according to the recommended installation drawing or modified as required to meet individual customer system requirements.

The cables connecting the power unit to the control unit are installed in a trench between these units. Generally it is not practical to move the control unit into place while the trench is open. Therefore, it is desirable to have all of these cables in place and the trench filled before the arrival of the units, or else wait until the control unit is in place before opening the trench. For the exact cable requirements refer to the field connection drawing for the particular installation.

The control unit to system connections are of three types, high voltage power connections, remote control connections, and the signals to the control unit about system conditions. The system condition signals convey such information as line voltage, position of user's load breaker, and system tie breaker position. The signals are necessary since the MU installation is equipped for such automatic operations as resynchronization.

The control unit to system connections are considered part of the MU installation. Therefore the breaker for that connection is shown on EMD drawings. The power connections are made on the outside of the control unit and all other connections are made at a single location in the relay room.

GENERATOR NEUTRAL

The generator neutral may be left ungrounded, or it can be connected with a solid or impedance type ground. Both a ground connection and a neutral connection are accessible in each power unit. It is recommended that the generator neutral connection, if any, be made by the customer to meet system requirements.

The main generator is built per NEMA standards which specify that it must be able to withstand a three phase short circuit at its terminals. It is possible, however, that under some conditions a single phase line-to-ground fault will produce fault currents exceeding those of a three phase short circuit. The customer should consider the possibility of such conditions occurring on his system and apply appropriate grounding accordingly.

SUPPLIES

Lubricating oil, cooling water, and battery electrolyte must be placed in the units before operation is started. Prelubrication may be necessary if the units have been stopped for over one month. See Part II of this publication for details.

Applicable Maintenance Instructions list lubricating oil specifications, diesel fuel specifications, and proper cooling water treatment.

PRE-SERVICE CHECKS

Before the MU installation is considered complete, the following inspections and checks should be made:

1. Check all rotating equipment to see that it is mechanically free and in satisfactory operating condition. Refer to applicable deprocessing and inspection Maintenance Instruction for additional information.

2. Check engine to generator alignment as indicated in applicable Maintenance Instruction. The alignment may have become disturbed because of shocks and stresses encountered during shipment.

3. Inspect air box and oil pan as indicated in Part II of this publication.

4. Remove all protective shipping materials, silica gel bags, and plywood coverings. Particular attention should be given to removing any blocking applied to protect electrical devices such as relays, contactors, and switches.

5. Prepare batteries for service, if 'shipped dry-charged, and check storage battery electrolyte level, specific gravity, and voltage in accordance with applicable Maintenance Instruction.

6. Remove and inspect circuit breakers. Make sure that the phase barrier stacks are properly installed. Manually close breaker to check that it is free. Return breaker to test position. Do not place breaker in connect position until ready to check phase rotation.

NOTE: Circuit breakers are shipped while blocked in the closed position. Blocks should be removed and the breakers moved to test or disconnect position before any power connections are made.

7. Check all wiring connections for tightness. See that all connectors and plugs are properly installed.

8. Fill day tanks with fuel oil. To do this it is necessary to make a temporary jumper connection at the ZSR to permit operation of the fuel transfer pumps without an engine running. Be sure to remove the jumper when finished.

9. Make sure that all air passages are open. Check fan compartment, radiators, and air intake filters.

10. Check operation of the lube oil circulating pump. Prior to initial operation, allow the pump to run for 15 minutes to thoroughly flush the turbocharger bearings.

CAUTION: The circulating pump switch controls operation of the immersion heater contactor. Do not energize the immersion heater until there is water in the engine cooling system.

PRECAUTIONS BEFORE STARTING ENGINE FOR THE FIRST TIME

It is recommended that the following checks be made immediately before starting the engine for the first time.

1. Check that unit automatic/manual switch is in the MANUAL position.

2. Circuit breaker should be in test or disconnect position.

3. Make sure that all necessary fuses are in their proper position. Static exciter fuses should be removed to prevent generator excitation at this time. The electrical tests of the generator will be made when the unit is ready for the phase rotation check.

4. Battery charger should be in operation.

5. Check all switches for proper position.

6. Check all valves for proper position.

7. Check lube oil level.

8. Check coolant level.

9. Check governor oil level.

10. Check that all handhole and oil filter covers are tight.

11. Check that overspeed lever is in set position.

After these checks are completed start engine manually from engine control panel, then make the following checks:

1. Exhaust damper valve should be open.

2. Lube oil pressure should be over 30 psi.

3. Fuel oil pressure should be over 10 psi.

4. Inspect top deck for proper lubrication.

5. Check all piping for leaks**.**

PHASE ROTATION CHECK

The final check to be made before the units are connected to each other is the phase rotation check. All units must be checked individually for A-B-C Positive phase rotation.

The phase rotation meter should be connected to the control unit bus metering circuit. This may be done at a voltmeter switch or at a 6 ampere fuse in this circuit.

To check the sequence of one unit, open line disconnect switches and place all other circuit breakers in test or disconnect. Only the circuit breaker of the unit being checked should be in the connect position. Start unit in deadline mode and bring to correct voltage and frequency.

If all connections have been made according to the wiring diagram the phase rotation will be correct on the first check.

OTHER TESTS AND CHECKS

After the phase rotation check has been completed the MU installation should be checked for proper operation.

The annunciator alarm system and engine settings should be checked.

SECTION 5

MANUAL OPERATION

The MU power plant has been designed for fully automatic operation. However, in some situations, it is desirable to operate an MU unit under manual control. The manual controls also provide backup protection in that a unit may be used even though there is a defect in the automatic Ac sequence.

AUTOMATIC/MANUAL SELECTION

Selection of automatic operation or manual operation is accomplished by turning the automatic manual switch AMS to the desired position. This is a two position rotary switch located beneath the start-stop switch. A unit may be switched from automatic to manual or from manual to automatic at any time.

Transfer from automatic to manual will cause the unit to remain in the condition that it is at the time of transfer. For instance, a unit which happened to be in idle when the switch was turned to manual will remain at idle speed indefinitely. It will not respond to automatic start or stop signals.

Transfer from manual to automatic will cause the unit to complete the sequence called for by the last automatic signal received, even if this signal was received while the unit was in manual.

MANUAL CONTROLS

START BUTTON

A start pushbutton is located on the engine control panel in the power unit. This button is effective only when the AMS is in manual and must be used because the start-stop switch in the control unit is not effective. The button must be pushed and held until the engine starts. After the engine starts it will go to idle speed and remain at idle speed indefinitely.

STOP BUTTON

A stop pushbutton is also located on the engine control panel. This button is effective regardless of the position of the AMS. Engine will unload, if loaded, and then stop. The MANUAL STOP fault on the annunciator will light and the unit will be locked out.

SPEED CONTROL

A governor control switch is located on the circuit breaker control panel in the control unit. This switch controls the governor motor which in turn changes the speed setting of the governor. When the control unit bus is dead the governor motor will not work and the speed must be changed by using the speed setting knob on the governor.

CIRCUIT BREAKER

A unit circuit breaker may be opened or closed when desired by use of the control switch on the circuit breaker panel. This switch will trip the breaker at any time, but will close

the breaker only if the voltmeter switch on the same panel is turned on. The circuit breaker may also be tripped mechanically by use of the button on the breaker inside the cubicle.

FIELD FLASHING

A field flashing button is located on the circuit breaker panel. This permits excitation of the generator field by the batteries when the control unit bus is dead.

START-STOP SWITCH

The start stop switch is used in both manual and automatic operation. This switch will always signal an automatic start or automatic stop; however, when the AMS is in MANUAL, the unit will not start until the AMS is returned to AUTOMATIC. When the start-stop switch is turned to STOP while the unit is in manual, the unit will stop immediately, the MANUAL STOP fault will light, and the unit will be locked out.

Typically, these manual controls are used only for the desired portion of a loading sequence. As an example the following sequence might occur when it is desired to synchronize manually.

1. Unit is given automatic start.

2. When voltage builds up operator turns AMS to MANUAL position. Unit will now remain at approximately full speed with generator excited until further signals are given to it.

3. Operator adjusts speed and voltage to match that of system.

4. Operator closes circuit breaker at moment of synchronism.

5. Operator returns AMS to AUTOMATIC position. Unit will now complete automatic loading sequence.

OPERATING SEQUENCE DESCRIPTIONS

The following operating sequence descriptions are divided into two parts as follows:

1. Manual Start, Synchronizing, And Loading

2. Automatic Start, Then Manual Control For Deadload Pickup

The steps marked ● indicate action taken by the operator.

MANUAL START, SYNCHRONIZING, AND LOADING

● 1. Automatic/manual switch placed in MANUAL position.

   a. MR relay circuit opened.

   b. IR relay energized.

   c. CCR circuit readied for CCR pickup at 200 RPM.

2. IR relay picks up.

   a. Activates start pushbutton on engine control panel in generating unit.

   b. UST relay picks up, GS-1 energized; ER circuit readied for ES56 (50 cycles) or ES87 (60 cycles) relay pickup.

   c. Power provided to engine speed panel.

   d. Manual field flashing pushbutton activated.

   e. Governor motor unloading circuit opened.

3. Start pushbutton on generating unit engine control panel pressed in and held in until engine starts. The following occurs.

   a. SMTO energized. SMTO timeout will indicate failure of Dyer drive to engage.

   b. SMR and STZ energized; start magnet operated.

      (1) If start magnet engages starting pinion, SMLS will momentarily close.

      (2) If engagement is not made, then at the end of 2 seconds SMR contacts 3-4 open and both STZ and SMR are released. After 2 seconds SMR contacts close and both SMR and STZ are again energized. This 2-second-on/2-second-off cycle continues until SMLS operates, indicating successful pinion engagement; or until SMTO times out, indicating failure to engage.

4. SMLS operates.

   a. STW energized; seals itself in through its own contacts in parallel with SMLS and the series contacts of STWX.

   b. Opens the circuit to SMR and STW.

   c. Readies the STSX and STSY circuit.

   d. After 1/4 second, STSX "A" contact closes and the coil of stepping switch STS is energized. This transfers STS interrupter contacts from 16-17 to 16-15.

   e. STSX and STSY de-energized.

   f. STS de-energized.

   g. Closed sequence contacts of STS advanced one step.

      (1) If the generating unit selected by STS is the unit being started manually, the ST contactor picks up, connecting the battery to the starting motor. Starting motor begins cranking the engine.

      (2) If the generating unit selected by STS is <u>not</u> the unit to be started, the selection circuit repeats steps 4a. through 4g. until it finds the generating unit to be started.

   h. Assume ST energized STS circuits open before STSX can pick up. This prevents further stepping.

5. At approximately 20 RPM, ZSR is picked up. This precludes ST pickup after dropout if engine is turning. Engine begins to fire at 75 to 100 RPM, and accelerates to idle speed.

6. At approximately 200 RPM, ESR picks up, causing the following:

   a. ST contactor drops out. Starting motor stops cranking.

   b. OAD is energized. (Will cause ENGINE fault unless MBR picks up in 1.5 minutes.)

   c. LR energized.

   d. LTR pickup circuit nullified.

   e. Annunciator STARTING fault circuit nullified.

   f. CCR pickup- circuit readied.

NOTE: If the engine fails to reach 200 RPM within 10 seconds after the starting attempt is initiated, STSY picks up to register a fault and lock out the unit.

7. At 175 to 225 RPM, oil pressure switch MB-1 operates, picking up MBR and causing the following:

   a. MBX picks up, nullifying OAD time delay and setting up ENGINE fault circuit for crankcase pressure and low water response.

   b. Backs up ESR in de-energizing the starting circuit.

   c. CCR readied.

   d. CS-2 readied.

8. Unit will run at idle until further manual controls are operated.

CAUTION: If a unit is operating during its timed idle period prior to complete automatic shutdown, movement of the automatic/manual switch from AUTOMATIC to MANUAL position at that time will nullify the timed shutdown, and the unit will idle indefinitely.

● 9. Operate the governor control switch GCS on the front of the breaker compartment door panel to raise speed.

● 10. Using GCS and the synchronizing lights or the synchroscope along with the voltage adjusting rheostat on the face of the panel, bring the generating unit into synchronization with the system.

● 11. Time the synchronizing light pulses and close the unit circuit breaker at the proper instant as the synchroscope pointer slowly approaches the 12 o'clock position.

● 12. Apply load.

AUTOMATIC START, THEN MANUAL CONTROL FOR DEADLOAD PICKUP

When it is necessary to pick up a deadload with an MU type installation that is not equipped for automatic deadload pickup, the following sequence is employed.

FIRST UNIT START

1. Deadline relay DLR dropped out.

    a. Breaker closing contactor energized to connect battery power to the breaker closing circuit.

    b. Control power transformer disconnected.

2. Automatic/manual switch placed in AUTOMATIC position.

3. Place the start/stop switch in control room momentarily in START position. Sequence is the same as that shown for Automatic Individual Unit Start through the subhead Advance From Idle to Approximately Synchronous Speed in Section 6.

4. At approximately 30 RPM less than synchronous speed the ES56 (50 cycles) or ES87 (60 cycles) relay is energized causing the following:

    a. ER and EXC energized, but since the MU bus is dead, no current is available, and fields are not excited.

    b. ERY energized to time out in 45 seconds. An ENGINE fault will be signaled if MB-2 does not pick up within the allotted time.

    c. ERX contacts close in 10 seconds. Since the generator field is not excited, a NO VOLTAGE fault will occur.

5. When the engine comes up to synchronous speed the operator will immediately turn the automatic/manual switch to MANUAL position. This nullifies the NO VOLTAGE fault circuit.

6. Place the FM-VM switch in GEN position.

7. Operator presses and holds in the FIELD FLASHING pushbutton.

    a. Field flashing relay FFR energized, FFR interlocks prevent starting attempts from being made on other units.

    b. FFC picks up to connect battery across generator field.

8. At approximately 90 control system volts, the operator quickly places the circuit breaker switch in the CLOSE position, then releases the field flashing pushbutton. Generator excitation is maintained by the control power transformer.

- 9. Operator may estimate the load that the MU installation will pick up and adjust frequency to slightly higher than 50 / 60 cycles as needed.

- 10. Operator adjusts voltage as required.

SECOND AND SUCCEEDING UNIT STARTS

- 1. Automatic/manual switch in AUTOMATIC position.

- 2. Start/stop switch momentarily placed in START position. Sequence is the same as that shown for Automatic Individual Unit Start through subhead Automatic Synchronization, Step 11 in Section 6. Unit will start and accelerate without delay to full speed, it will generate volts, synchronize, and close its breaker.

- 3. At breaker closing, the operator immediately places the automatic/manual switch in MANUAL position, or units will be tripped off the MC bus.

- 4. Bus tie breaker operated to connect load. The operator trims voltage and load as necessary.

SECTION 6

AUTOMATIC OPERATION

The exact operating sequence for any given installation can only be determined from the wiring diagrams and drawings for that particular installation, However, certain characteristics of the MU type generating plant are basic and can, with only minor interpretation, be applied to most installations. An understanding of the basic operating sequence will be of value in determining the sequence for a particular plant.

Descriptions of specific components are given in Section 7 of this manual. These are arranged alphabetically so that reference to the component description can be made during the course of sequence tracing. It is recommended that a quick familiarization with the operating sequence presented herein be made before a thorough study with back reference is made.

SETTING CONTROLS FOR AUTOMATIC OPERATION

Prior to placing the generating units into automatic mode of operation, the following items should be checked.

1. All fuses on the fuse panel, in the switchgear compartments, and the field flashing fuses in the generator control cabinets should be good and properly installed.

2. All high voltage fuses in the switchgear compartments should be good and locked in position.

3. All low voltage circuit breakers in the control unit should be on.

4. Immersion heater and fuel transfer switches located on the engine control panels should be on.

5. Main circuit breakers should be levered to connect position.

6. All knife switches in the circuit breaker compartments and the transformer compartment should be closed.

7. Main battery switch should be closed.

8. Annunciator should be clear of all fault indications.

WARNING: If engine is cold the immersion heater fault cannot be reset. In this case the engine will start automatically as soon as the automatic/manual switch is placed in the AUTOMATIC position.

After all of the above items are correct, the unit may be placed in automatic operation by turning the automatic/manual switch to the AUTOMATIC position.

BASIC OPERATING DESCRIPTION

BASIC PEAKING OPERATION, Fig. 6-1

Normally a remote momentary start signal is given individually to as many diesel driven generating units as are required for a particular peaking situation. After a start signal has been given to a unit, the battery operated motor will crank the engine, provided no fault has locked the unit out. The engine will start and warm up at idle speed for a timed

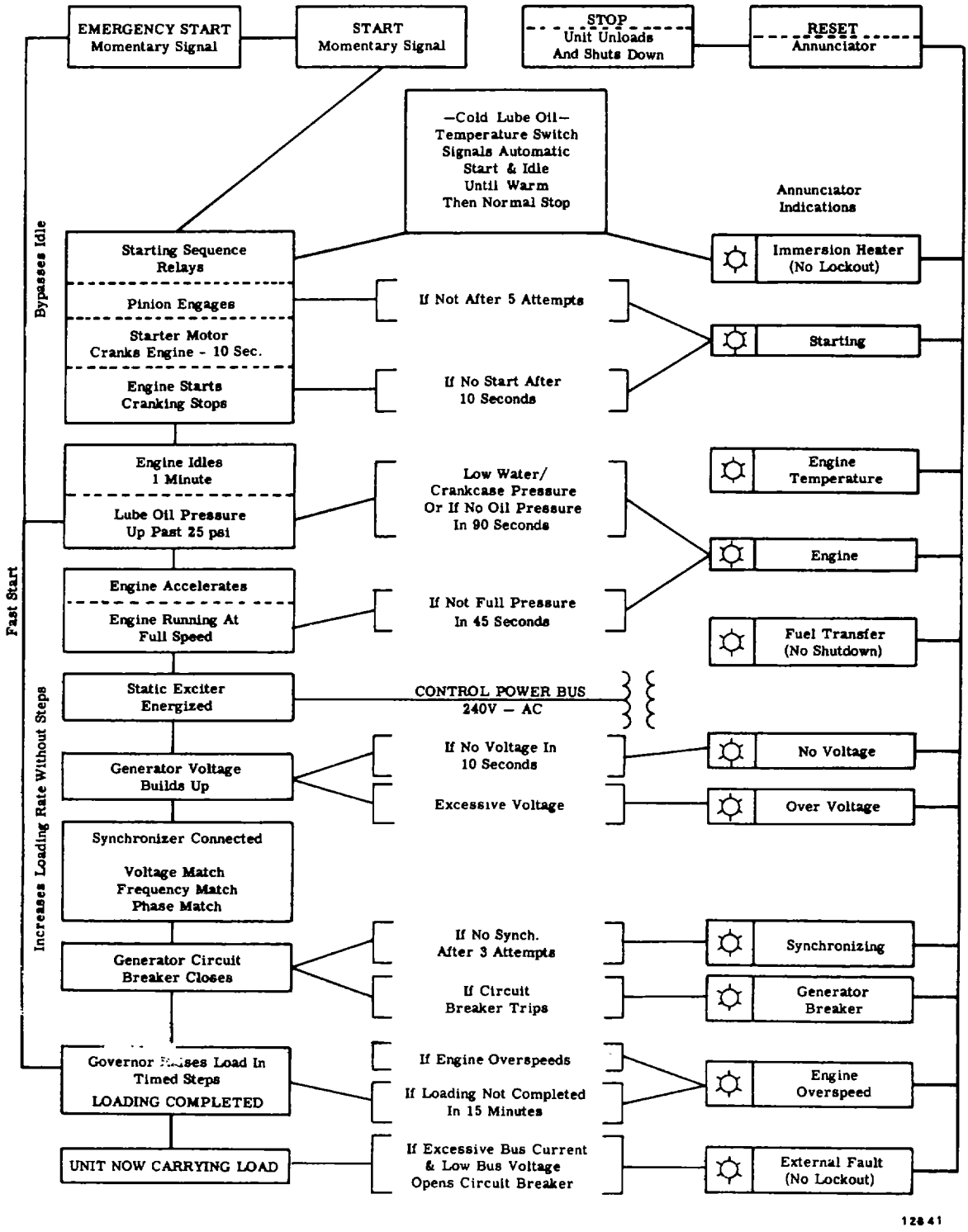


Fig. 6-1. - Typical Operating Sequence Block Diagram

period. If engine oil pressures are satisfactory after the warmup period, a speed setting solenoid in the engine governor is energized, and engine speed automatically increases to synchronous speed. Speed sensing equipment then initiates generator excitation; and when voltage appears, the governor speed setting motor is clutched in through a gear train. The governor motor is then connected to synchronizing equipment that uses static electronic components.

The synchronizer sends signals to an amplifier, the amplifier output operates the governor motor. Engine speed is controlled as necessary to synchronize the generating unit with the utility system. When the unit is synchronized, the generating unit main circuit breaker is automatically closed. The governor motor then operates in steps (runs for 1 second. rests for 5 seconds) to increase the speed setting of the governor. When the generating unit is connected to a synchronous system so large that it cannot affect the speed of the system, an increase in the speed setting of the governor, without an actual increase in engine speed, causes the generator to "lean" into the line load and increase the power output of the generator. The MU governor does not act to maintain a constant speed regardless of applied load; rather it calls for less speed as more load is applied. The engine and governor therefore accept load until the speed called for is equal to synchronous speed. This characteristic is called speed droop. It keeps the governor from calling for all available engine power in an attempt to bring engine speed up to the speed setting of the governor if that setting happens to be higher than system frequency dictates. The degree to which the governor no-load speed setting is higher than synchronous speed therefore determines the load on the engine.

The unit continues to accept load until the governor mechanism that controls the amount of fuel injected into the engine cylinders comes to rest against a mechanical rack stop. The position of the rack stop is normally set to restrict load as required for the particular MU installation. Further loading is accomplished by the operator as required.

PICKING UP AN ISOLATED DEADLOAD, Figs. 6-2 and 6-3

The basic MU power plant installation can be employed to pick up an isolated deadload through manual operation of controls. This requires the presence of an operator at the control center.

When deadload pickup is required, a start signal is given simultaneously to all generating units in the installation. However, since only one cranking battery is provided for all units, a stepping switch selects one unit at a time for cranking. After the first unit has started or has cranked for a timed period, the switch steps to apply cranking power to the next unit. The starting selector stepping switch operates until all units have been started.

For emergency deadload pickup the timed warmup period is nullified, and the engine goes to full RPM as soon as engine oil pressure is satisfactory. The first unit in an installation to reach full speed becomes the master unit. Its generator field is flashed by battery power, and the unit breaker closes to energize the dead MU bus. As other units come to speed, a synchronizing stepping switch selects one unit at a time for synchronizing. After that unit has synchronized with the master unit and its breaker has closed, the switch steps to synchronize the next unit. The synchronizing stepping switch operates until all units have synchronized with the MU bus and are "floating" on the MU bus or until a limited number of synchronizing attempts have been made.

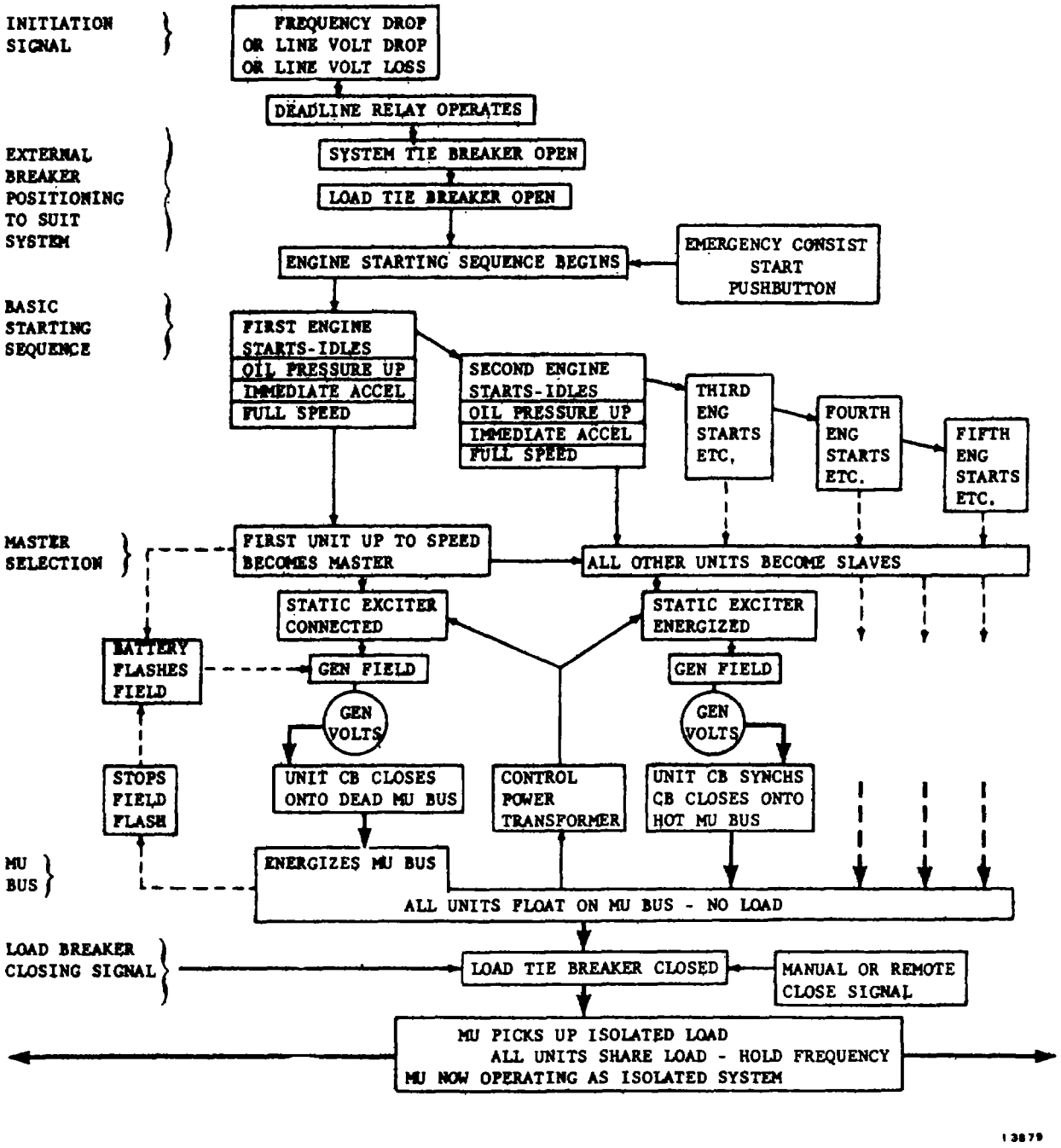


Fig. 6-2. - Deadline Starting And Loading Sequence Block Diagram

When all units have synchronized, the bus tie breaker is operated, and the MU installation picks up the isolated deadload. Battery powered field forcing is employed if voltage drops.

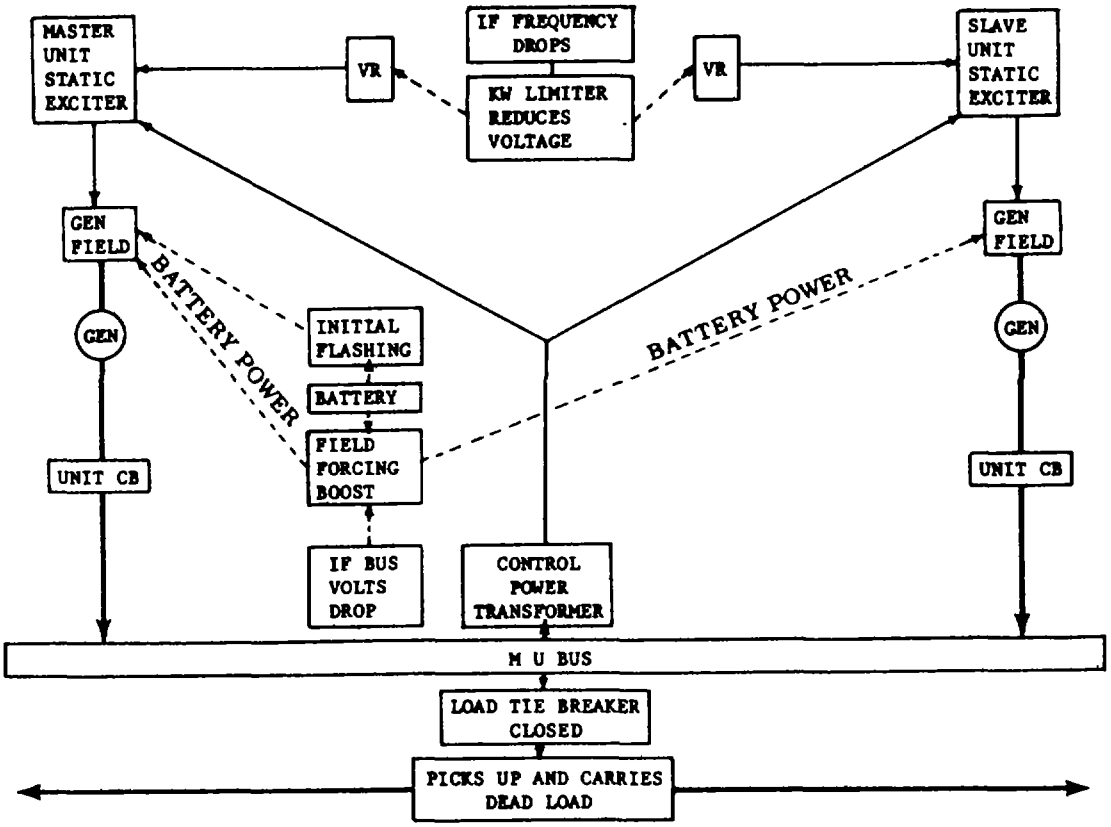


Fig. 6-3. -- Deadload Pickup Excitation Block Diagram

For deadload operation the engine governors are converted from straight mechanical hydraulic operation to combination electro-hydraulic/mechanical-hydraulic operation. The mechanical portion provides the basic speed reference while the electrical portion responds to load.

Current and potential transformers for each generating unit sense generator output and apply a signal to a load computer in each unit. The load computers in turn put out a signal that is proportional to generator load. This signal operates a transducer (force motor) that by means of governor mechanisms controls injection of fuel to the engine cylinders. Trimmer switches in the master unit governor forestall changes in frequency by applying corrective signals to the load computers of all units. Slave unit trimmer switches bring the governor speed setting of the slave units into coordination with the master unit. The entire MU plant operates as a single unit with zero speed droop.

SEMI-AUTOMATIC RESYNCHRONIZATION - RESTORATION OF SYSTEM TIE, Fig. 6-4

Equipment for semi-automatic restoration of a system tie after the MU installation has been carrying an isolated deadload is provided. In such equipment the MU plant uses its

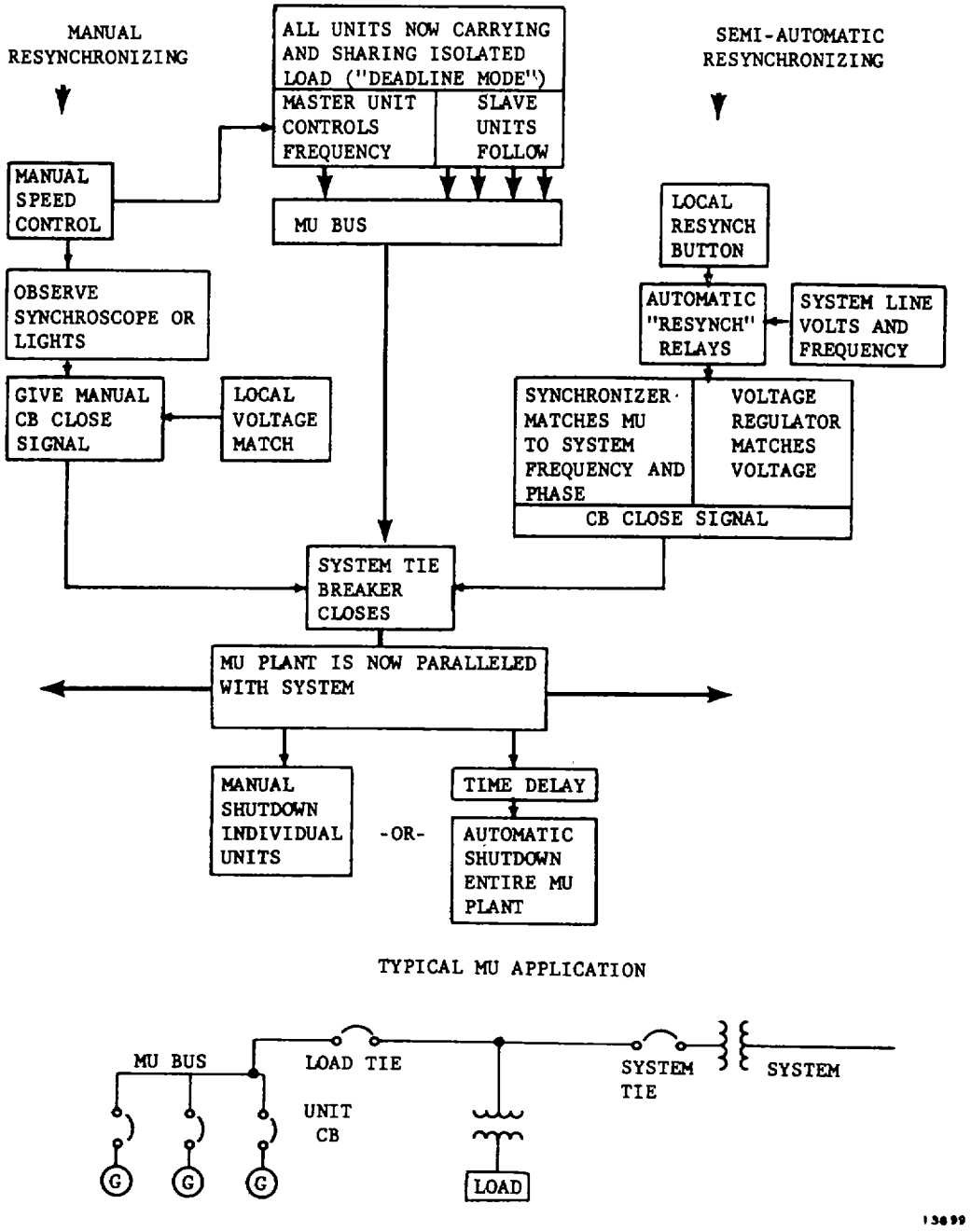


Fig. 6-4. - Resynchronization Block Diagram (Restoration Of System Tie)

synchronizing capability or resynchronize with the system. When synchronization is complete, a signal is sent, and the isolated load is connected to the system. The Mu installation will then, depending upon the option selected, revert to a peaking mode of operation or it will shed load and shut down. Initiation of resynchronization is by operator's signal.

BASIC OPERATING SEQUENCE

The basic operating sequence to be described here is simplified to include only the active portion of the full sequence. This means that any relays or circuits that are used for detecting faults or special conditions will be omitted until later. Since the sequence is the same for all units this description covers only one unit.

The block diagram, Fig. 6-1, illustrates the basic operating sequence. This article covers some of the details of the sequence. It is suggested that the applicable schematic wiring diagram be used when tracing the operating sequence. Fig. 6-5 points out the general circuit location on the diagram.

AUTOMATIC INDIVIDUAL UNIT START

START SIGNAL

1. Operator momentarily operates start switch.

    a. USR energized; picks up MR and locks USR in through normally closed contacts of START/STOP switch.

2. MR circuit energized; through AMS and NLO.

    a. MR energized; picks up USD for shutdown timing; picks up 52W for voltage match; readies ST, TCX, governor raise, and SYN circuits; locks out governor lower circuits; readies speed sensing circuit.

    b. MRXX energized; readies ERX.

    c. MRY energized; readies governor lower circuits.

AUTOMATIC CRANK SELECTION (Assume STS is not positioned at unit selected.)

1. MR has picked up. If ESR and MBR are not energized, the circuit will be made to wire DXJ and rectifier CR16.

2. This feed will energize SMTO, SMR, and STZ. SMTO timeout will indicate failure of Dyer drive to engage.

3. SMR and STZ energized - start magnet operated.

If start magnet engages starting pinion, the SMLS will momentarily close. If engagement is not made, then at the end of 2 seconds SMR contacts 3-4 open and both STZ

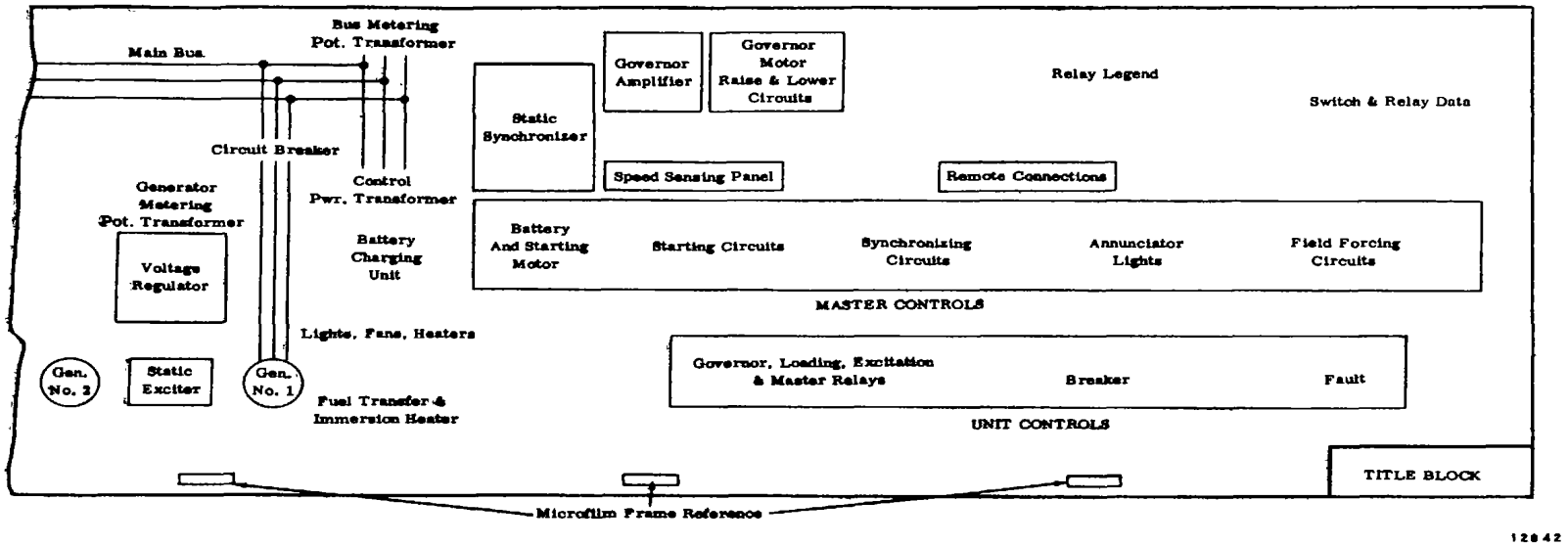


Fig. 6-5. -- Wiring Diagram Circuit Location Block Diagram

and SMR are released. After 2 seconds SMR contacts 3-4 close and both SMR and STZ are again energized. This 2-second-on/2-second-off cycle continues until SMLS operates, indicating successful pinion engagement; or until SMTO times out, indicating failure to engage.

4. SMLS operates.

   a. STW energized; seals itself in through its own contacts in parallel with SMLS and the series contacts of STWX.

   b. Opens the circuit to SMR and STZ.

   c. Readies the STSX and STSY circuit.

   d. After 1/4 second STSX "A" contact closes and the coil of stepping switch STS is energized. This transfers STS interrupter contacts from 16-17 to 16-15.

   e. STSX and STSY de-energized.

   f. STS de-energized.

   g. Closed sequence contact of STS advanced one step.

      (1) If the generating unit selected by STS is ready to crank (indicated by STW being energized), the ST contactor picks up, connecting the battery to the starting motor.

      (2) If the generating unit selected by STS is <u>not</u> ready to crank, the selection circuit repeats steps 4a through 4d until it finds a generating unit ready to crank.

   h. Assume ST energized. STS circuit opened before STSX can pick up. This prevents further stepping.

5. At approximately 45 RPM, ZSR is picked up.

   a. Opens SMR circuit.

   b. Readies OTX to set up generating unit shutdown, should the starting cycle fail to go to completion.

6. Engine starts. At approximately 200 RPM, ESR is picked up, causing the following.

   a. ST contactor drops out.

   b. OAD is energized. (Will cause ENGINE fault unless MBR picks up within 1.5 minutes.)

c. LR energized.

d. LTR pickup circuits nullified.

e. Annunciator ST fault circuit nullified by delayed STW dropout.

f. ITS energized.

7. At 175 to 225 RPM. oil pressure switch MB-1 operates, picking up MBR and causing the following:

a. MBX picks up, nullifying OAD time delay and setting up ENGINE fault circuit for crankcase pressure and low water response.

b. Backs up ESR in de-energizing starting circuit.

c. CCR readied.

d. GS-2 readied.

8. Unit will now idle for time set on ITS (1 minute).

ADVANCE FROM IDLE TO APPROXIMATELY SYNCHRONOUS SPEED

ITS times out.

1. GS-2 picked up - unit goes to synchronous speed.

2. MB-2 picks up at approximately synchronous speed.

FIELD EXCITATION

1. At approximately two cycles below operating speed the ES56 (50 cycles) or ES87 (60 cycles) relay is energized, causing the following:

a. ER and EXC energized. Field voltage is applied.

b. ERY energized to time out in 45 seconds. An ENGINE fault will be signaled if MB-2 does not pick up within the allotted time.

c. ERX contacts close in 10 seconds. If GV is not picked up within that time, a NO VOLTAGE fault will occur.

2. GV operates (through application of field).

a. Voids the no voltage fault circuit.

b. CCR is energized 1 second later.

3. CCR operates.

a. Synchronizing circuit readied.

b. Governor motor clutch energized.

c. Governor motor energized to move in the "raise" direction (through ITS-CCR series connection). Governor motor is run up to take up gear train slack.

d. ITS and GS-2 are de-energized from 3 to 7 seconds later.

e. Unit is now ready to synchronize.

AUTOMATIC SYNCHRONIZATION

1. Wire DZF energized (MR. CCR, 52V).
2. SYSX energized.
   a. Provides secondary holding path for SYSZ.
   b. Sets up the overall synchronizing time.
3. SYSY energized. Provides 1 second delay in operation of SYS to allow SYN of the selected unit to pick up.
4. SYS energized.
   a. SYS interrupter transfers from 16-17 to 16-15.
   b. SYSX and SYSY de-energized.
5. When both SYSX and SYSY are released, SYS is released.
6. Selector contacts advance one step.
7. This process repeats until the ready unit is found and its SYN relay is energized.
8. SYN energized.
   a. SYS circuit is opened.
   b. SR and SRF energized.
   c. Selected unit's voltage is fed into the static synchronizer (SYN and SR).
   d. Governor amplifier output is fed into selected unit's governor motor (SYN).
   e. Breaker closure is readied.
   f. RCL is energized to accumulate one synchronizing try.
   g. SR and SYN feeds line voltage into static synchronizer.
10. SRF forestalls breaker closure signal 1 second to allow synchronizer stabilization.
11. The unit's speed is now under the synchronizer's control and will be adjusted to match both phase and frequency. When this occurs, the 52Z relay closes, which in turn closes the generating unit breaker.
12. Should synchronization fail to occur within 20 seconds, SYSX times out.
13. SYSZ picks up.
   a. All SYN circuits are de-energized.
   b. SYSZ seals in until both SYSX and SYSY drop out.

14. SYN de-energized.

    a. RCL advances contacts one step. (On the third unsuccessful synchronizing try, a SYNCHRONIZING fault is registered and the unit is locked out).
    b. SYS circuit readied.

    c. SR and SRF de-energized. Line input to synchronizer opened. 52Z dropped.

    d. Unit input to synchronizer opened.

15. SYS energized.

    a. SYSX and SYSY drop out.

    b. SYS de-energized. Contacts advance one step. Advance continues until a ready unit is found.

LOADING SEQUENCE (Assume synchronizing was successful and breaker closed)

1. 52W de-energized, allowing voltage regulator to operate in droop.

2. 52V picks up.

    a. SYN circuit opened (same results as 14 above).

    b. GS-2 energized.

    c. Parallel holding path to ER established.

    d. 52TC circuit readied.

    e. 51 relay readied.

    f. RCL reset.

    g. Parallel holding path to GS-1 established.

    h. Parallel holding path to OTX removed.

    i. Synchronizing fault voided.

    j. FFR circuit readied.

    k. Completes circuit through GOV65(50 cycles) or GOV77 (60 cycles) (50 RPM over operating speed) and ESR to SLR.

3. Feed to SLR coil completed.

    a. Delayed pickup of SLR 3-5 contacts holds SLR energized for 5 seconds.

    b. SLR 3-5 contacts open after 5 seconds and SLR is de-energized. SLR 6-4 contacts close and the governor motor is driven for 1 second to raise through LR, MR, SLR, 52V, and CCS circuit.
    c. After 1 second SLR 3-5 contacts close to energize SLR. SLR 6-4 contacts open and the governor motor stops for 5 seconds.
    d. Governor motor operates for 1 second at 5 second intervals to raise load.

4. At approximately 25% load

    a. GOV RS opens. (No effect at this time, but serves to trip breaker on unloading when unit is shut down.)

b. RS25 switch closes above 25% load. Opens LLR contacts and prevents further automatic loading.

5. Upon further application of load in the second increment, when governor motor reaches a speed setting about 50 RPM higher than operating speed, the GOV65 (50 cycles) or GOV77 (60 cycles) switch operates and releases LR.

6. LR de-energized.

   a. OTX released. (LR out; 52V and MR energized.)

   b. Governor motor stops.

7. The unit is now at full load and will remain so until changed by the operator or shut down.

NORMAL STOP SEQUENCE

STOP SIGNAL

1. Stop signal is given.
   a. USR drops out.

   b. MR and MR auxiliaries drop out.

   c. MR contacts open to de-energize UST.

2. Unit unloads.

   a. MR contacts complete circuit to drive governor motor and lower speed setting.

   b. At 25% rack, the governor rack switch GOV RS closes.

3. Circuit breaker opens.

   a. GOV RS contact completes circuit to circuit breaker trip coil.

   b. Circuit breaker opens.

   c. Circuit breaker 52a switch drops out 52V and related auxiliary relays.

   d. GS-2 and ER de-energized.

   e. ER drops out EXC to stop generator excitation.

4. Unit idles.

   Time delay dropout of UST holds GS-1 energized.

5. Unit stops.

   a. UST contacts open to drop out GS-1. Injector racks drawn out to no fuel position,

   b. Engine stops.

   c. Lube oil circulating pump continues to run.

   d. Immersion heater temperature switch turns heater on and off to maintain engine temperature until next start.

SEMI-AUTOMATIC DEADLINE START

Fig. 6-3 illustrates the deadline starting and loading sequence as described in the following text.

START SIGNAL

1. Main bus dead; DLR dropped out.

   DLRZ energized; battery power connected to main circuit breaker closing coil by pickup of BCC.

2. MU load breaker open; 52WL relay picked up.

   DLRP circuit readied for remote operation.

3. System tie breakers open; 52WS picks up.

   a. Deadline sequence and lockout relay circuits readied.

   b. DLTS energized; fast start relay FST picked up; ITS nullified.

4. Operator momentarily operates a local or remote start switch. USR energized; picks up MR and locks USR in through normally closed contacts of START/STOP switch.

5. MR circuit energized through AMS and NLO.

   MR energized; picks up USD for shutdown timing; picks up 52W for voltage match; readies ST. TCX, governor raise, and SYN circuits; locks out governor lower circuits; readies speed sensing circuits.

6. MRXX energized; readies ERX, DLRA, and DLRB; energizes DLRV, DLRS, DLRW, and DLRT.

   a. DLRS pickup has no function during the starting sequence. It is employed when the MU installation is going from a peaking mode of operation to deadline.

   b. DLRT pickup recalibrates the voltage regulator for deadline operation.

   c. DLRV pickup energized DLRU and DLRY, and readies DLRP and the field forcing circuit. LRU connects the governor transducer to the load computer; DRLY nullifies GOV RS switch.

   d. DLRW pickup sets up the voltage regulators in parallel for KVAR sharing and nullifies the governor raise circuits.

   e. MRY energized; readies governor lower circuits.

AUTOMATIC CRANK SELECTION AND ADVANCE TO SYNCHRONOUS SPEED

The crank selection sequence is essentially the same in deadline operation as peaking, except that idle time starting relay ITS is not energized. The generating unit accelerates to synchronous speed when oil pressure reaches 28 psi (MBR picks up).

MASTER UNIT SELECTION

1. Engine speed of one unit in an installation reaches full RPM; ES56 (50 cycles) or ES87(60 cycles) picks up.
   a. ERY energized; ENGINE and ENGINE TEMPERATURE fault circuits readied.
   b. ER energized; ER picks up to energize the coil of SMSX; picks up excitation contactor EXC, but bus is dead. No excitation occurs.
   c. After 1/4 second, SMSX "A" contact closes and the coil of stepping switch SMS is energized. This opens SMS interrupter contacts 16-17.
   d. SMSX is de-energized.
   e. SMS is de-energized. Close sequence contact of SMS is advanced one step. If the generating unit selected by SMS is up to speed (ER picked up), the load sharing relay LSR picks up. If the generating unit selected by MS is <u>not</u> up to speed, the selection circuit steps the switch until a ready unit is found.

2. Assume LSR energized.
   a. The SMS circuit opened before SMSX could pick up. This prevents further stepping of SMS.
   b. Field forcing relay FFR energized by LSR pickup; FFR picks up FFC. FFC connects the battery across the alternator field.
   c. FFR pickup energizes ERX; this readies the NO VOLTAGE fault circuit. Delayed pickup of ERX allows 10 seconds for voltage buildup to pick up GV.
   d. KW limiter connected to master unit frequency generator.

3. Master Unit Generator Voltage Builds Up
   a. GV pickup energizes breaker closing coil 52CC and the circuit breaker of the master unit closes to energize the 4 KV bus.
   b. At 90 volts, FFCO picks up to drop out FFR and FFC.
   c. DLR picks up and DLRZ is de-energized; BCC drops out; circuit to 52CC opened; ERX held picked up.
   d. Generator excitation from control power transformer through EXC and the static exciter.
   e. 52A switch closes, energizing 52 relay and auxiliaries. Governor trimmer connected to load computer in master unit.
4. Field Excitation; Slave Units
   a. Master unit breaker has closed, energizing the MU bus.
   b. DLR picked up to activate the synchronizing circuits. Various auxiliary deadline relays are held picked up by closure of the master unit 52 relay and auxiliaries.
   c. At about 30 RPM lower than full speed, ES56 is energized: ER and EXC pick up and field voltage is applied. ERY is energized to time out in 45 seconds; and ENGINE

fault will be signaled if MB-2 does not pick up within the allotted time. ERX contacts close in 10 seconds; if GV is not picked up within that time, a NO VOLTAGE fault will occur.

d. GV operates (through application of field). NO VOLTAGE fault circuit nullified; CCR is energized 1 second later.
e. CCR operates
   (1) Synchronizing circuit readied.
   (2) Governor motor clutch energized.
   (3) Governor motor energized to move in the "raise" direction (through ITSX-CCR series connection). Governor motor is run up to take up gear train slack.
   (4) ITSX and GS-2 are de-energized from 3 to 7 seconds later.
   (5) Unit is now ready to synchronize.
f. Automatic synchronization occurs in the same manner as in the peaking mode of operation.
g. Signal from the synchronizer picks up 52Z, and the generating unit main circuit breaker closes; 52a switch closes, energizing 52 relay and auxiliaries.
   (1) LSRX energized; governor trimmer switches connected to slave unit governor motor.
   (2) Open DLRW contacts prevent the unit from attempting to load.
   (3) GS-2 again energized.

5. All units synchronized and on the line.
   Pickup of 52 and auxiliaries in all units energized DLRP. DLRP provides a signal to operate a system remote breaker, and the MU installation picks up an isolated load. If DLRP signal is not employed, an operator will provide the signal to pick up the deadload.

6. Transient Overcurrent
   a. Current sensing relays SC1 and SC2 pick up to energize OLTD.
   b. OLTD pickup holds DLRA energized.
   c. Time delay on pickup holds DLRA energized, delaying 51 overcurrent relay trip.
   d. On units equipped only for inherent deadload pickup, dropout of voltage sensitive relay FFCO applies starting battery current to the alternator field. See Fig. 6-3.

7. Load computers, governor transducers, governor trimmers, and KW limiter operative.
   a. Master Unit
      (1) DLRU energized; governor transducer (force motor) connected to load computer. Transducer receives signal proportional to load, and governor responds to control fuel setting of engine injectors.

(2) LSR energized; connects master unit frequency generator to KW limiter. Heavy load sends signal to voltage suppressing windings in all load computers.

(3) LSR energized; connects trimmer switches to governor trimmer motor to operate trimming rheostat and vary the signal to the load computer in the event of small frequency fluctuations due to load changes.

b. Slave Units

(1) DLRU energized; governor transducer (force motor) connected to load computer.
(2) LSR dropped out, LSRX energized; trimmer switches apply signals to governor motor of individual slave units. CCR is energized by LSR dropout.
(3) In the event of small speed setting errors in one of the slave units, the speed settings servo piston will be above or below its mid position. The trimmer switch contacts will close to raise or lower the speed setting by energizing the appropriate circuits to the governor motor. CCR is energized and the clutch is engaged.

RESYNCHRONIZING - SYSTEM TIE RESTORATION

As system power is restored with MU installation still carrying an isolated load, a signal if given by the operator to synchronize the MU installation with the system. When the MU plant is synchronized with the system a signal is given to connect the isolated load to the system. The MU installation will then, depending upon the option in effect, transfer to a peaking mode of operation and continue operation until shut down by signal, or it will run a predetermined time, then automatically go off the line. Fig. 6-4 is a block diagram illustrating the resynchronizing sequence.

RESYNCHRONIZING SEQUENCE

1. SYS resting in position No. 6.
2. Resynchronizing signal given.
   a. SYD, SYDY, SYDT, and SR energized. Remote signal compared to MU bus by static synchronizer. Signal transmitted to governor amplifier.
   b. SYD connects synchronizing signal from governor amplifier to governor motor of master unit only. Governor trimmer switches operate as slave units follow the master unit.
3. 52Z relay picks up to signal completion of resynchronization. The system circuit breaker closes, paralleling the MU installation with the system. The following options may be in effect.
   a. Deadline relays drop out and the MU installation reverts to base load operation until a shutdown is signaled.
   b. Deadline relays drop out; MU plant reverts to full power. After a predetermined time to ensure line restoration is firm, a shutdown is signaled. Units shed load and go to idle. They remain at idle until UST relay cycle is completed.

SECTION 7

DESCRIPTION OF ELECTRICAL DEVICES

This section of the operating manual contains descriptions of individual electrical devices as they are used in a MU installation. No attempt is made in this section to correlate electrical devices or to define sequences of operation. The purpose of this section is to provide a basis for primary understanding of the equipment and to provide the easiest means of back reference when operating sequences are being traced, as in Sections 5 and 6 of this manual.

The descriptions contained in this section of the manual will be of value in familiarizing operators with the control equipment.

A legend of relays and other electrical devices is located in the appendix to this manual.

MAJOR DEVICES

KW LIMITER

The function of the KW limiter is to protect the engine during an overload condition and to enable the MU unit to pick up a dead load which demands full KW output at breaker closure.

The KW limiter operates by reducing the alternator dead line voltage if the engine begins to lose speed (line frequency) due to an overload. The KW limiter receives a signal from the AC frequency generator mounted on the front end of the engine and driven by the camshaft. When the signal falls below a preset frequency, the KW limiter supplies a signal to the voltage regulator to reduce the alternator excitation and therefore, reduce the alternator voltage. Reducing the alternator voltage reduces the KW load on the engine. Therefore, when an overload condition exists in dead line operation the MU unit will not bog down, but continue to operate at rated load at a reduced voltage.

SPEED SENSING PANEL, Fig. 3-14

With the exception of output relays, the speed sensing panel is a static device consisting of a regulated power supply, a signal amplifier, frequency sensing circuits printed on interchangeable cards, and transistor switches. The power supply provides 12 V DC power for the amplifier, transistor switches, and the output relays. It consists of resistors and Zener diodes whose power is taken from the 120 volt control unit battery. The amplifier changes the signal from the engine mounted frequency generator into a constant voltage square wave signal at a usable value. The frequency sensing circuit provides to the transistor switch a DC signal proportional to engine speed. The transistor switch provides a signal to pick up the output relays at preset engine speed.

STATIC SYNCHRONIZER

The magnetic-amplifier controlled synchronizer functions to bring the diesel engine driven generator into synchronism with one or more parallel connected generating plants or with an infinite bus power distribution system. The synchronizer automatically applies generator output to the line at the moment of synchronism. A detailed description of the synchronizer is given in the applicable Maintenance Instruction.

VOLTAGE REGULATOR, MAGNETIC AMPLIFIER TYPE

A detailed description of the voltage regulator is given in the applicable Maintenance Instruction.

RELAYS AND SWITCHES

AMS, AUTOMATIC MANUAL SWITCH

This switch is located below the annunciator light panel. It is a two-position rotary snap switch that moves in a 120 degree arc. When the switch is placed in MANUAL position, the isolation relay IR will be picked up, the master relay MR will be dropped out, and the governor speed setting solenoid GS-2 is not energized. Control of the generating unit is then accomplished manually by means of controls on the door panel of the switchgear compartment, but the engine must be started from the control panel in the generating unit. With AMS in AUTOMATIC position, the MU plant is under control of the operator from the MC operator's panel.

BCC, BREAKER CLOSING CONTACTOR

The BCC transfers the circuit breaker closing circuit to the batteries so that the breakers may be closed with battery power when the control unit bus is dead. The dead bus causes DLR dropout, and an auxiliary DLR relay operates BCC to connect battery power for circuit breaker closing and to isolate the control power transformer from battery power. When power is reapplied to the main bus, either by the system or by an MU generating unit going on the line, the deadline relays pick up to drop out BCC.

CCR, CLUTCH CONTROL RELAY

This relay picks up to energize a clutch solenoid that engages the governor motor to a gear train. Movement of the gears changes spring tension on the governor flyballs. The relay is de-energized and the clutch is disengaged when the major speed settings of idle and full speed are being made by governor speed setting solenoids GS-1 and GS-2.

CS, CIRCUIT BREAKER CONTROL SWITCH

This switch provides manual control of the generating unit main circuit breaker. The switch is operated by a handle centrally located on the face of the switchgear cubicle. A window in the switch position plate shows a flag to indicate the last operation of the switch; a red flag indicates that the switch was last operated to the CLOSE position; a green flag indicates operation to the TRIP position. The flags are not necessarily in agreement with the red and green circuit breaker position indicating lights on the face of switchgear cubicle door, because devices other than the control switch CS act to operate the circuit breaker. However, the circuit breaker can be locked open by turning the switch handle to the TRIP position and pulling out on the handle to latch it in the PULL FOR LAMP CUTOUT position. All lights will then be out.

CAUTIQN: Under some circumstances the breaker may close momentarily 'before tripping and locking out.

CTR, CUBICLE THERMOSTAT

Each circuit breaker compartment is equipped with a thermostat CTR and a strip heater. The thermostat energizes the strip heaters when the temperature falls below 90 degrees F. This prevents accumulation of moisture in the switchgear.

C5, CLOSING TIME RELAY

This relay operates in conjunction with the lockout relay LOR to lock out the MU installation after a time delay when certain overcurrent conditions occur.

DLR, DEADLINE RELAY

The operating coil of the deadline relay is connected from the bus metering power transformer to system ground. The relaydrops out whenever there is no power on the MU bus. DLR dropout energizes the breaker closing contactor BCC to provide battery power for breaker closing and for relay control. On automatic deadload pickup, DLR dropout in conjunction with breaker operated switches and other equipment provided by the utility system brings about operation of variety of auxiliary deadline relays.

DLRP, DEADLINE RELAY AUXILIARY

When this relay is energized its contacts close to provide a remote signal that deadload pickup has been initiated.

DLRQ, DEADLINE RELAY AUXILIARY

During transfer from an overload rating (peaking) mode of operation to a deadline mode, delayed pickup of DLRQ momentarily de-energizes the governor clutch solenoid. This prevents speedup of the engines during transfer, and permits the speed setting to drop to governor solenoid GS-2 speed level for deadline operation.

DLRS, DEADLINE AUXILIARY RELAY

This relay times the pickup of DLRQ during transfer from an overload rating (pending mode of operation to a deadline mode.

DLRT, DEADLINE RELAY AUXILIARY

This relay is energized during deadline operation to transfer voltage regulator voltage calibration from a rheostat mounted on the door face of the circuit breaker compartment to a rheostat mounted inside the circuit breaker compartment door. This permits a normal reactive voltage setting in overload rating (peaking) without having a high voltage upon transfer to deadline.

DLRU, DEADLINE RELAY AUXILIARY (At Times May Be DLRT)

DLRU contacts connect the governor transducer (force motor) to the load computer during deadline mode of operation. Since the generating unit is equipped for semi-automatic

resynchronization and system tie restoration, the timed dropout of DLRU by DLRV contacts act through RPCR, the compensator and the load computer to temporarily hold the transducer energized during system tie restoration. This allows the governor motor and the mechanical/hydraulic portion of the governor to take control of generating unit loading with only minor fluctuation of load during changeover.

DLRV, DEADLINE RELAY AUXILIARY

This relay is energized when a deadline start signal is given with the MU load breaker open and at least one generating unit in an installation is at operating temperature. The relay is equipped with both immediate response and time delay contacts. The time delay contacts pick up as soon as the relay is energized, but are delayed on dropout to hold off dropout of auxiliary relay DLRU and DLRY. The immediate response contacts close to energize load sharing circuitry and to energize auxiliary relay DLRP.

DLRY, DEADLINE RELAY AUXILIARY

Contacts of DLRY short out governor rack switch GOV RS during deadline operation. Since during deadline mode, operation of the governor motor and dropping of load before shutdown cannot be employed, DLRY causes an immediate circuit breaker trip upon receipt of a stop signal.

DLRW, DEADLINE RELAY AUXILIARY

This relay connects all voltage regulators in an installation in parallel so that all units share equally the KVAR load. It also disconnects the governor motor from the magnetic amplifier, except for the trimmer circuits on slave units. In deadline mode of operation the governor transducers and the load computer control governor operation.

DLRZ, DEADLINE RELAY AUXILIARY

DLR dropout energizes DLRZ. DLRZ action picks up breaker closing contactor BCC to connect battery power to the breaker closing coil in the absence of current from the control power transformer. This relay also readies the breaker closing coil circuit for breaker close when field forcing relay FFR picks up.

DLTS, DEADLINE TIMER START RELAY

This time delay relay is employed to initiate a fast start. Delayed pickup of one of its contacts allows time for holding circuits to be established during the starting operation.

DSS, REDUCED VOLTAGE START AUXILIARY RELAY

This relay prevents fuel from being injected into the engine cylinders until the reduced voltage cranking system has had time to slowly rotate the engine a single revolution during engine start. When DSS picks up, a circuit to the governor idle speed setting solenoid GS-1 is completed and fuel will then be injected into the engine cylinders. Contacts of DSS also energize a contactor that shorts out a heavy duty resistor in the engine cranklng circuit and allows full voltage to the starting motor.

ER, EXCITATION RELAY

This relay picks up when engine speed reaches approximately 30 RPM lower than synchronous speed. Pickup of ER energizes the excitation contactor EXC and power is delivered to the generating unit static exciter. ER contacts also connect signals from the generator metering potential transformer and the bus metering potential transformer to the voltage regulator, and they disconnect the immersion heater contactor to protect against undesired heating should the immersion heater temperature switch be faulty. In addition, ER pickup holds the unit start relay USR picked up when the main circuit breaker closes, and it sets up the circuit to indicate a synchronizing fault should a unit fail to synchronize after three attempts.

ERX, EXCITATION RELAY AUXILIARY

This time delay relay is energized in conjunction with the excitation relay ER and the excitation contactor EXC. Its pickup 10 seconds after it is energized signals a generator NO VOLTAGE fault if generator voltage is not sufficient to cause pickup of generator voltage relay GV.

ERY, EXCITATION RELAY AUXILIARY

This relay is energized in conjunction with the excitation relay ER when engine speed reaches approximately 30 RPM lower than synchronous speed. Closure of its immediate response contacts sets up the circuit to register an ENGINE TEMPERATURE fault should the engine temperature switch close. Closure of its time delay contacts sets up the circuit to register an ENGINE fault should oil pressure switch MB-2 fail to open.

ES-0, ES-20, ES-56 and ES-87 ENGINE SPEED RELAYS

These relays are part of the speed sensing panel. The speed sensing panel is a static device that receives a signal from a frequency generator mounted on the front end of the engine and driven by the engine camshaft.

Engine Speed	Relay Number	Type Of Service	Relay Function
50 RPM	ES-0	All Units	Indicates that engine is not rotating. Prevents operation of the starter when the engine is turning. Ends overall timeout relay cycle.
200 RPM	ES-20	All Units	Disconnects the starting motor after the engine has started.
600 RPM 700 RIPM	ES-56 ES-87	50 , Base Load 60oU Base Load	Turns on generator excitation when proper engine speed is reached. (Two cycles lower than operating speed.)

ESR, ENGINE SPEED RELAY

This relay is energized by pickup of the speed sensing relay ES-20 at engine speed of approximately 200 RPM. This is a transient speed greater than cranking speed, so when it is attained the engine is running on its own and will come up to idle speed. The primary function of the engine speed relay is to disconnect the engine cranking circuit. Secondary, but necessary, functions relating to fault signals, synchronizing, and loading circuit setups consistent with proper engine operation. ESR signals that the engine is running.

ETI, ELAPSED TIME INDICATOR

This meter is energized whenever there is power on the main bus and the circuit breaker is closed. The meter has a synchronous drive motor and registers hours to tenths of an hour. The reading is cumulative.

ETS, ENGINE WATER TEMPERATURE SWITCH

This switch closes when water temperature at a manifold adjacent to the oil cooler reaches a temperature that indicates that water in the engine is approaching the boiling point. Because of heat losses between the engine and the temperature switch manifold, the temperature switch closes at a temperature approximately 15 degrees F. lower than the boiling point of water. When the switch closes, the HOT ENGINE light at the engine control panel comes on, and if engine is at operating speed, an ENGINE TEMPERATURE fault will shut the unit down.

EXC, EXCITER CONTACTOR

The exciter contactor operating coil is energized by the excitation relay ER. EXC contacts close to connect control power transformer output to the alternator field static exciter.

FCR, FAN CONTROL RELAY

The fan control relay is picked up when temperature switch TSF, located on the relay room wall, picks up at approximately 100 degrees F. Pickup of FCR energizes the exhaust fan located above the No. 2 switchgear cubicle and disconnects power from the strip heaters.

FFC, FIELD FLASHING CONTACTOR

Field flashing relay FFR contacts close to pick up field flashing contactor FFC. FFC contacts connect the 120 volt battery directly across the alternator field.

FFCO, FIELD FLASHING CUTOFF RELAY

The operating coil of this voltage relay is energized from the bus metering power transformer. When excitation can be sustained by power from the generating unit control power transformer through the static exciter. FFCO picks up to de-energize the field flashing relay and contactor, thereby disconnecting the battery from the alternator field.

FFR, FIELD FLASHING RELAY

The field flashing relay acts to close the field flashing contactor FFC and connect the battery in the MC control unit across an alternator field. Field flashing by the battery is necessary when the main bus is dead.

During manual deadload pickup, the field flashing relay is energized by pressing the field flashing pushbutton located on the door of the switchgear cubicle. On automatic deadload pickup, the field flashing relay is energized through action of a stepping switch.

Interlocks of the FFR relay prevent cranking from being attempted on any units in an installation while any one of the field flashing relays is picked up. This ensures full battery voltage for field flashing.

FSR, FAST START RELAY

The fast start relay is energized by pressing the consist start pushbutton located below the annunciator panel. The fast start relay is energized when a deadload start signal is given.

When the fast start relay picks up, the diesel engines are not held at idle for a timed period, and the slow load relay SLR is not activated. The generating units go up to full speed as soon as the engines start and build up oil pressure. When all units are synchronized, the breakers close and the units load quickly.

FTC, FUEL TRANSFER CONTACTORS

FTC contactors pick up to energize motor driven fuel pumps that supply fuel directly to the day tank of the fuel transfer unit and indirectly through equalizing piping to day tanks of all generating units in an installation.

The zero speed relay sets up the power supply to three fuel transfer switches; namely, FTSL (low), FTSN (normal), and FTSH (high). Power is also supplied to a solenoid operated valve FTSV in the main fuel supply line. Refer to the specific article for an explanation of switch and valve functions.

FTM, FUEL TRANSFER PUMP MOTOR

Two fuel transfer pumps with AC motors are provided for an MU installation. Both pumps and motors are located on one generating unit. They transfer fuel from a user supplied main fuel tank to day tanks in each of the generating units. Normally only one of the pumps operates. The other is provided as a backup should fuel level in the day tanks fall to an abnormally low level.

FTSL, FUEL TRANSFER SWITCH - LOW LEVEL

This switch is operated by a float mounted on the fuel day tank of the generating unit that contains the fuel transfer system. The FTSL contacts close when fuel drops to an abnormally low level in the day tank. A fuel transfer contactor is energized, and the second of

two fuel pump motors will operate. Normally the other fuel pump motor will have operated to maintain fuel level before the fuel level drops to close FTSL. When FTSL contacts do close, the FUEL TRANSFER annunciator light will come on, but engine operation will not be affected. However, operation of the fuel transfer system should be checked.

FTSN, FTSH: FUEL TRANSFER SWITCHES - NORMAL AND HIGH

These two switches are operated by a single float assembly mounted on the fuel day tank of the generating unit that contains the fuel transfer system. Dual contacts of FTSN close to pick up a fuel transfer contactor FTC when the float falls to 5-1/2 inches below the centerline of the float mounting assembly. FTC contacts closing energizes a fuel pump motor, and when the fuel level rises to the mounting assembly centerline, FTSN contacts open to stop the pump. Equalizing piping between units maintains fuel level in all day tanks in an installation.

One set of FTSH contacts closes to set up the power circuit to fuel transfer contactors FTC and fuel transfer solenoid valve FTSV when fuel level falls to 3-1/2 inches below centerline. The contacts open when fuel level is at centerline. A second set of FTSH contacts close to register a FUEL TRANSFER fault if fuel level rises to 3-1/2 inches above the centerline.

FTSV, FUEL TRANSFER SOLENOID VALVE

A fuel transfer solenoid valve is located in the fuel suction line between the main tank and the day tank of the generating unit equipped with fuel pumps. The solenoid opens the valve if the following conditions exist: any engine in an installation is running; fuel transfer switch on the engine control panel is in the ON position; fuel level is not abnormally high in the day tank.

GCS, GOVERNOR CONTROL SWITCH

The switch is equipped with a pistol-grip handle located on the switchgear cubicle door. It is used to adjust the speed of the diesel engine during manual speed setting, manual synchronizing, and manual loading of the generating unit in deadline operation.

GOV RS, GOVERNOR RACK SWITCH

This switch (located in the governor) closes at a fuel rack position of about 25% load. During normal unit shutdown, closure of the rack switch energizes the breaker trip coil, causing the unit main circuit breaker to open.

GOVERNOR TRANSDUCER

This transducer exerts a given amount of force per given electrical signal in the milliampere order. When working as a "force motor" during deadline operation, it controls the injection of fuel to the diesel engine cylinders by positioning governor mechanisms.

Load sensing equipment provides a milliampere signal proportional to engine load. This signal causes the transducer to exert proportional pressure against a restoring spring.

Governor linkage causes an increase in the amount of spring pressure as the amount of fuel injected increases. A balance point is thus attained when spring pressure related to the amount of fuel injected is in equilibrium with the pressure exerted by the governor transducer. Since transducer force is in proportion to electrical load, diesel fuel satisfies line requirements.

GOV 65.(50 CYCLES) OR GOV77 (60 CYCLES), GOVERNOR SWITCH

This switch is located on the governor drive gear case. It closes at 200 RPM to energize the loading relay LR, thus allowing the governor speed setting motor to be driven in the increase direction. A cam opens the switch again when speed setting gear train position corresponds to a speed 50 RPM higher than normal operating speed. This prevents further operation of the governor motor in the increase direction. The governor clutch remains engaged to lock the speed setting. Just before switch opens at 50 RPM higher than operating speed, governor linkage will have come to rest against a KW limiting rack stop and no further increase in power would be available from governor motor action.

GS-1 GOVERNOR SPEED SETTING SOLENOID - IDLE

This solenoid picks up to set the engine injector rack to obtain idle speed. It also acts as a shutdown solenoid, since it must be energized to allow the engine to run. GS-1 is not picked up during the first 4 seconds of engine cranking.

GS-2, GOVERNOR SPEED SETTING SOLENOID - SYNCHRONOUS SPEED

This solenoid picks up to set the injector rack to bring the diesel engine up to approximately synchronous speed. It is also energized when the circuit breaker is closed. The solenoid is de-energized after the clutch control relay CCR picks up to engage the speed setting gear train, which makes the finer settings for synchronizing.

GSS, GOVERNOR SOLENOID, HALF LOAD LIMIT

This governor solenoid Is employed to limit injector rack travel. For detailed description, see paragraph entitled Three Position Rack Stop Mechanism in the governor description portion of Section 2 in this manual.

GV, GENERATOR VOLTAGE RELAY

The operating coil of the generator voltage relay is connected at the bus metering potential transformer. When the generator is developing voltage, the relay picks up. Instantaneous response contacts of GV isolate the reclosure lockout relay during synchronizing and disconnect the NO VOLTAGE annunciator. Delayed response contacts pick up to energize the governor clutch control relay.

IHC, IMMERSION HEATER CONTACTOR

This contactor picks up to supply 240 V DC to the immersion heater when the immersion heater temperature switch closes, provided the excitation relay is not picked up.

IHTS, IMMERSION HEATER TEMPERATURE SWITCH

This switch closes to energize the immersion heater contactor IHC when water temperature in a manifold adjacent to the oil cooler drops below a specific temperature. The warm water in the oil cooler is used to heat engine oil that is continuously pumped through the engine during periods of shutdown.

IR, ISOLATION RELAY

The isolation relay is energized when the automatic-manual switch is in the MANUAL position and annunciator relays are set so that the normal lockout relay is energized. The isolation relay acts to energize several pushbuttons that are used during manual operation, and it sets up various circuits that during automatic operation would be activated by pickup of the master relay MR, which is dropped out during the manual mode of operation.

ITS, IDLE TIME STARTING RELAY

During normal automatic operation this relay is energized at engine start. Its time delay holds off pickup of governor solenoid GS-2, thereby preventing engine speedup until engine temperature and oil pressure have increased to an optimum level.

ITSX, IDLE TIME STARTING RELAY AUXILIARY

This relay picks up at the same time as the idle time starting relay ITS. Its function is to provide energy to drive the governor motor in a raise direction for timed period set by the clutch control relay CCR. This brings the speed setting made by the governor motor into close agreement with the speed set by speed setting solenoid GS-2.

LLR, LOW LOAD RELAY

This relay is energized after 25% rack setting to prevent further automatic loading. It will also permit further loading in increments by an operator manually at the MU site. (See note under SLR.)

LOR, LOCKOUT RELAY

This lockout relay, in conjunction with its auxiliary relays LORA and LORB, functions to prevent repeated attempts to pick up a deadload should the MU load breaker trip after the MU installation has gone on the line. Depending upon the type of installation and system, the lockout can be overridden either by manual interruption of the circuit or by operation of a system breaker interlock.

LORA, LORB: LOCKOUT RELAY AUXILIARY

Lockout relay LORA is energized when a deadline start signal is given and the MU load breaker is open. The relay sets up the circuit to energize LORB when the load breaker closes and the MU installation attempts to pick up the deadload. At that time LORB sets up the circuit to pick up LOR should the load breaker trip and close again.

LR, LOADING RELAY

The loading relay is energized by the cam switch when engine speed reaches 200 RPM: it is de-energized when the engine speed setting corresponds to 50 RPM over operating speed (full engine load). The function of the relay is to set up the circuit for driving the governor motor to increase the governor speed setting (increase engine load) and to provide indication to a remote location that the unit breaker is closed and the generating unit is loading. The relay also establishes the timing cycle set by the overspeed trip auxiliary relay OTX should the generating unit fail to load properly; it partially completes a connection to the unit breaker closing coil; and it provides a circuit to drive the governor motor to decrease load if the manual stop pushbutton is pressed or an engine fault occurs.

LS, GOVERNOR RACK LIMIT SOLENOID, LOADING

This solenoid is used to override the normal limit on injector rack travel. For a detailed description, see paragraph entitled Three Position Rack Stop Mechanism in the governor description portion of Section 2 in this manual.

LSR, LOAD SHARING RELAY

During deadline starting one unit is selected as a master in an installation. On that unit the master unit selector switch energizes load sharing relay LSR. Pickup of LSR allows the master unit governor trimmer switch to operate the governor trimmer motor, thereby controlling the signal to the load computers, which in turn control load of all units in the installation.

LSRX, LOAD SHARING RELAY AUXILIARY

During deadload starting, LSRX picks up when power is applied to the static exciter. However, in the unit that becomes the master unit in the installation, LSR pickup drops out LSRX. In all units except the master unit, LSRX connects the governor trimmer switches to the governor motor. This enables the governors in such units to make minor load compensations.

LTR, LOW (OIL) TEMPERATURE RELAY

The low oil temperature relay picks up to provide an engine start signal when the low oil temperature switch closes. The relay also opens the feed line to the governor solenoid GS-2, preventing increase in engine speed above idle. The engine will idle for 11 minutes after engine oil temperature reaches a satisfactory level. The unit will then shut down, or go on the line at proper temperature if a start was signaled while the automatic cold idle was in effect. Pickup of LTR will cause an IMMERSION HEATER fault to be registered, but the unit will not be locked out.

NOTE: Actual lack of oil or a defective lube oil circulating pump would cause LTR to operate. In the case of lack of oil, the engine would shut down in 90 seconds and an ENGINE fault would be registered in addition to an IMMERSION HEATER fault.

LTV, , LOW (OIL) TEMPERATURE SWITCH

This switch is located within the generating unit engine control cabinet. Its temperature sensing element is located in piping between the lube oil cooler and lube oil strainer. The switch closes at low oil temperature to energize the low oil temperature relay.

MBR, MAIN BEARING RELAY

The operating coil of MBR is energized when main bearing switch MB-1 closes. MBR contacts close to allow pickup of governor speed setting solenoid GS-2, governor motor clutch control relay CCR, and generator field flashing relay FFR. Other contacts open after the engine has started. These disable the engine starting circuits and set up the ENGINE fault circuit. MBR dropout occurs after initial pickup when oil pressure fails or a low water pressure or crankcase pressure indication is given.

MBX, MAIN BEARING RELAY AUXILIARY

The function of this relay is to void the oil alarm delay relay OAD and thereby activate the ENGINE fault circuit as soon as oil pressure is sufficient to pick up oil pressure sensing switch MB-1. This sets up the shutdown capability of the low water/crankcase pressure detector, which when tripped, brings about engine shutdown by dumping oil from a line leading to oil pressure sensing switch MB-1.

MB-1, OIL PRESSURE SWITCH

This switch is identified as MB (main bearing) because it operates to ensure proper lubrication. The switch functions to hold the engine at idle speed until oil pressure at the switch reaches about 28-30 psi. Switch contacts close to pick up main bearing relay or to shut the engine down if oil pressure is not satisfactory within a specific time.

MB-2, OIL PRESSURE SWITCH

This switch senses oil pressure from the same point as the MB-1 switch, but it is set to operate at a higher pressure. It functions to shut down the engine if oil pressure has not reached a satisfactory level within a specific time after the engine reaches full speed. Engine shutdown due to MB-2 dropout trips the ENGINE fault annunciator.

Notice that the low oil shutdown circuits and mechanism are employed during low water and crankcase pressure shutdown. Whenever an ENGINE fault indication is given, check the low water/crankcase (oil pan) pressure detector.

WARNING: Do not open the crankcase inspection covers until an overheated engine cools.

MR, MASTER RELAY

The master relay and its related auxiliary relays pick up when, with the automatic-manual switch in AUTOMATIC position and the normal lockout relay NLO energized (no fault registered), a start signal picks up the unit start relay USR. The master relay is not picked up during a manual start.

The function of the MR relay is to energize the unit engine starting circuit and the speed sensing panel and to partially set up circuits for control of synchronizing, excitation, and loading. MR also provides for normal and emergency unit shutdown.

MRY, MASTER RELAY AUXILIARY

The function of time delay relay MRY is to provide a temporary current path to drive the governor motor in the decrease direction during generating unit shutdown. This is necessary because loading relay LR contacts, which normally provide the current path to the governor motor, are open during normal operation and remain open until the governor speed setting drops below a value corresponding to 50 RPM higher than operating speed.

MSX, MANUAL STOP AUXILIARY RELAY

This relay is energized by pickup of the MANUAL STOP or ENGINE fault annunciator relays. When a manual stop signal is given while the unit is operating in the manual mode, the MSX relay functions to energize the breaker trip coil after load falls to 25% of full value. It also drops out the clutch control relay when generator excitation falls off, and it operates to drop generator excitation relays and establish the idling time period before engine shutdown.

NLO, NORMAL LOCKOUT RELAY

The normal lockout relay NLO is energized when protective relays on the annunciator panel are set. NLO is de-energized when protective relays trip. The generating unit is locked out when NLO is de-energized. The protective relays latch in the tripped position, and the reset pushbutton on the annunciator panel must be pressed to reset the relays, provided the fault is corrected. The NLO functions to prevent engine start or to bring about generating unit shutdown whenever a fault prevents NLO pickup.

OAD, OIL ALARM DELAY RELAY

Delayed closure of OAD relay contacts prevents a low oil alarm and shutdown while oil pressure is building up during the engine starting sequence. The operating coil of OAD is energized when engine speed reaches 200 RPM. If the main bearing relay has not picked up by the time that OAD contacts close, engine oil pressure is not satisfactory and a low oil shutdown will occur. If oil pressure builds up before OAD contacts close, pickup of MBX relay voids the OAD delay, enabling detection circuits to respond immediately to high crankcase pressure or low water.

OLTD, OVERLOAD TIME DELAY RELAY

This relay, in conjunction with SC1, SC2, DLRA, and DLRB functions to permit temporary overloading of the generating unit during deadload pickup.

OTIS, OVERSPEED TRIP LIMIT SWITCH

When the overspeed trip lever is in the tripped position, the lever closes the OTLS switch contacts and energizes the overspeed trip limit relay.

OTLX, OVERSPEED TRIP LIMIT RELAY

This relay is energized when the overspeed trip limit switch is tripped by action of the engine overspeed trip lever. It energizes thetrip coil auxiliary relay TCS and the breaker trip coil, it picks up the engine overspeed relay on the annunciator panel, and it prevents operation of the overspeed trip solenoid when the lever is in the tripped position.

OTS, OVERSPEED TRIP SOLENOID

This solenoid is energized through pickup of OTX caused by abnormal operation of the master relay, loading relay, or a main circuit breaker auxiliary relay. When energized, the solenoid trips the mechanical overspeed trip device mounted on the engine right bank camshaft. This accomplishes an engine stop that is independent of the governor or normal stop circuits. The overspeed trip must be reset by manually operating the trip lever.

OTX, OVERSPEED TRIP RELAY (OVERALL TIMEOUT)

This relay is energized after engine start or after an engine stop signal is given. Delayed pickup of its contacts energizes the overspeed trip solenoid OTS if the starting or stopping cycle does not go to completion.

RCL, RECLOSURE LOCKOUT SWITCH

This solenoid operated four-position stepping switch signals synchronizing attempts. When the switch operating coil is energized, an actuating lever within the switch is cocked, and shortly thereafter the interrupter contacts that are part of the stepping switch open. Interrupter contacts are located in the feed lines to the switch operating coil, but contacts of other relays related to synchronizing, place a shunt around the interrupter contacts for a timed period. This holds the operating coil energized while a synchronizing attempt is made. When the coil is de-energized, the cam actuating lever releases and drives the switch to the next position for another attempt. When the synchronizing attempt is successful, or after the third unsuccessful attempt, the switch steps to the No. 4 (recycle) position. After three unsuccessful synchronizing attempts, RCL contacts close to register a SYNCHRONIZING fault.

SC1, SC2; CURRENT RELAYS
These relays sense current from the generating unit current transformers to the load comnputer. This current is proportional to generating unit output. Pickup of SC1 takes place at low generator current to set up overload circuits. Pickup of SC2 at a greater value energizes OLTD and DLRB. These relays temporarily desensitize the 27 relay.
When OLTD is energized, two sets of its time delay contacts begin to time out. The timing continues as long as SC1 is picked up. When OLTD times out, one set of its contacts seal OLTD in against SC1 dropout, and another set activates the current limiting section of the voltage regulating unit. This remain in effect until SC2 drops out.

SLR, SLOW LOAD RELAY
This double acting time delay relay has delayed pickup when the operating coil is energized and delayed dropout when the coil is de-energized. An operating cycle is established

by using the delayed action of the relay contacts in feed to the relay operating coil. The intermittent "on-off' thus obtained is used to drive the governor motor intermittently during the loading sequence. This accomplishes slow loading and precludes an undesirable surge of power. The term slow loading is meant to imply that loading takes place at a rate slower than the capability of the engine governor speed setting motor.

NOTE: Slow loading should not be confused with incremental loading. The term incremental loading is meant to imply that load is applied in two increments. Load of a specific amount is applied automatically during the first increment. Additional load is then applied manually by an operator at the MU site (see LLR) during the second increment. However, the slow loading characteristic does allow (when an an operator is present at the MU site) transfer from automatic to manual operation during the loading sequence in order to hold load at a specific level. The operator may then manually apply or reduce load.

SM, STARTING MAGNET

This spring-loaded solenoid pushes the Dyer drive pinion in the mesh with the flywheel ring gear when STZ is energized.

SMLS, STARTING MAGNET LIMIT SWITCH

SMLS is mechanically actuated by full travel of the starting magnet plunger. It cannot be actuated unless the pinion of the Dyer drive is fully engaged with the ring gear. When SMLS closes, a circuit to the starting motor contactor is completed and the starter motor rotates.

SMR, STARTING MAGNET RECYCLE RELAY

This double acting time delay relay has delayed pickup when the operating coil is energized and delay dropout when the coil is de-energized. It employs its own contacts to establish a cycle of operation and intermittently energize STZ to bring about timed engagement attempts of the Dyer drive with the ring gear. If the Dyer drive has not engaged after five attempts, a second relay SMTO times out and signals a STARTING fault.

SMS, MASTER UNIT SELECTOR STEPPING SWITCH

This six-position solenoid operated stepping switch is used to complete a circuit to the load sharing relay LSR. Pickup of LSR in a given unit establishes that unit as the master unit for purposes of deadline operation. The master unit sets the frequency of the installation. Other units follow the master.

After a deadline signal has been given and at least one unit in an installation has started, come up to operating speed, and has power delivered to the generating unit static exciter, the stepping switch SMS operating coil is energized. An actuating lever within the switch is cocked, and shortly thereafter the interrupter contacts that are part of the stepping switch assembly open. SMS operating coil is de-energized and the actuating lever releases to drive the switch from position 6 to position 1. The switch will step until its action

energizes load sharing relay LSR on the unit that is ready to go. That unit becomes the master unit.

SMSX, MASTER UNIT SELECTOR STEPPING SWITCH AUXILIARY RELAY

The slight delay in pickup of SMSX contacts allows a complete step of SMS and pickup of load sharing relay LSR. This ensures proper sequencing of the load sharing circuits.

SMTO, STARTING MAGNET TIMEOUT RELAY

This time delay relay is energized at the time the first engagement attempt of the Dyer drive is made during the engine starting sequence. Delayed pickup, 20 seconds after the relay is energized, allows 5 engagement attempts before SMTO signals a STARTING fault.

SR, SYNCHRONIZING RELAY

Relays that are part of individual generating unit circuitry pick up to energize the synchronizing relay SR. SR directs one signal from the bus metering potential transformer and another signal from the generator metering potential transformer to a static synchronizing unit. The signals are compared by the static synchronizer, which sends a signal to the governor amplifier. The governor amplifier sends a signal to drive the governor motor in the increase or decrease speed direction to attain synchronous speed.

SRF, SYNCHRONIZING FORESTALLING RELAY

This relay is energized at the same time as SR, but its contacts close after a 1 second delay. The delay prevents premature closure of the generating unit main circuit breaker should the KB relay in the synchronizer pick up due to a transient signal.

SS, START-STOP SWITCH
This rotary snap switch is located below the annunciator panel. It is effective for engine start only when the automatic-manual switch is in the AUTOMATIC position, but it will shut down the unit in either mode of operation.

ST, STARTING CONTACTOR
The starting contactor located in the generator control cabinet of the generating unit connects the battery located in the control unit with the individual engine starting motor. Once a starting circuit is set up, the pickup of ST is controlled by the starting stepping switch STS.

STS, STEPPING SWITCH (START) RELAY

This six-position solenoid operated stepping switch is used to energize switchgear and complete a circuit between the control unit battery and the starting motor of only one generating unit at a time, thus preventing overloading of the battery.

When the switch operating coil is energized, an actuating lever within the switch is cocked, and shortly thereafter the interrupter contacts that are part of the stepping.

switch assembly open. The interrupter contacts set up a timing cycle for engine cranking. When the cycle is complete, the STS operating coil is de-energized, and the actuating lever releases to drive the switch to the next position.

The stepping switch is energized when a start signal is given. The switch then steps until it reaches a position where it completes the circuit to the starting contactor coil ST in a generating unit that is ready to start. When the starting contactor picks up, the circuit to the STS coil is interrupted, and the switch stops until ST is dropped out by speed or oil pressure sensing devices that indicate the engine is running. If ST dropout does not occur within 10 seconds, a timing relay signals a STARTING fault and the unit is locked out.

STSX, STEPPING SWITCH RELAY AUXILIARY

The slight delay in closing of STSX "A" contacts allows a complete step of STS and pickup of starting contactor ST and its interlocks. This ensures proper sequencing of the starting circuits.

STSY, STEPPING SWITCH AUXILIARY RELAY

The 10 second delayed closing of STSY "A" contacts establishes a limit to the cranking time devoted to any given generating unit. Pickup of STSY before engine speed or oil pressure have acted to drop out the starting contactor ST will register a STARTING fault on the annunciator and will lock out the unit after only one starting attempt. This can occur if an engine cylinder contains fluid and is hydraulically locked or if the starting motor pinion fails to mesh with the ring gear.

STW, STARTING RELAY AUXILIARY

STW is energized during the generating unit starting sequence when the Dyer drive engages with the ring gear and the starting magnet limit switch SMLS closes, indicating full engagement. Pickup of STW instantaneous response contacts allows the cranking sequence timing to begin, and delayed dropout of its timed contacts prevents immediate Dyer drive engagements on units where cranking has timed out but the engine has not started.

STWX, STARTING RELAY AUXILIARY

After 10 seconds of engine cranking, a time delay relay opens to drop out STWX. Contacts of STWX drop out the starting contactor.

STX, REDUCED VOLTAGE STARTING CONTACTOR

In about 4 seconds after a starting attempt is initiated, STX contacts close to short out a voltage dropping resistor in the circuit to the cranking motor. This allows the cranking motor to receive full voltage and turn at normal speed.

The purpose of the voltage dropping resistor is to accomplish slow rotation of the engine for the first revolution and thereby prevent the development of momentum that could result in engine damage should fluid be trapped in an engine cylinder.

STY, STARTING RELAY AUXILIARY

This relay transfers the DC control circuits to the battery charger during engine cranking. This prevents low control voltage due to the large load on the battery. A rectifier allows control supply from the battery when the charger is inoperative.

Contacts of STY may also be employed to ensure proper sequencing of starting stepping switch STS.

STZ, STARTING RELAY AUXILIARY

This relay is used during engine starting to set up the starting fault circuit for shutdown and lockout should the engine fail to start after cranking power has been applied for 10 seconds. This type of shutdown will occur if mechanical failure prevents the engine from rotating when cranking power is applied or if the engine rotates, but does not fire.

SYD, RESYNCHRONIZING RELAY

Operation of the resynchronizing pushbutton in the MC control unit, energizes SYD through contacts of synchronizing stepping switch SYS. Pickup of SYD energizes the synchronizing relay SR; and the resynchronizing signal to bring the MU installation into synchronization with a remote source of power is applied to the static synchronizer and from there to the governor amplifier and the governor motor.

3YDT, RESYNCHRONIZING RELAY AUXILIARY (TIMING)

When a resynchronizing signal is given, immediate response contacts pick up to hold the resynchronizing relays picked up for the period set into the delayed response contacts of SYDT. This limits the resynchronizing attempt to a specific amount of time - normally 40 seconds.

SYDX, RESYNCHRONIZING RELAY AUXILIARY

This relay inserts resistors and choke coils into voltage regulator circuits for purposes of voltage matching during resynchronizing. The circuit involved is sensitive to system stability, and accurate calibration and setting is required.

NOTE: The voltage regulators are normally installed with fishpaper under the taps of the particular resistors involved. The fishpaper should be left In place unless specific problems exist at the installation and personnel familiar with and competent to calibrate the circuit is available,

SYDY, RESYNCHRONIZING RELAY AUXILIARY

This relay picks up at the same pickup signal received by SYD. SYDY contacts operate to direct two signals to the static synchronizer; one from the bus potential transformer and the second from remote potential transformers. This enables the MU installation to synchronize with the remote source of power.

SYN, SYNCHRONIZING RELAY

The synchronizing relay connects the static synchronizer to the generator metering potential transformer. The stepping switch SYS ensures that only one SYN in an installation is picked up at one time. A timing relay in the synchronizing circuit limits the time of the synchronizing attempt to 20 seconds. After that time the SYN that is picked up drops out, and the stepping switch SYS steps to pick up another SYN relay.

SYS, STEPPING SWITCH SYNCHRONIZING RELAY

This six-position solenoid operated stepping switch is used to complete a circuit between the static synchronizer and the governor motor of a single generating unit at a time. It enables one set of synchronizing equipment to handle the synchronizing for all generating units in an installation.

When the stepping switch operating coil is energized, an actuating lever within the switch is cocked, and shortly thereafter the interrupter contacts that are part of the stepping switch assembly open. Through use of other relays with delayed action contacts, a timing cycle for synchronization is set up. When the cycle is complete the SYS operating coil is de-energized and the actuating lever releases to drive the switch to the next position.

The SYS is energized when generator speed and voltage are up and the governor motor clutch control relay is engaged in at least one generating unit in an installation. The clutch connects a gear train between the governor motor and speed setting elements in the engine governor. The switch then steps without delay until it reaches a position where it completes a circuit to a synchronizing relay in a generating unit on which the clutch control relay is picked up. When the synchronizing relay is picked up, the circuit to the SYS coil is interrupted and the switch movement stops until SYN is dropped out by a time delay relay that limits individual synchronizing attempts to 20 seconds.

Another stepping switch, RCL, limits synchronizing attempts on each generating unit to a total of three for any given attempt to put an MU installation on the line.

SYSX, STEPPING SWITCH RELAY AUXILIARY

The delayed closing of SYSX "A" contacts establishes a 20 second time limit for each synchronizing attempt. When the relay "A" contacts close, the synchronizing relay SYN drops out and the synchronizing stepping switch advances to select another generating unit for synchronizing.

SYSY, STEPPING SWITCH RELAY AUXILIARY

The slight delay in closing of SYSY contacts allows a complete step of SYS and pickup of synchronizing relay SYN. This ensures proper sequencing of the synchronizing circuits.

SYSZ, STEPPING SWITCH RELAY AUXILIARY

After 20 seconds of synchronizing this time delay relay opens to drop out the synchronizing relay SYN.

TCX, TRIP COIL RELAY AUXILIARY

When TCX is energized it signals a GENERATOR BREAKER fault. It is energized when protective devices signal a breaker opening by means other than a normal lockout. That is, a breaker opening is signaled while the master relay MR is still picked up.

TDR, REDUCED VOLTAGE TIMING AUXILIARY RELAY

This time delay brings about pickup of DSS and STX in about 4 seconds after a start is initiated. These relays in turn cause full application of power to the cranking motor and injection of fuel into the engine cylinders.

TSF, FAN TEMPERATURE SWITCH

This temperature switch picks up at approximately 100 degrees F. and drops out at approximately 90 degrees F. The switch energizes the fan contactor relay FCR that operates the MC unit exhaust fan.

USR, UNIT START RELAY

The unit start relay is used to either start or stop generating units. The start relay accomplishes this by picking up the master relay MR for starting and dropping out the relay for stopping. The unit start relay is operated by operation of the start-stop switch in the control unit.

WARNING: The USR remains picked up until a stop signal is given, even though a generating unit may be stopped by a fault. This means that the unit will automatically restart when the fault is corrected.

UST, UNIT SHUTDOWN TIMER

The unit shutdown timer relay acts to hold the diesel engine at idle speed for a timed period after a shutdown signal is given. This allows a gradual cooling down of the engine and turbocharger. The delay is overridden in the event of an ENGINE fault, an engine overspeed trip, or a manual stop.

ZSR, ZERO SPEED RELAY

The zero speed relay is energized by pickup of the ES-O relay on the speed sensing panel when engine speed reaches 40 to 50 RPM. ZSR pickup prevents any further attempt by the cranking motor pinion to engage the engine flywheel, and a delayed dropout of ZSR forestalls the next engagement attempt until the flywheel stops turning. ZSR also sets up circuits for operation of the fuel transfer pumps.

40-OC, ALTERNATOR FIELD OVERCURRENT RELAY

This relay is located in the generator control cabinet of each generating unit. Its operating coil is located in the line between the magnetic amplifier and the anti-hunt transformer 3-4 winding. The relay will pick up at 115 amperes DC.

ELECTRICAL DEVICES

Should a regulator failure occur, a condition of high generator voltage may exist. When the generating unit is operating in parallel with a system, high voltage would cause high reactive currents that would not be detected by bus overcurrent relays because they have voltage restraint. Therefore, the field overcurrent relay 40-OC senses generator field current and trips when it reaches a dangerous level. When the relay trips, the main circuit breaker will trip, the engine will go to idle and then stop, and the GENERATOR BREAKER fault light will come on.

40-OCX, ALTERNATOR FIELD OVERCURRENT RELAY AUXILIARY

Pickup of the alternator field overcurrent relay 40-OC energizes time delay relay 40-OCX. Pickup of 40-OCX contacts is delayed for 10 seconds before the contacts close to trip the generating unit main circuit breaker. This prevents breaker trip on alternator field overcurrent of a transient nature.

27, THREE PHASE UNDERVOLTAGE RELAY

A fault external to the MU installation will be detected by the 27 relay. When such a fault is detected, all generating units main circuit breakers in the installation will trip. However, the units will not be locked out and may be restarted remotely.

High current in the output of the MU installation can be caused by a fault external to the installation, in which case voltage will drop to a low level concurrent with high current, and the 27 relay will operate. If overcurrent is in the form of high reactive current due to regulation difficulties, voltage will remain high and the 27 relay will not operate.

27X, UNDERVOLTAGE RELAY AUXILIARY

When the 27 relay detects undervoltage, the 27X relay is energized, provided one or more unit main circuit breakers are closed. 27X contacts close to direct battery power to the generating unit main circuit breaker trip coils, and the breakers open. A table of common relays on the schematic wiring diagram indicates which 27X relay contacts relate to which generating unit circuit breaker.

27XX, UNDERVOLTAGE RELAY AUXILIARY

The 27XX relay is picked up in the same manner as the 27X relay. Pickup of the 27XX relay precludes pickup of any unit start relays, causes an EXTERNAL FAULT indication at the annunciator and brings about engine shutdown.

52, MAIN CIRCUIT BREAKER

The main circuit breaker used for each generating unit in an MU installation is an electrically operated air circuit breaker; 3 phase, rated at 1200 amperes at 4160 volts. Interrupting capacity is 250 MVA. The circuit breaker rolls into and out of switchgear cubicles. A guide track and locking mechanism are used to position the breaker in one of three positions; disconnect, test, or connect, Fig. 3-4. The breaker must be levered into the connect position to lock it in place. Handling tools are provided for breaker manipulation.

L..S. (BUS TIE) BREAKER

The load circuit breaker for each MU installation is an electrically operated air circuit breaker; 3 phase, rated at 1200 amperes at4160 volts. Interrupting capacity is 250 MVA. The circuit breaker rolls into and out of a weatherproof steel shelter mounted on a concrete slab. A transfer truck is provided with the shelter for handling of the breaker.

52a, MAIN CIRCUIT BREAKER AUXILIARY SWITCH

Main circuit breaker auxiliary switches identified as 52a are open when the main circuit breaker is open. The closed contacts set up circuits to various auxiliary relays, devices, and lights.

52aa, BREAKER CLOSING SOLENOID LIMIT SWITCH

Main circuit breaker auxiliary switch 52aa closes when the breaker operating mechanism is in the operated position. Closure of the 52aa switch energizes an auxiliary relay to drop out the breaker closing solenoid.

52b, MAIN CIRCUIT BREAKER AUXILIARY SWITCH

Main circuit breaker auxiliary switches identified as 52b are open when the circuit breaker main contacts are closed. Open 52b contacts drop out the 52W auxiliary relay, which establishes connections to windings in the magnetic amplifier type voltage regulator. Open 52b contacts turn out the green circuit breaker position light on the door of the switchgear cubicle.

52CC, MAIN CIRCUIT BREAKER CLOSING COIL

The coil is energized through operation of manual switches or through closure of relays when the unit is ready to go on the line.

52TC, MAIN CIRCUIT BREAKER TRIP COIL

The trip coil is energized through operation of various protective devices, through manual switch operation, or in the normal shutdown procedure when load falls to about 25% capacity. This opens the circuit breaker and takes the unit off the line.

52V, 52VX, 52VY; MAIN CIRCUIT BREAKER AUXILIARY RELAY

These auxiliary relays are energized by closure of the main circuit breaker auxiliary switch 52a. The relays perform functions related to closure of the circuit breaker.

52W, MAIN CIRCUIT BREAKER AUXILIARY RELAY

The 52W auxiliary relay is energized when, during generating unit operation, the generating unit main circuit breaker is open. It is de-energized when the circuit breaker is closed. The relay contacts operate in circuits that include the bias and control windings of the magnetic amplifier type voltage regulator used for each generating unit in an installation.

52Z, BREAKER CLOSING COIL RELAY

52Z Relay is energized upon a signal from the Static Synchronizer indicating that the MU Generating Unit is synchronized with the System or another MU Generating Unit. This signals the main circuit breaker closure of the unit, thus paralleling with the System or another MU Generating Unit.

55, LEADING VAR RELAY

As the generator field is reduced, either deliberately or otherwise, the magnetic coupling between the rotor and stator is weakened and the machine tends to pull out of step. It continues to carry load, but draws a high component of reactive power from the power system. This may be damaging to the generator and may cause voltage disturbances in the power system. The 55 relay is a directional power relay connected to read leading VARS and detect the out-of-step condition. Relay trip causes a direct trip of the generating unit main circuit breaker.

59, OVERVOLTAGE RELAY

Overvoltage protection is provided for the generator armature. The 59 relay initiates a normal shutdown with lockout. The OVERVOLTAGE fault relay must be reset before operation can be attempted again. Shutdown of the generating unit provides protection if overvoltage is caused by an internal fault such as a faulty regulator. Isolation of the unit, through normal shutdown and lockout, protects against an external fault.

67, REVERSE POWER RELAY

When the power output from the diesel engine is not sufficient to provide for all losses, the deficiency will be supplied by the power system, and the generator will run as a motor. This is undesirable in respect to both generator and engine. The 67 relay is used to detect motoring and trip the circuit breaker.

86, LOCKOUT SWITCH

This manually operated multiple stage switch is equipped with a magnetic tripping mechanism. When the tripping mechanism is energized by operation of protective relays, unit circuit breakers cannot be closed, and those that may be closed at the time of 86 relay trip will trip open. The switch must be manually reset.

87, THREE PHASE DIFFERENTIAL PROTECTION RELAY

The high voltage equipment within an MU installation is protected from internal faults by an overall differential zone that extends from generator neutral to the outgoing power bushing. Measurement of current flow is done by putting current transformers at the output of the installation and at each generating unit output. These current transformers are then tied together in such a manner that they balance out if there is no fault. Should a ground or phase fault occur, an unbalance is detected by the 87 relay, which through the differential trip device (86), trips all unit circuit breakers, removes excitation from

all generator fields, and stops all engines. The system does not discriminate, but treats the MU installation as one generating source.

Tripping of the unit circuit breakers does not isolate the MC control unit internal bus from the utility system. An extra contact of the differential trip device can be used to trip an isolating system breaker.

SECTION 8

ANNUNCIATOR OPERATION AND TROUBLE SHOOTING

This section provides a description of annunciator operation and a check list of areas to be investigated and corrections to be made in the event that operating difficulties are encountered. No attempt has been made to explain the normal mechanical or electrical functions. For such information refer to other sections of this manual.

ANNUNCIATOR

The annunciator, Fig. 3-9, is located on the control room wall. It contains neon bulb target lights that go on when annunciator relays are tripped by electrical or mechanical faults. A red FAULT light goes on when any unit in an installation has a fault. The individual target lights go on only when the UNIT selector switch is positioned to the number of the unit containing the fault. Certain fault lights are indication of conditions that have caused the affected unit to shut down and lock out, while other lights provide warning only.

The annunciator system consists of an annunciator relay panel for each unit in the MU installation. Each panel contains one two-coil operating (tripping) and reset relay for each fault indication. All fault relays are electrically connected to the fault display panel through the UNIT selector switch. This switch must be properly positioned to read or reset the relays. It is necessary to press the RESET pushbutton to put out the fault light, provided the fault has been corrected.

ANNUNCIATOR RELAY OPERATION

Each protective device, when actuated, gives a signal to energize the operating coil "0" (trip) of its own annunciator relay. When actuating signal is removed, the operating coil is de-energized, but the relay remains latched in the tripped position until the reset coil "R" is energized and the fault signal is removed. The relay cannot be reset or it will not remain reset if the fault has not been corrected.

Certain annunciator relays, in addition to giving a visual indication, will interrupt the circuit to the normal lockout relay NLO. When NLO is dropped out, the unit will go off the line and the engine will either stop immediately or will idle for a timed period before total shutdown.

TROUBLE SHOOTING

Since most operating difficulties will be detected by annunciator operation, trouble shooting will usually start by observation of the annunciator indicator panel. The operation of each annunciator target and its possible causes will be described individually.

1. Faults that cause annunciator light display, but that bring about no action other than the light signal. Action that does occur when these faults are registered is caused by faults themselves or by devices apart from the annunciator.

a. FUEL TRANSFER

b. IMMERSION HEATER

c. EXTERNAL FAULT

2. Faults that cause normal lockout, or shutdown and normal lockout with a timed idle period before the engine stops.

a. STARTING

b. SYNCHRONIZING

c. NO VOLTAGE

d. OVER VOLTAGE

e. GENERATOR BREAKER

f. ENGINE TEMPERATURE

g. MANUAL STOP

3. Faults that cause immediate shutdown and lockout.

a. ENGINE (low water, low oil, crankcase pressure)

NOTE: If a low water or low lube oil condition exists before an engine start is signaled, the engine will start and idle for 90 seconds, then shut down.

b. ENGINE OVERSPEED

DIFFICULTIES SIGNALED BY THE ANNUNCIATOR

FUEL TRANSFER - FT

The FUEL TRANSFER light indicates an abnormally high or low day tank level. This light will be displayed at all positions of the UNIT selector switch. Trip of the FT relay causes the light to come on, but it does not affect engine operation. The annunciator may be reset when day tank level returns to normal.

Possible Causes Of Fuel Transfer Fault:

1. Fuel level in day tank too high.

a. FTC contactor stuck closed.

b. FTSN or FTSH float switch defective.

2. Fuel level in day tank too low.

   a. Both fuel pumps inoperative or not energized.
   b. Fuel transfer solenoid valve FTSV inoperative or not energized.

   NOTE: The fuel transfer pumps will run only if at least one engine in an installation is running.
   c. FTSW switch on the engine control panel of the unit equipped with fuel transfer pumps may be in OFF position or fuel transfer fuses may be blown.
   d. FTSN or FTSL float switches defective.
   e. Fuel transfer pump strainers or filter may be plugged.
   f. FTC contactor defective.
   g. Fuel transfer solenoid valve may be stuck closed.
   h. A valve in the fuel supply line may be closed.
   i. Main supply tank may be empty.
   J. Fuel piping may be plugged, broken, or frozen.
   k. Pour point of fuel should be at least 10° F. lower than the lowest expected ambient temperature.

IMMERSION HEATER -IH

The immersion heater annunciator relay IH is energized when lube oil temperature in the piping between the oil cooler and strainer falls to 115° F. The unit will then start automatically and idle until oil temperature reaches 125° F. It will then shut down unless a peaking or deadline start signal was given while the engine was warming. If a start signal was given the unit will go on the line. If a deadline start signal was given, the MU installation will normally be prevented from picking up load until all units in the installation are warm.

Possible Causes Of Low Temperature:

1. Circulating pump motor switch on engine control panel in OFF position.

2. Circulating pump motor circuit breaker in control unit relay room in OFF position.

3. Immersion heater fuses on fuse panel blown out.

4. Immersion heater power disconnected. This power is normally taken from the control power transformer. Removable connecting links are located on the back of the fuse panel. Power may also be taken from a separate station service feeder.

5. Immersion heater contactor located in generator control cabinet is inoperative.

6. Immersion heater elements burned out.

To reset the IMMERSION HEATER fault annunciator relay, the RESET pushbutton on the annunciator panel must be pressed when the fault is corrected and the engine is warm.

EXTERNAL FAULT - EF

The EXTERNAL FAULT light indicates that a system line fault has occurred which resulted in excessive bus current accompanied by low bus voltage. The light will be dis played at all positions of the UNIT selector switch and will remain on until the annunciator is manually reset. When an external fault occurs, all 52 circuit breakers will trip open immediately, and all units will stop after a normal timed idle period. However, the units will not be locked out and may be restarted normally without resetting the annunciator.

STARTING - ST

The STARTING light indicates that the engine failed to start after it was given a start signal. The alarm will occur after five attempts to engage the starting motor pinion with the ring gear or after a cranking attempt of longer than 10 seconds duration. The annunciator starting relay ST will lock out the unit and prevent further attempts to start the unit.

Possible Causes Of Starting Failure:

1. If engine does not rotate -

    a. Starting fuse blown or removed.

    b. Defective cranking motor or solenoid.

    c. Starting sequence circuit fault. Check starting sequence fuse and relays.

    d. Hydraulic lock. Cylinder filled with fluid.

2. If engine rotates, but does not fire -

    a. No fuel supply to engine. Fuel should appear in the return fuel sight glass(nearest the engine), but not in the bypass sight glass. Check for plugged fuel oil strainer or plugged engine mounted fuel oil filters. Check for normal day tank fuel level. Refer to Section 2 and the Engine section of this manual for more information on the fuel oil system.

    b. Governor solenoid GS-1 not energized. Check for defective DSS or STZ relay.
    c. Engine rotates slowly only. Check for defective STX contactor, or defective relays STXT or DSS. The time setting of STXT may be incorrect.
    d. Injector fuel control rack binding.
    e. Emergency fuel cutoff valve closed.
    f. Governor oil level low (not visible in sight glass).
    g. Governor accumulator booster oil pump not operating.
    h. Overspeed lever tripped. Check for defective OTLS or OTLX.

SYNCHRONIZING - SY

The SYNCHRONIZING light indicates that the unit failed to synchronize after three separate attempts. The unit will shut down normally and remain locked out.

Possible Causes Of Synchronizing Failure:

1. Synchronizing sequence fuse blown or removed.
2. Circuit breaker closing fuses blown or removed.
3. Bus metering fuse blown (high or low voltage side of transformer).
4. Control power transformer high voltage fuse blown or removed.
5. Control power transformer circuit breaker in OFF position.
6. Circuit breaker knife switch open.
7. Governor motor fuse blown or removed (located on master control panel).
8. Synchronizing circuit fault.
9. Defective governor motor or gear train.
10. Defective static synchronizer.

NO VOLTAGE -NV

The NO VOLTAGE light indicates failure of the generator voltage to build up within 10 seconds after excitation is applied. A normal shutdown and lockout will result.

Possible Causes Of Voltage Failure:

1. No power to the static exciter.
    a. Control unit bus de-energized (peaking mode).
    b. Deadline field flashing system trouble (deadline mode).
    c. Controls not in correct position for desired mode of operation.
    d. Control power circuit breaker tripped.
    e. Control power transformer high voltage fuse blown.
    f. Field excitation fuse in fuse panel blown or removed.
2. Exciter contactor EXC not closed.
    a. Excitation relay ER on unit control panel not picked up.
    b. Engine speed relay ES87 not picked up.

3. Incorrect voltage regulator operation.

   a. Voltage regulator fuse blown (on regulator panel).

   b. High or low voltage generator metering power transformer fuses blown. (Located in and above the circuit breaker compartment).

   c. Faulty voltage regulator.

4. Static exciter faulty.

OVER VOLTAGE - OV

The OVER VOLTAGE light indicated 59 over voltage relay operation. Operation of the 59 relay causes the 52 circuit breaker to trip open, and the unit will undergo a normal shut down and lockout. The over voltage light will be on at the annunciator but the 59 relay target will not appear.

Over voltage can be caused by improper voltage regulator operation. Refer to Item No. 3 under the NO VOLTAGE heading.

GENERATOR BREAKER - GB

The GENERATOR BREAKER light indicates that the 52 circuit breaker was tripped open during operation under load; that is, automatic unloading and dropout of the master relay MR did not occur before the breaker tripped open. If the ENGINE or the ENGINE OVER SPEED light is displayed along with the breaker light the unit will have undergone immediate shutdown and lockout, and trouble shooting should center on the cause of engine alarm.

When the GENERATOR BREAKER light appears by itself, any one of numerous protective devices may have operated. The unit will have under gone normal shutdown and lockout.

Causes of a breaker light indication are:

1. Manual 52 circuit breaker control switch trip during automatic operation.

2. Differential relay 87 trip. Manual resetting of the 86 switch is required.

3. Reverse power relay 67 trip. Target will appear on the 67 relay.

4. Leading var relay 55 trip. Target will appear on the 55 relay. This may happen if generator excitation fails during operation.

5. Undervoltage relay 27 trip. Target light will appear on the 27 relay. The relay resets automatically, but the reset button on the relay must be pressed in to put out the light.

6. Field overcurrent relay 40-OC pickup.

7. ENGINE annunciator relay pickup. This alarm caused by:

   a. Engine oil pressure failure.

   b. Cooling water pressure failure.

   c. Excessive crankcase (oil pan) pressure.

8. ENGINE OVERSPEED annunciator relay pickup. This alarm caused by:
   a. Actual engine overspeed.

   b. Failure of a unit to complete a cycle and go on the line after a start signal is given.

   c. Failure of a unit to stop after a stop signal is given.

ENGINE TEMPERATURE - ET

The ENGINE TEMPERATURE light indicates that the temperature of the coolant leaving the engine is approaching the boiling point while the engine is running at full speed. High temperature is also indicated by the HOT ENGINE light on the engine control panel of the generating unit involved.

The ENGINE TEMPERATURE annunciator relay brings the generating unit to a normal stop and lockout after a timed idle period. The light goes out when the annunciator is reset, but the HOT ENGINE light on the engine control panel remains on until the engine cools.

Possible Causes Of A Hot Engine Light:

1. Broken fan belts.

2. Radiator air passages plugged.

3. Defective thermostatic valve element

4. Defective or improperly calibrated temperature switch.

5. Plugged radiator core.

It is possible to reset the annunciator while the engine is idling before shutdown, but no attempt should be made to place the unit on the line until the cause of the hot engine has been determined and corrected.

MANUAL STOP - MS

The MANUAL STOP light indicates that the engine was stopped by means of the stop push button on the generating unit engine control panel or by means of the start/stop switch in the MC unit control room. The annunciator must be reset before the unit can be restarted.

ENGINE - E

The ENGINE light indicates that one of the following three faults has occurred.

1. True lube oil pressure failure.

2. Positive crankcase (oil pan) pressure.

3. Low water pressure.

When the engine annunciator relay trips, the generating unit main circuit breaker immediately trips open and the engine stops immediately and is locked out. There is no timed idle before shutdown and lockout. The annunciator may be reset after the engine has stopped, and the low water or crankcase pressure reset buttons pressed if applicable, but the cause of the shutdown should be determined before attempting further operation.

WARNING: Do not open oil pan inspection covers if a crankcase pressure trip has occurred and there is evidence of an overheated engine. Hot oil vapors resulting from a hot bearing or other part can ignite with explosive force if air is admitted to the oil pan.

Possible Causes Of Low Oil Pressure:

1. Oil supply low - below dipstick “low” mark with engine running. If the oil level is checked with the engine stopped a false reading will be obtained.

2. Broken or leaking oil line.

3. Fuel dilution of lube oil.

4. Plugged lube oil filters or strainers.

5. Plugged lube oil cooler resulting in hot, thin oil.

6. Oil foaming.

Possible Causes Of Positive Crankcase Pressure:

1. Broken piston.

2. Broken piston rings.

3. Faulty oil separator operation.
   a. Plugged oil separator.

   b. Leaking separator pipe.

   c. Saturated oil separator (resulting from oil foam due to excessively high oil level in the oil pan).

   d. Plugged or broken air box drain line or crankcase ejector assembly.

4. Air box pressure in oil pan.
   a. Missing or broken lower liner seals.

   b. Broken top deck oil drain tube.

   c. Broken air box drain tube.

   d. Loose, broken, or missing crankcase bolt.
5. Oil pan explosion.

6. Faulty or improperly applied oil pressure relief valve releasing oil on crankcase pressure sensing diaphragm.

Possible Causes Of Low Water Pressure:

1. Loss of engine water.
2. Cavitation at water pump inlet.
    a. Plugged oil cooler.

    b. Piping from water tank to pump inlets plugged or disconnected.

NOTE: The low water detector is more sensitive at high engine speed than at low speed. If water level is slightly low, the device may trip at full engine speed, but not at idle speed. If water level is below the head to liner seals, the reset pushbutton will not remain set when it is pressed.

ENGINE OVERSPEED - EO

The ENGINE OVERSPEED light indicates that the engine overspeed mechanism has tripped, either from true engine overspeed at approximately 10% over synchronous speed or because failure of the generating unit to complete a normal sequence caused pickup of the overspeed trip solenoid OTS, with resulting overspeed trip action. Overspeed trip action causes immediate trip of the 52 circuit breaker and the unit immediately shuts down and remains locked out. The overspeed trip lever located at the camshaft must be manually reset, before the annunciator relay can be reset.

Possible Causes Of True Engine Overspeed Trip:

1. Sticking injector racks.

2. Improper governor operation.

    a. GOV 65 (50 cycles) or GOV 77 (60 cycles) switch set for too high speed, causing overspeed when load is suddenly dropped.

3. Air box flooded with lube oil.

Possible Causes Of Overspeed Trip Solenoid Action:

1. Failure of 52 breaker to close within a set time after engine start.
2. Failure of engine to stop within a set time after a stop signal is given.
    a. Injector rack stuck.

    b. Unit shutdown timer UST or overspeed trip time delay relay OTX improperly timed.

3. Improperly set ES56 (50 cycles) or ES87 (60 cycles) pickup causing failure of starting cycle completion.

DIFFICULTIES NOT SIGNALED BY THE ANNUNCIATOR

Some operating difficulties may be encountered which do not result in an annunciator fault indication. And some can be detected before they become serious enough to warrant annunciator operation.

Defective Annunciator System

A defect in the annunciator system can create unusual operation problems. For example, a blown annunciator fuse would prevent any target lights from lighting, and the annunciator could not be reset. However, this would not prevent a unit lockout in the event of another operating difficulty.

Annunciator system trouble can best be prevented by periodic checks of the various alarm circuits.

Lack Of Power

Should the engine start, respond to control, and apparently function properly, yet does not have proper power, a thorough check of the following items should be made.

1. Insufficient fuel. Check fuel oil system for proper operation.
    a. Return fuel sight glass (glass nearest engine) should be full, clear, and free of bubbles.
    b. Bypass sight glass should contain no more than a trickle of fuel.
    c. Pour point of fuel should be at least 100 F. lower than the lowest expected ambient temperature.
2. Insufficient air.
    a. Body air filters clogged with leaves or other matter.
    b. Engine air filters clogged.
    c. Faulty turbocharger operation as a result of:

        Excessive exhaust back pressure.
3. Improper governor settings and adjustments.
    a. GOV65 (50 cycles) or GOV77 (60 cycles) switch setting too low.
    b. Governor rack stop (3-position) setting incorrect.
    c. GOV RS switch setting too low.
4. Load computer improperly calibrated (deadload operation).

EXHAUST SMOKE ANALYSIS

When the engine is properly adjusted and is operating at the recommended working temperature, there should be no appreciable exhaust smoke. However, when first starting

the engine or after a prolonged period of “no load, “ blue or gray smoke may be noticed. This will clear up after a short time if operation is normal. Continuous exhaust smoke should be investigated as follows:

1. Black or gray exhaust smoke indicates incompletely burned fuel,

    a. Insufficient combustion air.

    b. Excess fuel or irregular distribution. Check injector rack setting and timing, or for faulty injectors.

    c. Improper grade of fuel. A fuel that is too heavy does not completely vaporize.

2. Blue exhaust smoke generally indicates lube oil entering the cylinder and being blown through cylinder during scavenging period. Check for internal fuel or lube oil leaks. (See next article on excessive lube oil consumption).

3. White exhaust smoke indicates misfiring cylinders. Check for the following:

    a. Faulty injectors.

    b. Low compression.

    c. Injector timing. See Part II, Section 6, of this manual for timing chart,

    d. Exhaust valve timing. See Part I, Section 6, of this manual.

    e. Improper grade of fuel.

EXCESSIVE OIL CONSUMPTION

Some periods a of high lube oil consumption are normal, such as break-in period of new power assemblies. In these cases added lube oil consumption will result until the oil control rings on the new assemblies have properly seated.

1. Lube oil leaks.

    a. Oil lines and connections.

    b. Gasket or seal leakage.

2. Oil control at cylinder.

    a. Oil control rings worn, broken or improperly installed.

    b. Scored liners or pistons.

LEGEND OF DESIGNATIONS FOR ELECTRIC SWITCHGEAR AND CONTROL SYSTEM

Certain conventions are used to designate devices that are auxiliary to a primary or main device. These conventions take the form of numeral or letter prefixes or suffixes to the primary designation. The following is intended as a guide to understanding the use of auxiliary designations.

Auxiliary Switch Designations (Such as 52a)

(a) Switch closed when device is in energized or operated position.

(b) Closed when device is in de-energized or non-operated position.

(aa) Closed when operating mechanism of main device is in energized or operated position.

(bb) Closed when operating mechanism of main device is in de-energized or non-operated position.

When several auxiliary switches are present on the same device, they shall be designated as 152a, 252a, etc.

Auxiliary Relay Designations (Such as 27X, 52VX)

The auxiliary relay is generally operated by the basic relay contacts, or it is energized at the same time that the basic relay is energized.

NOTE: The practice of identifying a relay that operates in place of an auxiliary switch with the letters CL or OP is not followed.

The following list is provided to define numeral and letter designations used on the MU type power plant installation to identify equipment. In general the designations are in close agreement with industry standards. The designations appear on MU wiring diagrams and on tapes affixed to the specific equipment. Note however, that not all the designations presented are in use on individual MU installations, and that some installations may use designations not shown in the legend. Refer to the applicable wiring diagram legend.

To aid in locating a particular piece of equipment, the legend includes a letter shown adjacent to the equipment designation. This letter identifies equipment location as follows:

B	Battery	R	Relay Room
CB	Circuit Breaker	SC	Switchgear Cubicle
CR	Control Room	SP	Switchgear Cubicle Door Panel
M	Master Control Panel	TC	Transformer Cubicle
MX	Aux. Master Control Panel	TP	Transformer Cubicle Door Panel
P	MP Type Generating Unit	U	Unit Control Panel

LEGEND	LOCATION	DESCRIPTION
A	TP	Ammeter
AMS	CR	Automatic/Manual Switch
AM SW	SP	Ammeter, Wattmeter, and Varmeter Switch
BCC	M	Breaker Closing Contactor
BVR	M	Battery Voltage Relay
BVRY	M	Battery Voltage Relay Auxiliary
CA		Condenser
CCR	U	Clutch Control Relay
CR		Rectifier
CS	SP	Circuit Breaker Manual Control Switch
CTR	SC	Cubicle Thermostat
C5		Closing Time Relay
DLR	M	Deadline Relay
DLRP	MX	Deadline Auxiliary Relay
DLRQ	M	Deadline Auxiliary Relay
DLRS	M	Deadline Auxiliary Timing Relay
DLRT	U	Deadline Auxiliary Relay
DLRU	M	Deadline Auxiliary Relay
DLRV	M	Deadline Auxiliary Timing Relay
DLRY	M	Deadline Auxiliary Relay
DLRW	U	Deadline Auxiliary Relay
DLRZ	M	Deadline Auxiliary Relay
DLTS	M	Deadline Timer Start Relay
DSS	M	Reduced Voltage Starting Auxiliary Relay
ER	U	Excitation Relay
ERX	U	Excitation Relay Auxiliary
ERY	P	Excitation Relay Auxiliary
ES-O	B	Engine Speed Relay - Zero RPM
ES-20	B	Engine Speed Relay - 200 RPM
ES-56 /87	B	Engine Speed Relay - 600 RPM/ 700 RPM
ESR	U	Engine Speed Relay
ETI	U	Elapsed Time Indicator
ETS	P	Engine Water Temperature Switch
EXC	P	Exciter Contactor
FCR	M	Fan Control Relay
FFC	P	Field Flashing Contactor
FFCO	B	Field Flashing Cutoff Relay
FFR	U	Field Flashing Relay
FM	TP	Frequency Meter
FM/VM	SP	Frequency Meter/Voltage Meter Switch
FSR	M	Fast Start Relay
FTC	P	Fuel Transfer Contactor
FTM	P	Fuel Transfer Pump Motor
FTSH	P	Fuel Transfer Switch-High Level (115 Gal.)
FTSL	P	Fuel Transfer Switch-Low Level (55-95 Gal.)
FTSN	P	Fuel Transfer Switch-Normal Level (75-100 Gal.)

LEGEND	LOCATION	DESCRIPTION
G0V77	P	Governor Switch-Closed from 200 RPM To 770 RPM
FSV7	At Fuel	Fuel Transfer Solenoid Valve
FTSV	Supply Tank	
GCS	SP	Governor Control Switch
GOV-RS	P	Governor Rack Switch-Open Above 200 KW
GOV SW	SP	Governor Control Switch
GOV 77	P	Governor Switch - Closed From 200 RPM To 770 RPM
GS-1	P	Governor Solenoid - Idle Speed
GS-2	P	Governor Solenoid - Synchronous Speed
GSS	P	Governor Solenoid - Half Load Limit
GV	U	Generator Voltage Relay
IH	p	Immersion Heater
IHC	p	Immersion Heater Contactor
IHTS	p	Immersion Heater Temperature Switch
IR	U	Isolation Relay
ITS	U	Idle Time Starting Relay
ITSX	U	Idle Time Starting Relay Auxiliary
L	P	Reactor or Magnetic Amplifier
LLR	U	Low Load Relay
LOR	MX	Generator Overload Lockout Relay
LOR A	MX	Lockout Auxiliary Relay
LOR B	MX	Lockout Auxiliary Relay
LR	U	Loading Relay
LS	p	Governor Rack Limit Solenoid, Loading
LSR	M	Load Sharing Relay
LSRX	M	Load Sharing Relay Auxiliary
LTR	U	Low (Oil) Temperature Relay
LTS	P	Low (Oil) Temperature Switch
MBP	P	Motor-Booster Pump
MBR	U	Main Bearing Relay
MBX	U	Main Bearing Relay Auxiliary
MB1	P	Main Bearing Switch
MB2	P	Main Bearing Switch
MR	U	Master Relay
MRY	U	Master Relay Auxiliary
MSS	U	Manual Stop Relay Auxiliary
NILO	U	Normal Lockout Relay
OAD	U	Oil Alarm Delay Relay
OLTD	U	Overload Time Delay Relay
OTLS	P	Overspeed Trip Limit Switch
OTLX	U	Overspeed Trip Limit Relay
OTS	P	Overspeed Trip Solenoid
OTX	U	Overspeed Trip Timing Relay
RAL	MX	Resynchronizing Auxiliary Relay
RCL	U	Reclosure Lockout Switch
RSTD	MX	Resynchronizing Time Delay Relay
SC	SP	Current Relay

LEGEND	LOCATION	DESCRIPTION
SLR	U	Slow Load Relay
SM	P	Starting Magnet
SMLS	P	Starting Magnet Limit Switch
SMR	U	Starting Magnet Recycle Relay
SMS	M	Master Unit Selector - Stepping Switch
SMSX	M	Master Unit Selector Auxiliary Relay
SMTO	U	Start Magnet Time Out
SR	M	Synchronizing Relay
SRF	M	Synchro Forestalling Relay
SS	CR	Start Stop Switch
STS	M	Starting Contactor
STSX	M	Stepping Switch (Start) Relay
STSY	M	Stepping Switch Relay Auxiliary
STW	U	Stepping Switch Relay Auxiliary
STWX	M	Starting Relay Auxiliary
STX	M	Starting Relay Auxiliary
STY	B	Reduced Voltage Starting Contactor
STZ	U	Starting Relay Auxiliary
STD	M	Starting Relay Auxiliary
SYDT	M	Resynchronizing Relay
SYSY	M	Resynchronizing Relay Auxiliary
SYTY	m	Resynchronizing Relay Auxiliary
SYDX	U	Resynchronizing Relay Auxiliary
SYN	M	Resynchronizing Relay (Unit To Bus)
SYNCX	MX	Synchronizing Time Lockout Relay
SYS	M	Stepping Switch (Synchro) Relay
SYSX	M	Stepping Switch Relay Auxiliary
SYSZ	M	Stepping Switch Relay Auxiliary
TCX	U	Trip Coil Relay Auxiliary
TDR	M	Reduced Voltage Riming Auxiliary Relay
TSF	R	Temperature Switch - Fan
USR	R	Unit Start Relay
UST	U	Unit Shutdown Timer
VM	TP	Voltmeter
VR	U	Voltage Regulator panel
WHM	TP	Watthour Meter
WM	TP	Wattmeter
ZSR	U	Zero Engine Start Relay
40 OC	U	Alternator Field Overcurrent Relay
40 OCX	P	40 OC Relay Auxiliary
27	P	Three Phase Undervoltage Relay
27U	TP	Undervoltage Relay Auxiliary
X	TP	Undervoltage Relay Auxiliary
52Tx	M	Main Generating Unit Circuit Breaker
52a	CB	Breaker Auxiliary Switch (Closed when breaker is closed)

LEGEND	LOCATION	DESCRIPTION
52aa	CB	Breaker Auxiliary Switch (Closed when breaker operating mechanism is operated)
52b	CB	Breaker Auxiliary Switch (Closed when breaker is open)
52bb	CB	Breaker Auxiliary Switch (Closed when breaker operating mechanism is in non-operating order)
52CC	CB	Breaker Closing Coil
52L	M	Breaker Auxiliary Relay
52TC	CB	Breaker Trip Coil
52V	U	Breaker Auxiliary Relay
52VX	U	Breaker Auxiliary Relay
52VY	U	Breaker Auxiliary Relay
52W	U	Breaker Auxiliary Relay
52WS	M	Tie Breaker Auxiliary Relay
52WL	MX	MU Load Breaker Auxiliary Relay
52X	CB	Breaker Control Relay
52Y	CB	Breaker Control Relay
52Z	M	Breaker Closing Coil Relay
52ZX	MX	Breaker Closing Coil Auxiliary Relay
55	SP	Leading VAR Relay
59	SP	Overvoltage Relay
60		Deadline Voltage Relay
67	SP	Reverse Power Relay
86	SP	Lockout Switch
86A, B, C	SP	Sections of 86 Switch
87	SP	3 Phase Differential Protection Relay

ANNUNCIATOR LEGEND

LEGEND	DESCRIPTION
O	Operating (tripping) Relay Coil
R	Reset Relay Coil
E	Engine
EF	External Fault
FT	Fuel Transfer
GB	Generator Breaker
IH	LImmersion Heater
MS	Manual Stop
NV	No Voltage
OS	Over Voltage
OV	Engine Overspeed
ST	Starting
SY	Synchronizing

TABLES OF FUSES AND CIRCUIT BREAKERS

MAIN FUSE PANEL

Upper Portion of Panel - AC			
Quantity	Amp.	Name	Affects
3 per unit	100*	STATIC EXCITER	Field excitation
3 per unit	100	IMMERSION HTR	Immersion heater elements
1	15	MC LTS	Control unit AC lights
1 per unit	15	UNIT LTS	Generating unit AC lights
1	20	MC RECEP	AC outlets - relay room fan
1	30	CB CLOSE	Main circuit breaker close and red-green panel lights
1	15	AC CONT	Fuel transfer contractors and solenoid valve. Elapsed time indicator
2	20	BATT CHG	Battery charger and voltmeter
2	30	STRIP HTRS	Strip heaters and control room exhaust fan
2	30	FUEL TRANSFER	Fuel transfer pump motors

*Dual element

MAIN FUSE PANEL

Lower Portion of Panel - DC			
Quantity	Amp.	Name	Affects
1	15	DC LIGHTS	Fuse test light, Control Unit DC lights
1	30	SPARE FUSE	
1	15	ANNUNCIATOR	Annunciator lights, GB, EF, FT annunciator operating coils, excitation contactor, field flashing relay
1	15	ST SEQ	Starting relays, all units
1	15	SYNCHRO SEQ	Synchronizing circuit relays
1 per unit	15	UNIT CONT	Unit control relays, governor solenoids, annunciator relays
1 per unit	30	UNIT SM	Starter pinion solenoid
1 per unit	20*	DL BRKR CLOSE	Deadline breaker closing red-green panel lights
1 per unit	400	UNIT START	Engine starting motor Governor accumulator booster pump motor

*Dual element.

FUSE LOCATIONS OTHER THAN MAIN FUSE PANEL

HIGH VOLTAGE FUSES					
Quan	Amp	Gen Volts	Location	Name	Affects
3	2 1 1	2400 3300 4160	Transformer Compartment	Bus Metering Pot. Transf.	Transformer Input
3 per unit	2 1 1	2400 3300 4160	Above Breaker Compartment	Gen. Metering Pot. Transf.	Transformer Input
3	65 40 40	2400 3300 4160	Transformer Compartment	Control Power Transformer	Transformer Input

OTHER FUSES				
Quan	Amp	Location	Name	Affects
3	6	Upper Portion of Transformer Compartment	Bus Metering	All Voltage Regulators Bus Voltmeter
3 per unit	6	Upper Portion of Circuit Breaker Compartment	Gen. Metering	Unit Voltage Regulator Gen. Voltmeter
2 per unit	20**	Upper Portion of Circuit Breaker Compartment	Breaker Closing	Breaker Closing Red-Green Panel Lights
3 per unit	1	Unit Control Panel	Voltage Reg.	Unit Voltage Regulator
1 per unit	0.5	Master Control Panel	Gov. Motor	Gov. Motor Windings
1 per unit	100	Generator Control Cabinet	Field Flashing	Field Flashing Contactor and Generator Field
3 Panel	1	Master Control	Remote Bus Voltage	Remote Bus Metering

**Dual element

CONTROL CIRCUIT BREAKERS			
Rating	Location	Name	Feeds To
400 Amp	Transformer Compartment	Control Power Circuit Breaker	15 Amp AC Control Fuse 100 Amp Static Exciter Fuses 100 Amp Immersion HTR Fuses* 30 Amp Fuel Transfer Fuses 30 Amp Circuit Breaker Close Fuses 20 Amp Battery Charging *Fuses* 30 Amp Strip Heater Fuses Lights and Receptacle Fuses* Circulating Pump Motor Circuit Breaker*
30 Amp	Breaker Compartment Door Panel	Strip Heater	Cubicle Thermostats & Strip Heaters
15 Amp	Edge of Main Fuse Panel	CPMCB	Circulating Pump Switch and Motor

*These are energized only when the removable links on the back of the fuse panel are in place.

ANNUNCIATOR INDICATION SUMMARY

Legend: NLO - NORMAL LOCKOUT
Unit unloads, breaker trips, 11 minute idle, engine stops, unit locked out.
ILO - IMMEDIATE SHUTDOWN AND LOCKOUT
Breaker trips immediately, engine stops without idle, unit locked out.
DO - Annunciator display only, no shutdown or lockout.

INDICATION	RESULT	TRIPPED BY	CAUSE	REMOTE RESET	RECOMMENDED ACTION BEFORE RESET AT MU SITE*
ENGINE	ILO	MB-1; MB-2	Positive Crankcase Pressure Low Oil Pressure, Low Water.	NO	Do not reset the annunciator until the cause of the shutdown has been investigated. Corrective action will usually be necessary before operation is permissible
EXTERNAL FAULT	Trips all 52CB's; Then normal	27	Low voltage with high current	YES	Unit is not locked out. Reset to shut off the indicator light
FUEL TRANSFER	DO	FTSL; FTSH	Low or high fuel level in day tanks.	YES	May be reset after normal day tank level is restored.
GENERATOR BREAKER	Immediate breaker trip; then NLO	TCX (Engine fault control switch, 27X, 67, 55, 40-OC, 86C)	Abnormal 52 circuit breaker trip	YES/NO	If ENGINE or ENGINE OVERSPEED faults are indicated, observe those recommendations. Reset 86 switch if tripped.
IMMERSION HEATER	Automatic start and idle until warm	LTS	Low lube oil temperature. Lube oil not circulating.	YES	Reset when lube oil temperature is normal. Investigate cause of low oil temperature.
MANUAL STOP	NLO	Manual Stop Pushbutton; Start/Stop Switch	Action by operator	NO	Should be reset by the operator who made the manual stop, or with the knowledge and approval of the operator who made the stop.
NO VOLTAGE	NLO	GV	Generator voltage low	YES	Make investigation as conditions warrant.
ENGINE OVERSPEED	ILO	True Overspeed or OTLX action	Engine overspeed. Normal sequence fails to go to completion.	NO	Investigate cause for overspeed trip. Overspeed trip lever on engine must be reset.
OVER VOLTAGE	NLO	59	Generator voltage high.	YES	Make investigation as conditions warrant
STARTING	NLO	SMTO and STSY Time out	Pinion did not engage. Engine did not start. Cylinder hydraulically locked.	YES	Cylinder test valves should be opened and the engine barred over manually
SYNCHRONIZING	NLO	RCL	Did not synchronize.	YES	Make investigation as conditions warrant.

*These are only general recommendations. Specific action must, of necessity be dependent upon, situations occurring in an installation.

GENERAL DATA

SPECIFICATION	TYPE OF UNIT		
		50 Base Load 0 Pole Gen	
Engine			
Model		16-567E4	
Type		2-Cycle, Turbo charged, "V"	
Number Of Cylinders		16	
Bore And Stroke		8-1/2 x 10 Inches	
Total Displacement, Cu. In.		9072	
Compression Ratio		14.5:1	
Rating, BHP, Nominal		1775*	
Operating Speed, RPM		600	
Lubricating System		Full Pressure	
Governor (Woodward)		LSG- 10	
Weight, Pounds (Engine Only)		Approximately 35, 000	
Synchronous Generator			
Model		A15	
Number Of Poles		10	
KW		1250	
KVA		1560	
Phase		Three	
Volts		4160 Wye/2400 Delta	
Amperes		217/376	
Power Factor %		80	
Field Excitation		45.2	
No Load Amperes		83.0	
Rated Load Amperes		15, 730	
Weight (Approximate)			
Air Intake And Exhaust System			
Air Intake		Exhaust Driven Turbocharger	
Air Intake Filter - Carbody		Disposable Impingement	
Air Intake Filter - Engine		Oil Bath	

*10% overload permissible for any 2 hours out of 24.

GENERAL DATA

SPECIFICATIONS	TYPE OF UNIT 60 Base Load 10 Pole Gen
Engine	
Model	16-567E4
Type	2-Cycle, Turbo charged, "V"
Number Of Cylinders	16
Bore And Stroke	8-1/2 x 10 Inches
Total Displacement, Cu. In.	9072
Compression Ratio	14.5:1
Rating, BHP, Nominal	2125*
Operating Speed, RPM	720
Lubricating System	Full Pressure
Governor (Woodward)	LSG- 10
Weight, Pounds (Engine Only)	Approximately 35, 000
Synchronous Generator	
Model	A15
Number Of Poles	10
KW	1500
KVA	1875
Phase	Three
Volts	4160 Wye/2400 Delta
Amperes	260.5/451
Power Factor %	80
Field Excitation	
No Load Amperes	31.5
Rated Load Amperes	75.0
Weight (Approximate)	15, 730
Air Intake And Exhaust System	
Air Intake	Exhaust Driven Turbocharger
Air Intake Filter - Carbody	Disposable Impingement
Air Intake Filter - Engine	Oil Bath

*10% overload permissible for any 2 hours out of 24.

GENERAL DATA

SPECIFICATIONS	TYPE OF UNIT		
		50 Base Load 10 Pole Gen	60 Base Load 10 pole Gen
Supplies - Each MP Unit	370		
Lube Oil - U. S. Gallons			
Operating Range - Gallons	150		
Cooling Water - Gallons	320		
(150 gallons anti-freeze for winter protection)			
Fuel Oil - Day Tank	120		
Governor Oil Supply	2 U. S. Pints		
Immersion Heater			
Voltage	240		
Heater Elements	15 KW		
Lube Oil Circulating Pump	1 HP		
Pump Operation	Continuous		
Power Source (Normally)	Control Transformer		
Dimensions And Weight - MP Unit			
Height - Shipping	11 ft. 4 in. Approx.		
- Installed	16 ft. 3 in. Approx.		
Width Over Eaves	10 ft. 4 in. Approx.		
Length	40 ft. 4 in. Approx.		
Approximate Weight			
- Less Supplies	103, 000		
- With Supplies	108, 150		
Dimensions And Weight - MC Unit			
Height Over Battery Box Vent	1l ft. 8 in. Approx.		
Width Over Eaves	10 ft. 4 in. Approx.		
Length	24 ft. 0 in. Approx.		
Approximate Weight When Equipped For Control Of Five Generating Units	45, 000 Pounds		

INSTRUCTIONS TO CHANGE 50 CYCLE UNIT TO 60 CYCLE UNIT

The following drawings were furnished with the unit and should be available for ready reference to identify terminals.

8386396	Wiring Diagram, Schematic
8386403	Wiring Diagram, MP36A
8386398	Wiring Diagram, MC-53 Interconnection
8386397	Wiring Diagram, Field Connection
8386399	Wiring Diagram, Master Control Panel
8386400	Wiring Diagram, Unit Control Panel
8386402	Wiring Diagram, Switchgear Cubicle
8298234	Governor Amplifier (50 Cycle)
8314451	Wiring Diagram, Annunciator (Master)
8314452	Wiring Diagram, Annunciator (Auxiliary)
8386401	Wiring Diagram, Trans. And Switchgear Cubicle
8296851	Regulator Panel

Within the text, wherever possible, a figure number from the Operating Manual, Part 1, is given in order to identify by illustration the item being changed or adjusted.

In order to change this unit from 50 cycle operation to 60 cycle operation the following modifications must be made:

A. Excitor - Fig. 2-25.

1. Remove jumper from rectifier to reactor L2 terminal. (6 places on each unit.)

2. Add jumper from rectifier to reactor L3 terminal. (6 places on each unit.)

B. Auxiliary Panel - Fig. 3-17.

1. Remove governor amplifier panel - 8298234.

2. Add governor amplifier panel - 8298233.

C. Static Synchronizer Panel - Fig. 3-17.

1. Remove jumper J2 between terminals 1 and 6.

2. Add jumper J2 between terminals 1 and 5.

3. Remove jumper between terminals 21 and 28.

4. Add jumper between terminals 21 and 25.

5. Remove jumper between terminals 22 and 27.

6. Add jumper between terminals 22 and 24.

7. Remove jumper between terminals 26 and 30.
8. Add jumper between terminals 23 and 30.
9. Remove jumper between terminals 27 and 29.
10. Add jumper between terminals 24 and 29.

D. Unit Control Panel - Fig. 3-15.

1. Remove elapsed time meter - 8340629.
2. Add elapsed time meter - 8303104.

E. Voltage Regulator On Unit Control Panel - Fig. 3-15.

1. Remove jumper between terminals 30 and 31.
2. Add jumper between terminals 30 and 32.
3. Remove jumper between terminals 35 and 36.
4. Remove jumper between terminals 33 and 34.
5. Add jumper between terminals 38 and 39.
6. Add jumper between terminals 37 and 15.
7. Add jumper between terminals 4 and 40.
8. Remove wire 49 from terminal 1 and connect to terminal 17 at L3 reactor.
9. Remove wire 50 from terminal 4 and connect to terminal 18 at L3 reactor.
10. Move RVE wire from terminal 17 to terminal 28.

F. Circuit Breaker Switchgear - Fig. 3-5.

1. Remove 59 relay - 8340229.
2. Add 59 relay - 8251954.
3. Remove 67 relay - 8305515.
4. Add 67 relay - 8272656.
5. Remove 55 relay - 8340227.
6. Add 55 relay - 8305499.

G. Bus Metering Transformer Compartment - Fig. 3-8.

1. Remove 27 relays - 8361831.

2. Add 27 relays - 8251910.

H. 5 KV Outdoor Switchgear

1. Remove the 50 cycle 87 relays.

2. Add the 60 cycle 87 relays.

I. On The Circuit Breaker Switchgear, Fig. 35, change 55 relay from 200 watt tap (50 cycles) to 300 watt tap (60 cycles).

ADJUSTMENTS TO CHANGE FROM 50 CYCLE TO 60 CYCLE OPERATION

In order to perform these adjustments it will be necessary to start the unit and keep it running throughout the adjustments. In performing the governor adjustments refer to Section 11 of the Engine Maintenance Manual, Part II.

GOVERNOR ADJUSTMENTS

Refer to Fig. 113 of Section 11, Engine Maintenance Manual, Part II for location of governor adjustment points.

1. Set 50% load and 162 MIS (milliamperes) in the transducer. With the 60 cycle solenoid (GS-II) energized, adjust the 60 cycle stop screw to synchronous speed, 720 RPM $\pm$ 2 RPM. Make this setting from the high speed side.

2. Check the speed at 0% load with 25 MLS, and at 100% load with 300 MLS. Speed should not exceed synchronous speed, 720 RPM $\pm$ 4 RPM.

3. With no load on the engine, set GOV 95 to open at 64 $\pm$ ½ cycles or 770-785 RPM.

4. On the three position rack limiter energize the loading solenoid (LS). Load the engine to the desired maximum overload or until the terminal shaft indicator is about halfway between 100% and maximum fuel. Make a mark in line with the terminal shaft pointer. Increase the load a small amount and then loosen the loading solenoid (LS) by loosening the four mounting screws on the side of the housing. Loosen the locknut and turn the eccentric, screw to line up with the mark. Tighten the coil assembly and locknut and check the setting. The loading solenoid (LS) should be set at 1650 KW.

5. Decrease the load to the peak load and mark the pointer position as before. Increase the load a small amount and de-energize the loading solenoid(LS). Loosen the eccentric screw locknut located on the linkage between the two coils of the three position rack limiter and turn the load limit rack eccentric screw to bring the pointer in line with the peak load mark. Tighten the locknut and check the setting. The load limit (mechanical) or rack stop adjustment should be set at 1500 KW.

After these adjustments have been made the governor should have the following settings as compared with 50 cycle settings:

	50 CYCLE	60 CYCLE
Engine Idle	450-470 RPM	450-470 RPM
Engine Full Speed	600-601 RPM	720-721 RPM
Motor Cutout Cam Low	200-300 RPM	200-300 RPM
Motor Cutout Cam High	642-657 RPM	770-785 RPM
Governor Rack Switch	Open at 400 KW	Open at 400 KW
Load Limit (Mech)	1200 KW	1500 KW
IS	1350 KW	1650 KW
GSS	550 KW	550 KW

SPEED SENSING PANEL ADJUSTMENTS

Refer to Fig. 314 of the Operating Manual, Part I, for location of speed sensing panel adjustment points.

1. Frequency generator input should be between 0 and 15 volts AC and proportional to frequency (0-300).

2. RE1 is not adjustable but should pick up from 17-21 cps.

3. RE2 (RH20) is to be adjusted for pickup from 79-87 cps.

4. RE4 (RH80) is to be adjusted for dropout from 261265 cps and (RH87) for pickup from 286-290 cps.

The speed head frequency versus engine RPM versus generator frequency for 720 RPM, 60 cycles is shown in the following table:

Speed Head	Engine RPM	Generator Frequency
17-21 cps	40-50 rpm	3.3-4.2 cps
79-87 cps	190-210 rpm	15.8-17.5 cps
261-265 cps	625-636 rpm	52-53 cps
286-290 cps	687-696 rpm	57.3-58 cps
300 cps	720 rum	60 cps

SC1 AND SC2 CURRENT RELAYS

Refer to Fig. 34 of the Operating Manual, Part I, for location of these relays, and wiring diagram for Transformer and Switchgear Cubicle. Change SC1 pickup from 2.6 amperes for 50 cycles to 4.4 amperes for 60 cycles. Change SC2 dropout from 2.2 amperes for 50 cycles to 3.8 amperes for 60 cycles.

VOLTAGE REGULATOR ADJUSTMENT

Refer to Fig. 315 of the Operating Manual, Part I, and M.I. 4520 for additional information of voltage regulator. Reset the current limit on the voltage regulator from 230 amperes (50 cycles) to 310 amperes (60 cycles).

KW LIMITER ADJUSTMENTS

There are four adjustments to be made on the KW limiter for proper operation. Fig. 317 of Operating Manual shows location of KW Limiter. See Fig. 1 for connections for bench adjustment or "in unit" adjustment.

1. Adjust RH2 to maximum resistance (full clockwise). RH2 is the stability adjustment. It adds damping to eliminate oscillations or engine hunting during KW limiter operation. If it is adjusted during operation it must be turned slowly and should be set such that sufficient margin is allowed for future contingencies where stability may be harder to attain, i.e. particularly tight rack limiter setting.

2. Adjust RH1 to maximum resistance. RH1 is a gain adjustment and will effect both the maximum output and the slope of the output characteristic. It will also effect the control frequency of the KW limiter.

3. Set the audio oscillator for 240 cps.

4. With VTVM (010 volts AC) across C4, adjust L1 for maximum volts AC. The adjustments on L1 and L2 determine the frequency at which the respective tuned circuits resonate. They are quite critical and the KW limiter will not function unless they are properly set. These adjustments must not be touched unless the proper equipment is available for checking and measuring.

5. Reset the audio oscillator for 320 cps.

6. With VTVM (0-10 volts AC) across C5, adjust L2 for maximum volts AC.

7. Reset audio oscillator for 290 cps. Output current should be 1.0 milliampere DC or less.

8. Reset audio oscillator for 287 cps. Output current should begin to increase to 2.0 to 10.0 milliamperes. If not, adjust L2 until output reads approximately 5 milliamperes DC.

9. Reset audio oscillator for 280 cps. Output current, should read approximately 30 to 40 milliamperes DC. Adjust RH1 to obtain this output, if necessary.

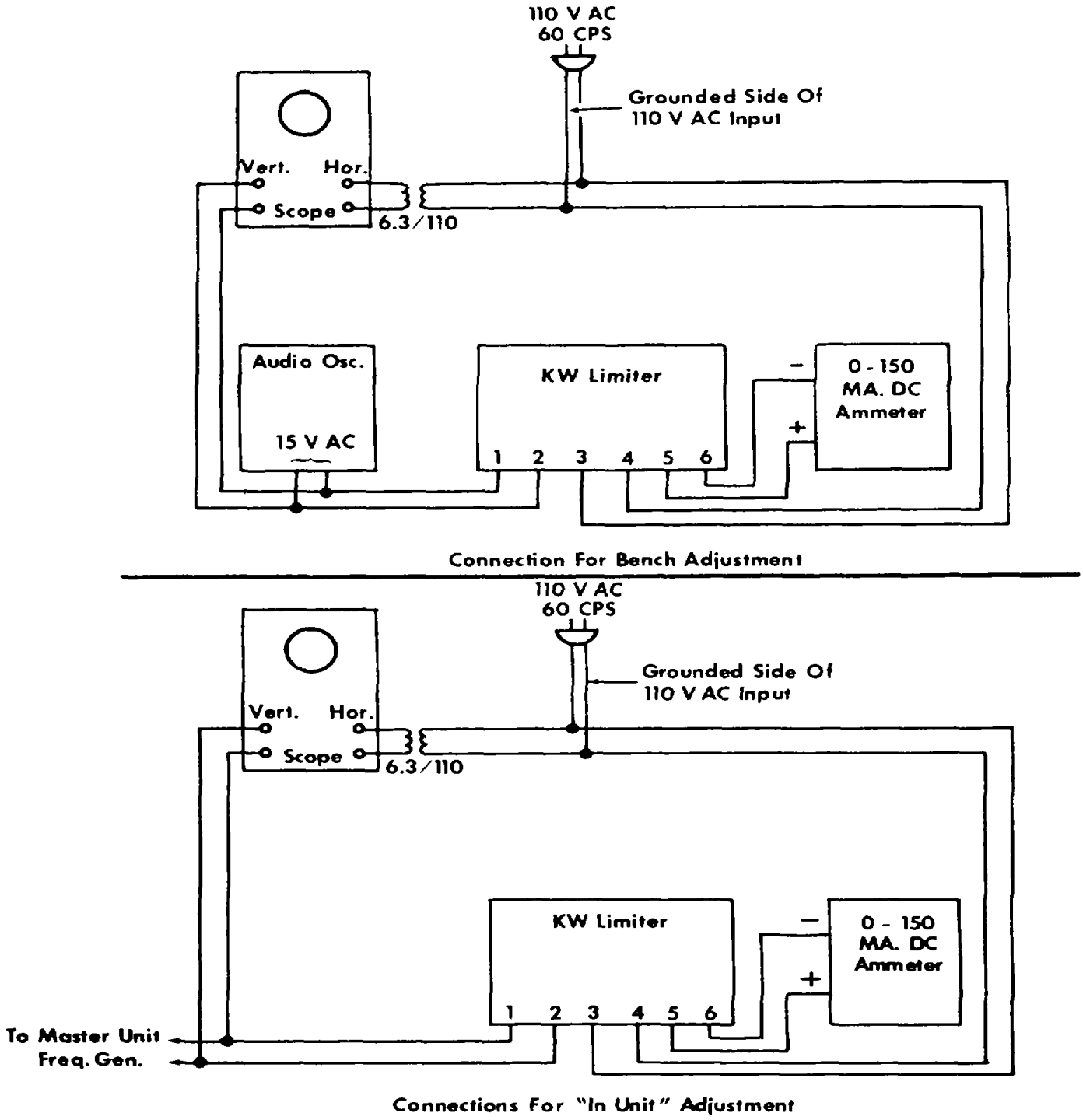


Fig. 1. - Connections For Bench Or "In Unit" Adjustments

10. Check several points on curve in Fig. 2. Some small adjustments to RH1 may be required to fit the nominal curve.

11. Turn audio oscillator to approximately 360 cps. Output should not exceed .75 milliamperes.

12. Slowly reduce frequency of audio oscillator while watching output meter (0-150 MA DC). No output should occur until 290 cps is reached. Then the output frequency relationship should follow that specified in the limits of operation section.

13. With power off turn RH2 until approximately 45, 000 ohms appear between wire 39 and wire 7.

KW LIMITER OPERATION CHECK

The following is the procedure to be followed to determine if the KW limiter and its associated circuitry are functioning properly. This check is made in a fully operational MU without the removal of any equipment.

1. Jumper the deadline relay (or deadline auxiliary relay) contact so as to provide terminals 3 and 4 of the KW limiter with 110 volts AC. (See schematic of MU.)

2. Jumper the deadline relay (or deadline auxiliary) contact so as to provide terminals 1 and 2 of the KW limiter with the speed head feed from any one of the running units. For purposes of this check that unit will be the master (speed head input should be 15 volts AC - 3 volts AC).

3. Remove the lead to terminal 5 of the KW limiter and connect a 0-100 MC DC meter* as follows:

    a. Plus meter lead to terminal 5 of the KW limiter.

    b. Minus meter lead to the wire just removed from terminal 5 of the KW limiter.

4. Jumper the deadline relay (or deadline auxiliary) contact which connects the KW limiter output to the voltage regulator.

5. Place any or all the units in isolation while running OFF the line at approximately 60 cps at rated voltage.

6. Gradually lower the speed of the “master” unit while watching the above meter. Output should not exceed 1 milliampere until 58 cps - .5 cps is reached. Output should begin to increase as the speed is lowered from that point. Note the exact frequency at which the meter reads 5 milliamperes.

7. Now lower the frequency 1 cps from this point. The meter reading should continue to increase as the frequency is lowered and at 1 cycle down the meter should read not less than 10 nor more than 30 milliamperes. Also the voltage on all running units should be substantially below 4160 volts (i.e. 3500 volts). Restore speed on this unit to 60 cps.

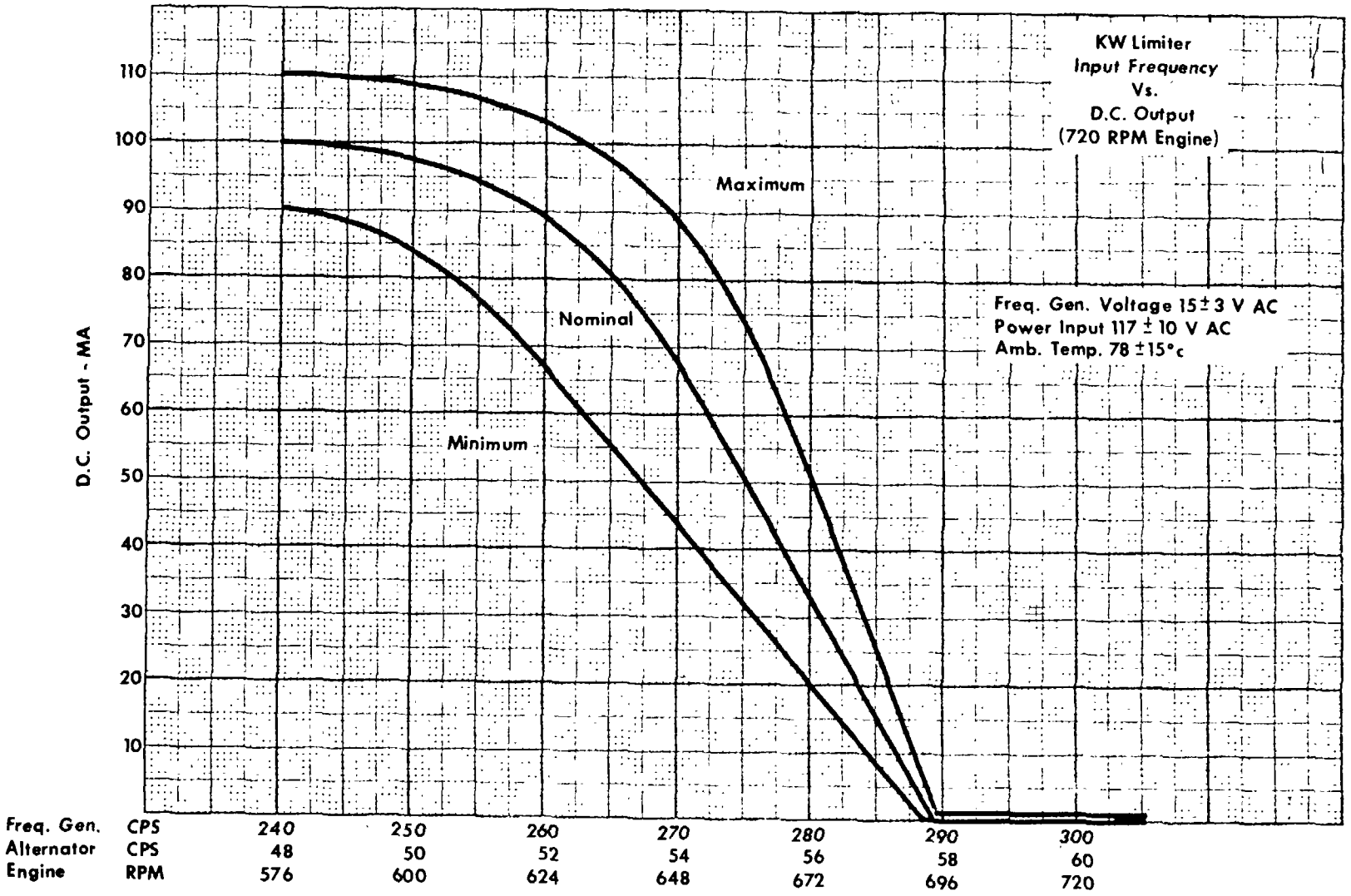


Fig. 2 - Curves Of KW Limiter Input Frequency Vs. D.C. Output

8. Change the jumper installed in 2 above to provide the speed head input from another running unit.

9. Repeat 6 and 7 for all running units.

Operation as above indicates proper operation of the KW limiter and associated circuitry.

*This meter should read DC only and cannot be of the AC-DC type.

PART II

ENGINE MAINTENANCE MANUAL
567E4

FOREWORD

This manual contains description and maintenance information for the Model 16-567E4 diesel engine. It is the intent of this manual to provide understandable and factual data to personnel designated to service the engine.

Each section of the manual contains the Description, Maintenance, and Service Data an applicable to the engine components covered in the specific section.

Service Data, consisting of the specifications regarding clearance and dimensional limits and a list of the service equipment required, is presented at the end of each section. The concentration of this information will facilitate maintaining and servicing the engine. In addition, it will provide an expeditious means of revising the manual when only specifications are changed.

Special tools, referred to in the text and shown in many of the illustrations. are not necessarily supplied with the engine, but are available on order.

To derive maximum service from the engine, it is recommended that personnel have an understanding *of* the equipment before attempting to perform any maintenance. It is further advised that due consideration be given the manufacturer's recommended maintenance procedure.

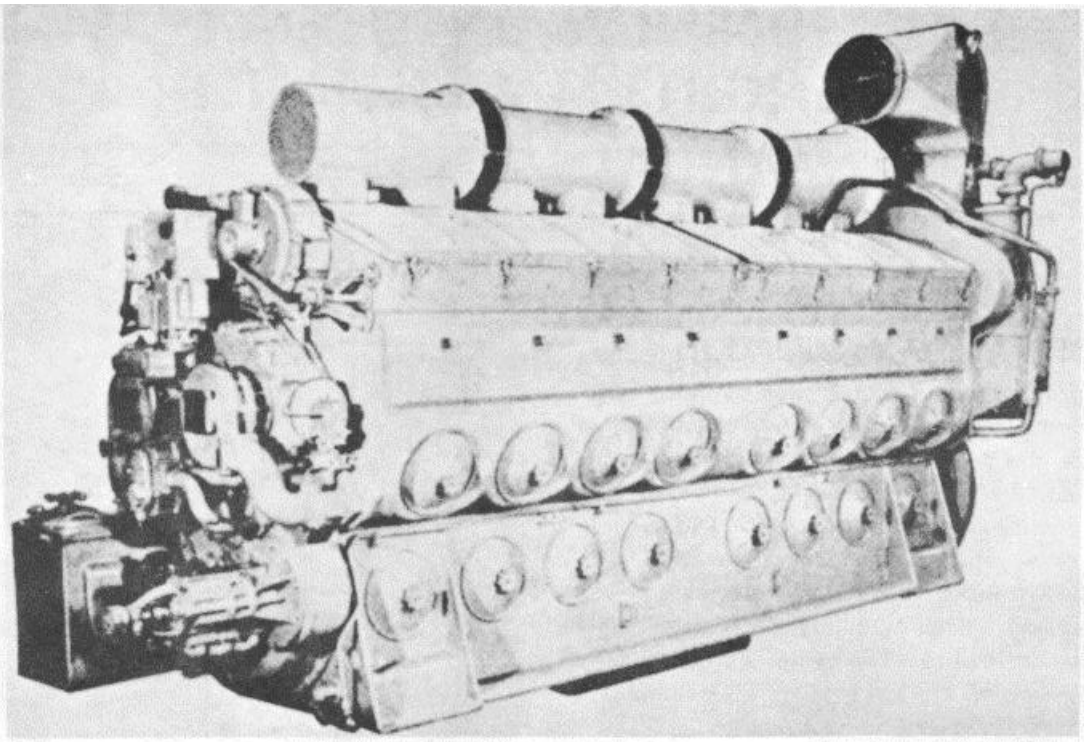
Wear limits are often given as diametric clearance. This means the total clearance on the diameter. Most diametric clearances can be measured by placing a feeler gauge on only one side of the object being checked. Other items may have to be checked by measuring the outside diameter of the bearing in which the shaft turns. A ball micrometer for measuring wall thickness of bearings. and a dial indicator for measuring diametric and longitudinal clearances will be found necessary. For measuring clearances such as piston to cylinder head, or oil pump gears to housing, the use of lead ribbon is recommended. The lead ribbon is inserted between the parts removed and measured to obtain the clearance.

Radial clearance is specified when the nature of the part is such that diametric clearance cannot be measured. The radial clearance is always one-half of the diametric clearance.

Longitudinal or thrust clearances are listed throughout the manual with all of the clearances removed at one end of the part being measured. Where it is not convenient to take out all of the thrust at one end the thrust at each end should be measured and added, to give the total longitudinal clearance.

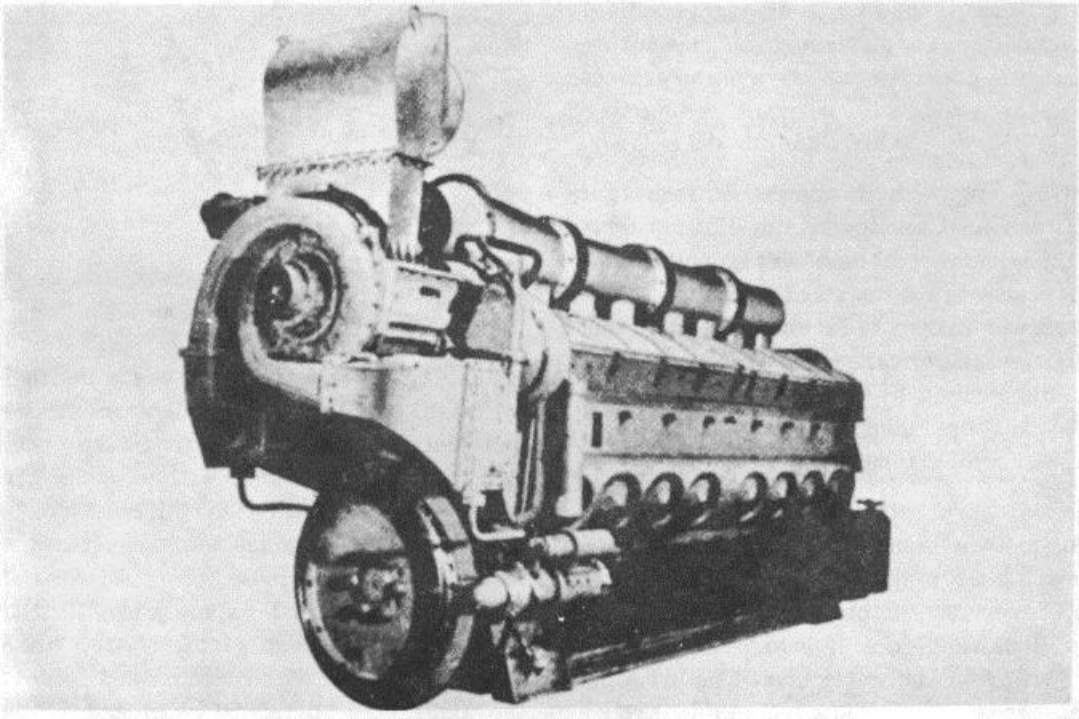
Clearance and dimensional limits used in this manual are defined as follows:

1. New limits are those to which new parts are manufactured. (Drawing tolerances.)
2. Rebuild limits are dimensions which should not be exceeded at the time of rebuild, in order to ensure satisfactory service until the time of the next scheduled overhaul. Unless specified otherwise, the limits given in the manual are rebuild limits.



13916

Three-Quarter Left Front View



13917

Three-Quarter Right Rear View

GENERAL ENGINE INFORMATION

OPERATING DESCRIPTION

In a two cycle engine each cylinder completes a power cycle in one revolution of the crankshaft. The piston does not function as an air pump during one crankshaft revolution as is the case in a four cycle engine which requires two revolutions of the crankshaft to complete one power stroke in each cylinder. A separate means is provided in a two cycle engine to supply the needed air and to purge the combustion gases from the cylinder.

The engine is equipped with a turbocharger, shown schematically in Fig.0-1, to efficiently provide the air needed for combustion and scavenging. The turbocharger provides an air supply greater than that provided by the positive displacement blowers used on other model engines.

During engine operation the turbocharger utilizes heat energy in the exhaust from the engine as well as power from the camshaft gear train to drive the turbine. However, when exhaust heat energy is sufficient to drive the turbine alone, the gear drive is disengaged by an overrunning clutch. The turbine then drives a centrifugal blower which furnishes air to the engine.

The air from the centrifugal blower is raised to a higher pressure and likewise to a higher temperature. It is desirable to reduce the air temperature to increase its density before it enters the air box surrounding the cylinders. The air temperature is reduced by passing it through the aftercoolers as shown in Fig. 0-1. Thus cooled air of greater comparable weight and having more oxygen is available to the engine.

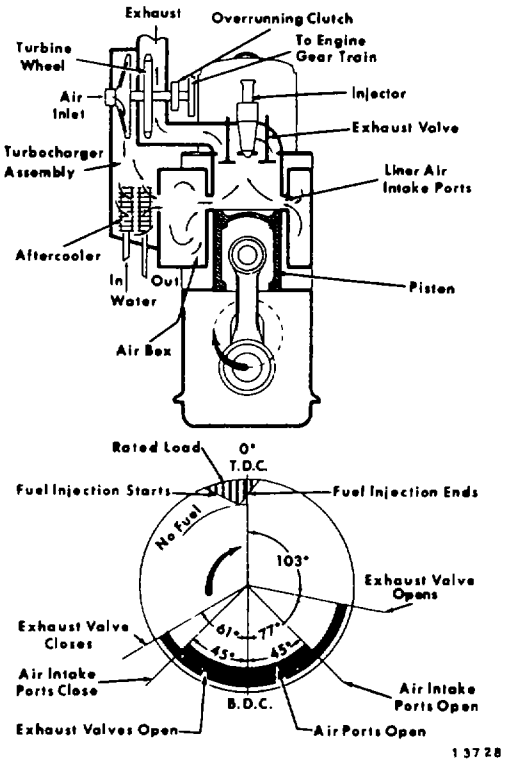


Fig. 0-1.- Schematic Illustration Of Engine Operation

Referring to Fig. 0-1, and assuming that the piston is at the bottom of its stroke and just starting up, the air intake ports and the exhaust valves will be open. Air under pressure enters the cylinder through the liner ports, pushes the exhaust gases left from the previous power stroke out through the exhaust valves and fills the cylinder with a fresh supply of air. When the piston is 450 past bottom dead center, the air intake ports will be closed by the piston as indicated on the timing diagram. Shortly after the air intake ports are closed, the exhaust valves will also be closed, and the fresh air will be trapped

in the cylinder. Closing the exhaust valves after the intake air ports provides for the greatest efficiency in cylinder scavenging of combustion gases.

As the piston continues upward, it compresses the trapped air into a very small volume. Just before the piston reaches top dead center, the fuel injector sprays fuel into the cylinder. Ignition of the fuel is practically instantaneous, due to the temperature of the compressed air trapped in the top of the cylinder. The fuel burns rapidly as the piston is forced down on the power stroke of the piston. As shown in the timing diagram, the piston continues downward in the power stroke until the exhaust valves open.

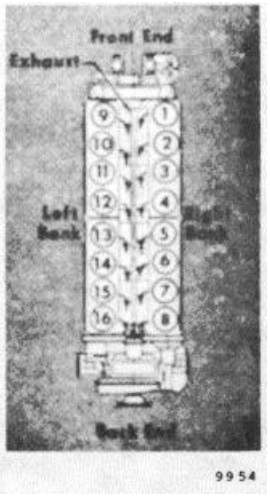
The exhaust valves are opened ahead of the air intake ports to permit most of the combustion gases to escape and reduce the pressure in the cylinder. When the air intake ports are uncovered by the piston at 450 B.B.D.C. as it continues downward, air from the air box under pressure can immediately enter the cylinder, scavenging the remaining combustion gases from the cylinder and providing fresh air for combustion. The piston is again at the original starting point of the description and the cycle of events is repeated.

ENGINE ARRANGEMENT

DESCRIPTION

This model diesel engine is a "V" type, two cycle engine, incorporating the advantages of low weight per horsepower, positive scavenging air system, solid unit injection and high compression. The accompanying sketch of a 16-cylinder engine serves to identify the cylinder locations, ends and banks of an engine as referred to in this manual. The governor, water pumps and lube oil pumps are mounted at the "Front End."

The turbocharger and generator are at the "Back End."



SERIAL NUMBERS

Major components of the engine are identified by serial numbers for historical record. When reference is made regarding a part having a serial number, the serial number should be included in the information as well as other identification used concerning the part. Following are major engine items identified with a serial number, and its location on the part.

ENGINE - serial number is shown on the engine nameplate located at the rightbank of the engine, and stamped at the upper left corner of the crankcase below the cover frame base.

CRANKCASE - serial number is on the right side of the main bearing caps, right side of each end "A" frame, and at the top left corner at the accessory end.

OIL PAN - serial number is located on the left side of the oil pan below the top rail at the accessory end.

CRANKSHAFT - serial numbers are located on the last crank pin throw and also at the front throw of the front half, in 1/2" high numerals with the EMD symbol.

CYLINDER HEAD-serial number is located at top face outside diameter opposite exhaust side.

CYLINDER LINER - serial number is located below the water inlet connection.

PISTON - serial number is located at the bottom inside diameter below the oil control ring.

PISTON CARRIER - serial number is located below the thrust washer platform on the outside diameter.

PISTON PIN - serial number is located at end of pin on same end as small identification hole.

FORK CONNECTING ROD - serial numbers are located in three different locations as the fork rod assembly consists of two basket halves and the rod. On basket half with dowel, number is located above basket-to-rod bolt hole. On other half, it is located below basket-to-basket bolt holes. On the rod, number is located to the left of center above serrations on the dowel side of rod.

BLADE ROD - serial number is located at end of slipper opposite the long toe.

CAMSHAFT ASSEMBLY - serial number of the assembly is located at the end of the accessory end stubshaft.

ENGINE GEARS - serial number is located on the rim of the gear.

GOVERNOR - serial numbers are provided on the governor nameplate.

WATER PUMP - serial number is located on the housing flange rim and is preceded by an "R" or "L" to show pump installation, at the right or left bank.

LUBRICATING OIL PUMP - serial number is located at the front end cover and is preceded by the letter "L" to identify it as a lubricating pump.

SCAVENGING OIL PUMP - serial number is located at end cover and is preceded by the letter "S" to identify it as the scavenging pump.

FUEL INJECTORS - serial number is located on same side as the injector rack, and is provided by injector manufacturer.

TURBOCHARGER - serial number is located on the nameplate attached to the turbocharger at the right side.

AFTERCOOLER - serial number is located at the center bolt surface at the water inlet side. (Core serial number located on nameplate on core.)

ENGINE PAINTING

If an engine is to be removed from service and completely overhauled and the interior repainted, the parts to be painted must be cleaned in a vat of caustic solution to remove old paint, grease and oil from the pores of the metal. The caustic solution must be thoroughly removed by washing the parts in clean hot water, and air dried with' an air hose. (Aluminum parts must not be washed in the caustic solution.) If caustic cleaning is not done before painting, the paint will peel off the interior of the engine and contaminate the lube oil lines. Mask off parts which are not to be painted.

Use crankcase primer paint on the following: interior of crankcase, oil pan, air

duct, top deck, cylinder head cover frames (except on seal surface), accessory and camshaft drive housings. Do not paint machined surfaces, liners, heads or seal surfaces.

To refinish the engine exterior, remove grease and oil with alkaline cleaner. Mask off water, fuel and oil fittings. If required, apply coat of primer. Then apply finish
coat.

567E4 SERVICE DATA

GENERAL ENGINE INFORMATION

SPECIFICATIONS

Bore	8-1/2"
Stroke	10"
Angle between banks	45^0
Compression ratio	14.5: 1
Displacement per cyl.	567 cu. in.
Rotation (Facing back end)	Counterclockwise
Firing order	1, 8, 9, 16, 3, 6, 11, 14, 4, 5, 12, 13, 2, 7, 10, 15
Exhaust valves (per cyl.)	4
Main bearings	10
Governor	Woodward Model LSG-10
Scavenging	Uniflow
Type of scavenging	Turbo-Centrifugal
Cooling system	Pressurized
Water pumps	Centrifugal type
Lubricating oil system	Full pressure
Oil pumps	
Main oil pump and piston cooling pumps	Two pumps in one housing, siamesed inlet, double discharge
Scavenging oil pump	Helical gear type
Fuel injection	Unit injector with needle valve
Fuel pump	Positive displacement
Engine starting	120 volt electric motor
Weight (approx.)	34, 425

RATINGS

Idle speed	460 RPM
Full speed	(50-cycle) - 600 RPM
	(60-cycle) - 720 RPM

TORQUE VALUES

(All given torque values may vary - 5%)

	FT-LBS
TOP DECK	
Camshaft stubshaft bearing bracket	75
Cylinder head crab nuts (studs and nuts lubricated)	1800
Injector crab nuts	50
Cylinder head-to-liner nuts	200
Top deck head frame bolts	30
Injector fuel lines	40

	FT-LBS
Rocker arm shaft nuts	300
Cam bearing blocks	32
Fuel manifold blocks	40
Cylinder test valve packing nut	65
Water jumper-to-head bolts	30
Exhaust manifold-to-crankcase	130
ACCESSORY END	
Accessory drive housing-to-crankcase and oil pan	65
Overspeed trip housing-to-crankcase	65
Water pump mounting bolts	65
Water pump elbows	65
Scavenging oil pump mounting bolts	5
Scavenging oil pump elbows	5
Lube oil pump mounting bolts	5
Lube oil pump elbows	65
Oil strainer housing mounting bolts	5
Governor drive housing mounting bolts	65
Governor-to-drive housing	65
Overspeed trip cover-to-overspeed trip housing	30
Fuel manifolds-to-filter	35
Oil strainer elbows-to-strainer housing	40
Accessory drive oil seal cover	40
Auxiliary drive flange retaining bolt	500
TURBOCHARGER END	
Camshaft drive housing-to-crankcase	65
Turbocharger mounting bolts - 3/4"	175
1/2"	65
Air ducts-to-turbocharger	35
Air ducts-to-crankcase	65
Aftercooler-to-air duct	35
Water piping-to-aftercooler	75
Water piping-to-engine	75
Turbocharger-to-manifold (oiled)	80
CRANKCASE AND OIL PAN	
Main bearing nuts	500 - 800
Piston cooling oil pipe bolts	20
Water jumper-to-liner	30
Water jumper saddle strap nuts	15
Crankcase-to-oil pan	450
Harmonic balancer-to-crankshaft	500
Accessory drive gear-to-crankshaft	300
Coupling disc-to-crankshaft	1500

567E4 SERVICE DATA
GENERAL ENGINE INFORMATION

	FT-LBS
Connecting rod-to-piston pin	450
Basket-to-connecting rod	190-200
Connecting rod basket	75

WATER PUMP

Impeller-to-shaft	80
Drive gear-to-shaft	265
Stationary bushing or pump seal-to-housing	(in.-lbs) 90-100

CRANKCASE AND OIL PAN

CRANKCASE

DESCRIPTION

The crankcase, Fig. 1-1, is the main structural part of the engine. It is a steel fabrication forming a rigid self-supporting assembly to accommodate the cylinder power assemblies, crankshaft, and engine mounted accessories.

The crankcase is primarily constructed around two cylinder banks. Each bank is formed by joining two channels into a long rectangular box-like structure. An upper and lower bore is provided in this structure for each cylinder liner, and a cylinder head retainer, Fig. 1-1, is located at the top of each cylinder bore. Openings are provided in each side at each cylinder for inspection, and scavenging air circulation.

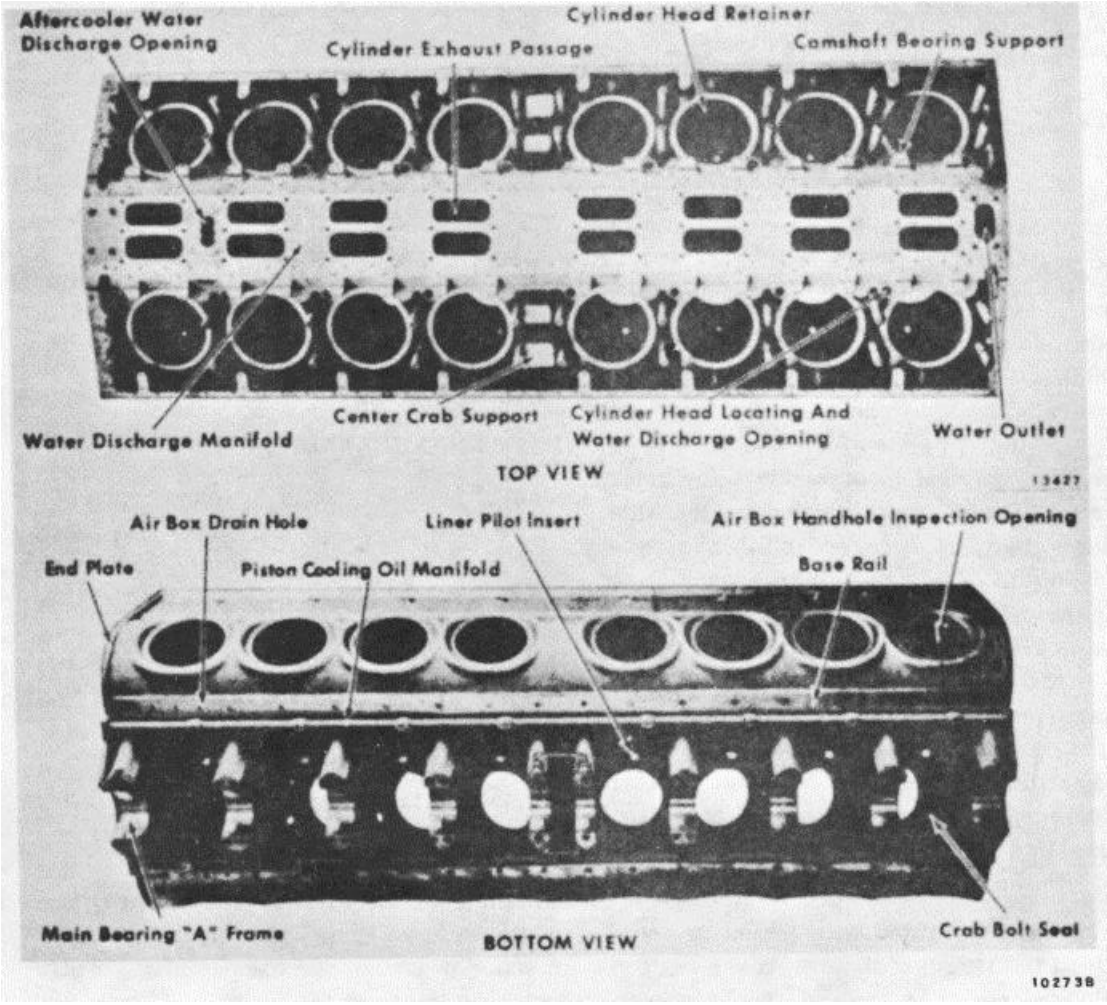


Figure 1-1. Crankcase

The cylinder banks are positioned at 45^0 to each other in the crankcase, forming a "V." The top of the "V" is closed by the water discharge manifold which extends the length of the engine. The sides of the manifold are closed by the camshaft bearing support wing plate and the seal plates which are part of the cylinder head retainer forgings. A water discharge opening is located at each cylinder location to receive the water discharge pipe from each cylinder head. This opening also serves to locate the power assembly properly in the crankcase. From each cylinder head retainer an exhaust passage extends through and to the top of the water discharge manifold. The bottom of the "V" is spanned by a plate to form the main lubricating oil manifold, which extends the length of the engine terminating at openings in each end plate.

The cylinder banks are joined and the front and back of the crankcase closed by the end plates. Air admission openings are provided in the rear end plate, and both end plates are drilled and tapped to accept the engine mounted accessories.

The sides of the crankcase are closed by side sheets having inspection openings which are normally closed with gasketed covers. The side sheets, end plates, and top and bottom plates form the air box or air reservoir which surrounds the cylinder liners. Plates extending above the side sheets between each end plate are provided with top bars to serve as a base for the cylinder head cover frame. These plates also create an oil channel along the outboard side of the cylinder head retainers. Combination drain and ventilating pipes extend from this channel, through the air box to the oil pan. At each cylinder, a tube extends from the outside of the top plate into the retainer pocket to accommodate the cylinder relief valve.

Base rails provided with mounting holes extend the length of the crankcase on each side and serve to support the crankcase on the oil pan. Separate drain holes in the base rails at the front end allow any liquid accumulation in the air box to drain into piping built into the front end of the oil pan. The piston cooling oil manifolds paralleling the base rails on the inside, have a flange at each cylinder location for the application of the piston cooling pipe.

As shown in Fig. 1-1, the main bearing "A" frames are located at each end of the crankcase and in between each cylinder location. The "A" frames are welded to the base rails and at the juncture of the cylinder banks to strengthen the bottom of the crankcase and support the crankshaft.

A main bearing cap is attached at a serrated joint to each "A" frame, and held by four main bearing bolts, except the two center "A" frames, which have two bolts.

The "A" frames and caps are line bored to accommodate the main bearings which support the crankshaft. A drilled passage extends from the top of each main bearing "A" frame bore into the main lubricating oil manifold. Oil tubes are inserted into these passages with their ends extending above the bottom of the manifold. The entire crankshaft and bearing oil supply is provided through these tubes.

MAINTENANCE

CLEANING CRANKCASE

The crankcase should be cleaned, to remove foreign material, after any work has been done on the interior of the engine, or if damage has occurred in the engine. This can be done by using a spray gun and solvent. The equipment near the engine should be protected against the spray. After spraying the top deck, wipe with towels saturated with solvent. Wipe all solvent trapped in corners and pockets. Use only lintless, bound-edge towels.

Cleaning of the air box with a spray gun while liners are in place is not recommended practice, due to possibility of dirt entering liners at the ports.

At any time cleaning is done on the crankcase, protection should be given to oil passages, bearing surfaces, gears, etc., to prevent gritty material from being trapped. Cleaning procedures should be in accord with accepted practice or as recommended by the supplier of cleaning material.

CRANKCASE INSPECTION

Serious crankcase failures can be avoided and longer crankcase life obtained by careful periodic crankcase inspection. Inspection may disclose small discrepancies which, if allowed to progress, might result in major failure, loss of service, or loss of the crankcase. Inspection and early trouble detection and repair are most important, since major repair generally cannot be done in the field. In instances where major repair is involved requiring extensive welding, it is essential that the crankcase be stress relieved and remachined where necessary. This tends to shorten crankcase life, as there is a limit to number of times this can be done.

In addition, when an engine failure occurs due to breakdown of parts, a careful inspection is essential at locations other than the immediate vicinity of the damaged area. (For example, an engine failure in which a connecting rod damages the liner pilot.) A rod may also strike and nick the stress plates. It is most important in this event that the stress plate be inspected in the holes opposite the liner and if any nicks are found, they must be blended out.

The stress plates are subject to shock loading and nicks may serve as possible stress concentrators and lead to cracking. It is recommended that a crankcase requiring rebuild or reconditioning be returned to the manufacturer for the work.

LOWER LINER BORE INSERT

DESCRIPTION

A replaceable phosphate treated cast iron insert, Fig. 1-2, is used in each lower liner bore of the crankcase to provide a wear surface at the lower liner pilot. Seals held in grooves in the lower liner pilot, prevent air

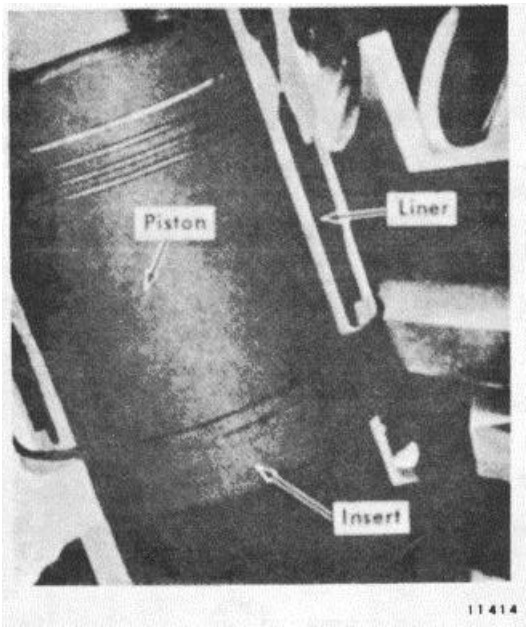


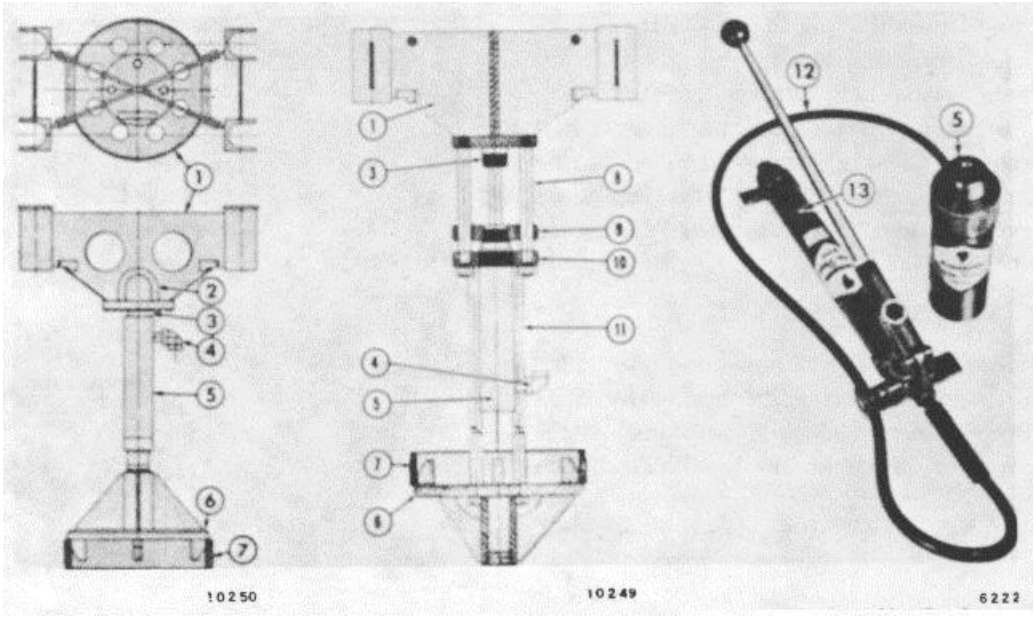
Fig. 1-2. - Lower Liner Bore Insert

passage between the insert and the liner. These seals are particularly important in turbocharged engines to prevent loss of air to the cylinders and a positive pressure buildup in the oil pan.

MAINTENANCE

When the inside diameter of the insert, installed in the crankcase, reaches the maximum limit, the insert should be removed and a new one installed.

Replacement of the insert in the lower liner bore of the crankcase requires the use of a sturdily constructed tool to apply and remove the insert safely and efficiently. The lower liner insert application and removal tool, Fig. 1-3, is specifically designed to do this work. This tool consists of a press and puller assembly and a 10-ton hydraulic jack. The hydraulic Jack consists of a 10-ton hydraulic ram, a high pressure hose, and a high pressure hydraulic pump.



a. Insert Application b. Insert Removal c. Hydraulic Jack

1. Crab Stud Holding Assembly
2. Hoisting Ring
3. Screw Plug
4. High pressure Hose Connection
5. 10-Ton Ram
6. Insert Plate
7. Insert
8. Holding Studs
9. Upper Plate
10. Ram Plate
11. Pulling Studs
12. High Pressure Hose
13. Hydraulic Pump

Fig. 1-3. Liner Bore insert Application and removal Tool

INSERT APPLICATION

The arrangement of the tool for insert application is shown in Figs. 1-3a and 3c.
The insert is installed as follows:

1. Coat the contact area of the outside diameter of the insert with white lead or similar lubricant.

2. Manually place the insert (7) in place in the lower bore, and position it for the pressing operation by starting it uniformly in the bore.

3. Assemble the tool as shown in Fig. 1-3a, with the ram screwed into the screw plug, and into the boss of the insert plate (6). The ram plunger should be in the retracted position. Disconnect the high pressure hose (12) if it is attached to the ram.

4. Lift the tool at the hoisting ring (2), and place the tool into the cylinder bore resting upon the cylinder retainer. The tool should be positioned so the hose connection is accessible from the stress plate inspection opening. Secure the tool using four crab nuts at the crab stud holding bosses.

5. Attach the high pressure hose (12) to the ram (5) at the ram connection (4), and using the hydraulic pump, extend the plunger to contact and press the bore until the shoulder is seated.

INSERT REMOVAL

The arrangement of the tool for insert removal is shown in Fig. 1-3b. The insert is removed as follows:

1. Assemble the tool for removal as shown and remove the four nuts hold-

ing the insert plate (6) and remove the plate. Also, remove the high pressure hose (12) from the ram (5) if it is connected.

2. Lift the tool using the hoisting ring and place in the cylinder, resting upon the retainer. Position the tool so that the hose fitting may be reached at the outboard side to permit hose application. Apply four crab nuts to secure the tool.

3. Place the ram plunger so that the insert plate bolts extend below the insert to permit insert plate application, as shown in Fig. 1-3b. Apply the insert plate and its holding bolts.

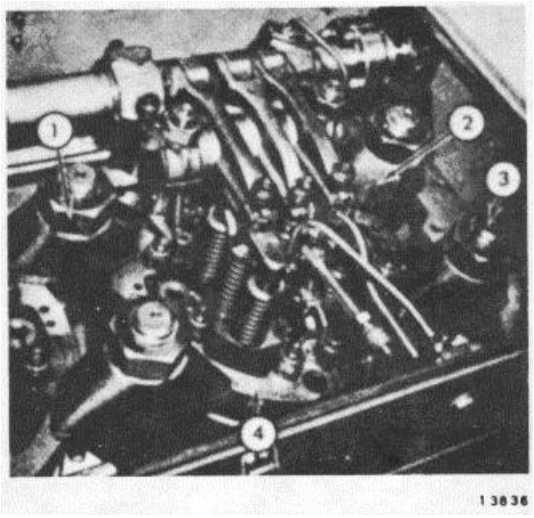
4. Connect the high pressure hose (12) to its fitting (4) on the ram (5) and using the pump (13) remove the insert (7) from the crankcase bore.

In the event that the insert application and removal tool is not available, the insert may be applied and removed using a mallet and a phenolic or wooden block.

CRAB BOLTS

DESCRIPTION

The cylinder head and liner are bolted together and this assembly is held in the cylinder head retainer by 1-3/4" crab bolts, head crabs, and nuts, Fig. 1-4. The crab bolts extend up through the cylinder bank upper deck plate adjacent to each cylinder retainer. The bolt heads have a spherical seating surface which seats in a like surface, the bolts being held in position by a separate plate and bolt for each pair of bolts. The square bolt heads fit corresponding holes in the plate which prevents their turning when being torqued. Head crabs, each contacting two cylinder heads, except for end or center crabs, hold the power assemblies firmly in place.
A spherical surface in the top of the crab receives a crab nut with a mating spherical seat.



1. Crab Nut
2. Crab
3. Crab Bolt
4. Cylinder Head
5. Retainer Plate
6. Retainer Bolt
7. Retainer Bolt Nut

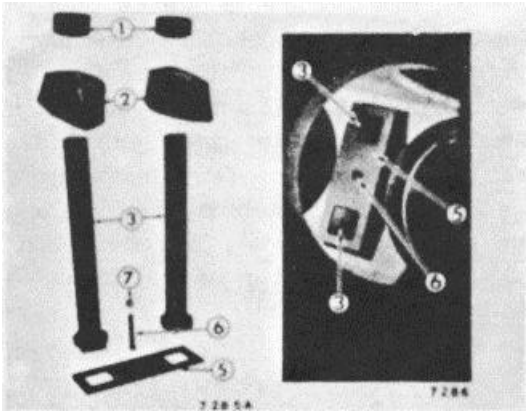


Fig. 1-4. Crab Bolt Installation

MAINTENANCE

The crab bolts can be removed through the air box by removing the crab bolt retainer plate bolt and retainer plate. The retainer plate and bolt are easily accessible only after liner has been removed.
Crab bolt threads may be cleaned up using a 1-3/4"-12 thread die, and nut threads may be cleaned up using a 1-3/4"-12 tap. Whenever crab bolt threads are exposed, they should be covered with thread protectors. Before reapplication of the crab nut, examine for burrs, roughness, or galling

which would affect the true torque value. Care should be taken to see that the spherical surface is smooth to provide good contact and prevent air leakage from the air box. The crab stud and nut threads should be lubricated at time of assembly, using a lubricant having specifications similar to Texaco Thread Tex #2303 (or equal), or as a second choice, engine lube oil.

Torque value of the cylinder head crab nuts is 1800 ft-lbs - 90 ft-lbs.

Crab bolt nuts should be tightened in two passes, half torque at each pass, tightening the diagonally opposite nuts alternately to form a letter "X." This method applies whether tightening an entire bank or a single cylinder. After final cylinder assembly, bring engine water temperature to 170°F. and retorque crab nuts and liner stud nuts to proper torque. Recheck at intervals specified in the Scheduled Maintenance Program.

NOTE: When liner and crab nuts are being retightened, those that move at less than the specified torque values should be tightened to proper value. Those which DO NOT MOVE, below or up to the proper values, should be checked by pulling up to a value not exceeding 10% more than recommended torque.

MAIN BEARING STUD BOLT APPLICATION

DESCRIPTION

The main bearing stud bolts are shown in Fig. 1-5. Each "A" frame has four 1-1/4" coated main bearing studs except the center "A" frames, which have two each, They pass through the "A" frame and main bearing caps with their lower ends 7" below the "A" frame serrations. A 5/16" transverse hole at the upper end of each stud accommodates a 1/4" bolt which passes through the stud and slots in the upper nut. Semicircular or D-shaped nuts are used at the upper end of the stud. The

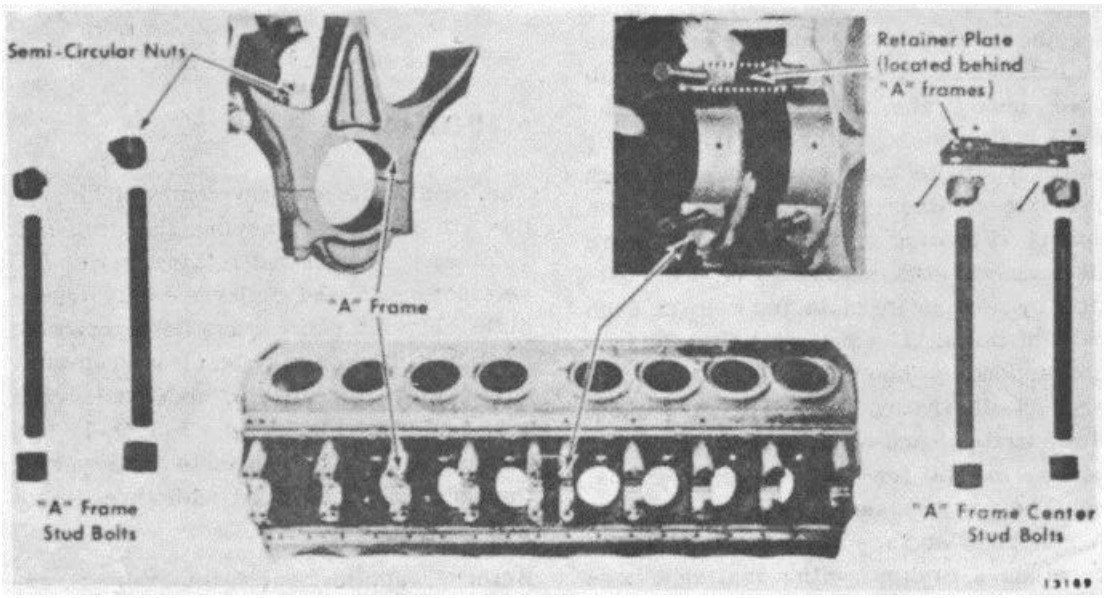


Fig. 1-5 . Main Bearing Stud Bolts

upper nuts have a spherical seating surface to match a similar surface in the "A" frame. Since the center "A" frames are separated from each other, a retainer assembly is used to prevent the upper nuts from turning. The retainer assembly is held in place over the nuts by the 1/4" bolts which pass through the nuts and studs.

MAINTENANCE

Thread size at both ends of main bearing stud bolt is 1-1/4"-12. A thread die can be used to clean up the stud bolts, while a tap can be used on the stud nuts. To aid in obtaining correct torque values, the threads should be cleaned before parts application.

Upon application, each stud is inserted into its place in the "A" frame and run into its nut until the 5/16" hole in the top of stud lines up with the bolt slot of the nut. The lower end of the stud should be 7" from the serrations on the "A" frame when the stud is brought out with the spherical surface of the upper nut contacting the mating surface in the "A" frame. This is to ensure that the lower stud nuts can be properly tightened when the bearing cap is applied. The 1/4" bolt and self-locking nut may then be applied to all the upper nut and stud assemblies except the center "A" frames. The upper nut flats contact each other when in place on all "A" frames except the center "A" frames, which are separated from each other. A retainer plate is used on the center "A" frame upper nuts to prevent them from turning. After the stud has been run into the nuts the proper amount, the retainer, which is like a channel, is placed over the nuts. The 1/4" bolts are then applied through the retainer and stud and across the nut slots. The bolt slots in the retainer are of different widths, one slot being larger to secure the bolt head and prevent it from turning when being tightened. The retainers are cut away on one side to provide clearance for a stiffener plate between the center "A" frames.

Main bearing caps are originally applied to the "A" frame and then are line bored; therefore, they are not interchangeable or available for replacement. They must be reapplied on the same "A" frame in the same original position as removed. Each cap and "A" frame is stamped on the right side with their bearing number, and in addition, all caps and the end "A" frame are stamped with crankcase serial number. Before cap application, check serrations in cap and "A" frame and remove any burrs or foreign material that would prevent a good mating fit.

Torque value of the castellated main bearing nuts is 500 - 800 ft-lbs, and 700 ft-lbs for self-locking nuts. For correct assembly the slotted nuts should be brought up to 500 ft-lbs and then tightened further until lineup of first lockwire hole is reached. This will ensure torque value being within the 500 to 800 ft-lb range.

For checking main bearing bore dimensions, a torque value of 650 ft-lbs should be used. With nuts torqued to this amount, check the out-of-round limit of the main bearing bore. Likewise, check that the main bearing bore dimensions are within the minimum and maximum limit. These are the average of six measurements, three taken at each end of the bore. The crankcase main bearing bore measurements must be within these limits to qualify and ensure that the bore is not closed in.

If an overheated bearing makes it necessary to check an "A" frame for "close in" with the crankshaft in the engine, it may be checked using a new upper main bearing. In this check, the "A" frame bore must be able to receive a new upper main bearing shell. Also, check the clearance

at each side between the bearing shell and the crankshaft at the split line above the serrations.

OIL PAN

DESCRIPTION

The oil pan, Fig. 1-6, is a steel fabricated assembly. It supports the crankcase and serves as the engine base. The engine oil sump, located centrally in the oil pan, is provided with oil drains.

An oil level bayonet gauge extends from the side of the oil pan into the sump. A scavenging oil pump suction line is built into the oil pan extending from the sump to the front end plate. Openings in each end plate allow oil from the camshaft and accessory end housings to drain into the oil pan. Hand holes at each cylinder location, provided with gasketed covers, allow access to enclosed engine parts. Liquid accumulations from the air box are drained through pipes located at the front of the oil pan into a common flange for discharge.

The seal arrangement between the crankcase and oil pan mounting rails consists of a silicone rubber cord placed in a groove outside the bolt line the entire length of each oil pan mounting rail. A small "O" ring seal placed in a counterbore seals the air box drain opening.

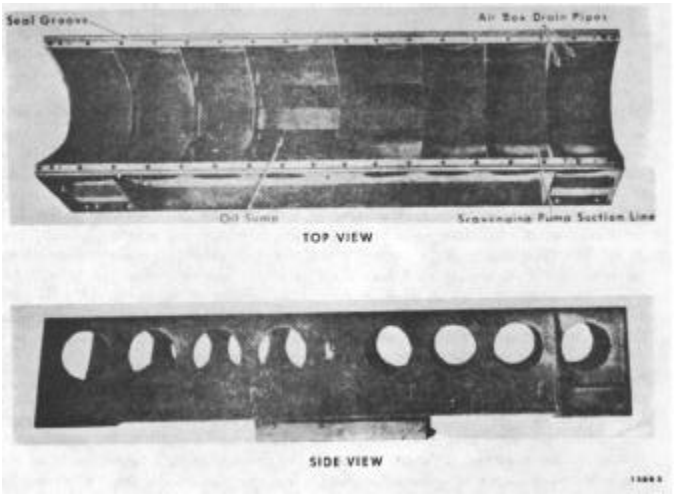


Fig. 1-6. Oil Pan

Dowels hold the crankcase to oil pan alignment after original assembly and, crankcase to oil pan bolts secure the assembly.

MAINTENANCE

CLEANING

The oil pan should be thoroughly cleaned at the time of an oil change or any time the engine is damaged. Particular attention should be given the oil drain pipes to make certain there is no accumulation of foreign material. Wipe out accumulation from corners and pockets of pan.

INSPECTION

Inspect the interior surfaces of the oil pan for loose or flaking paint.

In addition, inspect the seal grooves, air box drain pipes, end plates, and hand hole cover gasket surfaces for any nicks or roughness which would damage the seals or interfere with proper sealing.

CRANKCASE TO OIL PAN SEAL

DESCRIPTION

A round silicone seal cord placed in a groove, Fig. 1-6, in the oil pan mounting rail effectively prevents any leakage at the junction of the crankcase and oil pan. Particular attention in manufacture is given to the crankcase and oil pan mating surfaces and the groove in the oil pan to ensure that they are clean, smooth, and free of any burrs or nicks which would injure the seal. The groove depth in the oil pan is also maintained within close tolerances to realize the full effectiveness of the seal cord.

MAINTENANCE

Before seal application, inspect oil pan rails for nicks, burrs, or foreign material of any kind in seal grooves, and remove to provide a clean smooth surface. Any indentation in the seal grooves or base rails that would allow oil seepage must be filled with solder and finished flush with surrounding area.

Along outside edge of oil pan rail surface, apply one coat of Tite Seal #3, approximately 1/2" wide and about .015" thick, or thickness of ordinary playing card.

Install seals in the grooves without twisting or stretching and without lubricant. The individual seals for each model engine are longer than required, but do not cut off seal ends at this time.

Place crankcase over oil pan, and using lineup pin guides in the four corner holes, lower crankcase on oil pan. Apply taper dowel bolts and tighten. Check crankcase to oil pan alignment, using care not to damage seal cord.

CAUTION: Do not pull or stretch the ends of seal cord.

Assemble all crankcase to oil pan bolts with washers and snug four corner bolts to about 100 ft-lbs torque. Starting with the center bolt and alternating between the bolts to the left and right of center, tighten bolts to a torque of 100 ft-lbs. After tightening bolts on both sides of engine to 100 ft-lbs repeat tightening sequence bringing bolts to a final torque of 450 ft-lbs.

After all bolts have been tightened to 450 ft-lbs, cut seal cord ends to provide a seal protrusion from face of end plates of 3/32” - 1/64”. This seal protrusion will seal the three way joint of oil pan, crankcase, and end housing.

All crankcase to oil pan bolts must be tightened at regular intervals, in accordance with the Scheduled Maintenance Program.

AIR BOX DRAINS

DESCRIPTION

Accumulation of liquids from the engine air box is removed through drain holes in the base rails of the crankcase, Fig. 1-7, which are aligned with pipes located on each side of the oil pan at the front of the engine, Fig. 1-7. Both pipes connect to a common flange, Fig. 1-7, mounted on the oil pan end plate at the left-hand front of the engine.

Piping connected to the flange extends the length of the engine and up to the crankcase ejector assembly to provide constant draining for the air box. Other than a periodic check as to the condition of the piping, no maintenance is required. The crankcase ejector assembly is covered in Section 8 under Lube Oil Separator. (60 cycle unit)

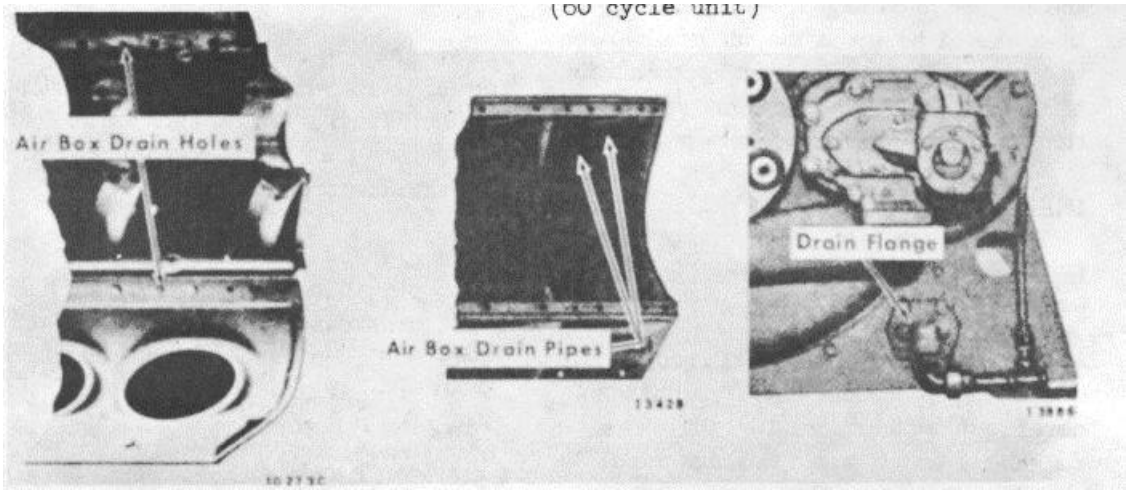


Fig. 1-7. Air Box Drain Installation

Piping connected to the flange extends along the side of the engine and into the exhaust silencer. Air box accumulation is thereby discharged out the exhaust stack. Other than a periodic check as to the condition of the piping, no maintenance is required.(50 cycle unit).

567E4 SERVICE DATA

CRANKCASE AND OIL PAN

SPECIFICATIONS

Upper liner pilot bore - New	12.091"
Limit	12.104"
Lower liner pilot insert bore - New	10.377" - 10.382"
(installed in crankcase) Limit	10.386"
Lower liner pilot bore in crankcase - New	11.062" - 11.065"
Limit	11.068"
Main bearing bore with bearing caps installed and torqued to 650 ft-lbs.	
Diameter of bore - Max.	8.252"
Min.	8.249"
Bore out-of-round - Limit	005"
Bearing shell to crankshaft clearance (Each side above serrations at split line) - Min.	0015"

EQUIPMENT LIST

	Part No.
Crab stud thread protectors	8034600
Crab nut tap 1-3/4"-12	8050688
Towels (bound-edge wiping towels)	8052752
Main bearing bolt thread die 1-1/4" -12	8060349
Main bearing nut tap 1-1/4" -12	8060387
Crab stud thread die 1-3/4" -12	8067409
Hydraulic jack 10-ton	8078281
Main bearing nut offset ratchet wrench	8191591
Spray gun (for engine cleaning)	8193041
Main bearing nuts powerench set	8250854
Crab nut powerench set	8250855
Main bearing cap lifter	8252846
Lower insert application and removal tool	8275379
Press and puller assembly	8275380

CYLINDER HEAD AND ACCESSORIES

CYLINDER HEAD

DESCRIPTION

The cylinder head is installed in the engine as shown in Fig. 2-1. Crab bolt nuts and crabs contacting each cylinder head hold it securely to the cylinder head retainer in the crankcase. A cylinder head seat ring, Fig. 2-2, is installed between the cylinder head and retainer to take any wear that may occur. The head is secured to the cylinder liner by eight equally spaced studs and nuts, and the assembly is firmly held in the crankcase, by the crabs.

Correct positioning of the cylinder head is ensured by alignment of the water discharge elbow, Fig. 2-3, and its mating hole in the crankcase. The crankcase has "built-in" siphon tubes at the second cylinder from front on left bank and second cylinder from rear on right bank to siphon the water from the water discharge manifold when the engine water is drained. Therefore, all cylinder heads use the short tube water discharge elbow.

The cylinder head is made of high strength cast iron alloy having special design cast passages for water and exhaust gases. Drilled water holes, Fig. 2-4, at the bottom of the cylinder head match the water discharge holes in the liner. Exhaust passages in the cylinder head line up with mating elbows in the crankcase, which conduct the exhaust gases through the water manifold to the exhaust manifold.

A well is located in the center of the cylinder head for application of the unit fuel

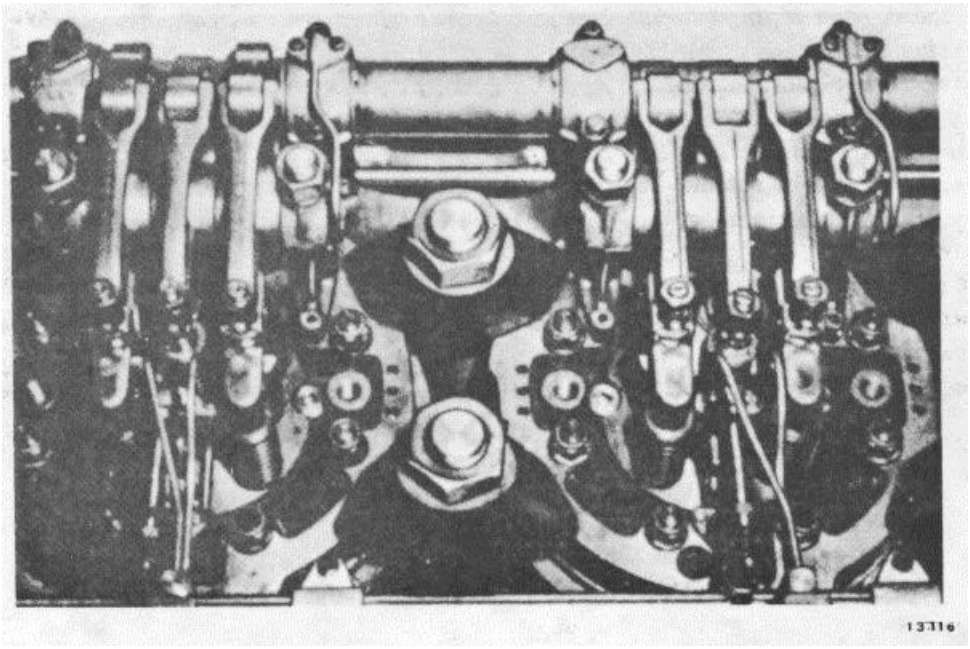


Fig. 2-1. Cylinder Head Installation

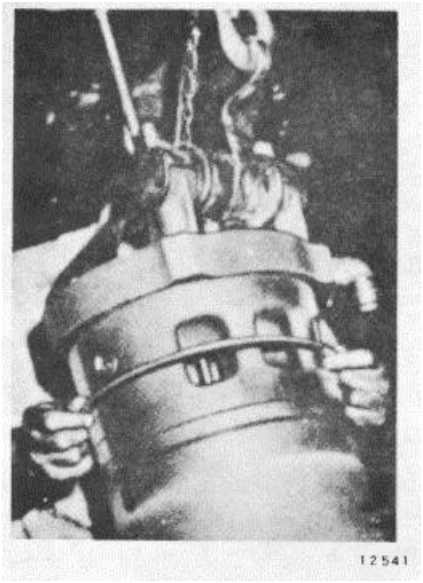


Fig. 2-2. Installing Seat Ring

injector. To ensure correct positioning of the injector in the head, a mating hole for the locating dowel on the injector is located in the head.

Fig. 2-5 shows the rocker arms, exhaust valves, valve bridges with springs, valve guides, overspeed trip pawl, fuel injector, and other related items making up a complete cylinder head assembly.

CYLINDER HEAD REMOVAL AND DISASSEMBLY

Engine cooling water system must be drained before attempting to remove the cylinder head. If the cylinder liner is to be removed, remove piston cooling pipe assembly and

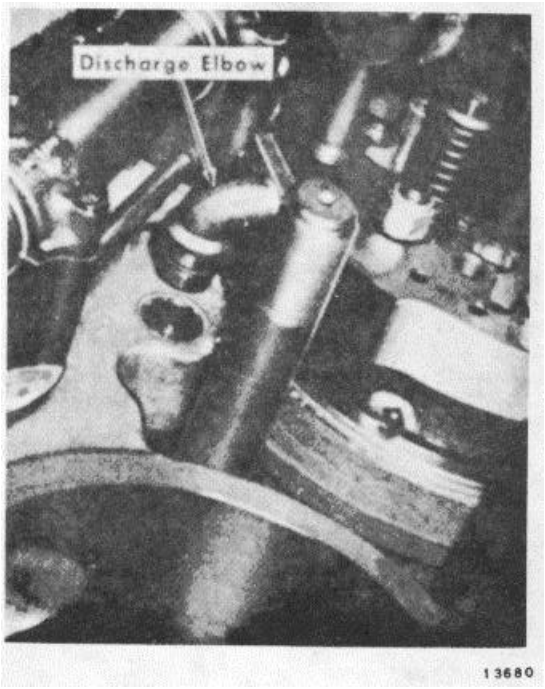


Fig. 2-3 . Water Discharge Elbow

water jumper line before starting to remove cylinder head.

1. Remove cylinder test valve.

2. Remove rocker arms, rocker arm shaft, and valve bridges.

   a. Disconnect c a m s h a f t bearing to rocker arm oil line.

   b. Remove rocker arm shaft cap nuts and remove caps.

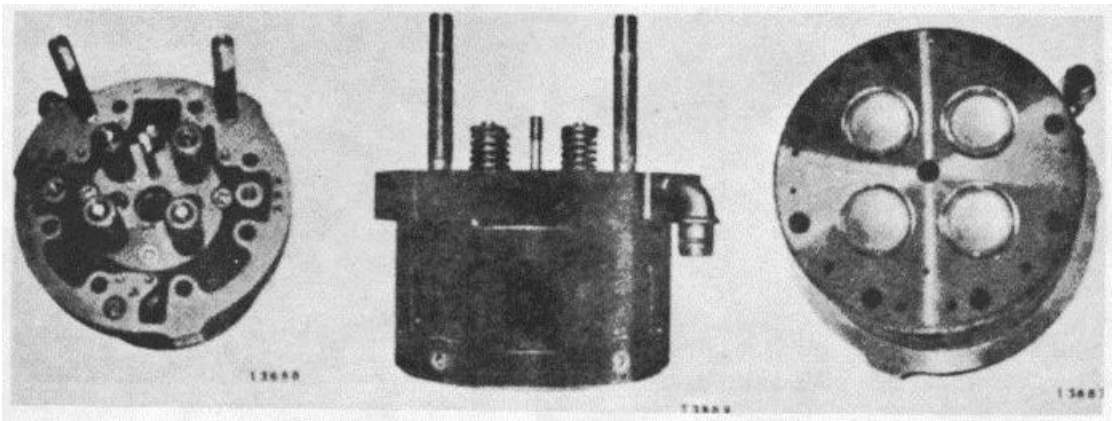


Fig. 2-4. Cylinder Head

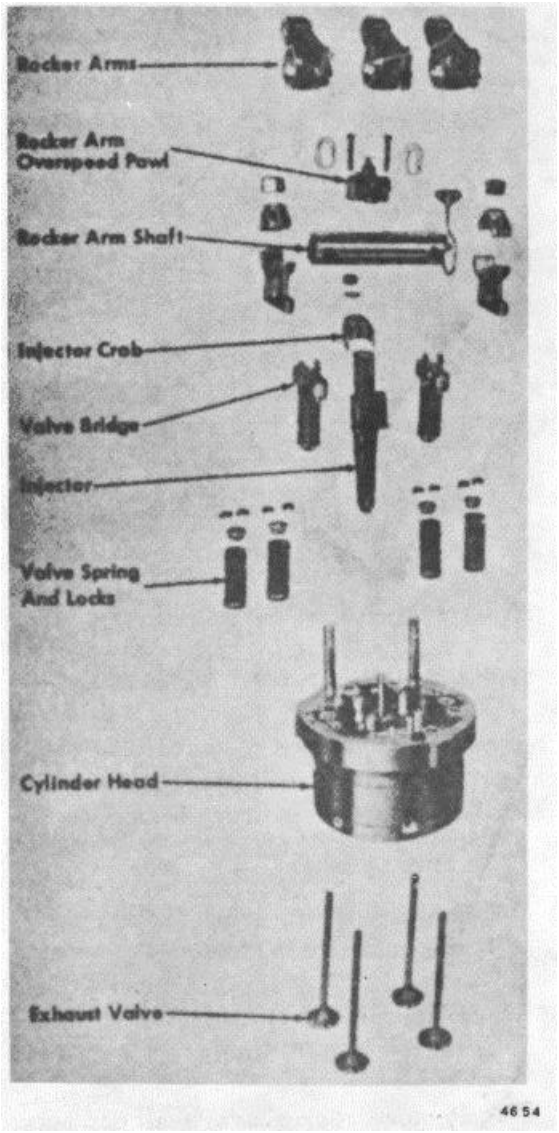


Fig. 2-5. Complete Cylinder Head Assembly, Exploded View

c. Remove, rocker arm assembly, being careful not to let shaft fall from rocker arms.
d. Remove valve bridges.

3. Remove injector.

   a. Disconnect fuel oil lines from injector and fuel oil manifold.

   b. Remove adjustable injector link.

   c. Remove injector crab.

   d. Using a pry bar, Fig. 2-6, remove injector. Protect injector from dirt and damage by using a holding rack, or a shipping container.

4. Remove cylinder liner stud nuts and washers.

5. Remove crab nuts and crabs.

6. Place crab stud protector tubes over studs to protect threads.

7. Remove cylinder head, using a head removing fixture. Protect water outlet elbow. Place head in carrying basket to protect machined gasket seat surface from damage.

NOTE: Check the old cylinder head gasket for any indication of bulging on the diameter, as this is an indication of hydraulic lock due to liquid accumulation in the cylinder. In the event of a bulged gasket, the connecting rod should be thoroughly checked as it may be bent.

8. Remove cylinder head seat ring.



Fig. 2-6. Removing Fuel Injector

EXHAUST VALVE AND
SPRING REMOVAL

Removal of the exhaust valves and spring assemblies completes the cylinder head disassembly.

1. As shown in Fig. 2-7, remove exhaust valve springs using single valve compressor and adapter screwed into the head, or the multiple valve compressor which compresses all four valve springs at the same time.

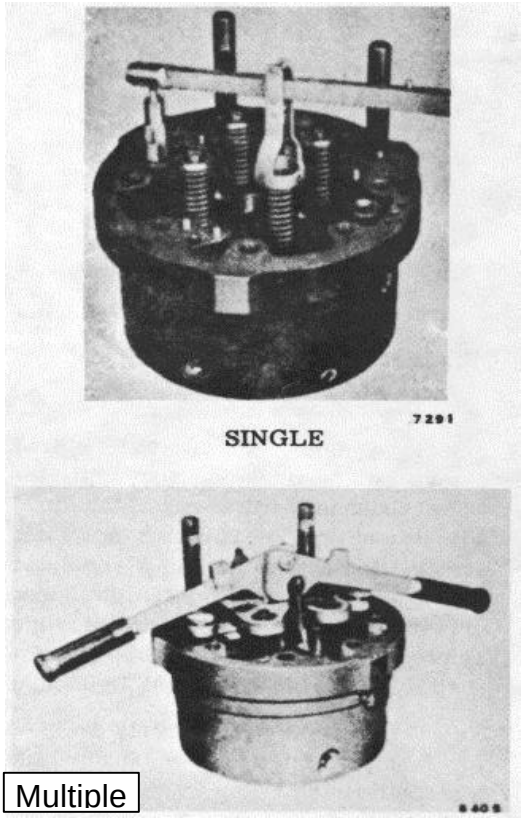


Fig. 2-7. Compressing Valve Springs

2. Compress the springs sufficiently to remove the valve locks and spring seats, and then remove the springs.

3. After spring removal, the exhaust valves can be removed from the bottom of the head.

NOTE: Valve springs can be removed and replaced without removing the cylinder head from the engine. If this is done, the piston must be at top center to prevent the valves from falling into the cylinder when the valve locks are removed.

MAINTENANCE

Cleaning

1. Cylinder heads should be thoroughly cleaned after disassembly. Cleaning procedure should be in accord with accepted practice or as recommended by the supplier of cleaning material.

2. All loose material should be removed from the stud holes in the head using stud hole cleaner, Fig. 2-8.

3. Clean the cylinder test valve threads using a standard 1/2" pipe thread tap.

Inspection

Inspect the cylinder head for cracks using the Magnaflux procedure outlined in Maintenance Instruction 1754. If satisfactory, proceed with the following service operations on the cylinder head.

Grinding Valve Seats

Either a 115-volt or 230-volt valve seat reconditioning tool set may be used in grinding the exhaust valve seats. Valve measurement points are shown in Fig.2-9.

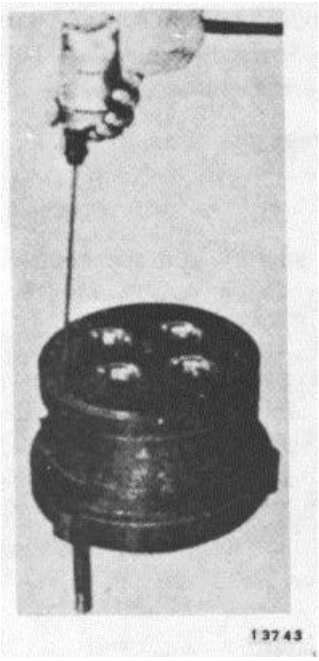


Fig. 2-8. Cleaning Stud Holes

1. Dress grinding wheel before using on each cylinder head. Mount as in Fig. 2-10. Wipe pilot with oil-soaked cloth for lubrication. Do not get oil on the

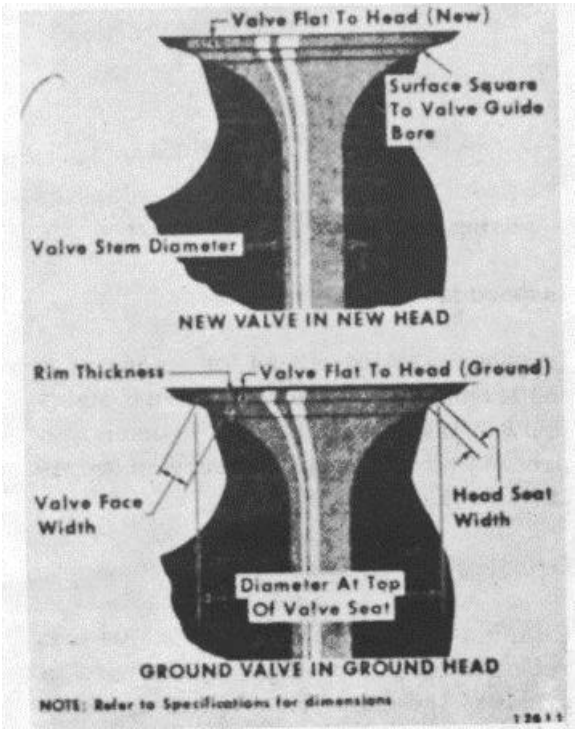


Fig. 2-9. Valve Measurement Points



Fig. 2-10. Dressing Valve Seat Grinding Wheel

grinding wheel. Adjust the spiral sleeve on the dressing tool until the wheel touches the diamond. Make final adjustment with diamond adjusting screw. Holder and grinding wheel are then revolved with the high speed driver which should be held as straight as possible. Move the diamond steadily across the wheel, taking light cuts.

Keep grinding wheel properly dressed for fast grinding, seat accuracy, and a smooth finish.

2. Using a valve guide cleaner and a 115-volt or 230-volt drill, clean guide as shown in Fig. 2-11. Any evidence of

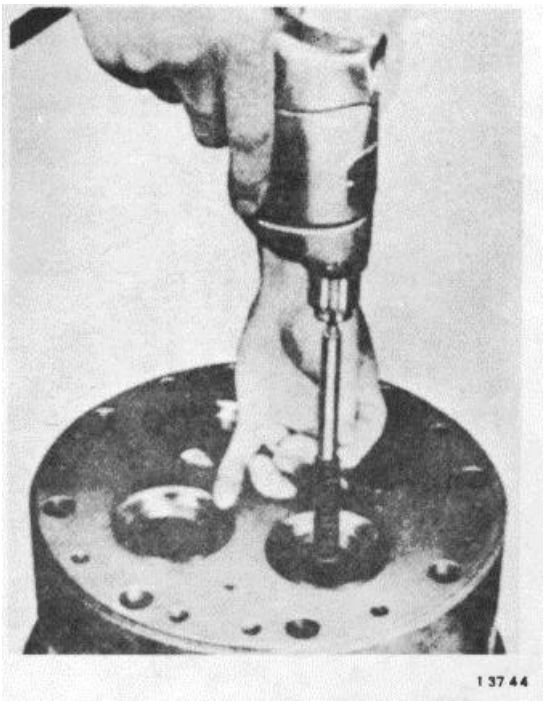


Fig. 2-11. Cleaning Valve Guide

galling inside of guide must be entirely removed by reaming, or the guide should be replaced. The I.D. of the guide should not. exceed the limit when measured at the bottom and 1/2" from top and bottom.

3. Select a tapered pilot which will bring the shoulder on the pilot above the valve guide. Press pilot firmly into guide, using pin. Wipe pilot with an oily cloth.

   A fixture, Fig. 2-12, is available for checking tapered pilots. To ensure satisfactory results, pilot runout should not exceed .0005".

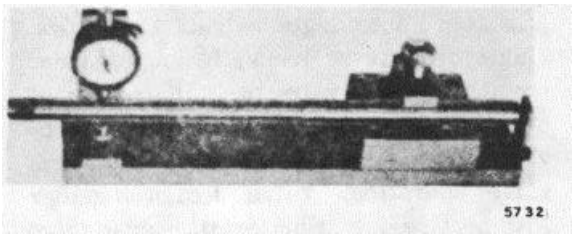


Fig. 2-12. Tapered Pilot Checking Fixture

4. Ream inside and outside of valve seat to dimensions listed in Specifications. Use a reamer pressure fixture, Fig. 2-13, to apply an even, adjustable pressure on the reamer. First, use an inside reamer to ream clearance inside of valve seat. Then use an outside reamer until the top outside of the valve seat is narrowed to the proper width. After completion of reaming operations, blow out cuttings with air hose and wipe parts clean.

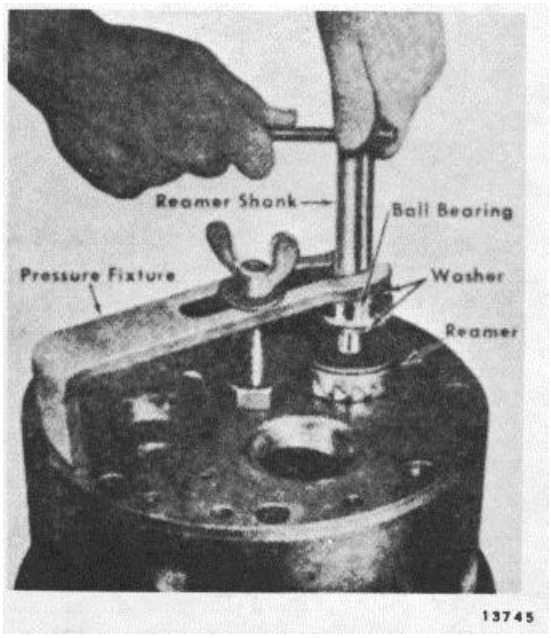


Fig. 2-13. Reaming Valve Seat

5. Place grinding wheel holder with wheel over pilot. Insert abrasive cloth between the grinding wheel and valve seat, and clean seat by turning holder by hand. Remove abrasive cloth and proceed to grind with driving motor, as shown in Fig. 2-14. No pressure is required when grinding and the driving motor should be run at top speed. Hold driving motor as straight as possible and grind until valve seat is true. Raise grinding wheel off seat before stopping motor.

6. Check valve seat width. If over limit, ream with outside reamer, then grind

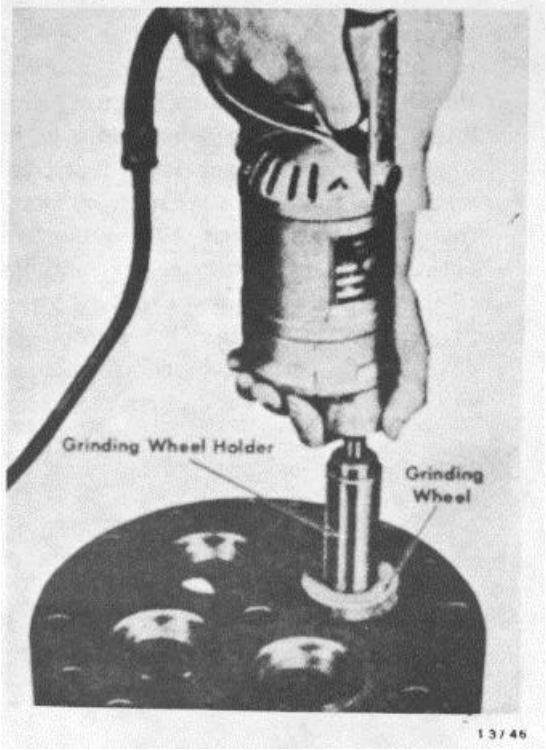


Fig. 2-14. Grinding Valve Seat

lightly to remove any raised edge caused by reamer.

7. Use dial indicator included in the valve seat reconditioning set to measure trueness of valve seat. Place indicator over pilot, Fig. 2-15, and adjust so indicator is depressed slightly and ball of valve seat rider is at the center of the valve seat. Rotate valve seat rider and observe indicator reading. Valve seat out-of-round will be indicated on dial. indicator reading must not exceed the limit. An attempt should be made to obtain a perfect valve seat, since it is a very important factor in valve life.

Valve Guides

Cast iron valve guides treated with a nitriding process for longer wear are used in the cylinder heads. Nitride treated guides can be identified by the radius at

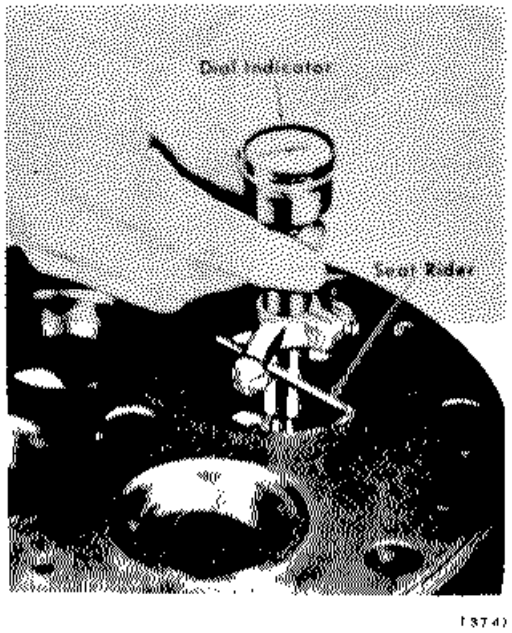


Fig. 2-15. Checking Valve Seat Roundness

the top of the valve guide, and a satin-like appearance. The valve guides are a press fit in the cylinder head and can be pressed in or out without damage by using valve guide installing or removing tool. Although the valve guides are precision guides and generally do not require reaming after assembly, it is recommended that a .626" reamer or plug gauge be inserted after guide installation to ensure the minimum diameter.

EXHAUST VALVES

DESCRIPTION

The exhaust valves, Fig. 2-16, are the long stem design, having an extended stem end above the single valve lock groove.
Single bead valve locks, having extended length, hold the valve in a tapered spring seat. Precision type valve guides provided with ample length, ensure excellent valve operation. Valve design together with heat resistant materials used in valve manufacture ensure a long service life.

MAINTENANCE

When exhaust valves are removed, they must be handled carefully to avoid nicks and scuffs that might make the valve unfit for use. Piling valves on top of each other may cause nicks on the outside diameter or throat radius and these can lead to valve failure. Before the valves can be reused, they must be reconditioned within the dimensional limits listed in the Specifications at the end of this section, and should meet the following visual inspection to ensure continued trouble-free service.

Cleaning

Thoroughly clean the exhaust valves using a suitable solvent to remove the carbonaceous material. If necessary, after drying, the valves may be given a finish cleaning using a soft wire brush.

Inspection

In the inspections listed herein, "acceptable" indications are those which will permit valve reuse, and" rejectable" indications are those which are cause for scrapping the valve. The valve surfaces referred to are identified in Fig. 2-16.

1. Acceptable Indications

   a. Light pitting on the valve face that can be cleaned up within the maximum allowable valve face limit.

   b. Lightly scuffed valve stems which can be reconditioned by buffing.

   c. Extremely light wear in lock groove.

2. Rejectable Conditions

   a. Indications found in the cup area, Fig. 2-17, are defects which reject a valve.

   b. Any cracks found on the outside diameter or rim section o the valve, Fig. 2-18, are cause for rejection. Fig. 2-18, are cause for rejection.

      Such rim cracks are often difficult to see, but should be carefully watched for since they eventually lead to failure. They usually extend some distance into the valve face.

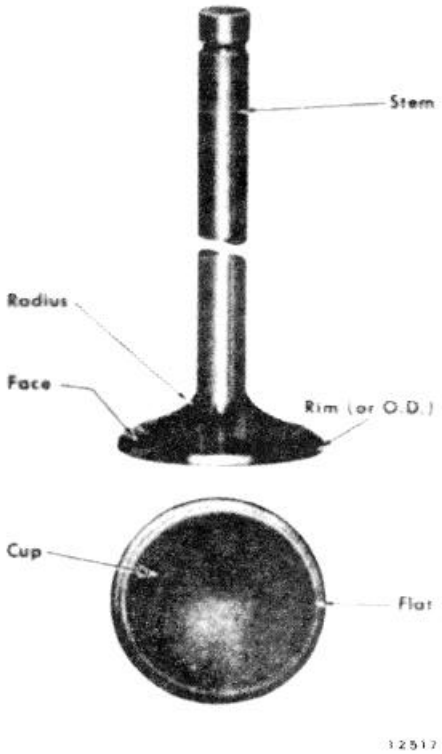


Fig. 2-16. Exhaust Valve

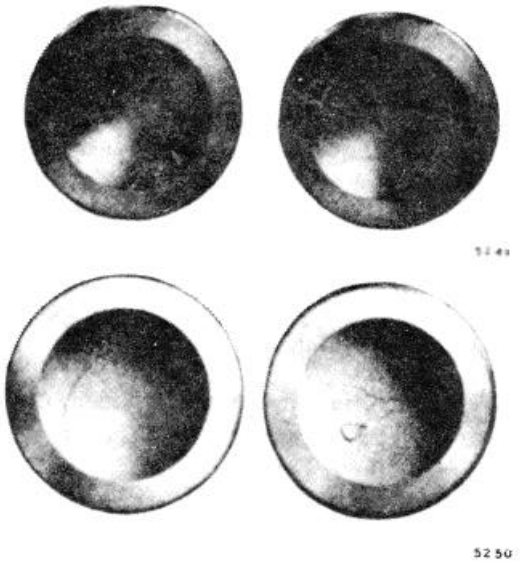


Fig. 2-17. Cup Defects

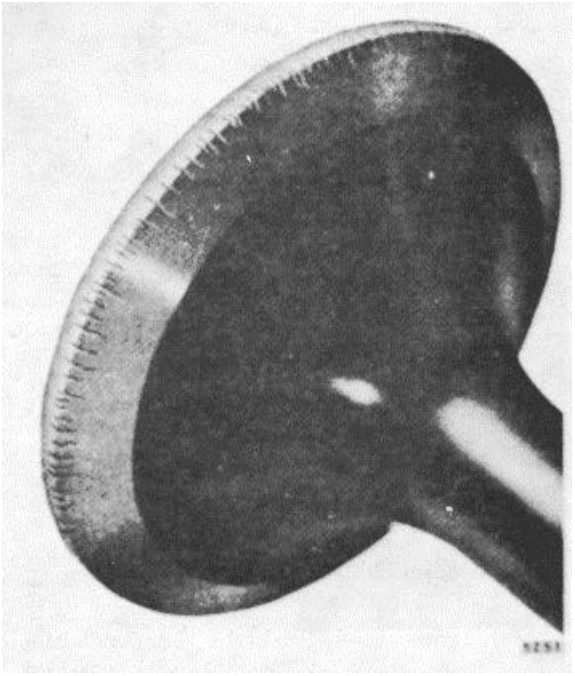


Fig. 2-18. Face And Rim Defects

The face area, Fig. 2-18, is the critical area of the valve. Grinding cracks, channeling, and thermal cracks are cause for valve rejection. It is recommended that this examination be made with the aid of a 3x magnifying glass.

c. Reject and discard valves that may have been damaged to the extent that critical surfaces have been nicked or scuffed.

Grinding Valves

For grinding valves, follow instructions supplied with the 115 or 230-volt grinder. A complete listing of the equipment required for the machines is contained in the Service Tool Catalog.

Exhaust Valve Installation.

After the exhaust valves have been reconditioned, they are applied to the reconditioned cylinder head. Position the head properly and complete the assembly of valve springs, spring seats, and valve locks.

Valve Springs

1. The valve springs and valve bridge springs should be inspected, before installation, for any nicks or unusual wear. Valve springs should be cleaned with a suitable solvent and a soft wire brush. Do not hydroblast or grit blast. Valve springs should be protected so as to prevent rusting.

2. Minimum free length of the valve spring is 3-31/32". New valve springs are approximately 4-1/8" long (free length). With the spring applied and the valve closed, spring length is 3-3/8" and with the valve open 2-11/16". Pressure required to compress the spring to 2-11/16" dimension should be 213 to 225 pounds with a new spring, while a used spring should require at least 175 pounds to compress it to the 2-11/16" dimension. The spring should not show any set after being compressed with the coils touching.

3. Valve spring seats should be clean and smooth and the thickness of the spring seating surface should not be less than the minimum limit.

Valve Locks

1. Valve spring seat locks, Fig. 2-19, are single bead type to fit the single groove valves used. The valve locks may either be the smooth top type or the grooved top type. Lock halves used on the same valve maybe either smooth or grooved top as locks are interchangeable.

2. Examine the valve locks for signs of excessive wear on the upper portion of the bead and for evidence of excessive fretting in the ground diameter which engages the valve stem. If these conditions exist, the locks should be replaced.

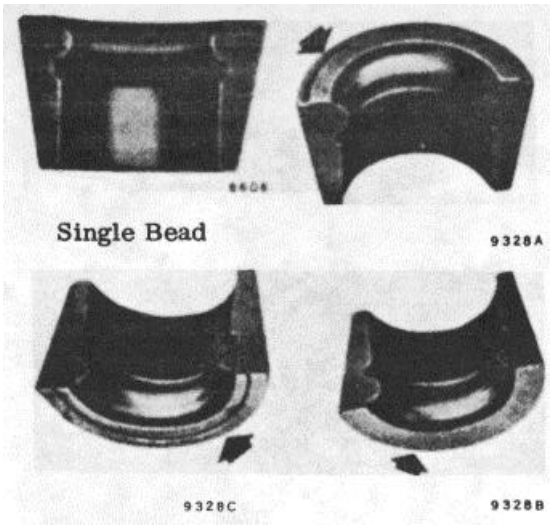


Fig. 2-19 - Valve Spring Seat Locks

Checking Valve Stem Height

After reconditioning valves and valve seats, the height of the valve stems above the cylinder head must be checked. This is done with the use of the valve checking tram as shown in Fig. 2-20. Clean off bottom feet of tram, and that portion of cylinder head on which tram rests. Hold tram down firmly on cylinder head and with use of feeler gauge and screw, determine the difference in valve stem heights. The difference between valve stems under the same bridge should not vary more than 1/16". If the difference varies more than 1/16", the high valve should be replaced or the low valve ground in, provided this does not exceed the limit. End of valve should not be ground off as tip is hardened.

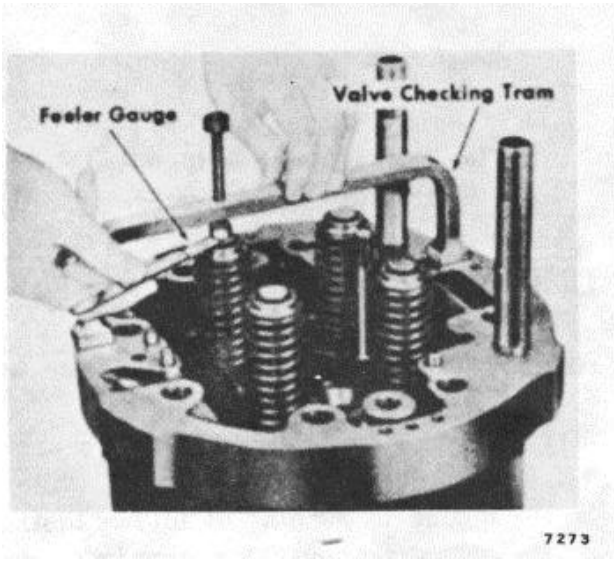


Fig. 2-20. Checking Height Of Valve Stems

Testing Valve Seats

To check valve seat seal, assemble valves and springs in cylinder head and place head in an angular position resting on the rocker arm studs, with the valve seats up. Be sure that the bottom of the head is clean.

Valve seat seal tester, Fig. 2-21, is used to test the valve seat seal. Apply soap or a suitable lubricant to the concave surface of the tester vacuum cup and attach to cylinder head, carefully covering one valve. Be sure seal is not formed on the head of the valve, thereby testing the cup portion of the valve instead of the seat. Place tester with the handle in the 6 o'clock position, so tester will fall off readily when vacuum is depleted. If the tester falls off in less than three minutes, the valve seating is defective and the head seat and/or valve face must be reworked. To remove the tester, open the trigger valve. Check the valve seat seal tester occasionally by applying it to a vertical piece of

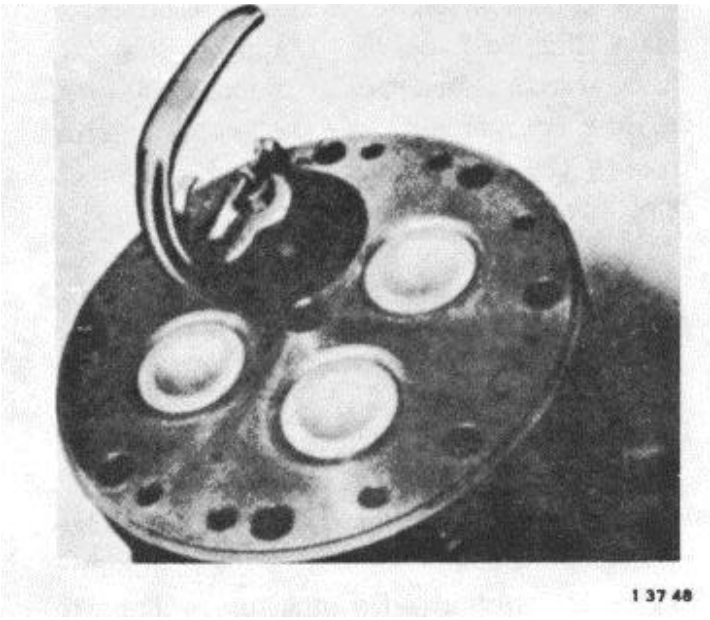


Fig. 2-21. Testing Valve Set Seal

glass, as the release valve or rubber cup may become defective. New vacuum cups are available.

VALVE BRIDGE AND HYDRAULIC LASH ADJUSTER

DESCRIPTION

The valve bridge operates two exhaust valves from one rocker arm. A spring and spring seat are held on the valve bridge stem by a lock ring. The spring seat rests in a socket in the cylinder head and the spring applies pressure so that the valve bridges will stay in contact with the rocker arm.

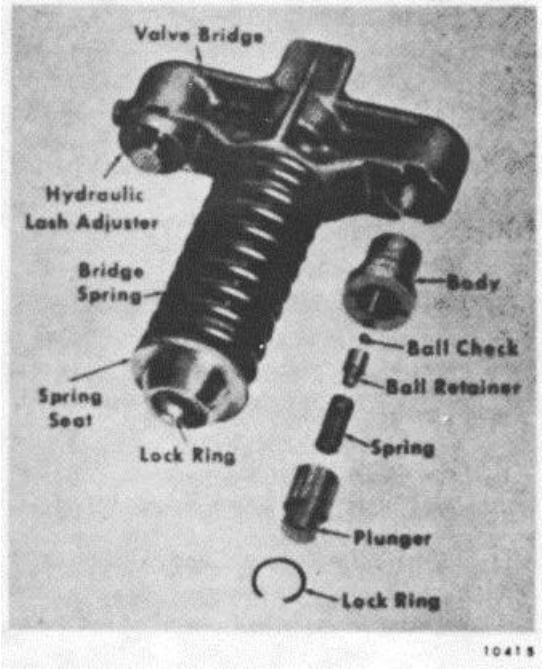
The hydraulic lash adjuster maintains zero lash between the end of the valve stem and the valve bridge. The assembly consists of a body, plunger, spring, ball check, and ball check retainer. A lock ring retains parts within the body as shown in Fig. 2-22.

Lube oil flows from the rocker arm through a drilled passage in the valve bridge to the top of the lash adjuster, past the ball check and into the body. When the rocker arm depresses the valve bridge, a slight movement of the plunger in the lash adjuster seats the ball check, trapping the oil. Since the oil is practically incompressible, further movement of the rocker arm causes the lash adjuster plunger to force open the exhaust valve.

MAINTENANCE

PREPARATION

Prior to disassembly of the valve bridge and lash adjuster assembly, clean assembly with solvent. Do not use a caustic type cleaner, as the brass spring seat will be damaged.



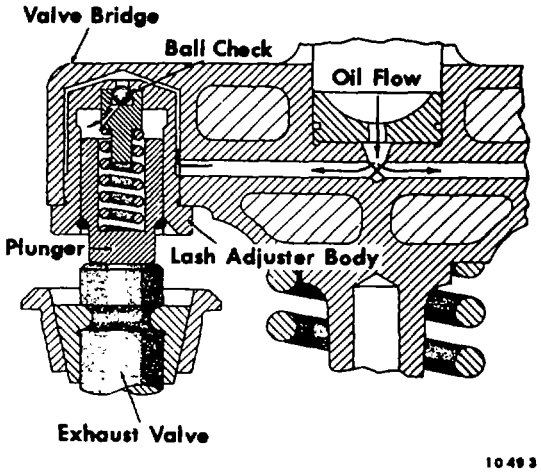


Fig. 2-22. Valve Bridge And Hydraulic Lash Adjuster

LASH ADJUSTER

REMOVAL

NOTE: Inoperative lash adjusters are noisy and can be located while engine is running at idle by their sharp tapping. To correct this condition, remove lash adjuster and clean or replace parts, as

necessary. (Noise, caused by cold oil, may be noticed at times with good adjusters when first starting an engine.)

To remove lash adjuster assembly, clamp valve bridge in vise, as shown in Fig. 2-23, and use lash adjuster puller. Pulling arm is used with puller for removing long travel lash adjuster.

Internal parts of the lash adjuster can be removed for cleaning or replacement and reinstalled without removing lash adjuster body from valve bridge. Use installer tool with plug to compress the lash adjuster plunger, and remove the lock ring as shown in Fig. 2-24, using lock ring remover. However, proper reconditioning and testing can only be done if the lash adjusters are completely removed from the bridge. They can then be disassembled, cleaned, inspected, reassembled, and qualified.

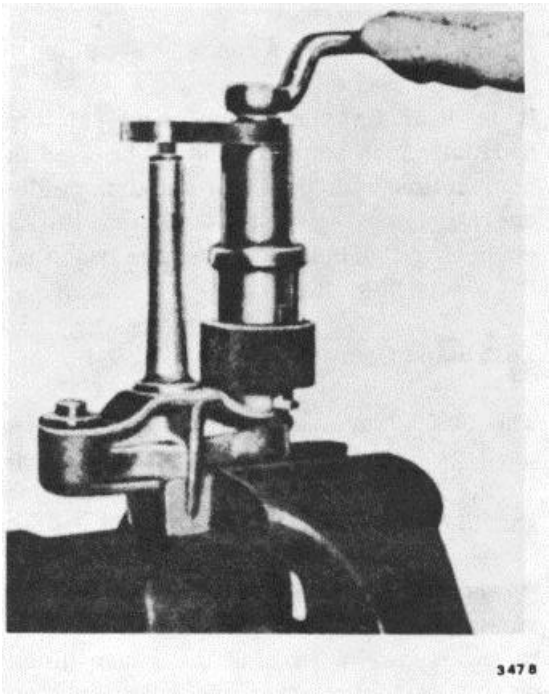


Fig. 2-23. Removing Hydraulic Lash Adjuster

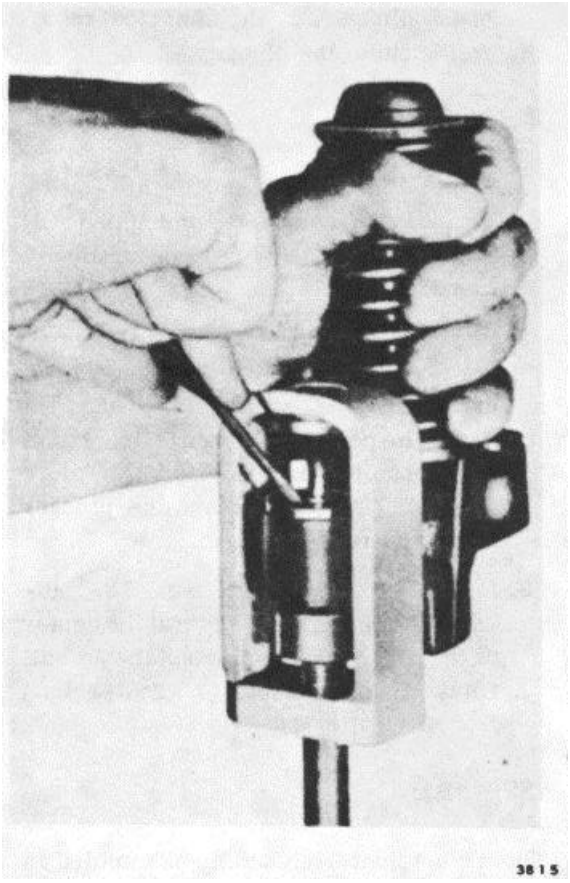


Fig. 2-24. Removing Lock Ring

DISASSEMBLY

1. Disassemble the lash adjusters taking care not to damage the machined surfaces on the inside diameter of the body or the outside diameter of the plunger.

2. When the lash adjuster is disassembled, the spring and ball check should be replaced with new parts.

CLEANING

1. Lash adjuster parts may be cleaned using fuel oil. Lacquer deposits can be removed with alcohol, lacquer thinner, or other suitable solvent. Completely remove any dirt, lacquer, or metal particles.

2. Do not buff the outside or inside diameter of the body, the outside diameter

of the plunger, or the spherical radius on the tip of the plunger.

INSPECTION

1. Inspect the body for scores, scratches, or galled areas on the machined outside diameter, and replace if any are found.

2. Inspect the plunger also for scores, scratches, or galling on the outside diameter, and replace if evidenced. Also, inspect the plunger tip, and if the contact point is worn flat more than .250" in diameter, the plunger should be replaced.

3. Inspect the ball retainer .166" diameter counterbore depth at the center of the ball depression. Replace the ball retainer if the depth is greater than .143".

ASSEMBLY

The lash adjuster should be assembled in a clean area, as it must be free of dirt, lint, and metal particles.

QUALIFYING LASH ADJUSTERS

It is recommended that lash adjuster test stand, Fig. 2-25, be used to qualify the lash adjusters for use in the engine. This test stand automatically measures the time required for the lash adjuster plunger to travel through .060" while it is subjected to a 30-pound ram load, and rotated about 10 RPM relative to the lash adjuster body.

A gauge block and oil loading tool, Fig. 2-25, are supplied with the stand. The gauge block is used to check and adjust the tripping point of the microswitches, if necessary, to ensure that the leak down time is measured over exactly .060" travel of the lash adjuster plunger. The oil loading tool is used to charge the lash adjuster with oil and bleed off any air which might cause incorrect leak down time intervals.

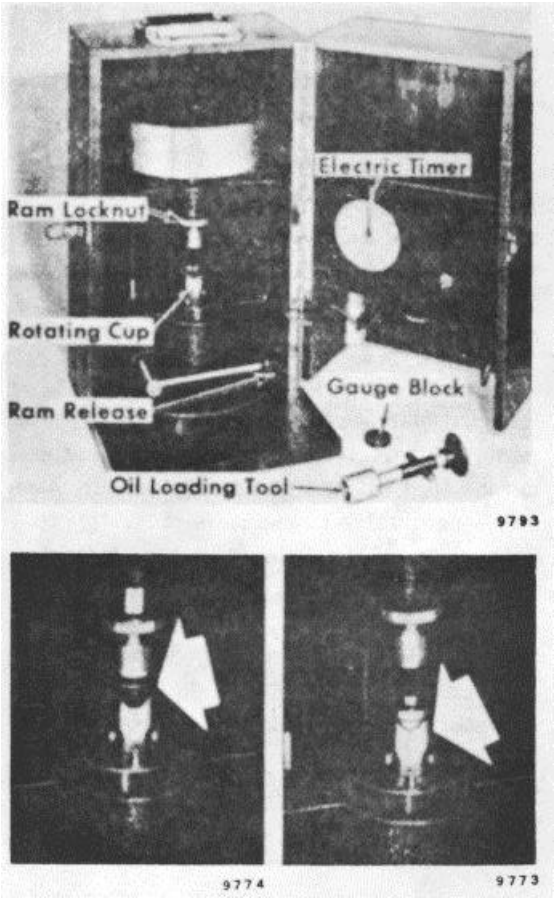


Fig. 2-25. Lash Adjuster Test Stand

It is essential that only Electro-Motive hydraulic lash adjuster test oil be used in conjunction with this test stand since the operation of the test stand and limits governing the lash adjuster are based on the use of this oil.

Test Stand Operation

The .060" travel of the ram starts when the tip of the ram is .375" from the top of the rotating cup. This starting point should be checked with the .375" gauge block supplied with the test stand, and it should be checked often enough to be sure it has not changed. This check is to be made by placing the gauge block on top of the rotating cup with the step facing up, and then lowering the ram by turning the ram release. The time

clock on the test stand should start the very moment the ram load contacts the gauge block. If the timer does not start, or starts too soon, the ram should be readjusted. This is done by loosening the ram locknut, turning the ram tip up or down to the proper adjustment, and retightening the locknut. The time clock start and stop microswitches are permanently set so that the time for the .060" travel is automatically recorded on the time clock. (If a microswitch has to be replaced, the .060" between microswitch positions should be set by inverting the gauge block which has a .060" step on it.)

Test Procedure

1. Place the lash adjuster assembly in oil loading tool and immerse it into a container of lash adjuster test oil that is deep enough for the hole in the lash adjuster to be well below the oil level.

2. Completely depress the lash adjuster plunger at least 10 times to ensure that any air trapped inside is pumped out.

3. Retract the spring-loaded plunger in the oil loading tool and allow the ball check to seat in the lash adjuster Try to depress the lash adjuster plunger two or three more times to ensure that the ball check is seating. The assembly should feel firm, without any "give" to it.

4. Take the lash adjuster out of the test oil and remove the oil loading tool being careful that the spring-loaded plunger does not unseat the ball check. Wipe the excess oil off the lash adjuster and place it in the rotating cup on the test stand.

5. Turn the switch on to rotate the cup. Lower the ram until it rests on the lash adjuster plunger and release handle so that the plunger carries the full 30-pound load.

NOTE: Be sure the lash adjuster body is rotating around the plunger.

6. The time for .060" travel (leak down time) will be automatically recorded on the time clock. The "leak down time" should be within limits of seven seconds minimum and 40 seconds maximum, based on a normal temperature of 75° F. for the oil and lash adjuster. If the temperature of the oil and the lash adjuster is other than 750 F., the limits should be determined by the following Table 1.

Table 1

Oil and Lash Adjusters Temp. ° F.	Min. Leak Down Time Seconds	Max. Leak Down Time Seconds
60	12.8	70.6
65	10.2	54.8
70	8.4	45.2
75 (Base)	7	40.0
80	6	36.0
85	5	32.6
90	4.2	30.2
95	3.6	28.4
100	3.2	27.8

The temperature of the test oil and lash adjuster should be allowed to become stable before leak down checks are made. If a lash adjuster fails to pass the minimum "leak down time, " it should be refilled and retested to be sure that the failure was not due to air trapped in the lash adjuster.

VALVE BRIDGE

DISASSEMBLY

Mount valve bridge spring compressor in vise, Fig. 2-26. Install valve bridge in compressor, compress spring, remove lock ring, and remove spring seat and spring.

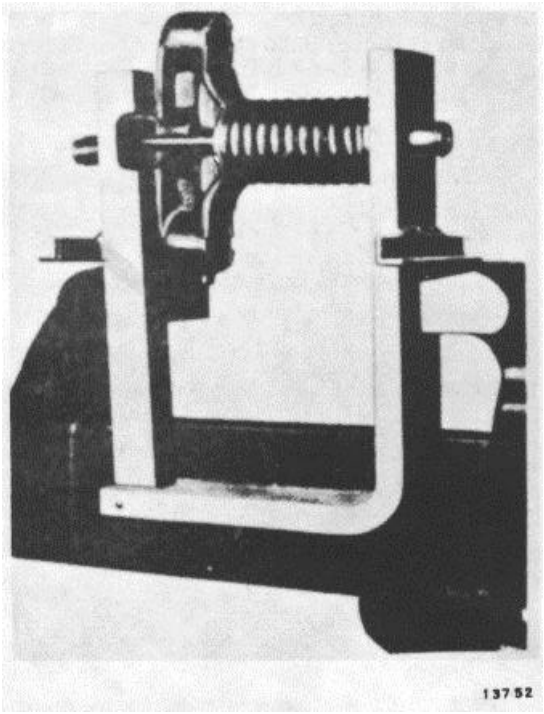


Fig. 2-26. Compressing Valve Bridge Spring

INSPECTION

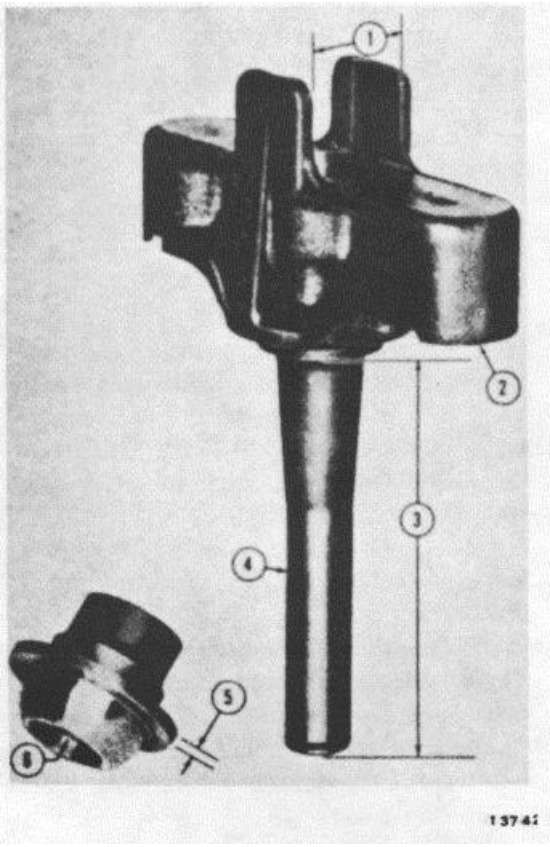
Visually inspect valve bridge parts and replace those that are damaged beyond repair. Check the pin in the end of the valve bridge to see that it is tight. Also check the valve bridge for a bent shank. If the shank is slightly bent, it may be straightened and re-used.

Inspect the valve bridge and spring seat at the points shown in Fig. 2-27 and refer to dimensions in the Service Data at the end of this section.

ASSEMBLY

Using the valve bridge spring compressor in Fig. 2-25, assemble a qualified spring, spring seat and lock ring to the valve bridge.

Install the lash adjuster assembly in the valve bridge with the use of an installer tool as shown in Fig. 2-28.



Refer to Service Data for applicable dimensions.

1. Distance between rocker arm guide ears.
2. Lash adjuster socket diameter.
3. Valve bridge shank length.
4. Shank diameter from shank end to 2.50" above shank end.
5. Spring seat rim thickness.
6. Spring seat shank bore.

Fig. 2-27. Valve Bridge Measurement Points

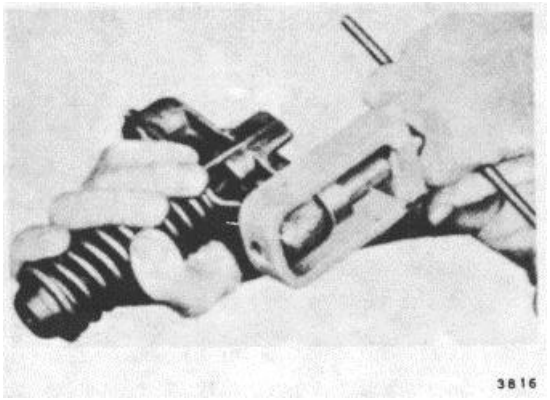


Fig. 2-28. Installing Lash Adjuster

ROCKER ARM ASSEMBLY

DESCRIPTION

Three rocker arms, Fig. 2-29, are mounted on the cylinder head. Two rocker arms actuate the four exhaust valves, the third operates the injector. The rocker arms are operated directly by the camshaft through a cam follower roller mounted at the fork end of each rocker arm. The opposite end of each rocker arm has an adjusting screw and locknut for setting the injector timing and adjusting the hydraulic lash adjusters. The injector rocker arm, although similar in appearance to the exhaust rocker arm, is stronger than the exhaust rocker arm, and can be identified by the yoke at the cam follower end which is square-shaped on the injector rocker arm, but V-shaped on the exhaust rocker arm. Also, only the injector rocker arm has the machined notch for the over-speed trip. Injector and exhaust rocker arms are not interchangeable.

An oil jumper line from the camshaft bearing carries oil to the rocker arms through drilled passages in the rocker arm shaft. Rocker arms are drilled to supply oil to the valve bridges, lash adjusters, and to the cam follower.

MAINTENANCE

1. Inspect the rocker arm bushings, cam follower rollers, inner race, Fig. 2-30, and rocker arm shaft for evidence of heat discoloration, excessive wear, shelling or scuffing due to lack of lubrication, and for fatigue cracks.

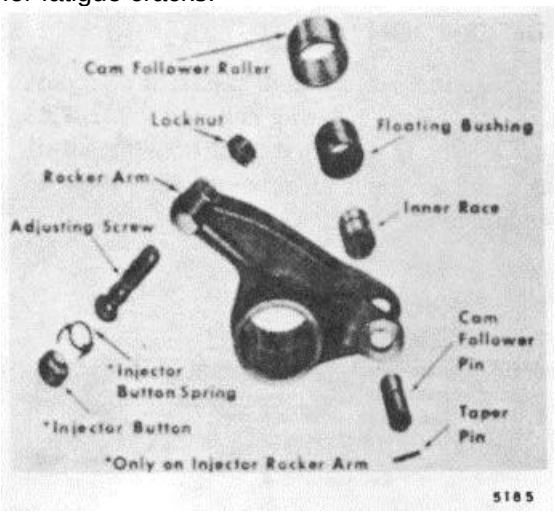
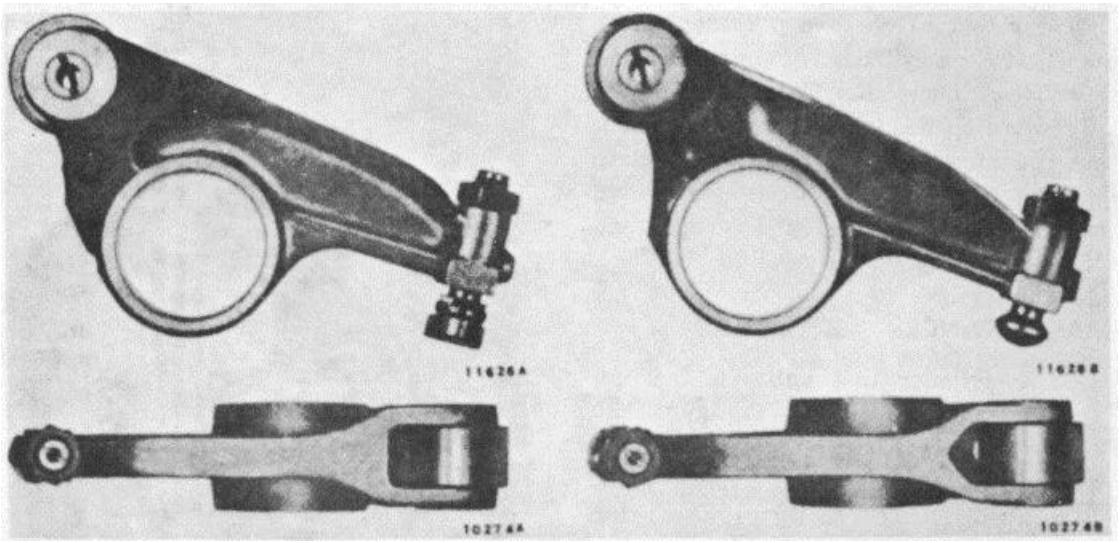


Fig. 2-30. Rocker Arm, Exploded View



INJECTOR **EXHAUST**

Fig. 2-29. Rocker Arms

2. Check all oil holes to make certain that they are clean.

3. All adjusting screws should be checked for hand-free operation and any galling on the ball end.

4. All adjusting screw buttons should be visually checked for galling or cracking.

CYLINDER TEST VALVE

DESCRIPTION

The cylinder test valve consists of a body, needle valve, packing nut, and seal. This assembly is inserted in a housing within the crankcase and screwed into the cylinder head, Fig. 2-31.

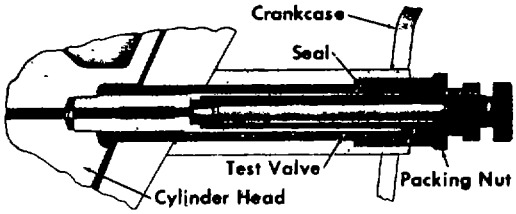


Fig. 2-31. Cylinder test Valve

Cylinder test valves are provided on the engine at each cylinder. At anytime maintenance or inspection is performed, the valves are opened to relieve compression, thus reducing the effort required to rotate the crankshaft. A cylinder test valve wrench, Fig. 2-32, is used to open and close the valves.

MAINTENANCE

1. If a cylinder test valve is leaking, check that packing nut, Fig. 2-31, has been torqued to 60-65 ft-lbs. If nut has been overtightened, change seal, Fig. 2-31, and correctly torque packing nut. Should valve continue to leak, remove the valve from the engine and ream the valve seat as shown in Fig. 2-33.

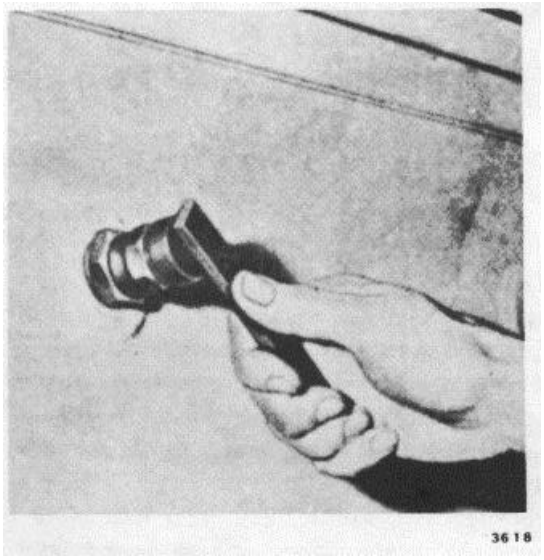


Fig. 2-32. Test Valve Wrench

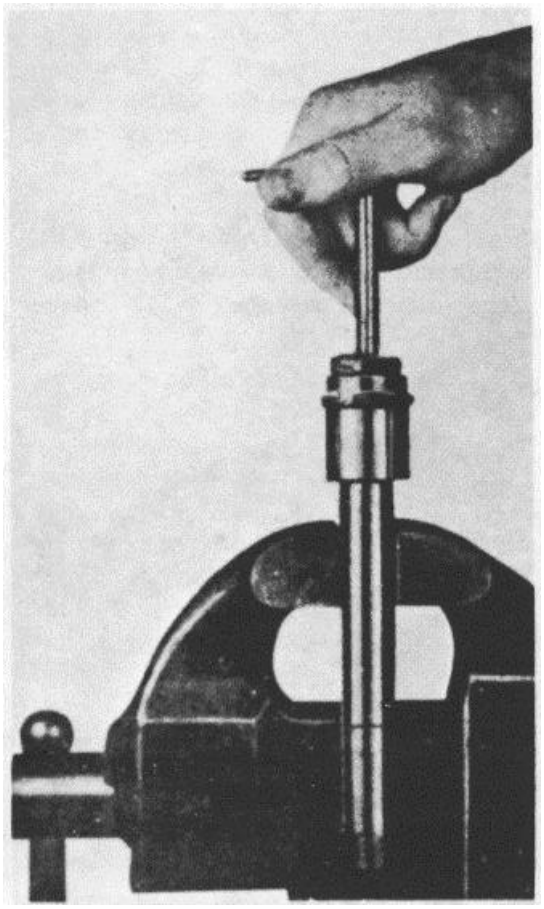


Fig. 2-33. Reaming Test Valve Seat

2. If reaming will not correct the leaking due to a scored or damaged valve stem face, it should be reconditioned within the limits shown in Fig. 2-34. Reharden the tip to a depth of.005"-.010".

3. The cylinder test valve body may be reworked to the dimensions shown in Fig. 2-34. Use reamer to recondition the valve seat. If necessary to exceed the 1/4" maximum diameter of valve seat, Fig. 2-34, recut bottom of 1/2" diameter counterbore and reface hexagon end to hold the 6-1/16" nominal dimension.

4. After reconditioning, air test the valve assembly at 90 psi air pressure.

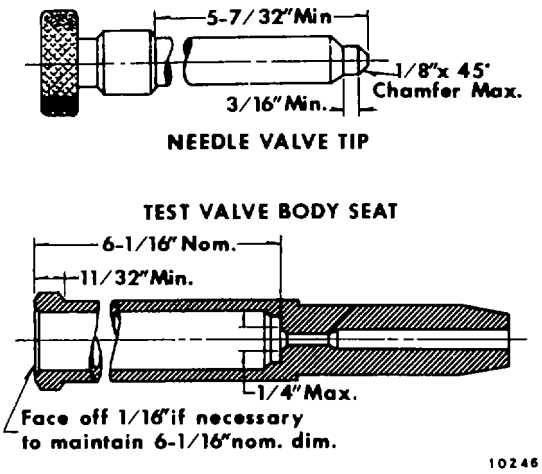


Fig. 2-34. Test Valve Reconditioning Limits

CYLINDER HEAD INSTALLATION

PREPARATION

Before installing the cylinder head, be sure that the retainer inner surface and exhaust elbow in the crankcase are clean. Examine the cylinder head to ensure that it is clean internally, and in particular that the bottom surface is clean and free of dirt, nicks, or scratches which would cause water seal or gasket leakage. Clean the liner stud holes, Fig. 2-8. If stud hole cleaner is not available, a wire brush can be used to remove rust, scale, or dirt from these holes. It is recommended that just prior to installation of any cylinder head, a small quantity of green soap be applied to the bottom of all water and stud holes to prevent dirt dropping on the water seals or cylinder head gasket surface during installation of the head.

Liner stud nuts should be examined and
discarded when bottom of nut or threads are galled, or insert area cracked, torn, or frayed. Inspect cylinder head nut washers for damaged surface or warped condition, and replace if required.

The copper-clad steel liner-to-head gasket is installed with the notched hole in the gasket placed over the liner pilot stud. Examine counterbore in liner water holes to be sure these areas are free of dirt, oil, and nicks that would damage the water seals.

Install new seal rings in clean grooves of water discharge elbow. Clean flange surface on cylinder head for the elbow and apply elbow to head. Torque value of elbow to head socket-head screws is 30 ft-lbs. The discharge water elbow also serves to position the cylinder head in the crankcase. The elbow may be removed to change seals, if necessary, and reapplied with the head installed after removal of the crab above it, otherwise the cylinder head installation need not be disturbed. A thin shim used between the elbow flange and cylinder head, to hold the seal in place, aids in elbow application when the cylinder head is in place.

INSTALLATION

1. Check cylinder head seat ring to be sure thickness and wear step conform to limits listed in the Service Data. Apply cylinder head seat ring to top of retainer. Lower head into position slowly. Line up water discharge elbow with mating hole in crankcase.

2. Apply cylinder liner stud nuts and tighten snugly. Use lube oil or a lubricant having specifications equal to Texaco Thread Tex #2303 on threads and bottom of nuts. At this initial tightening, apply only 75 ft-lbs torque.

3. Apply crabs and crab nuts. Use a lubricant on the threads as in Step 2 above. Pull crab nuts down snugly.

4. Tighten liner stud nuts in sequence as shown in Fig. 2-35, to a torque of 200 ft-lbs ± 5%.

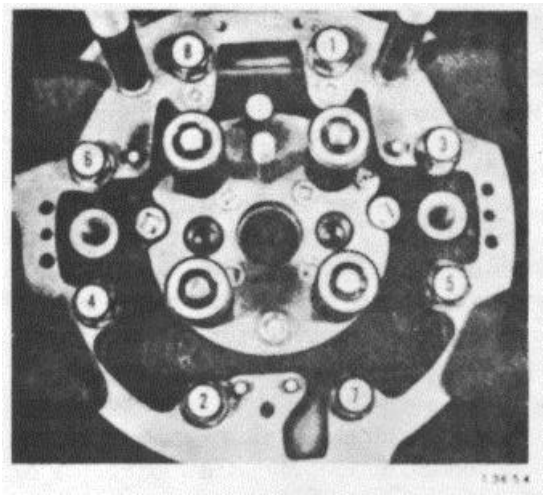


Fig. 2-35. Head-To-Liner Nut Tightening Sequence

5. Tighten crab nuts alternately forming the letter "X", and in two passes, half torque each pass. A power wrench which has a mechanical ratio of 12:1 may be used. A socket, box wrench, and a 60" extension can also be used. Torque value for the crab nuts is 1800 ± 90 ft-lbs.

6. Install injector. Connect fuel oil lines and adjustable link. Injector crab nut torque value is 40-50 ft-lbs. (Time injector as described in Fuel Oil System, Section 10.)

7. Install valve bridges (with protruding boss toward camshaft for uniform assembly), rocker arms, and lube oil lines. Set the valves as described in the next procedure, "Adjusting Hydraulic Lash Adjusters."

8. Install cylinder test valves.

9. If the liner water inlet line and piston cooling oil pipe were removed, clean the piston cooling oil pipe with the cleaning tool and apply to engine. Check alignment in piston carrier with "P" pipe gauge.

10. After assembly is installed, everything tightened properly, adjustments set, and engine is ready to run, start engine and raise water temperature to 170° F. After running, shut down the engine, recheck torque on crabs and liner stud nuts, and inspect condition of assemblies.

NOTE: When liner and crab nuts are being retightened, those which move at LESS than the specified torque values, should be tightened to the proper torque value. Those nuts which do not move below or up to the proper values, should be CHECKED by pulling up to a value not exceeding 10% more than the recommended torque. Special offset box socket wrenches used with a standard torque wrench are available to tighten inaccessible cylinder head nuts under installed rocker arms.

ADJUSTING HYDRAULIC LASH ADJUSTERS

Application of properly operating lash adjusters, correct setting, and subsequent inspection at regular maintenance intervals is very important to valve operation. Improperly set or defective lash adjusters cause the exhaust valves to be subjected to increased stress which leads to ultimate failure and probable damage to the engine.

After complete cylinder head assembly has been installed, the lash adjusters must be set.

1. Rotate crankshaft so that piston is at or near top center of the cylinder being set.

2. Loosen rocker arm adjusting screw locknuts.

3. Turn rocker arm adjusting screw down until the last valve just touches the hydraulic lash adjuster plunger, or use a .001" shim between valve tip and adjuster plunger, and then turn it down 1-1/2 turns.

4. Check valve bridge spherical seat to be sure that it is spring-loaded against the cylinder head spherical seat. If the bridge spring spherical seat is not spring-loaded against the cylinder head spherical seat, turn down the rocker arm adjusting screw until no movement is felt, and then turn it another 1/4 turn.

5. Tighten rocker arm adjusting screw locknut.

6. After running the engine for two or three minutes, or after first squeezing oil out of lash adjuster by forcing down the rocker arm, check the clearance between lash adjuster bodies and the end of the valve stems with the piston near top center. If the clearance is less than minimum, the cylinder head should be removed for reconditioning or rejection. Use minimum clearance gauge, Fig. 2-36, to gauge clearance between lash adjuster and exhaust valve. This gauge is 1/16" thick and it should fit between lash adjuster body and valve stem top, to ensure the minimum clearance.

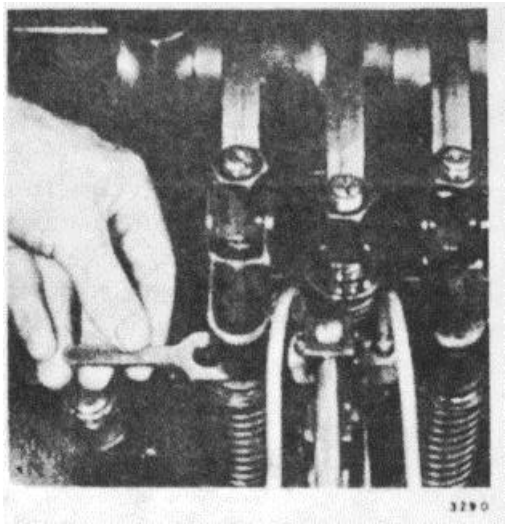


Fig. 2-36. Checking Lash Adjuster To Valve Clearance

TRACING A DEFECTIVE OR NOISY CYLINDER

A cylinder that is not firing properly will have a cooler exhaust stack, compared to one that is firing properly (engine at idle). This is caused by:

1. Badly leaking exhaust valves.

2. Defective injector.

3. Improper injector timing or control rack setting.

4. Dirty injector filter.

5. Air bound injector.

6. Excessive ring blow-by.

7. Cracked piston.

To determine if injector is at fault, disconnect injector adjustment link on the suspected cylinder and, with engine running at idle, push control rack open slowly and return to idle position as soon as observation has been made. If injector is operating properly a pronounced laboring of the cylinder will be detected.

Erratic injector operation can also be determined by making each cylinder injector inoperative, when the engine is running at idle speed, and noting any change in the operation of the engine. Injectors can be made inoperative by inserting a brass bar between the cam follower roller and the rocker arm, using the bar as a lever to lift the cam follower roller from contact with the camshaft.

An exhaust valve leak can be detected when standing outside the engine room by a pronounced blow at the exhaust stack, with engine idling or with the layshaft lever held to reduce engine speed slightly below idle engine speed.

REPAIR OF DAMAGED SEATING SURFACES

It is permissible to rework cylinder heads which have damaged seating surfaces to the limits shown in Fig. 2-37.

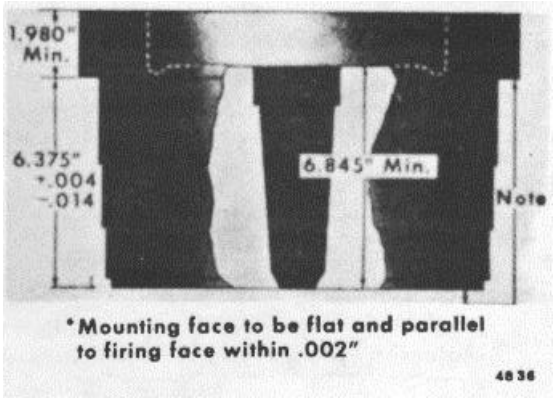


Fig. 2-37. Rework Limits

567E4 SERVICE DATA
CYLINDER HEAD AND ACCESSORIES

SPECIFICATIONS

Exhaust Valves	
Diameter of stem - New	.6215" - .6225"
Valve stem diameter - Limit	.6205"
Diameter of head	2-1/2"
Valve seat angle	30°
Valve seat out-of-round	.002"
Lift	.686"
Number per cylinder	4
Valve flat to head - New	± .015"
Valve flat to head (ground) - Max.	.093"
Valve seat square to guide bore - Max	.005" T.I.R.
Valve rim thickness - Min	.109"
Valve face width	.343"
Cylinder head seat width for valve face - Max.	.093" -.125"
Diameter at top of valve seat (ground) - Max	2.425"
Valve Springs	
Free length (approximately) - New	4-1/8"
Min	3-31/32"
Length - valve open	2-11/16"
Length - valve closed	3-3/8"
Pressure with valve open - New	213-225 lbs.
2-11/16" length- Min	175 lbs.
Valve bridge spring - same as valve spring. Spring must not show any set after being compressed with coils touching.	
Valve spring seat thickness - Min.	.145"
Rocker Arm	
Rocker arm shaft diameter - Min	2.246"
Rocker arm bushing inside diameter - Max	2.254"
Press bushing to rocker arm	.002" - .004"
Inner race outside diameter - Min	1.048"
Floating bushing inside diameter - Max	1.055"
Floating bushing outside diameter - Min	1.4435"
Cam follower roller inside diameter - Max	1.4505"
Valve Guide	
Inside diameter (Not installed) - New	.6275" - .6305"
(Installed in head) - Min	.626"
Limit (1/2" from bottom and top)	.632"
Limit (bottom)	.634"
Valve stem to guide clearance - Limit	.010"
Press fit in head	.0005" - .002"
Cylinder Head Seat Ring	
Thickness standard - New	.190" - .194"

Minimum thickness	.148"
Uniform thickness within	.002"
Maximum wear step	.003"

Valve Bridge

Refer to Fig. 2-27 - circled numbers coincide with callouts on illustration

①	Distance between rocker arm guide ears - Min	.935"
	Max	.940"
②	Lash adjuster socket diameter - Min.	.8745"
	Max.	.8750"
③	Valve bridge shank length - Min	4.062"
	Max	4.187"
④	(Shank diameter from shank end to 2.50" above the shank end - Min	.6230"
	Max.	.6235"
⑤	Spring seat rim thickness - Min	.093"
	Max.	.125"
⑥	Spring seat shank bore - Min.	.6245"
	Max.	.6275"

EQUIPMENT LIST

	Part No.
Test Valve Wrench	8032587
Valve Spring Compressor (single)	8033783
Adapter (use with 8033783)	8034054
Box Socket Wrench	8034085
Crab Stud Protector Tubes	8034600
Valve Seat Reconditioning Tool Set (115 volt)	8035775
Injector Removing Pry Bar	8041183
Valve Seat Reconditioning Tool Set (220 volt)	8041445
Valve Checking Tram	8042773
Electric Drill, 1/4" (115 volt)	8045450
Cylinder Head Carrying Basket	8060247
Electric Drill, 1/4" (230 volt)	8062140
Cylinder Test Valve Seat Reamer	8064804
Crab Nut Socket	8065580
Lash Adjuster Puller	8070866
Valve Bridge Spring Compressor	8070883
Valve Bridge Lock Ring Guide	8070903
Piston Cooling Pipe Gauge	8071720
Lash Adjuster Installer	8072927
Cylinder Head Removing Fixture	8075894
Lock Ring Remover - Lash Adjuster	8080632
Crab Nut Box Wrench Handle - 60"	8084091
Piston Cooling Pipe Cleaning Tool	8087086
Lash Adjuster Minimum Clearance Gauge	8107788
Valve Guide Cleaner	8141439
Lash Adjuster Pulling Arm (long travel adjusters)	8154408
Injector Holding Rack	8159228

567E4 SERVICE DATA
CYLINDER HEAD AND ACCESSORIES

Valve Seat Reamer (inside)	8192191
Pressure Fixture - Valve Seat Reamer	8194884
Cylinder Head Stud Hole Cleaner	8211907
Valve Seat Seal Tester	8213518
Vacuum Cup (spare for 8213518)	8213519
Valve Grinder (115 volt)	8218405
Valve Grinder (230 volt)	8218998
Valve Guide Installer - Remover	8224241
Valve Seat Reamer (outside)	8227358
Valve Spring Compressor (multiple)	8239430
Crab Nut Power wrench	8250885
Lash Adjuster Test Stand	8267432

PISTON ASSEMBLY AND CONNECTING RODS

PISTON ASSEMBLY

DESCRIPTION

The piston assembly, Fig. 3-1, consists of a cast iron alloy piston, four compression rings, and two oil control rings. A "trunnion" type piston carrier, Fig. 3-2, is used with the piston assembly to allow the piston to rotate or "float" during engine operation. The carrier supports the piston at the internal piston platform. A thrust washer, Fig. 3-2, is used between the platform and the carrier. The carrier is held in position in the piston by a snap ring inside the piston as shown in Fig. 3-3. Oil taken up by the two oil control rings passes through the three rows of oil holes in the piston.

The piston carrier has a circular boss located centrally on its upper platform which pilots in a bore in the center of the piston platform, and also pilots in the piston at the bottom outside diameter of the carrier. A bearing insert, Fig. 3-4, is applied in a broached slot in the carrier. Tangs at each end of the bearing insert are bent into a counterbore on the carrier to prevent endwise movement. The highly polished piston pin, Fig. 3-4, is applied in the carrier in contact with the bearing insert, and the assembly is bolted to the upper end of the connecting rod, as shown in Fig. 3-3.

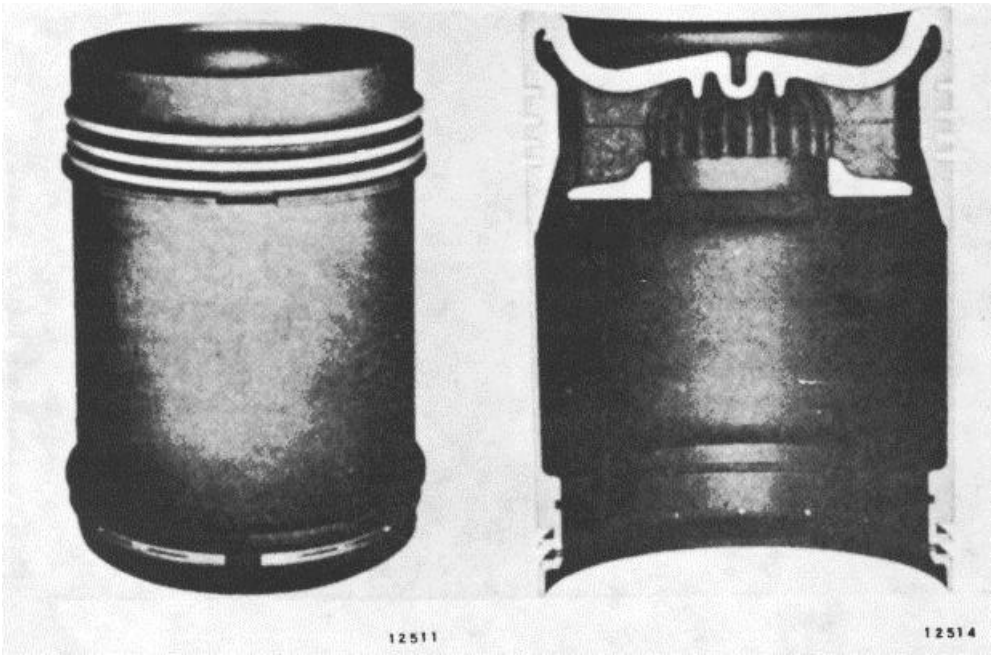


Fig. 3-1. Piston Assembly

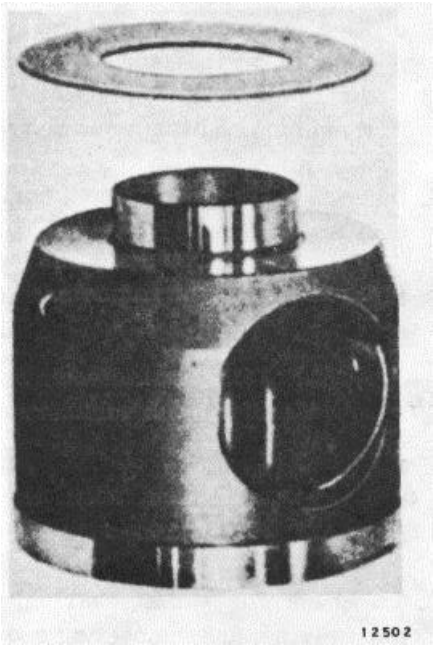


Fig. 3-2. Piston Carrier And Thrust Washer

Internal parts of the piston are lubricated and cooled by the piston cooling oil. Cooling oil is directed through a drilled passage in the piston carrier, circulates about the piston crown area, and then drains through two 5/8" holes in the carrier located at the taper as shown in Fig. 3-4.

Pistons are given a phosphate treatment to aid skirt lubrication during engine operation. This process etches the surface and produces a non-metallic, oil absorbent, antifriction coating that promotes rapid break-in and reduces subsequent wear. Information on piston treatment is given in Maintenance Instruction 1758.

The piston pin, Fig. 3-4, is made of steel alloy material, with the outer surface carburized, ground, lapped, and polished to a mirror finish. The pin is mounted in the concave " saddle" at the top of the connecting rod and oscillates in the bearing insert in the carrier. Two 7/8" bolts, each provided with a non-removable spacer, pass through the upper end of the connecting rod and screw into the piston pin. These bolts are tightened to 450 ft-lbs torque.

INSPECTION

Piston and connecting rod assemblies can be inspected while installed in an engine provided the engine is shut down and the air box and oil pan inspection covers are removed.

Precautions should be taken before proceeding to prevent the engine from being started.

Open all cylinder test valves to facilitate rotation of the crankshaft, using the turning jack.

1. Rotate crankshaft until piston of cylinder being inspected is at bottom center.

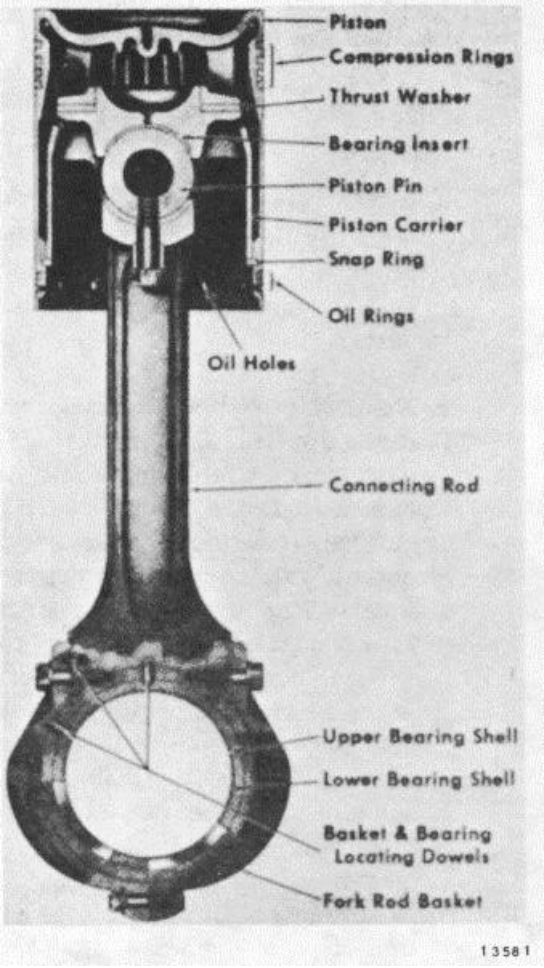
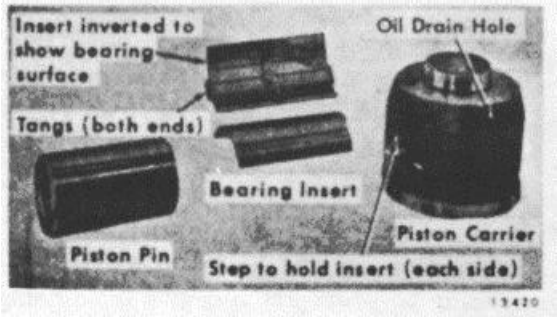


Fig. 3-3. Piston And Connecting Rod Assembly, Cross-Section



2. Inspect cylinder wall and top of piston. A wet piston crown would indicate a leaky injector. Check cylinder walls to make sure there is no scoring and inspect for water leaks.

3. Visually inspect for the following ring conditions at the liner ports.

   a. A ring in good condition will be bright and free in its groove.

   b. Broken ring. The ring face will normally be black if broken opposite the gap. Milling may also be evident above and below the liner ports.

   c. Worn ring. Replace all rings when chrome plating is worn through on first ring. While the ductile cast iron used in the chrome plated top ring will function satisfactorily in contact with the liner, the degree to which a ring is allowed to wear before replacement should be governed to some extent by the severity of the service. An engine which seldom runs at full power is more tolerant of ring condition than an engine which usually operates at or near full load. The chrome ring wear classifications shown in Fig. 3-5, used in conjunction with the description of each ring wear "type, " will serve as a guide during ring inspection.

   d. Ring blow-by. Vertical brown streaks on the face of the ring indicate blow-by. Replace these rings when the condition becomes severe.

4. Inspect piston skirt for scoring or scuffing.

5. Inspect air box for foreign material, and any signs of water or oil leakage.

OIL PAN INSPECTION

1. Inspect back of upper connecting rod bearing for cutting or signs of overheating.

2. To check for thrust bearing, piston pin bearing, and connecting rod bearing wear, take a lead reading of piston to cylinder head clearance. Any increase since previous lead reading will indicate wear.

3. With piston at top center, inspect lower liner walls for scoring.

4. Inspect oil pan for foreign matter.

MAINTENANCE

PISTON AND CONNECTING ROD REMOVAL

When inspection indicates service on the piston is necessary, the piston and connecting rod should be removed as an assembly.

Preparation

1. Remove cylinder test valve assembly.
2. Remove piston cooling oil pipe.
3. Remove cylinder head as outlined in Section 2.
4. Apply piston pulling eyebolt in tapped hole in piston crown.

A new or like new ring. This classification will only be evidenced during the first phase of top ring life.

On a shallow groove ring. these classifications will be evident on the C top ring for a relatively short time. On a deep groove ring, these classifications will be evident for the major portion of ring life.

Chrome grooves are completely worn away, showing only a smooth chrome face. This will exist for the major portion of shallow groove ring life. It will be evident for a short time on only a small percentage of deep groove rings.

This wear pattern designates that rings are starting to wear into the cast iron, except for the grooves, which still contain chrome. Inspection will readily reveal the alternate bands of chrome and cast iron.

Chrome is completely worn off and wear is concentrated on the cast iron. Rings in this classification are to be considered worn out and should be replaced.



Fig. 3-5. Chrome Ring Wear Classifications

Fork Rod Removal

1. Remove fork rod basket bolts. Remove basket halves and lower bearing shell.

2. Pull piston and rod assembly, holding rod as it clears crankshaft to prevent it striking piston skirt or liner. Apply fork rod protector boot and complete removal of piston and rod assembly.

Blade Rod Removal

1. If opposite fork rod and piston are not to be removed, then it will be necessary to hold this assembly out of the

way using a fork rod support. This is done by removing basket and lower bearing then placing fork rod piston at top center. The support is then applied to outboard side of fork rod using two basket bolts. Rotate crankshaft in normal direction so that support will rest in oil pan. Protect upper bearing and continue rotation to position blade rod for removal.

2. Raise piston and blade rod assembly and carefully remove upper bearing shell. Prevent rod from striking piston skirt or liner.

3. Apply blade rod protector boot and complete removal of blade rod assembly.

Piston And Rod Disassembly

1. Place piston and rod assembly on a wooden topped work bench and remove piston snap ring, Fig. 3-6, using snap ring remover. Care should be taken in handling piston assembly

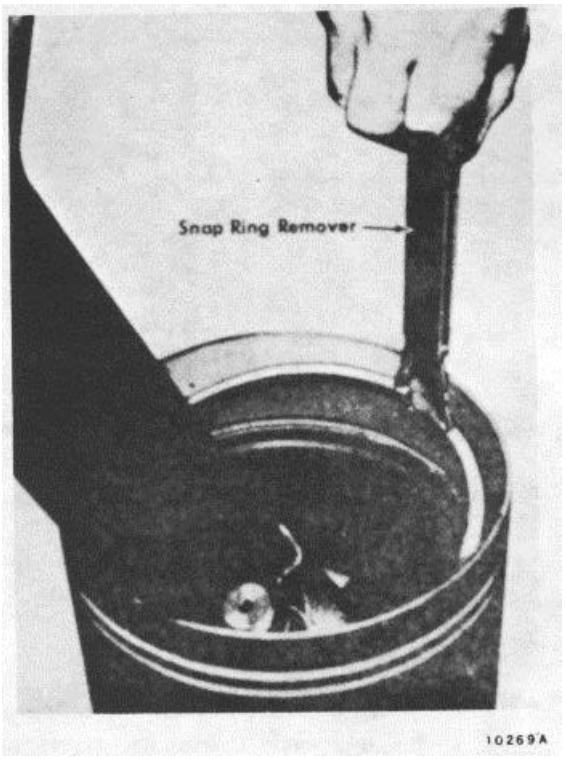


Fig. 3-6. Removing Piston Snap Ring

to avoid nicking or scraping the piston skirt.

2. Place rod and carrier in holding fixture, Fig. 3-7, and remove piston pin bolts. This fixture has two mandrels which enter the piston pin bore to hold the pin while the rod bolts are removed. It must be securely mounted on a work surface. If fixture is unavailable, a vise having copper protected jaws may be used to hold the connecting rod. Clamp rod horizontally with pin close to vise so pin bolts may be removed without twisting rod.

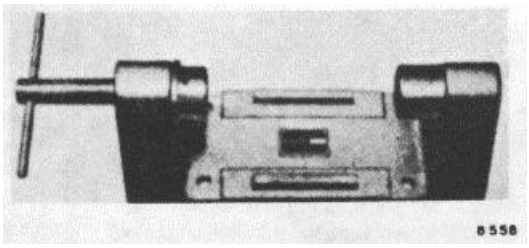


Fig. 3-7. Carrier Holding Fixture

3. Remove pin from carrier.

4. At the time of piston and rod disassembly, check that the thickness of the thrust washer exceeds the minimum dimension listed in the Service Data.

CLEANING

Cleaning procedures should be in accord with accepted practice or as recommended by the supplier of cleaning material.

Pistons

1. Remove the piston rings using ring expander as shown in Fig. 3-8, and discard the old rings.

2. Immerse the piston in an alkaline solvent solution and allow to remain until the carbon deposits are loosened.

3. Wash the piston using steam or hot water and blow dry using compressed air.



Fig. 3-8. Removing Piston Rings

4. Remove any carbon deposits from the compression ring grooves. Light grit blasting or a piece of compression ring can be used for this purpose.

5. Using 3/32" and 5/32" drills in the respective holes, clean the oil passages in the oil ring grooves.

Piston Pin And Carrier

CAUTION: Abrasive material, including steel wool, should not be used to clean piston pins or bearing inserts.

1. It is recommended that the piston pin and carrier assemblies be cleaned using a high flash point petroleum solvent, such as Stoddards solvent (140° F. flash point) or equal. These parts should never be washed in an alkaline or caustic solution.

2. Clean the carbon from the oil grooves in the insert with a suitably pointed wooden stick. Embedded particles do no harm if they do not project above the bearing surface; no attempt should be made to remove them. Parts of the assembly should be adequately protected against rust and corrosion at all times.

INSPECTION

Piston

1. The phosphate treated surface of the piston skirt should be inspected for satisfactory condition. If the coating is worn through, and bare metal in excess ofd approximately three square inches is exposed, the piston should be re-coated as outlined in Maintenance Instruction 1758.

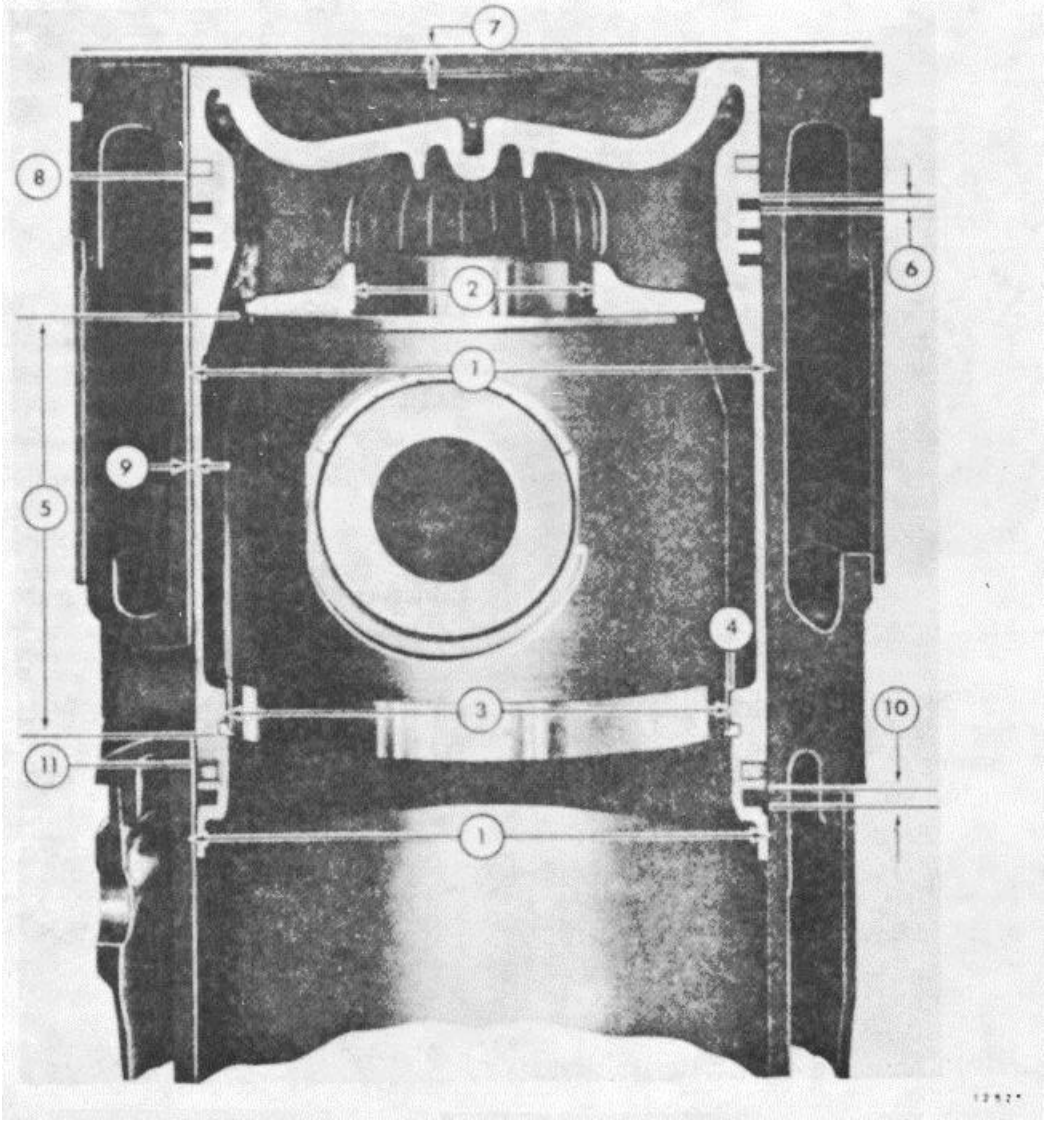
2. Inspect the piston surface for excessive scoring or other mutilation which would reject the piston.

3. Check all points of measurement as shown in Fig. 3-9. Discard any pistons that exceed the limits listed in the Service Data.

4. Check piston ring groove wear step. Check wear step on top ring groove lower face, Fig. 3-10. Top ring breakage can be caused by excessive wear step.

A piston ring groove gauge, Fig. 3-11, is available to make the wear step measurement. Gauges also are available for measuring wear step in oversize ring grooves. Each gauge consists of a number of separate width indicators precise to .001". Standard ring groove gauge has indicators from .194" through .203". See Tool Catalog for oversize ring gauge numbers.

To measure wear step, it is first necessary to determine the (original ring groove width, because it may vary from .194" to .197". Insert gauge blocks in ring groove, and by trial, determine the largest one which enters its full depth. This will indicate the original



Refer to "Specifications" at end of section for applicable dimensions.

1 - Piston skirt diameter
2 - Piston platform bore
3 - Piston inside diameter
4 - Piston to carrier pilot clearance
5 - Piston platform to bottom of snap ring groove
6 - Compression ring groove width
7 - Piston to cylinder head clearance
8 - Compression ring to land clearance
9 - Piston to liner clearance
10 - Oil ring groove width
11 - Oil ring to land clearance

Fig. 3-9. Piston Measurement Points

width of the ring groove being measured. Then insert the largest block that will enter the groove up to the wear step. The size of the wear step is determined by subtracting the small block dimension from the large block dimension.

When a wear step, in excess of maximum allowable, is found on the lower face of the top compression ring groove, the groove may be recut to remove the wear step, provided the finished width does not exceed .201" for use with a standard ring.



Fig. 3-10. Piston Ring Groove Wear Step

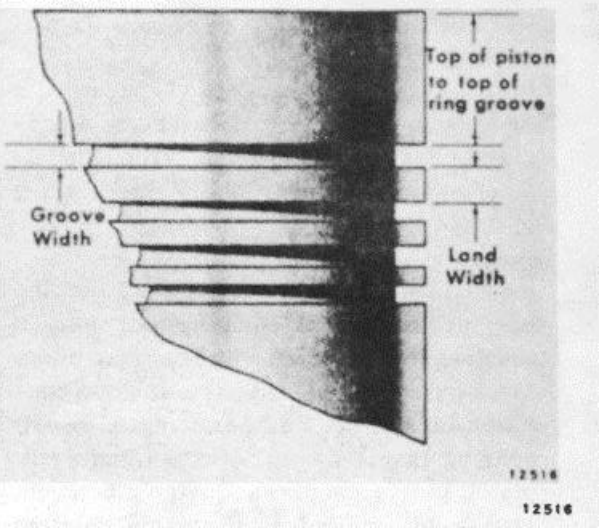


Fig. 3-12. Oversize Ring Grove Measurement Points

If the ring groove is worn beyond a width of .201", it is possible to machine the top ring groove to use oversize ring. See Fig. 3-12 and Service Data for measurement points and limits.

When performing either of the preceding operations, care must be taken to keep the ring groove faces parallel to each other and at right angles to the centerline of the piston. The surface finish must be smooth to avoid excessive wear.

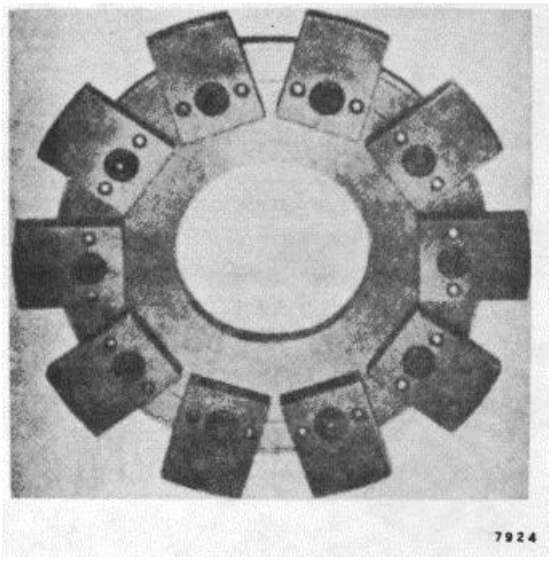


Fig. 3-11. Piston Ring Groove Gauge

5. Inspect the piston for cracks using Magnaflux method as outlined in Maintenance Instruction 1754.

6. Remove undercrown deposits. Pistons that have been found dimensionally and structurally satisfactory for reuse, should also have the heat dam area thoroughly cleaned of undercrown deposits. Undercrown cleaning should be accomplished using a sand or grit blast cleaning in conjunction with liquid cleaning. Maintenance Instruction 1759 outlines a recommended procedure and details of construction for a fixture to use in grit blast cleaning of pistons.

Carrier

In this assembly, Fig. 3-4, a broached slot or recess in the carrier, receives a precision bearing insert. A hardened polished piston pin runs against the bearing insert.

Normal bearing wear does not affect the carrier. Maximum permissible wear on the insert, piston pin, and carrier pilots are given below. Used parts in good condition should not be interchanged. A new bearing insert should be used when a new piston pin is used. The piston pin should always be applied in the same relative position to the bearing insert. The small hole in the piston pin should be matched with the piston cooling oil inlet hole in the carrier as a convenient means of keeping the pin and insert in the same relative position for maximum performance.

Except in extraordinary cases of pilot wear, carriers may be expected to have an indefinitely long life. Also, the bearing insert need not be removed for measurement unless its appearance is questionable and/or the wear on the piston pin is well advanced.

Measure the carrier to determine that the dimensions do not exceed the limits shown in the Service Data.

Piston Pin

1. Inspect the pin. The bearing surface should be free of any roughness and have a mirror finish.

2. Fretting on the pin, only where it contacts the connecting rod, may be removed using a fine stone.

3. Check the 7/8"-14 bolt threads in the pin by retapping. If the threads are damaged, replace the pin.

4. Check the pin diameter.

CONNECTING ROD ASSEMBLY

DESCRIPTION

The "trunnion type" connecting rods, Fig. 3-13, are interlocking, blade and fork construction. The blade rod moves back and forth on the back of the upper crankpin bearing and is held in place by a counterbore in the fork rod.

One end of the blade rod slipper foot is longer than the other and is known as the "long toe." The blade rods are installed in the right bank of the engine, with the long toe toward the center of the engine.

The fork rods are installed in the left bank of the engine. Serrations on the sides of the rod at the bottom match similar serrations on the fork rod basket, Fig. 3-13. The rod basket consists of two halves, held together at the bottom by three bolts and self-locking nuts. The fork rod and basket are bolted together at the serrations. Fork rods and baskets are not interchangeable since they are line bored as an assembly. Both the fork rod

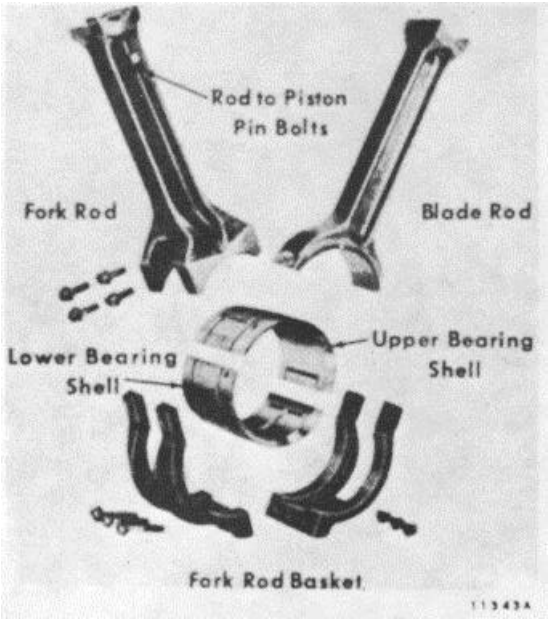


Fig. 3-13. Connecting Rods Bearing Shells And Basket

and basket are stamped with an identical assembly serial number for matching and identification purposes.

The top of each rod is machined to the contour of the piston pin.' Piston pins are held to the connecting rod by two bolts, having non-removable spacers.

MAINTENANCE

CLEANING

Cleaning procedures should be in accord with accepted practice or as recommended by the supplier of cleaning material.

CAUTION: Abrasive material, including steel wool, should not be used to clean connecting rods or bearing shells.

INSPECTION

Fork Rod

1. After all parts are clean, check the tapped holes in the fork rod. If threads are worn, the bolts holding the basket may loosen during operation and damage the engine.

Plug gauge, Fig. 3-14, is available to check the fork rod bolt threads. One end of the gauge is marked "GO" and the opposite end "HI." The gauge should be used according to the following procedure.

a. Thread the "GO" portion of the gauge into each of the holes, Fig. 3-14, and check for binding, which may indicate damaged threads. Normally, this gauge should enter the holes freely and a slight shake or wobble is permissible.

b. An attempt should then be made to screw the "HI" portion of the gauge into each of the holes. This is not a "no go" gauge, therefore, rods may be entirely satisfac-

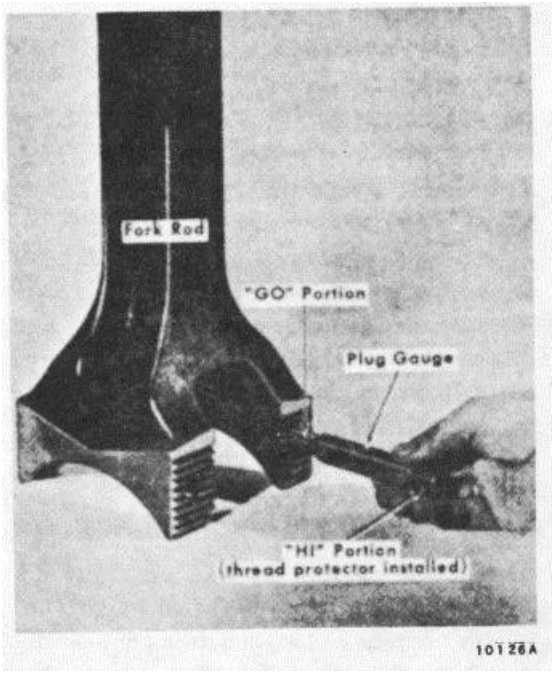


Fig. 3-14. Checking Fork Rod Bolt Threads

tory even though the gauge may be screwed in the threads, even to the extent of bottoming.

Normally, in rods having little wear, this gauge will be difficult to thread into the holes more than a couple of turns. In many cases, however, the gauge can be threaded into the rod but will be snug and tight. While threaded in, check for shake or wobble taking care that the gauge is not bottomed in the hole which would cause binding and a false reading.

The fork rod should be scrapped if shake or wobble is experienced with the "HI" gauge.

To further ensure proper torque values, it is recommended that new bolts be used.

If bolts are reused, they should first be qualified by careful inspection,

discarding any that may be bent or have threads showing signs of galling, wear, nicks, or other imperfections.

2. Fork rod serrations should be checked for nicks, burrs, and cleanliness. Check tightness of upper bearing loeating dowels. Step dowels are available in the event oversize dowels are required. Inspect for cracks in serrations and rod visually and by Magnaflux. Maintenance Instruction 1754 covers connecting rod Magnaflux inspections.

3. Check fork rod bore by fastening basket securely in place using 175 ft-lbs torque on basket bolts. (Normal basket bolt torque is 190-200 ft-lbs on assembly.) Torque value of lower basket bolts is 75 ft-lbs. Measure bore at points 600 apart as indicated in Fig. 3-15. The average of these dimensions must not exceed the specified maximum. If bore is beyond this dimension, the rod and basket should be reworked.

4. Fork rod rework will be required for any of the following conditions:

   a. Average of three 600 measurements across fork rod and basket bore exceeds specified maximum.
   b. Nicks, burrs, or fretting on fork and basket serrations.
   c. Damaged threads in bolt holes (see step 1), or loose dowels.
   d. Damaged or distorted basket.
   e. Excessive rod twist in length of saddle.
   f. Out-of-parallel in excess of limit in length of saddle.
   g. Length of rod between bore centers is less than the minimum.

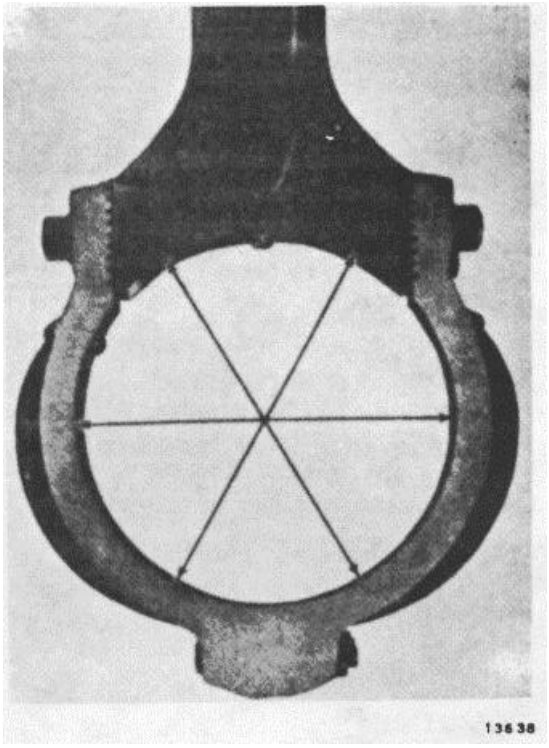


Fig. 3-15. Checking Fork Rod Bore

   h. Fork counterbore exceeds maximum depth.

5. Fork rod assembly should be scrapped if any one or more of the following conditions exist:

   a. Fatigue cracks through basket serrations and rejectable Magnaflux indications as outlined in Maintenance Instruction 1754.
   b. Heat discoloration in basket or fork.
   c. Rod bent or damaged beyond repair.
   d. Length of rod between bore centers is less than minimum.

Blade Rod

1. The blade rod is checked on a 7.692" diameter mandrel to observe slipper surface for "open" or "closed" ends. Blade surface should be bright, shiny,

and smooth. Rod should be scrapped if this surface shows heat discolorations.

NOTE: The flame hardening process, produces a blue black color on the top side of the blade rod slipper foot. This discoloration is normal and has not been caused by overheating during operation. The slipper surface, however, should show no discoloration.

2. Blade rod rework will be required for any of the following conditions.

   a. Scarred, pitted, or deeply rust-etched slipper surface.

   b. End of slipper closed in beyond limit.

   c. End of slipper opened beyond limit.

   d. Excessive twist along saddle length.

   e. Out-of-parallel exceeds limit along saddle length.

   f. Length of rod between bore centers is less than minimum allowable.

3. Blade rod should be scrapped if any one or more of the following conditions exist.

   a. Rejectable Magnaflux indications as outlined in Maintenance Instruction 1754.

   b. Heat discoloration on slipper surface.

   c. Less than minimum flange thickness on slipper shoulder.

   d. Twist, out-of-parallel, or damage beyond repair.

   e. Length of rod between bore centers is less than minimum.

CHECKING ROD LENGTH, TWIST, AND BORE PARALLELISM

The connecting rod checking fixture, Fig. 3-16, is available for accurate inspection of the connecting rod length, twist, and parallelism of piston pin saddle to bearing bore. All 567 and 645 engine connecting rods can be checked on this fixture. When used to check "trunnion" type connecting rods, a 1" spacer plate is used as shown in Fig. 3-16. Also, the contact point and the gauge plate having a 1.4126" dimension, included with the carrier fixture, are used when checking "trunnion" type connecting rods.

With the 1" spacer plate applied under indicator assembly as shown in Fig. 3-16, place the 1.4126" indicator gauge plate on permanent gauge block of fixture, and with the contact point on the 1.4126" plate, set indicator to "0." Place rod on fixture and by placing the contact point at each top edge of contour, determine the screw adjustment needed to bring rod to vertical position and then tighten screws.

Check slipper surface for open ends by trying a .003" feeler gauge at each toe end, between slipper surface and arbor. Blade rods with open ends may be used providing a .003" feeler gauge cannot be inserted more than two inches from each end of slipper when rod is mounted on the 7.692" arbor. Slipper surface close-in is evidenced by the ends having no clearance and the slipper surface being open. Rods with closed-in slipper surface may be used providing a clearance less than the limit is obtained when measured anyplace between ends of slipper on 7.692" arbor.

After adjusting indicator and placing rod in vertical position, set indicator contact point at top inside edge of saddle, and run indicator along length of saddle. Indicator deflection shows rod twist which should not exceed limit in the length of the saddle.

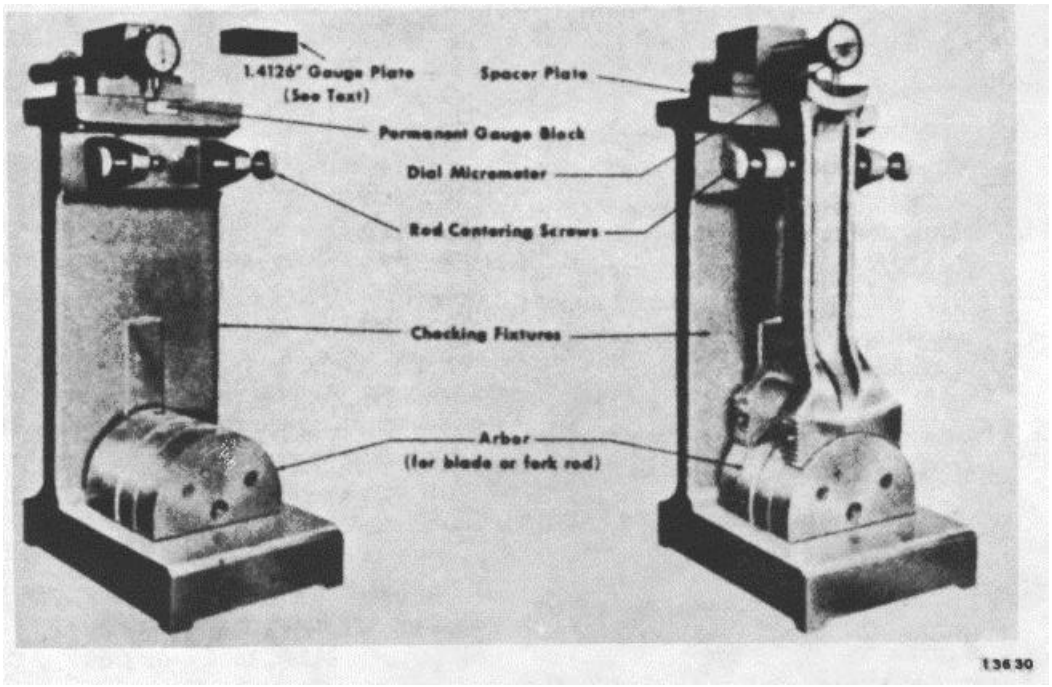


Fig. 3-16. Checking Connecting Rods

Place indicator at one end of bottom of saddle and note indicator reading. Check along length of saddle bottom, circumventing bolt holes, to check out-of-parallel. Indicator must not show more than maximum deflection along length of saddle.

Replace indicator on 1.4126" gauge plate and check indicator dial "0" setting. Slide indicator contact point off block to bottom of saddle and note deflection to indicate a bent or shortened rod. Deflection or reading must not exceed .010" to allow reuse of the rod, to give a generated rod bore centerline dimension not less than minimum allowable. A .021" indicator reading shows the rod bore centerline dimension below limit, and the rod should be scrapped.

CONNECTING ROD BEARINGS

DESCRIPTION

Connecting rod bearings consist of upper and lower shells, Fig. 3-13. They are semicircular in shape and have a steel back with a layer of lead bronze bearing material covered by a lead tin coating on the inside diameter. The upper bearing has, in addition, a bearing surface in the center of the outer diameter consisting of a layer of bronze bearing material with a pure lead-flash overlay. This provides a bearing surface for the slipper of the blade connecting rod.

Dowels in the fork rod and basket hold the bearing shells in proper position. Two dowels in the fork rod locate the upper shell and one dowel in the basket locates the lower shell.

There is no provision for connecting rod bearing adjustment. When bearing clearance exceeds the limit given in the specification, they should be replaced. After bearing shells are once used on a crankpin and have accumulated numerous dirt scratches, they must not be used on any other crankpin.

Lubricating oil is supplied to the crankpin bearing through a drilled passage in the crankshaft from an adjacent main bearing.

A circumferential oil groove at the center of the lower bearing supplies oil to a drilled passage in the upper bearing for the blade rod bearing surface. Oil is distributed over this surface by a "fish-back" or oil groove down the bearing center having grooves at right angles along its length.

MAINTENANCE

CHECKING CONNECTING ROD BEARINGS

The connecting rod bearings should be checked whenever the piston and rod assembly is removed from the engine. To make this check, apply bearings to fork rod and basket in which they are to be used. Tighten basket bolts to 175 ft-lbs torque and measure across the bearing bore at points 600 apart. This is similar to the procedure used when checking fork rod basket bore, Fig. 3-15. The average of these three readings must not be less than is necessary to ensure a clearance between crankpin journal and bearing within the specified limits. After operation, rod bearings may give indication of being tight across the split line when loose on the crankpin. However, rod bearings intended for use should be mounted n the fork rod and then checked.

NOTE: After bearings have once been used, they should not be used on any other journal.

Check upper bearing step thickness as shown in Fig. 3-17. This will indicate blade rod bearing surface wear. Step thickness should not be less than minimum limit.

Bearing shells will usually be dirt scratched to some degree, but unless condition is severe, the bearings can be reused.

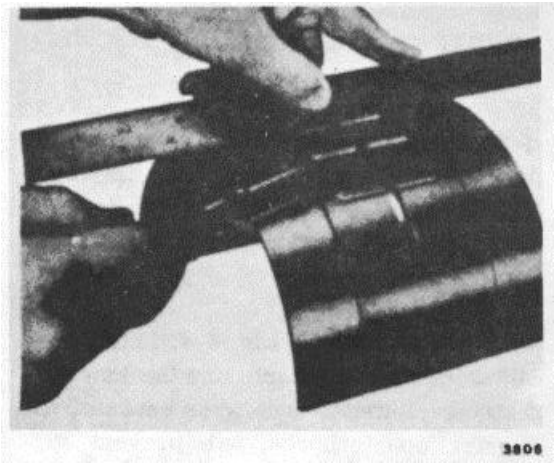


Fig. 3-17. Checking Rod Upper Bearing Shell

ASSEMBLY AND INSTALLATION

ASSEMBLY

APPLYING PISTON RINGS

1. Place the cleaned and inspected piston on clean work bench and check the ring grooves to be sure that they are free of all foreign material.

2. Using piston ring expander, as shown in Fig. 3-8, carefully apply all new piston rings.

   To apply the spring-loaded oil control ring in the bottom groove, apply the spring to the groove, then apply the ring so the spring will fit in the groove in the ring.

NOTE: The end junctions of the spring should not line up with ring gap.

3. Stagger the compression rings so the gaps of the first and second rings are 180° to each other, the third 90° to the second ring and the fourth ring 180° to the third. The oil control ring gaps should be at 180° to each other.

APPLYING BEARING INSERT TO THE CARRIER

If the bearing insert in the carrier is damaged or worn to the minimum thickness or if a new piston pin is to be used, a new carrier insert bearing should be installed.

The bearing insert, Fig. 3-4, is installed in the carrier by centering the insert so that the slotted tangs, when bent into the carrier counterbores, will prevent endwise movement of the insert. Carefully wipe out the insert slot in the carrier. Also, examine the insert to make sure it is clean. Apply the insert by entering it at one end of the carrier slot, and sliding it along the carrier bore. Center the insert so that the tang slots when bent will be adjacent to the counterbores of the carrier. Using indenter tool or a pointed tool with a 1/16" radius, strike the center of the tangs, so as to bend them into the carrier counterbore.

ASSEMBLY OF CARRIER, PISTON PIN, AND CONNECTING ROD

1. Examine all mating surfaces of the parts to be sure they are clean and smooth.

2. Apply some clean oil to the carrier bearing insert and to the piston pin, and insert the pin in the carrier.

NOTE: Install the piston pin so hole in end of the pin is at the same end as the piston cooling oil inlet hole in the carrier. Maximum performance is obtained when these parts are kept in their same relative positions.

Manually oscillate the pin while slowly moving it across the bearing insert, to check freedom of movement.

3. Place the connecting rod on the pin and apply the connecting rod to piston pin bolts.

NOTE: When assembling rod and carrier, the piston cooling oil hole in the carrier must be on the same side as the dowel pin in the serrations of the fork rod and on the side opposite to the "long toe" of the blade rod. This will ensure proper position of the hole when assembly is installed in the engine.

4. Place the assembly in carrier holding fixture, Fig. 3-7, to torque bolts. (If fixture is not available, place rod horizontally in vise with pin close to vise, and torque in vertical plane. If the rod is held improperly, the applied torque is sufficient to permanently twist the rod.). Torque value of rod to pin bolts is 450 ft-lbs (plus or minus 5 per cent). Use 300 ft-lb torque wrench with extension to torque pin bolts. The extension end with plug and socket fits the bolt head, and the torque wrench drive is connected to the other end. To torque bolts to 450 ft-lbs, a torque reading of 300 ft-lbs is required, using the extension.

ASSEMBLY OF CONNECTING ROD, CARRIER, AND PISTON

1. Place piston open end up--and check that the interior is clean and that platform is free of any foreign material. Apply some clean oil to the platform.

2. Oil the carrier platform and apply the thrust washer to the carrier.

   Check that thrust washer thickness is within specified limits.

3. Place the carrier and rod assembly in the piston. Check the carrier for free rotation in the piston.

4. Using snap ring remover as shown in Fig. 3-6, install the snap ring in the piston to hold the carrier.

   Check that snap ring to carrier clearance does not exceed maximum limit.

INSTALLATION

Before installing piston and rod, the liner should be serviced as outlined in Section 4.

1. Set piston ring compressor and guide in place on cylinder liner. Oil cylinder wall, ring compressor, and piston. Place crankpin on bottom center.
2. Apply connecting rod protector boot, then lower assembly into liner, using eyebolt in piston crown. Be sure piston cooling hole is positioned to outboard side of engine, on same side as short toe on blade rod and dowel in serration of fork rod.
3. Suspend piston and rod assembly and prepare connecting rod bearing for application. Oil inside and outside of bearing shells and install upper bearing in position on crankpin.
4. Lower blade rod to rest on upper bearing. Remove eyebolt from piston and apply to fork rod piston. Apply boot to fork rod and lower rod to bearing. Fork rod dowels should enter bearing dowel holes without binding. Remove piston eyebolt.
5. Apply lower bearing to doweled basket half and install basket half to fork rod, tightening basket to fork rod bolts just sufficient to mesh the serration and hold the bearing in place. Then apply other basket half to fork rod, tightening rod bolts to mesh the serrations.

   When applying fork rod baskets, be sure that the serial number on prong of dowel half is on the dowel side of the rod. Current assembly basket halves, without dowel holes, have the serial number at the bottom, waking it easy to spot misapplication of this basket half to the dowel side. If fork rod 5/8"-18 tapped holes are damaged or are too large, replace the fork rod and basket, as outlined under Connecting Rod Assembly.
6. Apply the three 1/2" lower basket bolts, washers, and lock nuts. Torque value of these bolts is 75 ft-lbs.
7. Complete basket to fork rod bolt application by tightening to 190-200 ft-lbs torque. Retighten assembly according to the Scheduled Maintenance Program.
8. Install cylinder head as outlined in Section 2.
9. Install piston cooling oil pipe and check alignment. Use piston cooling pipe gauge, Fig. 3-18. Insert small end of gauge in piston cooling pipe. Turn crankshaft slowly to bring piston to its lowest position. At same time, rotate gauge by hand to make sure it does not bind in hole. If gauge indicates misalignment, replace pipe assembly. Do not use gauge to align pipe. Piston cooling pipes should be checked before application, with cooling pipe cleaner.

PISTON TO CYLINDER HEAD CLEARANCE

The piston to cylinder head clearance governs to a great extent the efficiency of the engine and should be maintained within specified limits for best operation. In addition, if regular inspections are made, piston to head clearance may be used as an indication of wear in the parts of the piston and connecting rod assembly. Recorded or charted clearance readings will aid in the prevention of serious trouble resulting from excessive wear of parts, as their condition will be indicated by comparing successive piston to head clearances.

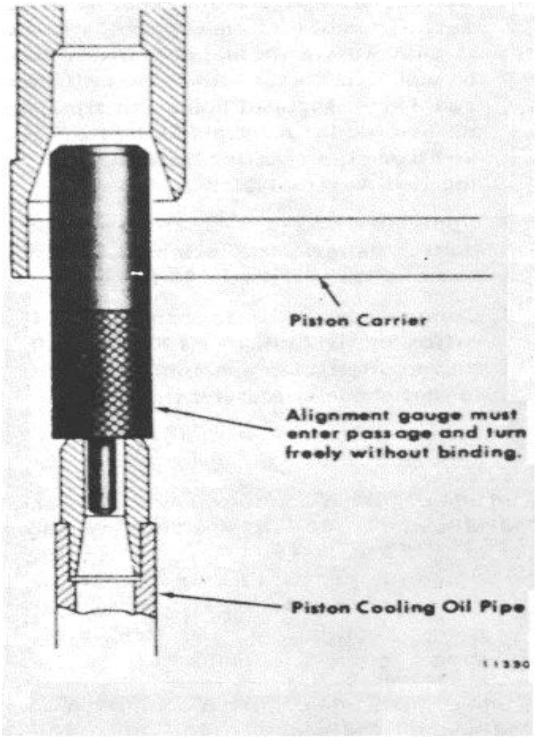


Fig. 3-18. Piston Cooling Oil Pipe Alignment

The engine records that are furnished include piston to head clearance readings taken at the time of manufacture. Such readings are listed for each cylinder and should be checked against subsequent readings to determine condition of the assembly. By recording the original and each successive reading in its proper place on a chart, a definite indication of the condition of the parts will be apparent. Readings of the piston to head clearance may also be started on reinstalled piston and rod assemblies, by taking the clearance of the new installed assembly.

It is recommended that compression lead readings be taken on all cylinders at intervals specified in the Scheduled Maintenance Program. More frequent inspections should be made on assemblies which show excessive or dangerous rates of increase in the clearance.

The following method is recommended to obtain the piston to head clearance. Rotate the crankshaft to place the piston to be checked at bottom dead center. Place a 1/8" soft lead or solder wire shaped to the contour of the piston crown, with the ends of the wire not over 8-1/4" apart, on top of the piston, through the liner ports. Position the lead wire directly above the piston pin parallel to the engine crankshaft. The engine is then barred over one revolution and the wire removed and both ends measured with a micrometer. The clearance reading will be the average of the two measurements taken. If the difference between the two ends of the wire is more than .005", the clearance should be rechecked as the wire may have rotated on the piston to a point at right angles to the piston pin.

The time necessary for taking readings on an engine may be lessened considerably with a saving of wire by using the wire holder and wire as listed in the Equipment List. Also, observing the location of various pistons as crankshaft is rotated, will make it possible to take all readings in two revolutions of the crankshaft.

The new and condemning limits of piston to head clearance are listed in the Specifications. The limits of various individual parts of the assembly govern their respective replacement. These limits may be found in the Service Data at the end of this section.

In conjunction with the piston to head clearance, the snap ring clearance should also be checked. If it is found that the piston to head clearance is within the limit, but the snap ring clearance is at, or sufficiently near, the condemning limit, the piston assembly should be removed and the piston thrust washer checked.

567E4 SERVICE DATA

PISTON ASSEMBLY AND CONNECTING RODS

SPECIFICATIONS

Connecting Rod	
Connecting rod basket bore (See Text) - New	7.624" - 7.625"
Max	7.626"
Blade rod bearing seat diameter (See Text) - New	7.692" -7.693"
Clearance between shoulder on blade rod and counterbore in fork rod - New	.008"-.013"
Max	.025"
(This clearance measured by placing feeler gauge between blade rod and top of upper bearing.)	
Depth of counterbore in fork rod for slipper on blade rod - New	.385"-.3865"
* Limit	.400"
(* Provided the preceding maximum .025" clearance is held.)	
Blade rod shoulder thickness - New	.3445" -.346"
* Limit	.335"
(* Provided the preceding maximum .025" clearance is held.)	
Connecting rod length - New	22.998" - 23.002"
(Generated bore centerline dimension) - Rework Limit	22.990"
Scrap Limit	22.979"
Saddle end for piston pin	
Twist (In length of saddle - see text) - Limit	.006"
Parallelism (In length of saddle - see text) - Limit	.004"
Blade rod slipper	
"Closed in" (Checked on 7.692" arbor - see text) - Limit	.007"
"Opened out" (Limit of feeler that can be inserted 2" from end of 7.692" arbor - see text) - Limit	.003"
Connecting Rod Bearings	
Bearing inside diameter (Average of three 60° measurements) - New	6.5066" -6.5100"
Bearing to crankpin clearance - New	.007" -.011"
Limit	.015"
Bearing shell thickness - New	.5587" -.5595"
Thickness limit (Standard) - Min	.5530"
(1/32" U.S.) - Min	.5686"
(1/16" U.S.) - Min	.5843"
Upper connecting rod step thickness - Limit	.027"

Piston

Refer to Fig. 3-9 - circled numbers coincide with callouts on illustration.

(1)	Piston Skirt diameter - New	8.488" - 8.490"
	Limit	8.485"
	Out-of-round	.005"
	(Check diameter approx. 5" below the compression ring grooves and below the oil ring grooves. Take two readings 90° to each other, at each location.)	
(2)	Piston platform bore (upper carrier pilot) - New	3.565" -3.567"
	Limit	3.570"
	(Check at two places 90° to each other.)	
	Piston platform should be square to piston O.D. within .003" total indicator reading.	
(3)	Piston inside diameter (lower carrier pilot) - New	7.487" -7.490"
	Limit	7.494"
(4)	Piston to carrier pilot clearance - New	.003"- .007"
	Limit	.011"
(5)	Piston platform to bottom of snap ring groove - New	6.376" - 6.380"
	Limit	6.387"
(6)	Standard compression ring groove width - New	.194" -.197"
	Max	.201"
	No. 1 compression ring groove may be recut for	
	1/64" Oversize rings (.209" + .003" - .000") - Max	.216"
	1/32" Oversize rings (.225" + .003" - .000") - Max	.232"
	providing	
	Top of piston to top of ring groove -	1.480" -1.490"
	Width of land - Min	.343"
	Ring groove wear step (50 cycle unit)	.003
(7)	Piston to cylinder head clearance - New Min	.026"
	Max	.068"
	An increase in compression clearance of .030" from the assembly value at the time of installation condemns the assembly. Any sudden increase should be investigated immediately.	
(8)	Compression ring to land clearance	
	No. 1 groove, chrome ring - New	.004"-.0085"
	Max	.012"
	No. 2 and 3 groove, chrome ring - New	.0075" -.012"
	Max	.016"
	No. 4 groove, taper ferrox ring - New	.0075"-.0115"
	Max	.016"
(9)	Piston to liner clearance	
	When measured 6" below top of liner,	
	except at liner ports - New	.0095" -.0135'
	Max	.020"

567E4 SERVICE DATA
PISTON ASSEMBLY AND CONNECTING RODS

(10)	Oil ring groove width - New	.251" -.254"
(11)	Oil ring to land clearance - New	.002" -.006"

Carrier

Carrier height (top of platform to bottom of carrier) - New	5.999" - 5.995"
Limit	5.992"
Carrier top pilot diameter - New	3.560" - 3.562"
Limit	3.557"
Carrier bottom pilot diameter - New	7.483" - 7.484"
Limit	7.480"
Clearance (carrier to piston snap ring) - New	.002" -.015"
Limit	.025"
Carrier bearing insert thickness - New	.150" -.151"
Min	.146"

Piston Pin

Diameter - New	3.684" - 3.685"
Min	3.664"

Piston Thrust Washer

Thickness - New	.185"-.188"
Limit	.175"
Thickness variation - Max	.003"

EQUIPMENT LIST

	Part No.
Piston ring compressor and guide (standard size) (.030" and .060" oversize - 8065453)	8034087
Piston pulling eyebolt	8040413
Fork rod support	8052958
Blade rod protector boot	8062033
Fork rod protector boot	8062034
Piston cooling pipe alignment gauge	8071720
Motor driven flexible shaft buffer, 115 V	8084282
Motor driven flexible shaft buffer, 230 V	8084283
Piston cooling pipe cleaning tool	8087086
Wire (lead, 1/8" dia. - 50 lb. spool)	8136471

Torque wrench, 3/4" drive (0-300 lbs.)	8157121
Snap ring remover	8171633
Piston ring expander	8194036
Torque wrench extension (used with torque wrench 8157121)	8210136
Piston carrier holding fixture	8236589
Wire holder (has contour of piston crown to hold small lengths of lead wire for piston to head clearance)	8243220
Wire (lead, 1/8" dia., used with holder 8243220 or alone - 5 lb. Spool	8243661
Connecting rod checking fixture	8257730
Fork connecting rod basket thread gauge	8265955
Piston ring groove gauge Standard (.194" - .203")	8275503
Bearing insert to carrier indenter tool	8311268

DESCRIPTION

The cylinder liner, Fig. 4-1, is designated as a fabricated design liner because of the method of construction. Fabricated liners consist of a cylinder casting having two separate water jackets applied and brazed to the casting making an integral cylinder liner assembly.

A row of air inlet ports completely en-circles the liner as shown in Fig. 4-1. The bottom of the ports is slightly below the top of the piston when it is at bottom dead center. A water inlet flange on the outboard side of the liner, below the ports,

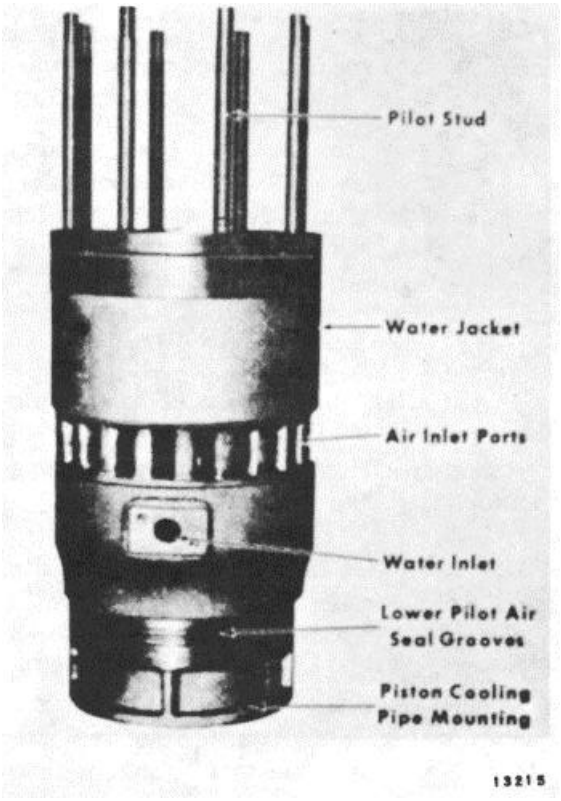


Fig. 4-1. Cylinder Liner

provides a connection for the individual liner water supply line. A water deflector, Fig. 4-2, at the water inlet, prevents the inlet water from impinging directly on the inner liner wall.

The inlet water circulates around the bottom of the liner, progressing upward to discharge into the cylinder head through twelve drilled holes. A counterbore, Fig. 4-3, around each drilled hole accommodates a synthetic rubber water seal which seals the water passage when the cylinder head is installed. A thin copper clad steel gasket provides a combustion seal between the cylinder head and the liner.

The liner is secured to the cylinder head by eight studs and nuts, and this entire assembly is held in place in the crank-case by the cylinder head crabs. A "pilot stud" locates the liner in proper angular relation to the cylinder head and ensures alignment with the piston cooling pipe mounted at the bottom of the liner.

The liner is piloted in the crankcase at the upper and lower pilots. The upper pilot bears directly against the crankcase, while the lower pilot fits into an insert ring in the crankcase. Two seal rings are applied at the lower pilot to prevent loss of air from the air box.

MAINTENANCE

INSPECTION IN ENGINE

The air box handhole covers provide access to the cylinder liner upper bores while the oil pan handhole covers provide access to the lower bores.

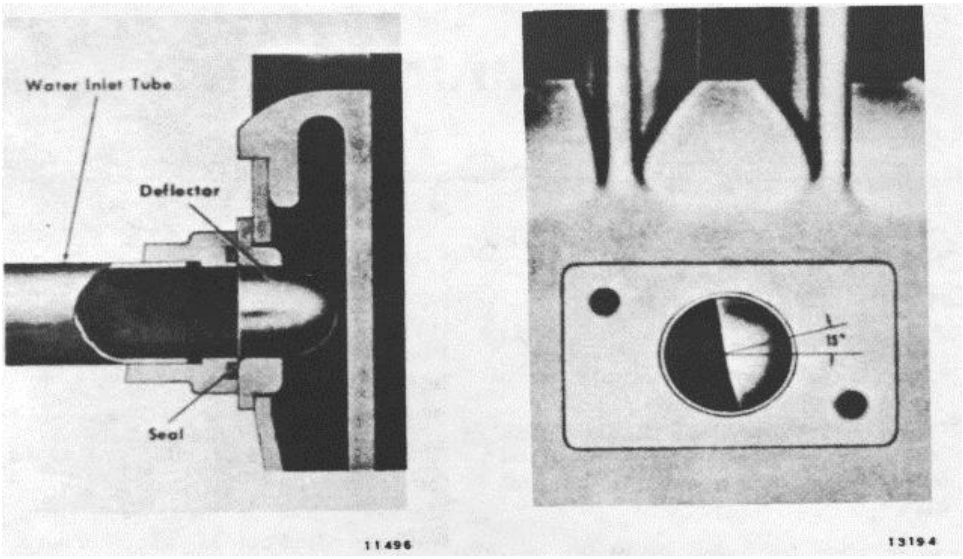


Fig. 4-2. Water Inlet Deflector

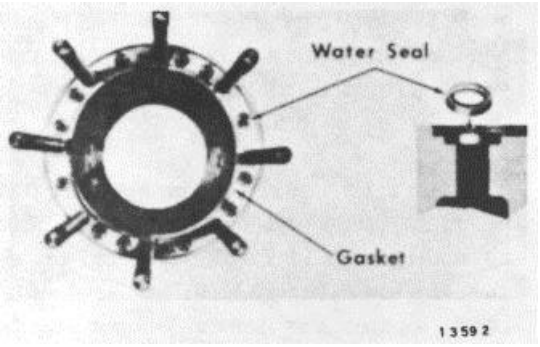


Fig. 4-3. Water Seal

1. Open the cylinder test valves and position the piston either below the ports for upper bore inspection or near top dead center for lower bore inspection.

2. Check the liner walls for scuffing or scoring above the ports.

3. Inspect externally for evidence of water leaks at liner to cylinder head gasket and water inlet line.

REMOVAL

1. Remove cylinder head and piston and connecting rod assemblies as described in Sections 2 and 3.

2. Remove piston cooling oil pipe and liner water inlet line.

3. Apply cylinder liner lifter to liner studs and remove the liner. Use care when handling to avoid damage to the liner studs and liner pilot.

NOTE: Check the head to liner gasket. A bulged gasket is an indication of hydraulic lock and a careful check of the connecting rod is required.

CLEANING

General liner cleaning procedures should be in accord with accepted practice or as recommended by the supplier of cleaning material.

To ensure that all water scale deposits and other foreign materials which are so detrimental to water seal life are removed from the seal counterbores, the details for construction of a cleaning tool are shown in Fig. 4-4. With the liner removed from the engine, the tool should be used prior to washing the liner so that all the

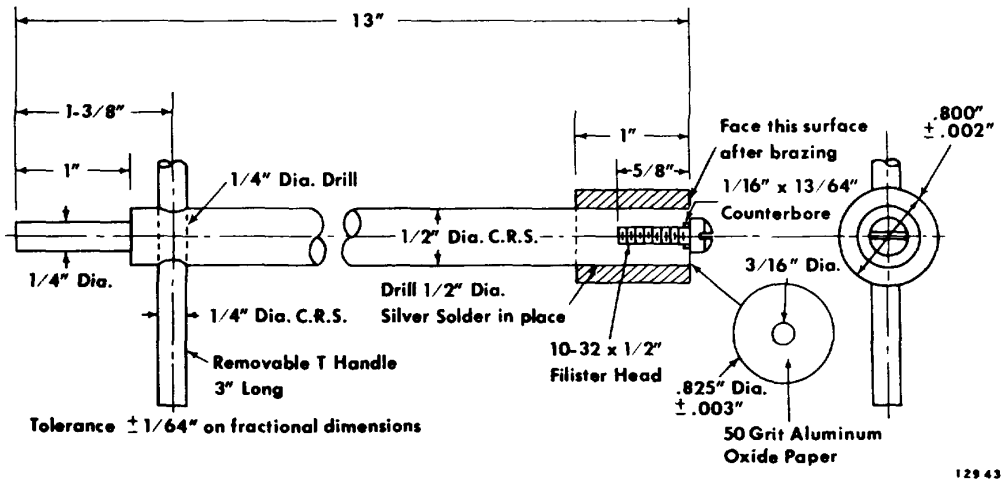


Fig. 4-4. Counterbore Cleaning Tool

loosened deposits will be removed in the wash. Only the grade of abrasive as specified in Fig. 4-4 should be used to clean the counterbores without damaging the seating surfaces. Insert the tool in an electric or air powered drill which turns around 2000 RPM. Place a few drops of fuel or lubricating oil in the counterbore and, exerting a very light pressure on the tool, rock tool back and forth slightly for approximately five seconds per counter-bore.

When the cylinder head is removed, but the liner remains installed in the engine, use the T-handle with the tool and manually clean counterbores so deposits will not enter cylinder.

MEASURING LINERS FOR WEAR

The cylinder liner should be measured in planes parallel and at right angles to the crankshaft.

Wipe interior of liner clean before measuring bore, and check for physical defects that would require rework on the liner. A liner bore gauge, Fig. 4-5, or standard inside micrometers may be used

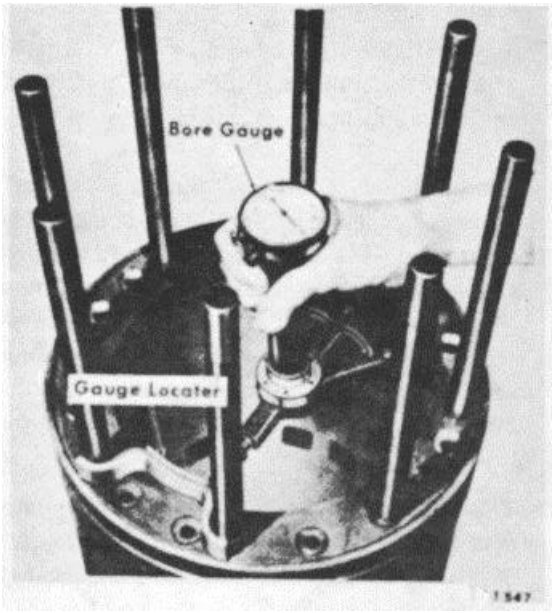


Fig. 4-5. Liner Bore Gauge

to measure liner bore diameter. The gauge is of a special design for liner bore measurement, and will provide accurate measurement when used carefully. It has a three-pronged centering and measuring end that fits the liner bore. A dial indicator, mounted on an upright that extends down to the measuring prongs, gives instant reading of bore diameter. The upright allows the gauge to be raised and

lowered in the bore with visual measurement shown on the dial. A master gauge is used to calibrate the bore gauge.

A dial gauge locator should be used with the liner bore gauge. The gauge locator fits over the top of the liner and hangs down inside the liner bore. It has four 1/2" drilled holes spaced at 2", 6", 12", and 16" from the top to locate the measurement positions.

A special box to protect the liner bore gauge also provides a place for the master gauge and the gauge locator.

NOTE: Dimensional wear limits are listed in Service Data at the end of the section.

New cylinder liners have a bore diameter which falls between a low and a high limit, as well as at the port relief zone.

Accumulated liner and piston wear will increase piston to liner clearance and this clearance is a limiting factor at time of reapplication. No liner should be matched with a new or used piston where the diameters result in a piston to liner clearance exceeding the maximum limit, at a point six inches below the gasket face of the liner.

The liner bore should be checked for out-of-round at two points 2" and 6" below top of liner, Fig. 4-6, using the dial gauge locator as a guide. Take two readings 90° apart, to determine wear and out-of-round. Should the out-of-round exceed the limit, the liner must be rebored to the next oversize, regardless of other wear measurements which still may be within limits.

Using the maximum piston to liner clearance as a guide, worn liners may be used again, providing they are not over out-of-round limit, and are matched with pistons having a diameter which will not exceed the limit on piston to liner clearance.

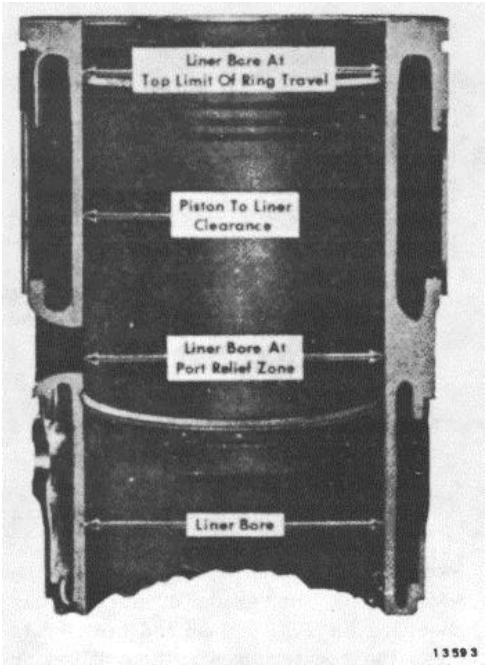


Fig. 4-6. Liner Measurement Points

Maximum piston and liner usage. is obtained by selective assembly within the clearance limit.

Liners will wear tapered, with maximum wear normally occurring at the top limit of piston ring travel. Check that wear at top of ring travel, taking two readings 90° apart, is within specified limit. A liner worn to this dimension will leave some stock to allow for cleaning up the bore to the first oversize. If this limit is exceeded, it may not be possible to rebore liner to the first oversize. It would then have to be rebored to the next oversize, losing a great amount of its wear life. Consequently, it is suggested that no liner be reinstalled if the bore diameter at top of ring travel exceeds the maximum.

OVERSIZE LINERS

Liners can be rebored to .030" or .060" oversize. The dimensions of oversize liners are the same as shown in the Service Data, except that the diameters

are increased by .030" or .060", as the case may be. Standard or .030" oversize liners worn beyond their limits may be returned to Electro-Motive for refinishing to the next oversize. (Corresponding over-size piston assemblies must be used with oversize liners.)

REMOVING LINER RIDGE

After a long period of use, a wear ridge, caused by piston ring action, will appear near the top of the liner bore. After the liner is removed from the engine, the wear ridge must be entirely removed before honing the liner. Unless complete removal of the wear ridge is accomplished, it is not possible to properly hone the critical area of the liner at the top of the ring travel. In addition, removal of the wear ridge precludes any possibility of interference with new piston rings.

The cylinder liner ridge reamer, Fig. 4-7, is used to remove the ridge at the top in-side bore of the liner. A reamer is also available for 1/32" -1/16" oversize liners. Reamers may either be manually or motor operated. If the reamer is motor operated, a speed reducer must be used. which

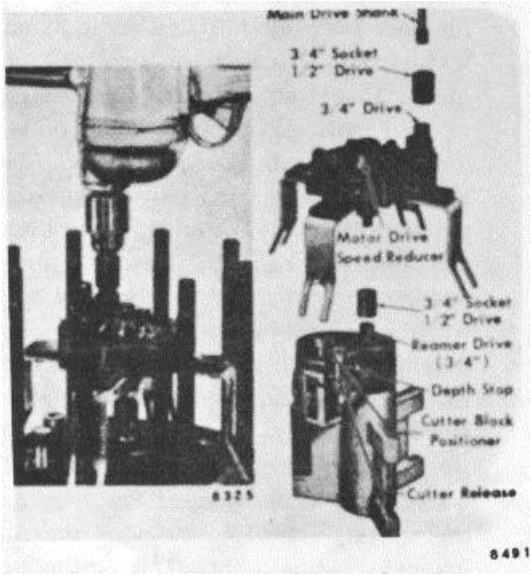


Fig. 4-7. Application Of Liner Ridge Reamer And Speed Reducer

is mounted on the reamer. The operating motor used with the speed reducer can be an ordinary heavy-duty electric drill having a no load speed of approximately 500 RPM.

Extra cutting blades may be obtained for reamers. Refer to "Equipment List" at the end of this section.

Reamer cutting blades also may be re-sharpened. To resharpen a dull cutter, it is necessary only to lightly grind the leading angle which does the cutting, using a grinding wheel suitable for grinding tungsten carbide tools. The clearance angle is 80 and must not be exceeded when grinding. It is better to provide "less" than more clearance, as these cutters will not stand up if given greater clearance.

In addition, a cutter should not be used if the guide portion has been reduced to a length of 21/32" by resharpening, because the guide will not extend far enough past the pin hole to prevent undercutting. For resharpening service on the cutters, refer to the reamer manufacturer.

Liner ridge is removed as follows:

1. Oil liner wall just under the ridge, and see that felt pad in back of cutter is full of oil.

2. Retract cutting blade so it will be away from the liner wall when the reamer is installed, and position the depth stop on the blade retard cam. Position cutter blade at bottom of its travel.

3. Lower reamer into the liner until the depth stop rests on top of the liner.

4. Tighten reamer centering nut to hold reamer in correct position in the liner. Rotate the reamer to check centering, and adjust if required.

5. Operate the blade retarder cam to swing stop out of the way and release

cutter so it can move out to contact the liner wall.

6. Operate reamer manually or by motor until ridge is entirely removed, carrying the cut into chamfer at liner top if necessary.

7. After completing ridge removal, remove reamer, and clean liner by wiping off oil and cuttings.

HONING LINERS

After removing the cylinder liner ridge, the cylinder liner must be honed. The purpose of honing is to remove glaze and to provide a wall finish that will hold lubrication and provide quick and proper seating of new piston rings. Light scuffing and scoring on the liner wall may also be removed by honing. However, if this condition is too advanced, the liner should be scrapped or returned to be rebored over-size, depending upon its condition.

Equipment Required

1. Hone kit.

2. 1/2" heavy-duty electric drill with 345-500 RPM motor - 115 or 230 volt.

3. Stone cleaning brush.

4. It is also necessary to provide a fixture to hold the liner during honing.

This fixture provides for the support of the liner, a counterbalance arrangement to facilitate motor and hone handling, and other details that should be provided when honing liners.

Honing Procedure

1. Install the liner properly in the honing fixture. Chuck the driving shank of the hone in the drill motor as shown in Fig. 4-8. Place stone support on the hone body. Note that one end is marked top. Check that stones and guides are firmly secured in their master holders. Remove the center pinion and adjustment assembly from the hone body by pulling it straight out. Wire brush stones to ensure they are clean. Insert stones and guides as far as they will go in their proper holes, marked "X" on the hone body. The two stones are applied on opposite sides of the body. Apply splined shaft and lower hone into the liner bore. Raise spline shaft assembly about 1/4" to prevent adjustment gears from meshing, and turn to expand hone to fit the liner bore. Push the spline shaft assembly back down, engaging its internal gear with gear on the hone body. Expand the stones firmly against the walls by turning the wing nut micrometer adjustment. (During the adjustment the stones should not protrude more than 1/2" out of the liner bore.)

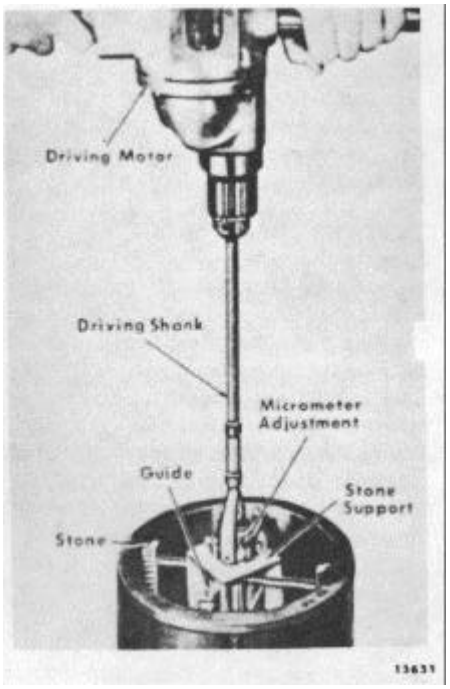


Fig. 4-8. Honing Cylinder Liner

2. Always maintain firm stone pressure against the liner walls to ensure fast stock removal and accurate work. To ensure a constant heavy pressure it may be necessary to increase the pressure after several strokes. If pressure is correct, the stones will emit a steady grinding noise. The driving shank is made with a weak section, so that if the hone is improperly used, causing it to bind, the shank will break.

3. The liner maybe honed "wet" or "dry." Both methods produce identical results. However, if stones and guides are once used with "wet" honing, they should not again be used for dry honing. Also, stones and guides must be kept together in sets. Keep same guide blocks with the same stones, do not mix sets. When honing "dry" the liner and hone must be absolutely dry. Kerosene is considered best for "wet" honing. During wet honing the liner must be continuously flooded. There cannot be any "in-between" in the method used.

4. If the liner does not have a scuffed or scored condition, merely break the glazed surface by stroking rapidly a maximum of 15 strokes, being sure that a heavy pressure is retained on the stones.

5. If the liner is scuffed or scored, remove any material buildup (and consequent scuffing) and any heavy scoring. Do not attempt to remove any isolated dirt scratches as they do not significantly affect operation. Honing out these scratches needlessly reduces liner life. After the surface has been "cleaned up" the hone should be re-moved and the stones brushed, using a wire brush to remove any loading of the stones. The liner should then be honed with the clean stones using a heavy pressure and 6 to 10 rapid strokes.

6. A correct honing operation should result in a characteristic "cross-hatch" pattern on the liner wall surface. In no case should an attempt be made to produce a polished or mirror finish. It is important to remember that when using the correct stones (identified by W47J43 stamped on stones and guides), too rough a finish will not be produced. Do not remove any more metal than is necessary to obtain the desired finish.

7. After honing, the liner should be thoroughly cleaned of abrasive or iron dust and given storage protection until ready for use.

MARKING USED LINERS AND PISTONS IN STOCK

It is suggested that used pistons and liners, which are not going back into an engine immediately, but are to be placed in stock, be thoroughly cleaned, inspected and checked for size. The dimensions as checked can be chalk marked on the out-side of the liners and on the crown of pistons. This will allow liner and piston combinations to be selected with a mini-mum of delay.

INSTALLATION

Check the liner pilot surfaces in the crank-case to see that they are clean and smooth, Refer to Fig. 4-9 for crankcase and liner measurement points and to the Service Data at rear of section for dimensional limits.

Before installing the liner, inspect it for cleanliness and general condition. Check water seal counterbores around the drilled water discharge holes. Make sure they are free from nicks which may cut the seals, and be sure they are clean. Apply the water seals at the gasket surface, as

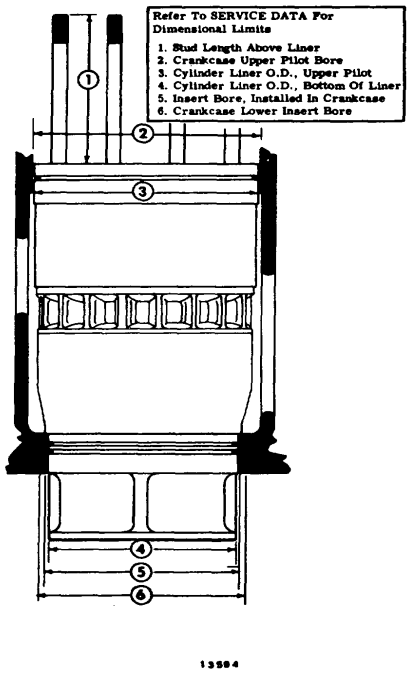


Fig. 4-9. Crankcase And Liner Measurement Points

shown in Fig 4-3. Check water inlet tube deflector for fit and position. The deflector has a press fit in the liner. Wipe the in-side of the liner with a clean oily cloth.

Using liner lifter, install liner into position in the crankcase bore. Preliminary alignment can be obtained by centering water inlet connection with relation to the inspection hole in the stress plat.

After liner is in position complete assembly by installing connecting rod assembly as outlined in Section 3 and cylinder head as outlined in Section 2. Then apply piston cooling oil pipe and water inlet tube assembly, using new seals.

567E4 SERVICE DATA
CYLINDER LINER

SPECIFICATIONS

Cylinder liner bore (except through port relief zone) - New	8.4990" - 8.5015"
Cylinder liner bore (port relief zone only) - New	8.5125" - 8.5165"
Piston to liner clearance (6" below liner gasket face) - New	.0095" -.0135"
Max	.020"
Cylinder liner bore out-of-round (measure at two points 2" & 6" below top of liner - 90' apart) - Max	.005"
Cylinder liner bore (top limit of piston ring travel) - Max	8.520"
Length of studs above top of liner	9-1/2"
Crankcase upper pilot bore - New	12.091"-12.094"
Limit	12.104"
Cylinder liner O.D. (at upper pilot) - New	12.0865" - 12.0895"
Limit	12.085"
Cylinder liner O.D. (bottom of liner) - New	0.3725" - 10.3755"
Limit	10.371"
Insert bore (installed in crankcase) - New	10.377" -10.382"
Limit	10.386"
Crankcase lower insert bore - New	11.062"-11.065"
Limit	11.066"
Cylinder liner stud torque - Min	50 ft-lbs

EQUIPMENT LIST

	Part No.
Hone kit (less motor)	8039177
Wire brush (honing stones)	8078883
Drill (1/2") - 345-500 RPM, 115 volt (AC or DC)	8104770
Drill (1/2") - 345-500 RPM, 230 volt (AC or DC)	8104771
Cylinder liner lifter	8116358
Cylinder liner ridge reamer	8228303
Reamer speed reducer (used with 8228303)	8228304
Cutter blade (reamer)	8228305
Liner bore gauge	8275258
Master gauge (used with 8275258)	8278540
Gauge locator	8278541
Cylinder liner ridge reamer (1/32" - 1/16" oversize)	8295520
Honing fixture (facility drawing)	File 543
Cleaning tool (water seal counterbore)	File 686

CRANKSHAFT

DESCRIPTION

The crankshaft, Fig. 5-1, consists of two drop forgings of carbon steel material with induction hardened main and crank-pin journals. Main bearing journals are 7-1/2" in diameter and crankpins 6-1/2" (nominal). The two crankshaft halves are joined at a flanged connection. Counter-weights are provided to give stable operation and all crankshafts are dynamically balanced.

As shown in Fig. 5-2, all main bearings are supplied with clean lubricating oil under pressure from a main lubricating oil manifold extending the length of the engine. The oil is introduced into the unloaded top half of the bearing, and is carried by a groove in the upper bearing shell to spreader grooves at the split line and a drilled oil passage in the main journal. This permits the use of a lower main bearing shell of greater area, with no oil groove in the load zone. Drilled oil passages conduct the oil from the main crankshaft journal to the crankpin journal. Additional oil passages conduct oil to the harmonic balancer and accessory drive gear at the front end of the crankshaft.

MAINTENANCE

INSPECTION

Whenever main or connecting rod bearings are removed, the crankshaft journals should be inspected. Check for scoring and cracks, and signs of distress, as will generally be evidenced first in the bearings. When the crankshaft is removed from the engine, it should be visually and dimensionally inspected, and Magnaflux inspected if possible. See Maintenance Instruction 1754 for crankshaft Magnaflux inspection.

The journals of the crankshaft are induction hardened. Excessive heat resulting from lack of lubrication, insufficient bearing clearance, or other causes will usually produce thermal cracks on the journal. Damaged crankshafts can usually be re-conditioned to re-establish journal size and condition to use standard size bearings. In some instances, crankshafts may have to be reground requiring the use of undersize bearings.

Attempts to grind crankshafts in the field have proven unsuccessful as during the

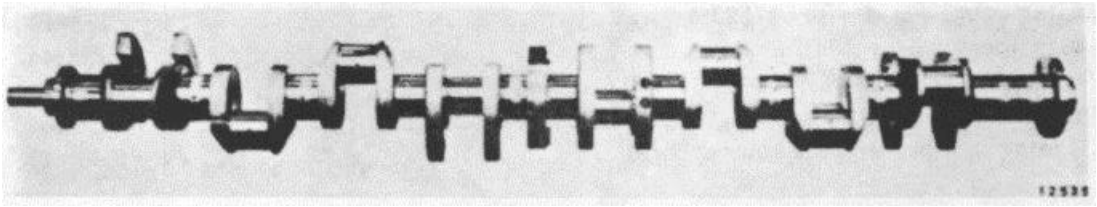


Fig. 5-1. Engine Crankshaft

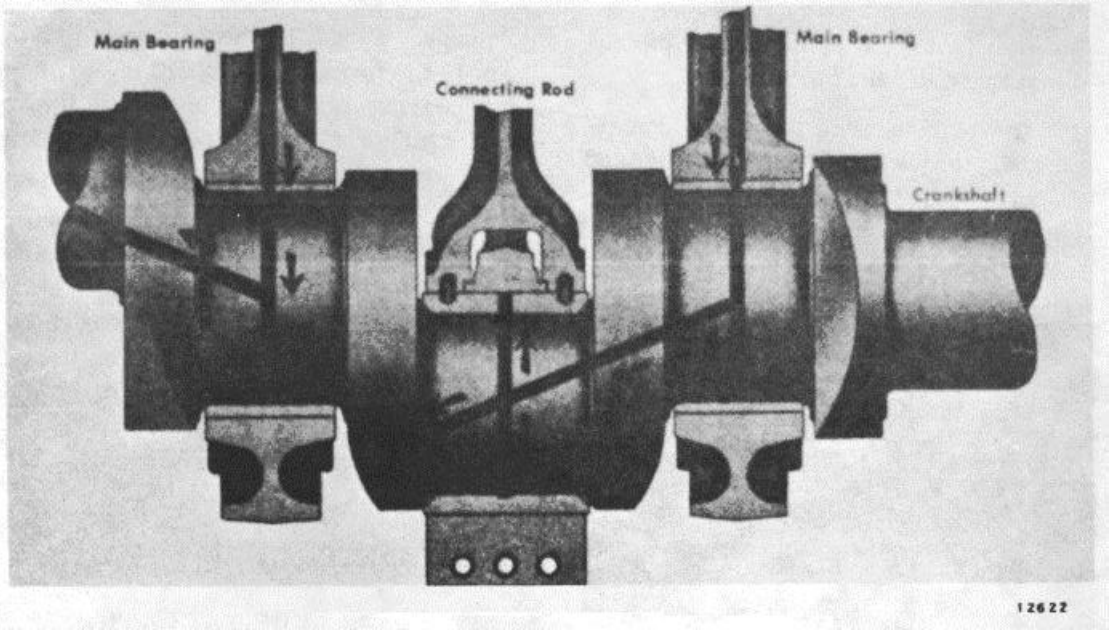


Fig. 5-2. Crankshaft Oil Passages

regrinding process, the depth of the induction hardened zone must be checked, and when necessary, rehardened. This requires special induction hardening equipment.

INSTALLATION

NOTE: All dimensional wear limits are contained in Service Data at the end of the section.

1. Place the crankcase on its side to facilitate application of the crankshaft.

2. Be sure that the crankcase "A" frame bores are clean and dimensionally satisfactory when the "A" frame caps are torqued.

3. Apply the main bearings to the "A" frame bores and caps, lining up the bearing tangs properly.

   If a new crankshaft is used, all new lower main bearings should be applied.

   However, used upper main bearings in satisfactory condition may be applied with either a new or used crankshaft.

   If the crankcase has been reconditioned by line boring the "A" frames, all original lower main bearings regard-less of condition must be replaced, even if the same crankshaft is used. Upper main bearings in satisfactory condition may be reapplied.

4. Check the inside diameter of the main bearing bores with the main bearings applied and nuts torqued to 650 ft-lbs. The diameter should be such that the specified clearance is maintained between the main bearings and the crankshaft being applied. Then remove the bearing caps.

5. Inspect the crankshaft and be sure it is clean. Oil the crankshaft journals and main bearing shells using clean oil.

6. Position the crankshaft in the "A" frame bearings. Apply end bearing caps to hold the crankshaft in place.

7. Place the thrust collars in their respective "A" frame counterbores, as

shown in Fig. 5-3, and apply the remaining caps and bearings.

8. If the main bearing nuts are castellated, torque to 500-800 ft-lbs and apply lockwire. If they are self-locking nuts, torque to 700 ft-lbs.

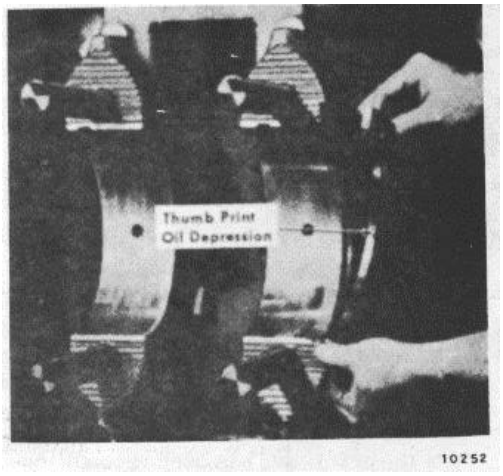


Fig. 5-3. Applying Thrust Collar

MAIN BEARINGS

DESCRIPTION

The main bearing shells, Fig. 5-4, are precision type steel-backed lead bronze, with a thin layer of lead tin for break-in

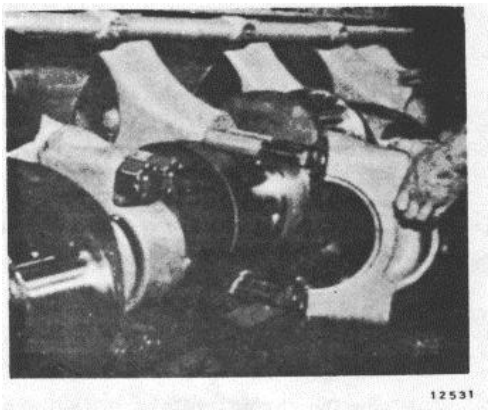


Fig. 5-4. Main Bearing Shells And Caps

purposes. Tangs in the bearings locate them in the proper axial position and prevent bearing turning. Upper and lower bearing shell halves are not interchange-able.

Lower main bearing shells have two tangs on each side which fit into the main bearing cap. Upper main bearing shells have one tang which fits into a groove on the right side of the "A" frame bore. Upper shells can be rotated out, in a direction opposite to normal crankshaft rotation, when the lower bearing and cap are removed.

MAINTENANCE

REMOVAL AND INSTALLATION

The lower main bearings are removed with the caps. All upper main bearings, except the two center bearings, are removed by inserting the upper main bearing shell remover into the journal oil passage and rotating the crankshaft opposite to normal rotation. Upper bearings on Journals with-out oil holes can be removed by using a small piece of brass to push out the bearing while rotating the crankshaft. When installing upper bearings, they should be rotated into position by hand. This will ensure proper alignment of bearing tang. Do not install bearing with remover tool.

SCHEDULED RENEWAL

Lower main bearings should be replaced at the intervals specified in the Scheduled Maintenance Program. This renewal should be made in complete engine sets. Steel-backed upper main bearings have approximately twice the life expectancy of the loaded lower half. Upper main bearings should not be removed at scheduled lower bearing maintenance intervals unless lower bearing shows signs of distress. However, upper half main bearings should be inspected at major overhaul

periods and, if dimensionally satisfactory, should be cleaned up and reused. See preceding crankshaft installation procedure for additional information.

INSPECTION
Interim inspection of the lower main bearings should only be necessary when abnormal conditions are observed in the engine, such as contamination of lube oil due to dilution with fuel or water, or foreign material being found in the lube oil filters, screens, or engine oil pan.

This should be a visual inspection made by dropping the cap and bearing. The lead-tin overlay on the bearing is primarily provided for "break in" purposes. The fact that part, or all, of this coating may have worn away should cause no concern, as long as all bearing shells have the same relative appearance. DO NOT UNDER ANY CIRCUMSTANCES REVERSE THE BEARING IN THE CAP.

Replacement of an individual lower main bearing in distress should be made only if all other lower main bearings have some lead-tin overlay remaining in the loaded areas. If one or more of the other lower main bearings has all the lead-tin overlay worn off the loaded area, then ALL lower main bearings must be renewed to ensure crankshaft alignment. If any lower main bearing shows definite signs of distress, the upper main bearing should also be examined. Used lower bearings should not be installed on any crankshaft journals other than the journals from which they were removed. Used bearings must be installed in their original position relative to shaft rotation.

CRANKSHAFT THRUST COLLAR

DESCRIPTION

The two thrust collars, Fig. 5-5, are solid bronze and are semicircular in shape. One face of each collar has "thumb print"

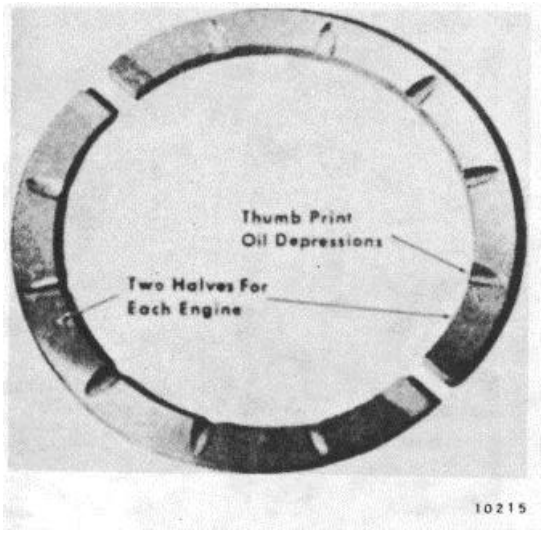


Fig. 5-5. Crankshaft Thrust Collars

oil depressions to ensure adequate lubrication. They are placed in the counter-bore of each center bearing "A" frame and are held in position by the bearing caps. Their purpose is to limit the longitudinal movement of the crankshaft.

The thrust surfaces are lubricated by main bearing leak-off oil and are installed with their "thumb print" oil depressions away from the "A" frame in which they are placed.

MAINTENANCE

Thrust collars which exceed clearance limit should be replaced.

HARMONIC BALANCER

DESCRIPTION

The harmonic balancer, Fig. 5-6, is used on the engine to dampen torsional vibration in the crankshaft. Construction and parts of the harmonic balancer are shown in Fig. 5-7. The harmonic balancer drive springs receive oil from the crankshaft through radial passages in the spring housing.

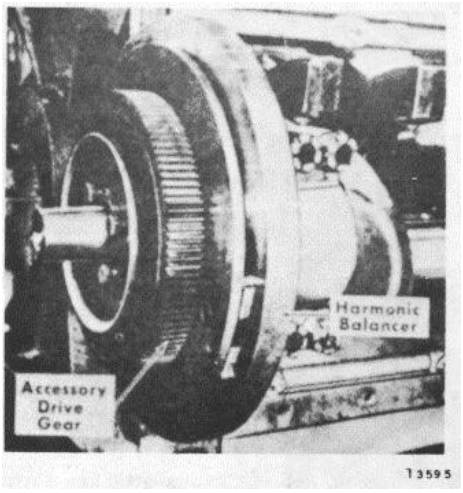


Fig. 5-6. Harmonic Balancer And Accessory Drive Gear

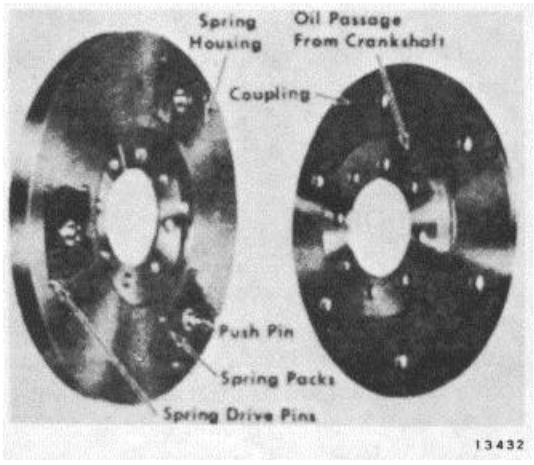
MAINTENANCE

The harmonic balancer should be inspected at intervals specified in the Scheduled Maintenance Program. The balancer should be removed from the crankshaft, disassembled, spring leaves or packs re-placed, and push pins rotated to present a new contact surface to the springs.

DISASSEMBLY

Prior to disassembly, identify the assembly of the front and rear couplings so that they will be reassembled in the same position. Place supports around the outer periphery of the spring housing to raise balancer above top of work bench. Using a brass or other soft metal drift, slightly smaller than end of push pins, drive push pins from top of coupling. Drive alternately on push pins until front coupling can be removed. After front coupling is removed, drive push pins from spring packs and housing. Support rear coupling and drive out push pins.

Fig. 5-7. Harmonic Balancer With Front Coupling Removed



INSPECTION

Examine balancer parts and remove burrs, particularly on spring pins and push pins. Spring pins having 1/8" flat or more should be rotated. Spring pins which are loose or galled on the end should be replaced with oversize pins.

Check spring pins for equal height on each side of the spring housing. Although it is doubtful that the 1/2" spring pins will make impressions in the coupling inner face, the face should be checked. Couplings having impressions exceeding maximum allowable depth should be re-placed. Impressions less than maximum allowable depth should be blended.

Check surfaces of spring cells nearest circumference of spring housing for non-uniform wear, due to centrifugal force and flexing of the springs. Replace spring housing if wear exceeds maximum limit. Replace all outer spring leaves. If inner spring leaves are galled, replace with new leaves as required.

Clean oil passages in couplings and spring housing.

ASSEMBLY

Prior to reassembly, remove any burrs or roughness from coupling mating surfaces. Place the rear coupling on a work

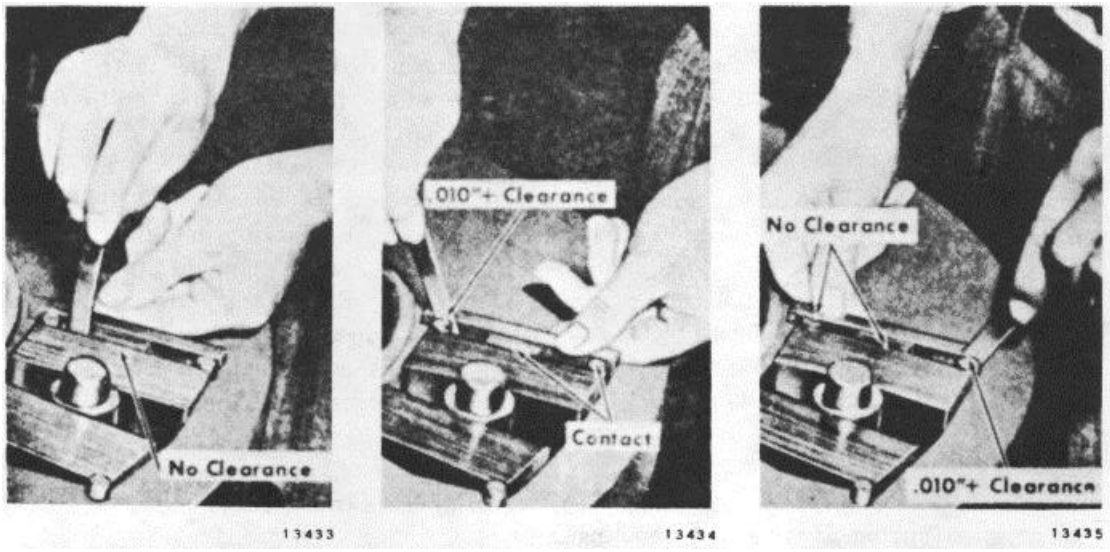
bench and drive push pins in place, being sure worn surfaces of pins are not in a position to contact springs. Use white lead or other suitable lubricant on push pin ends.

Place spring housing on the coupling, with side marked "FRONT" up. Apply spring packs to each side of push pins. About 82 to 84 spring leaves are required for each pack and their weight is about 4 lbs. 5-1/4 ozs. Stack leaves before applying and remove any that are longer, shorter, or wider than the majority of other leaves. The leaves do vary in thickness. Space springs to obtain same clearance on both sides in relation to spring pins. Apply packs with several leaves less than normally required, as it is much better to add leaves when checking, than to attempt leaf removal once assembled. Leaves can be added by starting one corner of the leaf and tapping down into the pack, using a light steel hammer.

After all packs of about right quantity have been applied, each pack should be gauged using a deflection gauge. Apply gauge as shown in Fig. 5-8A and check for clearance between springs and gauge block. With gauge in position, there should not be any clearance between gauge block and springs. Make this check on each pack. If one pack has more clearance than the opposite pack, insert leaf in side having least clearance. If clearance still exists, add leaves to each pack until there is no clearance between gauge block and springs as shown in Fig. 5-8A, and the gauge bar ends just clear the spring pins.

When gauge is held so center block contacts the springs and one end of the bar contacts a spring pin as shown in Fig. 5-8B or C, there should be a minimum clearance between the opposite bar end and spring pin. This clearance should also be obtained with the gauge bar placed against the other pin.

Follow the preceding gauging sequence on pairs of spring packs diametrically opposite starting packs. Repeat sequence on adjacent packs until all packs have been gauged and proper quantity of spring leaves added. Recheck all spring packs.



Block To Spring
A

Bar To Pin - L.S.
B

Bar To Pin - R.S.
C

Fig. 5-8. Harmonic Balancer Spring Gauging

Upon completion of spring pack assembly, install front coupling. Line up identification marks which were placed on front and rear couplings at disassembly. Place coupling over push pins. Drive coupling down evenly against the shoulder of the push pins. Mark location of oil passages on coupling hub to aid installation of balancer to crankshaft, as oil passage must line up with oil hole in crankshaft.

Raise the assembled balancer clear of the bench using a sling in the mounting holes. Using a .0015" feeler gauge, check that gauge can not be inserted between the coupling mounting flanges. If it can be inserted, foreign particles or burrs are present on the flange surface which will require disassembly of the balancer to clean.

With the balancer still suspended, check clearance between top of spring pack and coupling. A .010" feeler gauge should pass between coupling and spring pack. If gauge does not pass, lightly tap the coupling above the pack with a rawhide mallet, at the same time checking with the gauge. This procedure will provide the necessary clearance.

INSTALLATION

Prior to installing the harmonic balancer on the crankshaft, use an air hose to re-move any foreign matter, and oil spring packs with engine oil.

Place balancer on crankshaft with side stamped "FRONT" facing out. Apply two mounting bolts diametrically opposite and tighten a l t e r n a t e l y to draw balancer against flange on crankshaft.

If original spring housing and couplings are being used, the four dowels can probably be installed without reaming. However, if a new coupling and/or a new spring housing is used, it will probably be necessary to ream the dowel holes before dowels can be installed.

After the four dowels are installed, re-move the two mounting bolts. Install the dowel retainer plate and apply the four 1/2" bolts to the dowels, hardened washers, and the four 7/8" mounting bolts. Torque 7/8" mounting bolts to 500 ft-lbs, tighten 1/2" bolts, and lockwire.

ACCESSORY DRIVE GEAR

DESCRIPTION

The coil spring design accessory drive gear, Fig. 5-6, dampens the transmission of crankshaft torsional vibrations to the accessory gear train. The accessory drive gear meshes directly with and provides the drive for the lube oil scavenging pump and the main lube oil and piston cooling oil pump. It also provides drive, through intermediate gears, to the governor drive gear and the water pump drive gears.

As shown in Fig. 5-9, the gear consists of two discs, hub, gear, four coil springs, eight spring segments, two dowels, and four mounting bolts. The oil slinger is applied when the gear is installed on the crankshaft. Each coil spring is contained within two spring segments. Slots in the outer disc align with tabs on the front of the segments. The hub serves as a pilot for the gear and spacer for the discs. The complete assembly is mounted on the crankshaft, and force is transmitted through the discs, spring segments, and coil springs to the gear.

Lubrication for the gear is supplied from the crankshaft through drilled holes in the hub to the gear.

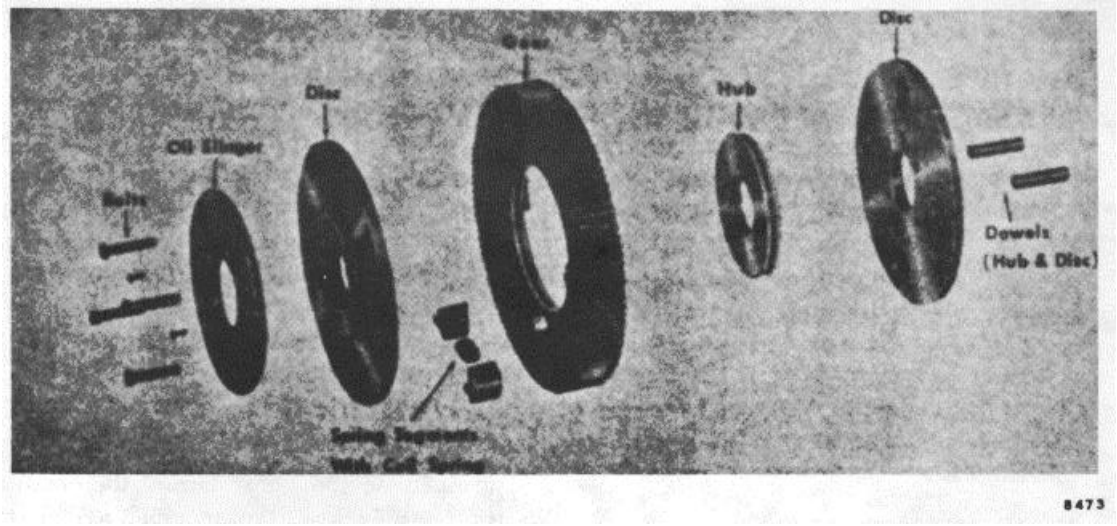


Fig. 5-9. Accessory Drive Gear, Exploded View

MAINTENANCE

The accessory drive gear should be removed and inspected at intervals specified in the Scheduled Maintenance Program or at the time of a complete engine overhaul. The accessory drive gear requires very little maintenance. At inspection intervals, it should be disassembled for inspection of parts.

Parts which show obvious damage should be replaced.

GEAR

The gear should be inspected for rough or scored surfaces on the gear teeth, and Magnaflux inspected as outlined in Maintenance Instruction 1754.

If wear in excess of maximum limit occurs on the drive side of holes, the gear should be reversed. The serial number side of the gear is placed adjacent to the oil slinger at original installation. To identify the drive side when gear is reversed, the original serial number should be ground off and re-stamped on the opposite side.

The maximum bore diameter is permissible, provided that the hub to gear clearance does not exceed the maximum limit. (This bore may be chrome plated and reground to new dimension.)

HUB

A hub having a 7.4975" diameter may be used if the maximum hub to gear clearance is not exceeded.

DISC

The disc may be re-used providing the spring segment bores do not exceed maximum diameter and are otherwise in good condition.

SPRING SEGMENTS

Spring segments should be marked, prior to disassembly, as to their relative position in the gear.

Wear should be checked on the right hand segment half (viewed at 12 o'clock position) where the segment contacts the gear bore when driving the gear. If wear at this point exceeds maximum limit, the segment half should be replaced.

When reassembling spring segments, relocate the segment, originally on the

driven side, to the drive side, and place the replacement segment at the driven side of the gear.

SPRINGS

Springs may be re-used providing a pre-load exists at assembly of the spring and segments in the gear.

PHOSPHATE TREATMENT

It is recommended that the gear, hub, discs, and segments be phosphate treated before reassembly.

ASSEMBLY

Before reassembling the drive gear, be sure all parts are clean and well lubricated. Place the slotted disc on the bench with the slots facing down, and apply the gear over the disc. Align the holes in the gear and disc. Place a coil spring between two segments, and with the tabs down, and the assembly pressed together, start it into the gear. Drive the assembly all the way down, using a rawhide mallet, until the tabs enter the slot in the disc. Repeat this operation for the three remaining spring assemblies. After they are in place, install the hub in the gear bore, and apply the top disc. Line up the dowel holes in both discs and hub, and apply the dowels. A snug dowel fit should be maintained by reaming, and if necessary, applying over-size dowels. A bolt and nut should be used to clamp the assembly together until it is applied to a crankshaft.

When applying the assembly to the crank-shaft, apply the oil slinger, dowel bolts, hardened washers, and mounting bolts. Torque the mounting bolts to 300 ft-lbs and lockwire.

RING GEAR AND COUPLING DISC (FLYWHEEL)

DESCRIPTION

The ring gear is used only for starting the engine with the starting motors or when rotating the crankshaft with an engine turning gear device. The ring gear pilots on the engine side of the coupling disc and is bolted to the coupling disc.

The coupling disc serves as the coupling between the engine crankshaft and the driven shaft. The coupling disc has a flat face flange with diametric pilots. It is connected to the crankshaft flange by sixbolts fitted to the crankshaft gear. See Fig. 5-10, for ring gear and coupling disc installation.

Degree and top dead center markings are stamped on the outer rim of the coupling disc. Holes are also provided around the circumference of the rim for insertion of a turning bar to manually rotate the crankshaft.

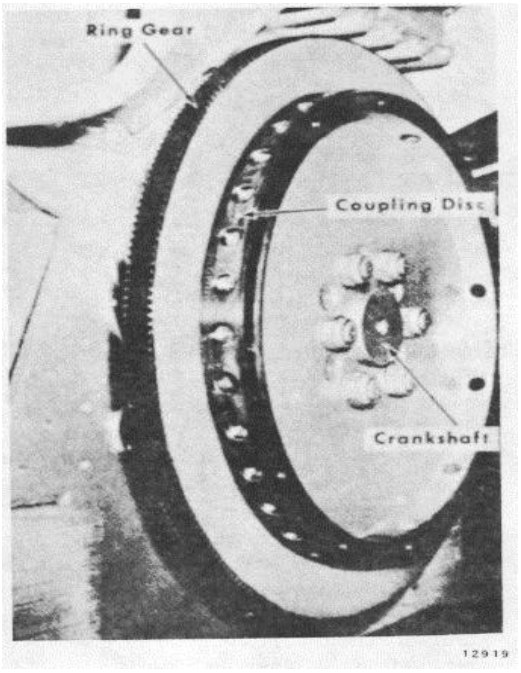


Fig. 5-10. Ring Gear And Coupling Disc Installation

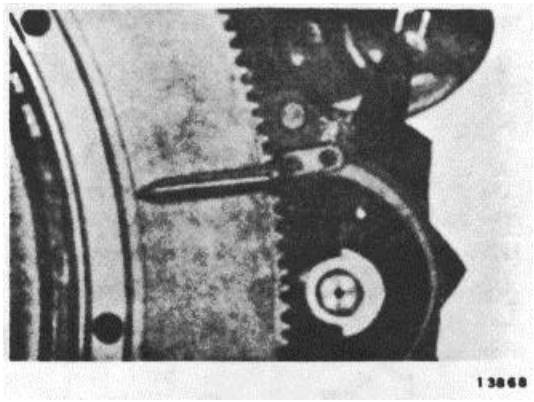


Fig. 5-11. Flywheel Pointer Location

The flexible coupling is termed a serrated coupling because of the joint between the two discs. A "V" channel is provided in the rear face of the engine coupling disc rim, while a "V" serration is located on the forward face of the generator coupling disc near the rim. This design results in a self-centering unit, with the serration acting as a guide when the coupling is assembled.

MAINTENANCE

Engine coupling discs are interchangeable, providing top dead center pointer location on the engines is the same. Engine half couplings can also be aligned to different generators equipped with serrated coupling disc. The serrated coupling is assembled without using body bound bolts and for this reason has no reamed holes. All rim bolts are the same size. The engine disc should be applied to the crankshaft with the small "O" marks on the coupling and crankshaft coinciding. This will position the coupling with the pointer at the 0° mark on the rim when the No. 1 piston is at TDC.

Tighten the 1-1/2" engine coupling bolts to a torque value of 1500 ft-lbs. Tighten the rim bolts uniformly (to avoid cocking the coupling on the serrations) to a torque value of 295 ft-lbs. The gap between the coupling halves at the rim bolts should not be less than minimum after the rim bolts have been properly torqued.

Face runout and rim concentricity should be checked after installation of coupling disc to crankshaft, and with crankshaft positioned to avoid thrust interference. Eccentricity of rim taken at the machined groove and runout on rim face should not exceed specified maximum indicator reading listed in Service Data.

CRANKSHAFT GEAR

DESCRIPTION

The crankshaft gear, Fig. 5-12, is mounted on the crankshaft at the rear end of the engine. The gear meshes with the No. 1 idler gear and provides the drive for the No. 1 and 2 idler gears, the camshaft drive gears, and the turbocharger drive gear. It is bolted to the engine coupling disc portion of the flexible coupling, providing the drive for the main generator. The gear is lubricated by leak off oil from the camshaft gear train.

MAINTENANCE

Gear teeth should be inspected for indications of fatigue. cracks, pitting and

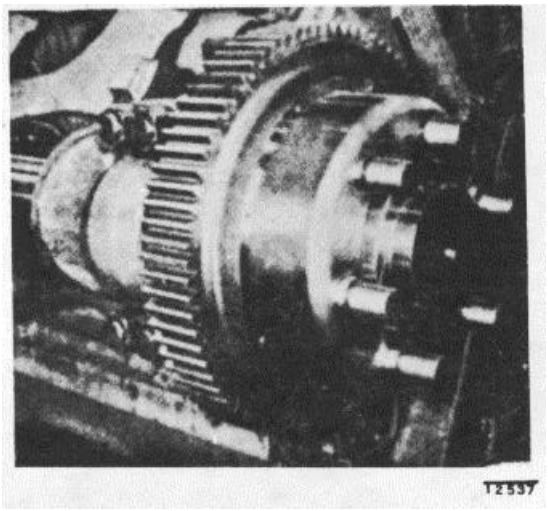


Fig. 5-12. Crankshaft Gear

other signs of distress. When possible, Magnaflux inspection in accord with Maintenance Instruction 1754 is recommended. Although no wear should occur at the oil slinger attached to the crankshaft gear, the clearance between the oil slinger and the oil seal retainer assembly should be checked when reassembled.

AUXILIARY DRIVE COUPLING

DESCRIPTION

The auxiliary drive coupling assembly, Fig. 5-13, is bolted and keyed to the tapered front end of the crankshaft to provide a power takeoff connection for components driven from the front of the engine.

MAINTENANCE

The auxiliary drive coupling does not re-quire any routine maintenance. However, replacement of the rubber center-bonded joints may be required or desired.

To facilitate removal and replacement of the rubber joints, use a remover-installer tool. When installing the rubber joints, a small amount of rubber lubricant should be applied only on the leading pressed rubber edge of the joint. Lubricant should be mixed well with three to five parts water and should be stirred occasionally while in use.

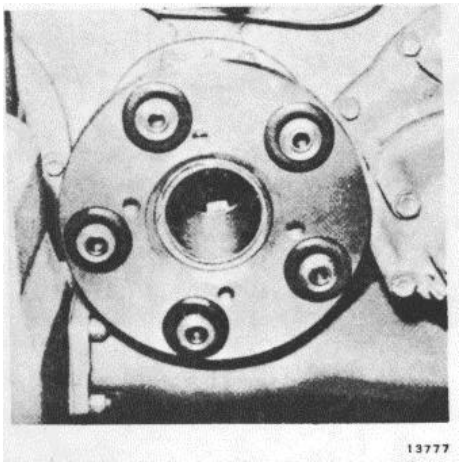


Fig. 5-13. Auxiliary Drive Coupling

The rubber joint must be installed past the normal location to properly seat the lips on the joint. The remover-installer tool must then be reversed and the joint positioned so that the required dimension is obtained from the outer surface of the coupling assembly to the shoulder of the joint. A gauge is available to measure this distance.

A minimum of 72 hours drying time is recommended before installing or utilizing the rubber center-bonded joint.

When installing the auxiliary drive coupling, the 1-1/4" - 12 bolt should be tightened to a torque of 500 ft- lbs.

567E4 SERVICE DATA

CRANKSHAFT AND ACCESSORIES

SPECIFICATIONS

Crankshaft	
Diameter, main journal - New	7.498" - 7.500"
Limit	7.4965"
Diameter, crankpin journal - New	6.498"-6.500"
Limit	6.4965"
Main Bearings	
Diameter (inside) installed, with main bearing nuts torqued to 650 ft-lbs. (average of 6-60° measurements) - New	7.5065" - 7.5095"
Min	7.505"
Clearance (diametric) main and connecting rod bearings to crankshaft - New	.007"-.011"
Limit	.015"
Number Of Main Bearings	10
The following measurements are not applicable to normal main bearing maintenance, but they should be checked when an engine has been torn down for reasons other than main bearing trouble.	
Wall thickness variation between adjacent lower main bearings having crankpin between them - Max	.002"
Wall thickness variation between center lower main bearings with no crankpin between them - Max	.0015"
Main Bearing Thickness	
Standard - Min	.368"
Undersize 1/32" - Min	.3835"
Undersize 1/16" - Min	.3990"
Thrust Bearing Clearance - New	.008" -.018"
Limit	.030"
Thrust Bearing Collar Thickness	.368" -.369"
Harmonic Balancer	
Number of leaves per spring pack (approximate)	84
Inner coupling face spring pin wear depth - Max	.020"
Wear limit on end of spring pack cell (housing) - Max	.050"

Clearance between end of gauge bar and spring pin (center block touching springs and opposite end of bar touching spring pin) - Min	.010"
Clearance between coupling mounting flanges - Less than	.0015"
Clearance between top of spring pack and coupling - Min	.010"

Accessory End Gear Train

	No. Of Teeth	Ratio To Crankshaft
Governor drive gear	113	1:1
Water pump drive gear	37	3.05:1
Lube oil pump drive gear	80	1.412:1
Scavenging oil pump drive gear	80	1.412:1
Accessory drive gear	113	1:1

Backlash (all drive gears above) - New	.008"-.016"
Limit	.025"

Accessory Drive Gear

Hub to gear clearance - New	.0015" -.003"
Max	.0035"
Diameter of gear spring segment holes - New	2.006"-2.010"
(wear on drive side of gear) - Max	.001"
Gear bore diameter - New	7.500" - 7.501"
Max (If hub to gear maximum clearance is not exceeded)	7.502"
Hub outside diameter - Min (If hub to gear maximum clearance is not exceeded)	7.4975"
Disc spring segment bore - Max	2.013"
Spring segment wear (right half as viewed from 12 o'clock position) - Max	.001"

Flexible Coupling

Clearance between coupling discs at rim bolts, after bolts are torqued - Min	.0015"
Eccentricity of rim (taken at machined groove) - Max	.005" T.I.R.
Rim face runout - Max	.005" T.I.R.

567E4 SERVICE DATA
CRANKSHAFT AND ACCESSORIES

Crankshaft Gear	
Clearance between oil slinger and oil seal retainer	.090" - .110"
Shims to obtain required clearance	
8035526	.010"
8035527	.020"
8035528	.030"
Auxiliary Drive Coupling	
Dimension from outer surface of coupling assembly to shoulder of Joint	.460" - .480"

EQUIPMENT LIST

	Part No.
Upper main bearing shell remover	8055837
Spring pack deflection gauge (harmonic balancer)	8080197
Harmonic balancer dowel puller	8225989
Auxiliary drive coupling rubber joint remover - installer tool	8239562
Rubber joint checking gauge	8254465
Rubber lubricant (1 pt.)	8258834

(For additional engine tools, see Tool Catalog)

CAMSHAFT GEAR TRAIN DESCRIPTION

Power necessary to drive the camshafts, and the turbocharger before it becomes free wheeling, is supplied through the gear train at the rear of the engine. Fig.6-1 shows the gear train before the camshaft drive housing and turbocharger are installed, and Fig 6-2 shows a cross-section of the gear train.

As shown in Fig. 6-1, the gear train consists of a crankshaft gear mounted on the crankshaft, two idler gears, and the left and right drive gears all of which are spur gears. The turbocharger drive gear is mounted on the No. 2 idler gear assembly. Rotation of the camshaft drive gears is inboard of the engine, at the same speed as the crankshaft.

Oil passages in the base of the idler gear stubshaft receive oil from the main oil manifold at the rear of the engine. One passage conducts oil from the manifold upward to the left camshaft drive gear stubshaft bracket through a jumper, and downward from the manifold to the lower idler gear stubshaft and bearing. Another passage conducts oil from the main oil manifold to the right bank camshaft drive stubshaft bracket and on to the turbocharger oil filter manifold supply line. After passing through the filter, the oil enters the return line of the filter oil manifold, returning to the upper idler gear stubshaft bore and bearing. Filter oil enters the turbocharger oil system from the upper idler gear stubshaft.

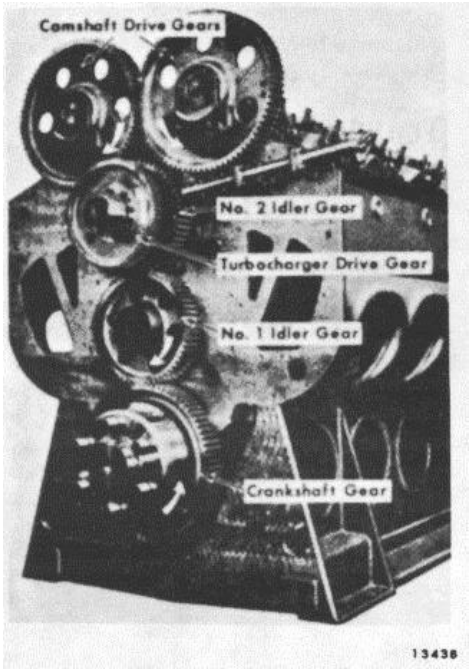


Fig. 6-1. Camshaft Gear Train

Installation of the camshaft drive housing and turbocharger assembly completely encloses the gear train.

MAINTENANCE

Gear teeth should be inspected for fatigue indications, cracks, pits, or other evidence of failure. Whenever possible, inspection by Magnaflux methods is recommended in accord with the procedures in Maintenance Instruction 1754. Gears should also be inspected for excessive backlash by inserting a feeler gauge the entire length between teeth. Excessive

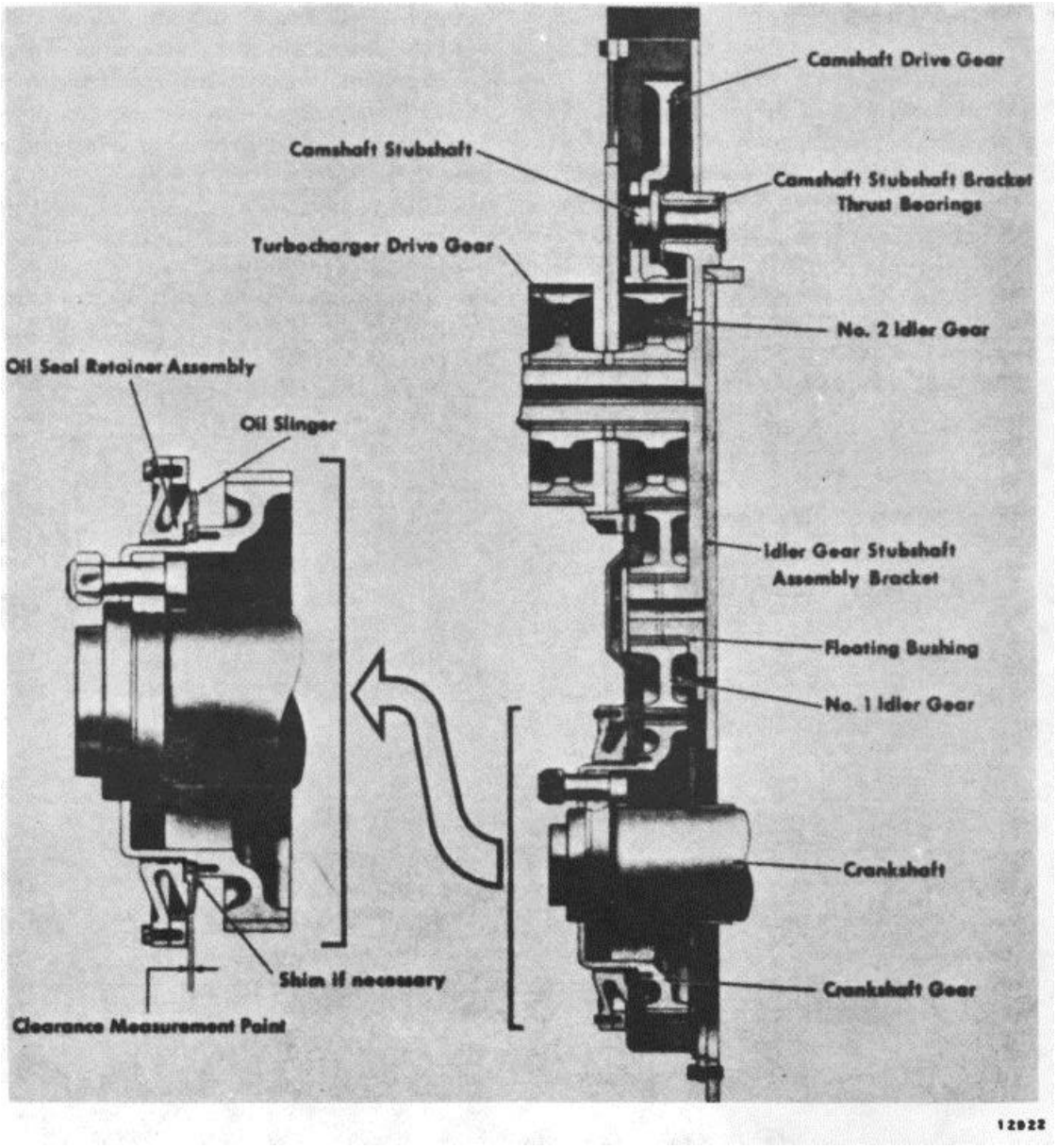


Fig. 6-2. Camshaft Gear Train, Cross-Section

backlash can cause improper valve operation and injection periods. Backlash clearance limits are given in the Specifications. Clearances between gear stub- shaft and bushings and thrust clearances must also be maintained within specified limits.

Although no wear should occur at the oil slinger, Fig. 6-2, the dimension between crankshaft gear oil slinger and the oil seal retainer should be checked with the crankshaft positioned toward the generator. Measure the distance from the outer face of the camshaft drive housing to the face of the oil slinger. Then measure the distance from the inner face of the oil seal retainer mounting flange to the inner face of the retainer tapered flange. The difference between the two measurements equals the clearance. If required, add or remove oil slinger shims to obtain proper clearance.

CAMSHAFT ASSEMBLIES

DESCRIPTION

The camshaft assembly, Fig. 6-3, consists of flanged segments, front and rear stubshafts, and a spacer used between the center segments. Each segment spans four cylinders. Segment flanges are marked as shown in Fig. 6-3 to aid in correct assembly. At each cylinder there are two exhaust cams, one injector cam, and two bearing journals. Two bearing blocks at each cylinder, equipped with steel-backed lead base babbitt lined inserts, support the camshaft.

Flanged stubshafts, mounted at each end of the camshaft in stubshaft bearing brackets, provide support for the drive gears and counterweight assemblies. One piece, thin steel-backed bronze bearing inserts are used in the stubshaft brackets. The camshaft drive gears and counterweight assemblies are bolted and doweled to the rear stubshafts, which are provided with thrust bearings. Counterweights are bolted and doweled to the front stubshafts also. The overspeed trip is incorporated in the right front counterweight.

Oil reaches the hollow camshafts through the rear stubshaft bearings which receive the oil from the main oil manifold through connecting oil lines. Each camshaft bearing is supplied with oil from the camshaft center bore. One bearing cap at each cylinder location is flanged for an oil line to the rocker arm shaft.

MAINTENANCE

CAMSHAFT REMOVAL

The camshaft may be removed without disturbing the stubshafts by removing

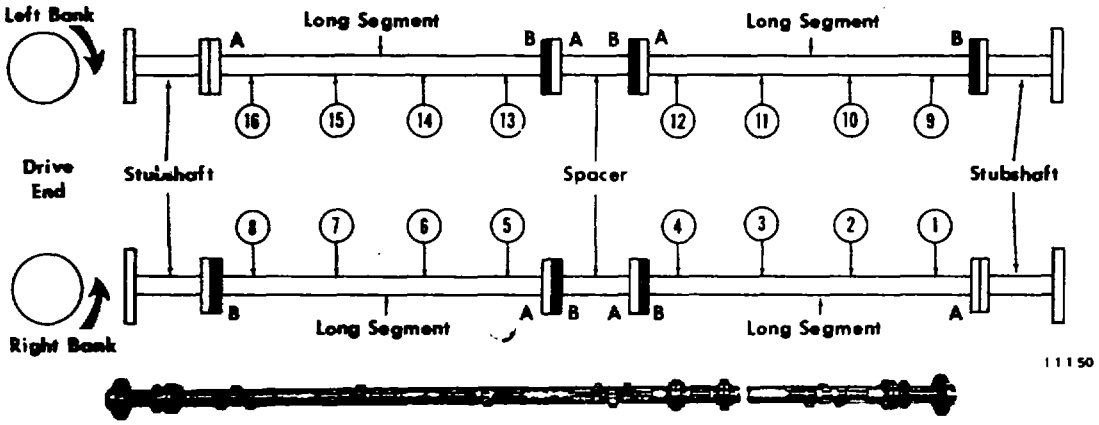


Fig. 6-3. Camshaft Assembly

the dowel bolts connecting the segment and stubshaft flanges, removing oil lines from segment bearing blocks to rocker arms, and removing rocker arms. Remove segment bearing block caps to allow camshaft removal. If the camshaft is removed for reasons other than bearing replacement, an attempt should be made to retain relative position of the bearing shells on reinstallation of the camshaft. This may be accomplished by immediately replacing caps after camshaft removal, or if the entire block is removed, by inserting block bolts and wiring the free ends of the bolts.

CAMSHAFT INSPECTION

After removal of camshaft, wash and remove all dirt from oil passages. Visually inspect stubshafts and segments paying particular attention to cam lobes and journals for pitting, chipping, excessive scoring, and heat discoloration. Journals and cams with light pit marks, minute flat spots, and light score marks may be reused after blending and removal of sharp edges by hand polishing. Check inside of dowel bolt holes for burrs and remove.

Camshaft segments and stubshafts that show heat discoloration should be Magnaflux inspected and hardness tested. See Maintenance Instruction 1754 for Magnaflux procedures. Discoloration on the unfinished portion of the camshaft should be disregarded as it results from a production process and may be seen even on a new camshaft.

CAMSHAFT ASSEMBLY

The camshaft must be assembled as shown in Fig. 6-3. One dowel bolt hole in each segment flange is smaller than .the others to ensure correct angular position. After assembly of camshaft and stubshaft, check for concentricity between the stubshaft and camshaft journals and maximum runout over total length of the shaft. Support the camshaft on precision rollers at the number 1, 7, 10, and 16 camshaft bearing journals. See Service Data for limits.

CAMSHAFT INSTALLATION

Camshaft assemblies installed on an engine must conform to segment sequence and position as indicated in Fig. 6-3. On right bank camshafts, the "A" marking on each flange is toward the front of the engine. On left bank camshafts, the "B" marking on the flange must be toward the front of the engine.

Check segment journal to bearing clearance and thrust clearance at rear stubshafts. Limits are listed in the Service Data. Clearance measurement can be obtained with feeler gauges.

Upon installation or replacement of the camshaft, lubricate freely all moving parts, place the assembly in properly aligned position after replacing blocks and bearings as removed. Rotate camshaft to check for binding. Apply flange dowel bolts and reassemble rocker arms and associated parts. Check valve timing of at least one cylinder to check segment positioning and then make other adjustments such as exhaust valve setting and injector timing.

CAMSHAFT COUNTERWEIGHT APPLICATION

Counterweight replacement usually is not necessary. However, when counterweights are installed, they should be applied in the position as shown in Fig. 6-4.

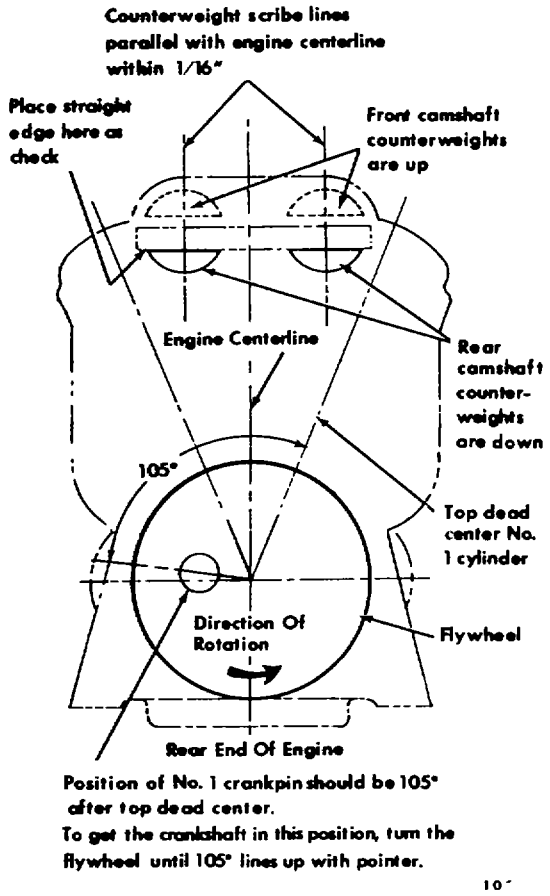


Fig. 6-4. Camshaft Counterweight Timing

VALVE TIMING

DESCRIPTION

Valve timing is very important as it ensures correct relationship of valve operation with the other events in the cylinder power cycle.

Items which govern correct valve timing are given in the following procedures.

MAINTENANCE

LOCATING TOP DEAD CENTER

If it should become necessary to check the position of the flywheel or the flywheel pointer for top dead center, proceed as follows:

TABLE 1
FIRING ORDER AND TOP DEAD CENTER

Firing Order	Top Dead Center
1	0°
8	22-1/2°
9	45°
16	67-1/2°
3	90°
6	112-1/2°
11	135°
14	157-1/2°
4	180°
5	202-1/2'
12	225°
13	247-1/2°
2	270°
7	292-1/2°
10	315°
15	337-1/2°

1. Remove injector from No. 1 cylinder.

2. Turn crankshaft in normal direction of rotation until piston is just before top center.

3. Insert top dead center checking rod through injector hole and screw into piston puller hole in crown of piston.

4. Attach dial indicator to a bolt screwed into threaded lifter hole in cylinder head, Fig. 6-5. Place indicator as shown, and depress a few thousandths of an inch.

5. Set indicator at zero and mark flywheel at pointer. Turn crankshaft in normal direction until piston moves up to and past top dead center and indicator returns to zero.

NOTE: The distance the piston travels after the indicator is attached should be within the range of the indicator.

6. Continue turning crankshaft until piston moves approximately .010" past

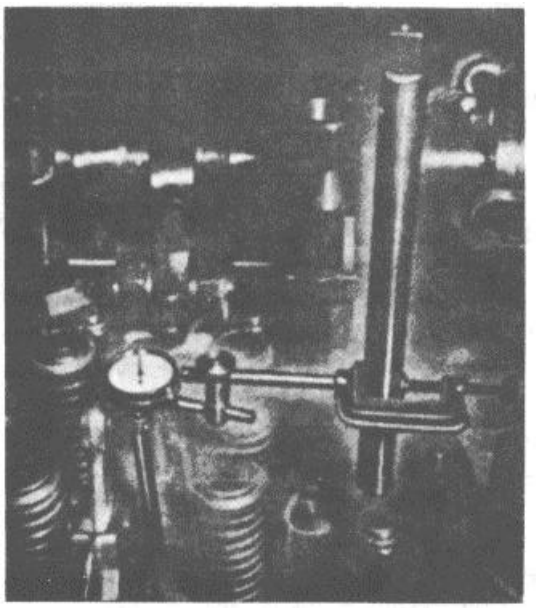


Fig. 6-5. Locating Top Dead Center

zero, then turn crankshaft in opposite direction until indicator returns to zero. This will compensate for clearance in bearings and piston assembly.

7. Mark flywheel again at pointer. Divide distance between the two marks. This point will be top dead center for No. 1 piston.

CHECKING EXHAUST VALVE TIMING

To check timing, place a dial indicator on the rocker arm adjusting screw as shown in Fig. 6-6. Valve end of rocker arm must be in its highest position, so that the exhaust valves are closed. Press indicator down approximately .100" and set dial to zero.

Turn crankshaft in normal direction of rotation until flywheel is at 106° A.T.D.C. of cylinder being checked. If timing is correct, the valve bridge will have moved down .014". Timing must not be later than 110° or earlier than 104° A.T.D.C. of cylinder being checked.

TIMING EXHAUST VALVES

When any items at the back of the engine are removed for replacement, such as camshaft assembly, stubshafts, or gears, the exhaust valves should be timed as follows:

1. Remove or loosen all rocker arms except the one on which the dial indicator is resting, as shown in Fig. 6-6. Each camshaft must be timed to the crankshaft. Checking timing of any one cylinder of each bank is sufficient.
2. Locate top dead center for the cylinder to be checked. Remove the dowels and bolts from the camshaft drive gear and remove gear. The camshaft can be rotated by placing a socket and wrench on flange bolt nuts.

3. Rotate the camshaft in its normal direction of rotation until the valve bridge on which the dial indicator is resting moves down .014".

4. Turn the crankshaft in the normal direction until flywheel pointer is at 104° after top dead center of the cylinder being checked. If a new gear

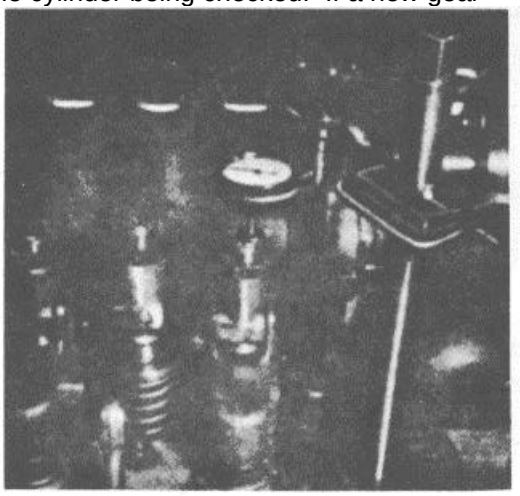


Fig. 6-6. Timing Exhaust Valves

train has been installed, the timing may be as early as 104° but not later than 106°. Unless a new gear train has been installed, it is preferable to set timing as near to the 106° mark as possible. With flywheel at 104° A.T.D.C. of the cylinder being checked, the dowel holes in the camshaft drive gear applied and dowel holes in the camshaft stubshaft should be in line or approximately in line with each other. If by turning the crankshaft from 104° to 106° A.T.D.C., the dowel holes can be made to line up, then the bolts should be tightened. If the dowel holes do not line up within this tolerance, remove the camshaft gear from its stubshaft. Turn the gear 180° and replace on stubshaft or move the gear one tooth and replace on the stubshaft. The dowel holes should then line up.

5. If it is not possible to line up the dowel holes perfectly, they may be reamed oversize and oversize dowels installed. This will eliminate the necessity of redrilling the gear and stubshaft. Secure gear to its stubshaft.

6. The crankshaft should now be rotated in its normal direction and the timing checked so that the valve bridge of the valve being checked has moved down .014", when the flywheel timing pointer is at 104°-106° A.T.D.C.

7. After timing has been completed, the relative positions of the mating parts should be identified similar to the method used on new engines, shown in Fig. 6-7. The mating parts are marked with No. 1 piston at top dead center.

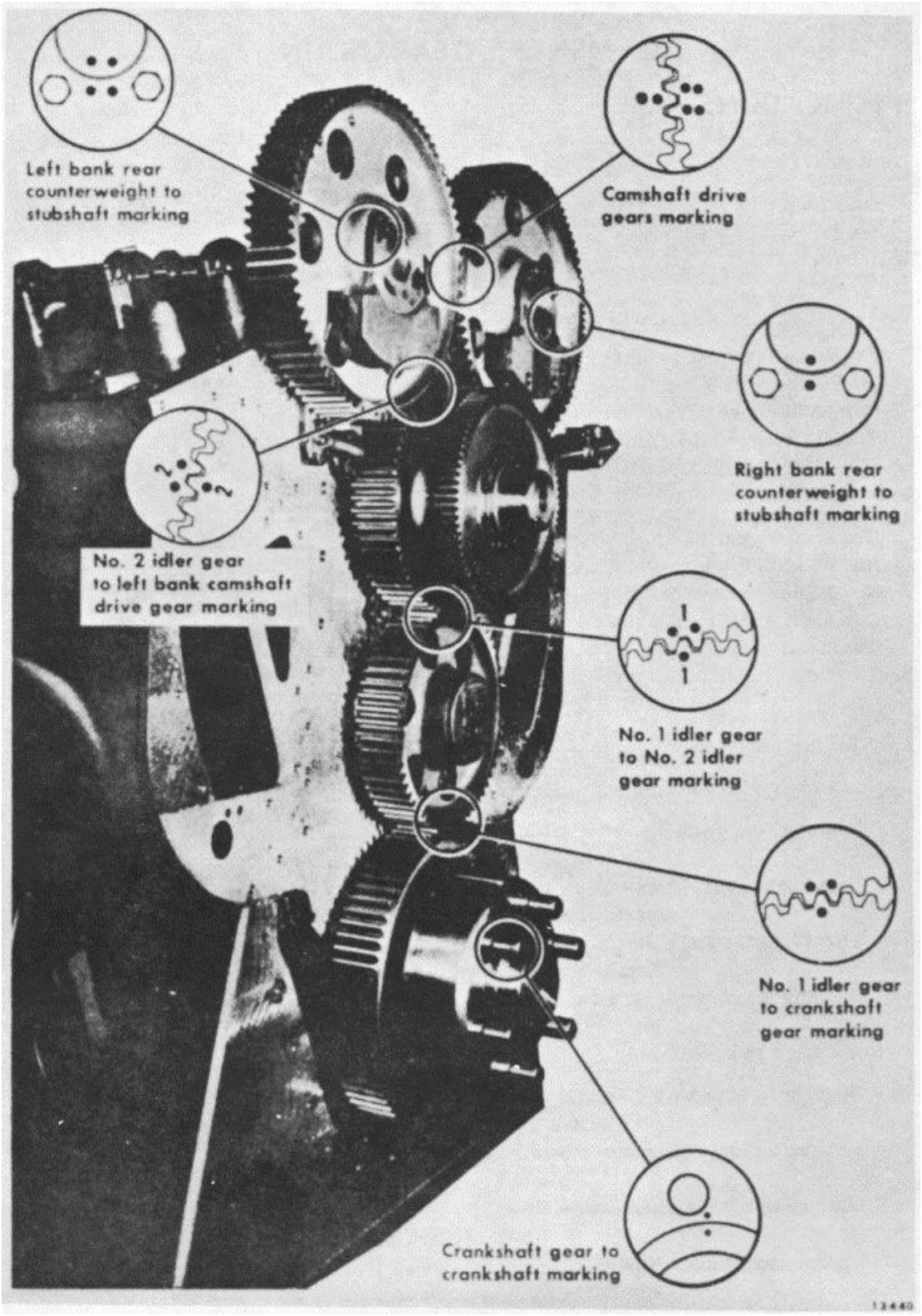


Fig. 6-7. Camshaft Gear Train Marking

567E4 SERVICE DATA

CAMSHAFT GEAR TRAIN

SPECIFCATIONS

Crankshaft Gear

Oil slinger to oil seal retainer clearance	.090" - .110"

Gear Data

	No. of Teeth	Ratio to Crankshaft Gear
Crankshaft (60 cycle unit)	79	1:1
Idler, Nos. 1 & 2	58	1.362:1
Camshaft Drive	79	1:1
Turbo Drive (on No. 2 idler)	87	1.362:1
Crankshaft Gear (50 cycle unit)	79	1:1

Gear Backlash

Crankshaft gear to No. 1 idler - New	.007" - .014"
No. 1 to No. 2 idler - New	.007" - .014"
No. 2 idler to camshaft drive - New	.007" - .016"
Camshaft drive to camshaft drive - New	.007" - .022"
Limit (all gears above)	.025"
Turbocharger drive to turbocharger - New	.006" - .010"
Limit	.020"

Gear Train Clearance

No. 1 idler gear assembly

Bushing to stubshaft - New	.005" - .008"
Limit	.016"
Bushing to gear - New	008" - .010"
Limit	.018"
Thrust clearance - New	.009" - .017"
Limit	.025"
Bushing minimum length	3-27/32"

No. 2 idler gear assembly

Bushing to stubshaft - New	.004" - .007"
Limit	.011"
Stubshaft sleeve diameter - New	3.999" - 4.001"
Limit	3.9975"
Idler gear bushing diameter - New	4.005" - 4.006"
Limit	4.0085"
Thrust clearance - New	.045" - .077"
Limit	.080"

Camshaft And Stubshaft

Camshaft journal diameter - New	2.496" - 2.498"
Limit	2.495"
Diametric clearance, segment journal to bearing - New	.002" - .006"
Limit	.010"
Taper length of journal - Limit	.001"
Runout (journal) T.I.R. when supported on adjacent journals - Limit	.002"
Runout (base circle relative to journal) - Limit	.003"
Mounting flange (not convex) flat within* - Limit	.0005"
Mounting flange square with longitudinal centerline within, T.I.R.* - Limit	.001"

* (Correct by grinding faces)

Dowel bolt holes in flanges

One hole	.439"
Three holes	.5015"
Stubshaft journal diameter - New	2.497" - 2.498"
Limit	2.495
Diametric clearance, journal to bearing - New	.0035" - .0075"
Limit	.010"
Stubshaft thrust clearance - New	.010" - .018"
Limit	.025"
Dimension between thrust faces - Max	4.195"

Camshaft Timing

Ideal timing setting, valve open .014" - A.T.D.C.	106°
Timing of new gear train not earlier than - Max.	2°
or	
at .014" valve opening - A. T. D. C.	104°
Limit of lag - camshaft behind crankshaft due to worn gears - Max.	4°
or	
at .014" valve opening - A.T.D.C	110°
Flywheel pointer setting - T.D.C. of No. 1 cylinder	0°

Overspeed Trip (60 cycle unit)

Clearance, trip latch to flyweight - Min	.010"
Trip setting - RPM	855-870

EQUIPMENT LIST Part No.

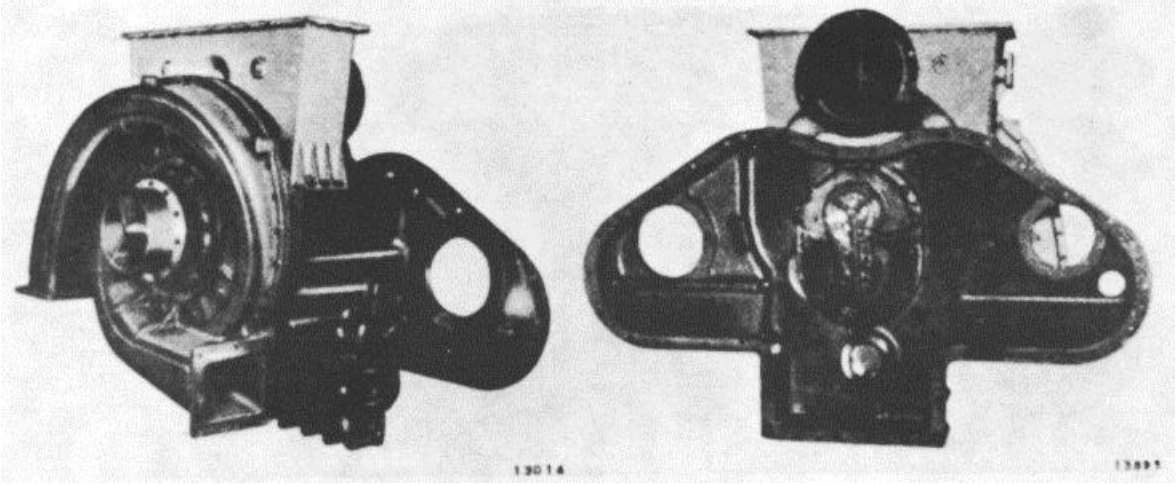
Top dead center checking rod	8051833
Dial indicator	8255423
Feeler gauge set	8067337

AIR INTAKE AND EXHAUST SYSTEMS

TURBOCHARGER

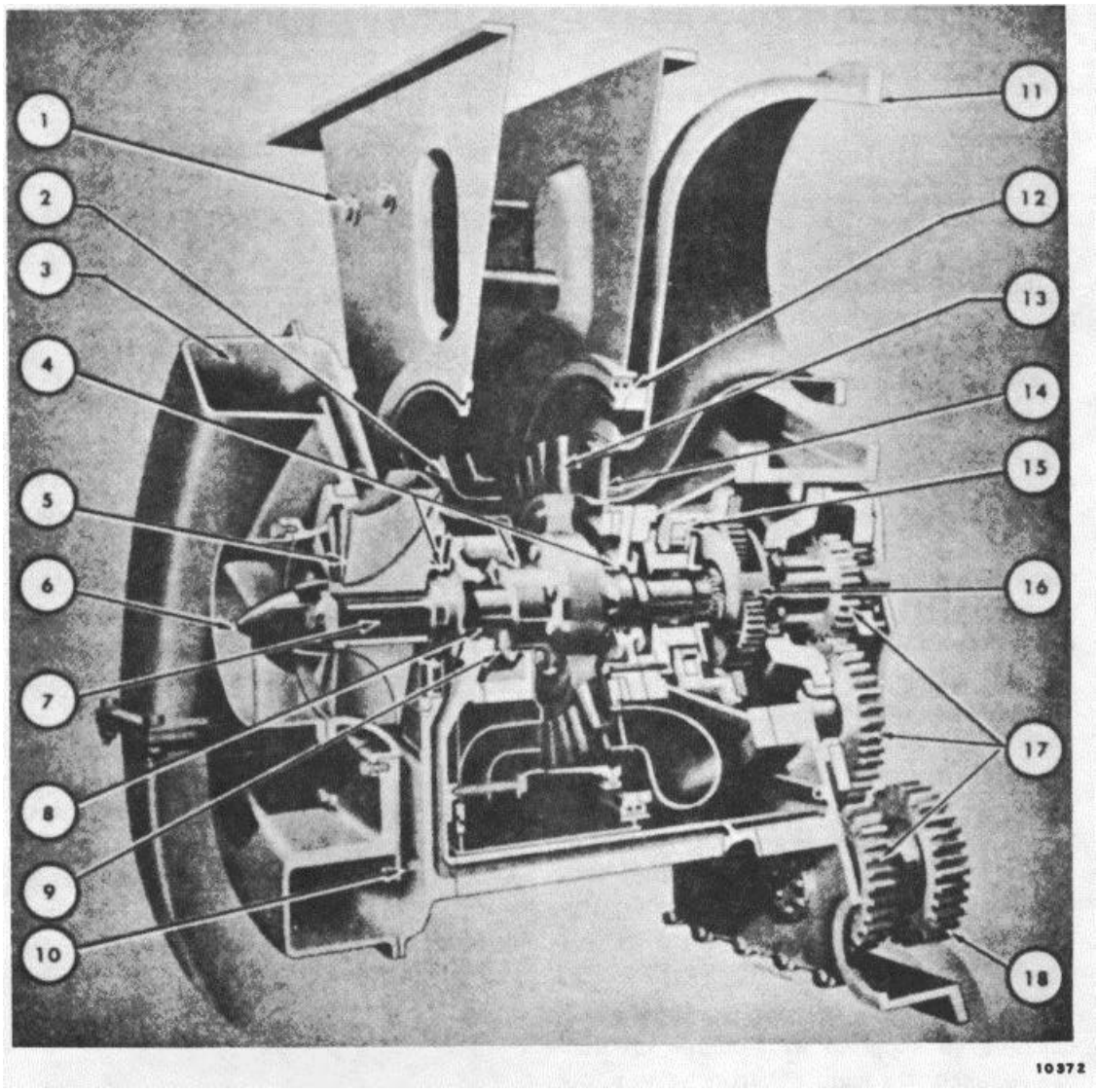
DESCRIPTION The turbocharger assembly, Fig. 7-1, is primarily used to increase engine horse- power and provide better fuel economy through the utilization of exhaust gases. As shown in Fig. 7-2, the turbocharger has a single stage turbine with a connecting gear train. The connecting gear train is necessary for engine starting, light load operation, and rapid acceleration. Under these conditions there is insufficient exhaust heat energy to drive the turbine fast enough to supply the necessary air for combustion, and the engine is actually driving the turbocharger through the gear train assisted by exhaust gas energy. When the engine approaches full load, the heat energy in the exhaust, which reaches temperatures approaching 1000° F., is sufficient to drive the turbocharger without any help from the engine. At this point, an overrunning clutch in the drive train, Fig. 7-2, disengages and the turbocharger drive is mechanically disconnected from the engine gear train.

The turbine shaft is driven by the engine gear train through a series of gears in the turbocharger. A turbocharger drive gear is bolted to the No. 2 engine idler gear, which is mounted on a stubshaft. The drive gear meshes with the turbocharger idler gear, driving the carrier shaft gear. The carrier shaft drives the sun gear on the turbine shaft through three planet gears when the turbocharger is being driven by the engine. The sun gear meshes with the planet gears which, in turn, mesh with a ring gear in the



Front View Rear View

Fig. 7-1. Turbocharger Assembly



1. Exhaust Duct
2. Diffuser
3. Compressor Discharge Scroll
4. Labyrinth Oil Seals
5 Impeller
6. Compressor Air Inlet Nose Cone
7. Turbocharger Shaft
8. Bearing
9. “Heat Dam" Thrust Washer
10. Compressor Diffuser
11. Turbine Inlet Scroll (Engine Exhaust Inlet)
12. Exhaust Seal Rings
13. Turbine Blades
14. Stationary Nozzle Ring
15. Overrunning Clutch
16. Planetary Gear Assembly
17. Drive Gear Train
18. Engine Idler Gear

Fig. 7-2. Cutaway View of Turbocharger

overrunning clutch assembly. The ring gear is fixed when the engine is driving the turbine because the direction of torque at the ring gear locks the overrunning clutch. When the turbine is being driven entirely by exhaust gas energy, the direction of torque is reversed and the clutch overruns, allowing the ring gear to rotate.

The overrunning clutch consists of 12 rollers in tapered slots, as shown in Fig. 7-2. The slots are formed by the combination of a stationary clutch support and the pockets in the cam plate. The cam plate, ring gear support, and the ring gear are dowelled and bolted together, and rotate as a unit. When the engine is driving the turbine, the rollers are wedged in the small side of the cam plate pockets, as a result of the direction of torque, locking the cam plate to the stationary clutch support. This locking action pre- vents the ring gear from turning. Because the planet gear shafts are driven as a part of the carrier shaft, the planet gears rotate in the locked ring gear to drive the sun gear on the turbine shaft. When the exhaust energy becomes great enough to drive the turbine without help from the engine, the torque at the sun gear, planet gears, and ring gear reverses direction. This causes the rollers to move to the wide end of the cam plate pocket, unlocking the clutch, permitting it to overrun, and allowing the ring gear to rotate. From this point on, with increased load and speed, the turbocharger overruns the engine drive and the planet gears slowly turn the ring gear.

When the engine is running, the turbocharger is supplied with engine oil that has passed through a turbocharger oil filter mounted on the camshaft drive housing at the right rear side of the engine. Oil leaving the turbocharger empties into the gear train housing and returns to the oil pan. A low oil pressure switch is connected through an oil line into the turbocharger oil system.

To ensure lubrication of the turbocharger when the engine is started, and to provide significant dissipation of heat from the turbocharger after the engine is shut down, a separate electrically driven turbo lube oil circulating pump is used. Lubricating oil from the pump goes through an off- engine auxiliary turbo lube oil filter, a soak back filter, a check valve, and into the turbocharger. The check valve prevents the soak back oil from entering the main oil system when the engine is shut down. Another check valve, located in the flexible soak back line, prevents main system oil pressure from entering the soak back system when the engine is running. The soak back pump motor is controlled by a switch, which is normally left in the ON position.

Except under emergency conditions, the engine should be allowed to run at idle speed for two minutes after every start. This applies also if the cooling system water temperature is below 130° F. at the time the engine is started; and when starting the engine after oil filter changes, to provide a full oil system. Prolonged operation at no load or low load is also not recommended, since such operation can result in an accumulation of oily car-V bon in the exhaust system.

MAINTENANCE

REMOVAL

1. Remove root hatch.
2. Disconnect and remove the water lines to and from the aftercooler assemblies.
3. It is advisable to remove the aftercoolers from the ducts rather than to remove them as an assembly, because of the weight involved.
4. Remove the soak back oil line clamp from the right aftercooler duct.

5. Disconnect soak back oil line from check valve on turbocharger housing.
6. Remove both aftercooler ducts.
7. Remove the oil separator assembly.
8. Remove the expansion joint between the turbocharger and the engine exhaust manifold.
9. Disconnect the exhaust stack from the top of the turbine exhaust duct. Remove the stack through the roof hatch.
10. Remove air duct assembly from turbocharger air inlet assembly and remove air inlet.
11. Connect lifting chains to eyes screwed into the four tapped bosses on the turbocharger. Maintain even tension on all four chains so that turbocharger will hang properly. If a hand-operated chain hoist is available, it should be used between the chain device and the main lifting crane to simplify vertical positioning and tension adjustment during turbocharger removal. Do not allow chains to drag against the exhaust duct.
12. Remove bolts attaching turbocharger housing to camshaft gear train housing. The turbocharger is now held in position by the No. 2 idler gear stubshaft and the lifting device.
13. Using jackscrews between the turbocharger housing and the gear train housing, jack the turbocharger away from the engine until the turbocharger clears the No. 2 idler stubshaft.

NOTE: Care should be exercised, when removing turbocharger, that No. 2 idler gear is not disengaged from camshaft drive gear, as engine timing will have to be checked if gear is disengaged.

14. Using a 1-ton crane, lift the turbocharger clear of the engine and place it in shipping container for transportation.

PREPARATION FOR INSTALLATION

The following steps should be adhered to if the turbocharger is being replaced because of a failure, if not, some of the steps may be ignored. The turbocharger should remain in the shipping container until actual application.

Air Box Inspection

1. Clean the air box to remove all evidence of aluminum dust and chromate or borate water stains.
2. Inspect the cylinder assemblies for broken valves, valve blow, cracked pistons, broken piston rings, scored pistons and liners.
3. Determine the cause of the turbocharger failure and correct any conditions that might have aggravated the failure.
4. Clean all gasket surfaces on the engine, the turbocharger to be applied, and the air ducts. Remove any nicks or burrs so as to present a smooth surface.

Gear Train Inspection

1. Visually check the gear train for nicks, burrs, evidence of improper backlash, and uneven or excessive wear. Make any necessary corrections.

2. Clean the No. 2 idler turbocharger locating stubshaft, using an oil stone. Remove all indications of fretting. Inspect the seal groove for nicks and burrs, and smooth the surface after removal of any nicks or burrs.

3. Check the gear train area and remove any metallic debris that might be found.

Exhaust Manifold Inspection

1. Inspect the exhaust manifold for any foreign material, such as, pieces of exhaust valve heads, debris from any cylinder assembly failure, and fragments of manifold expansion joints. Completely remove any foreign material found. The manifold should be removed. if in doubt, to look for foreign material, cracked leg baffles, which should be removed, and cracked expansion joints, which should be re-placed.
2. Inspect the condition of the exhaust manifold leg gaskets and the torque on the bolts. which should be 130 ft-lbs. Also, check the manifold connector fasteners which should be 80 ft-lbs. Check the condition of the adapter to turbocharger bellows connections, and other locations where possible leaks might occur in the exhaust system.
3. Inspect the adapter assembly between rear extension joint and chamber assembly for condition of screen. If foreign material is present in the exhaust manifold, it is recommended that the screen be Magnaflux inspected.

Lubricating Oil System

1. Remove the disposable turbocharger oil filter element. Install a new element and check that the filter bowl is full of clean lubricating oil and that the spring and gasket is in place. Clean soak back filter and bowl.
2. If required, drain and completely clean the system.
   a. If the oil system is contaminated with debris, flush the system as outlined in Maintenance Instruction 1757, and install new filter elements.
   b. Install new main oil filter elements, and clean and check the main oil filter relief valves.
   c. Recharge the oil system after the replacement turbocharger is applied and the oil system and all filters have been conditioned to receive the new clean oil.
   d. Check the soak back pump function and operation. Check the soak back pump bypass relief valve for proper operation.

Air Intake Filter Inspection

Before installing the turbocharger, the engine air intake filters should be checked for foreign material. Completely clean filter if foreign material is found.

INSTALLATION

1. Apply the lifting device to the turbo- charger as described in the turbo- charger re m ova 1 procedure. (The turbocharger shipping container, plus the masking of all openings on the turbocharger is the best protection and insurance against damage, rust, and contamination that can be given the turbocharger prior to installation.)
2. To determine the impeller eye clearance, remove the nose cone before removing the turbocharger from the container pedestal. Chalk mark an impeller blade at the 12 o'clock position when the eye clearance is re- checked after turbocharger installation. Two sets of feeler gauges should be used when making this check. Clearances should be determined with a heavy drag on the feelers. Refer to Service Data at the end of section for clearance limits. Perform check as follows:
   a. Insert approximately the same feeler gauge thicknesses at the ends of the impeller blades at the 3 and 9 o'clock positions simultaneously to determine the available horizontal clearance. Record the clearances.

b. A feeler gauge should be used at the 12 o'clock position to determine the upper vertical clearance. Leaving the feeler gauge in position at the 12 o'clock position, use another feeler to determine clearance at the 6 o'clock position. Record the clearances obtained.

3. Apply a thin coat of gasket compound to the camshaft drive housing and apply a new gasket to the housing.
4. Apply a new "O" ring seal to the engine No. 2 idler stubshaft.
5. Apply some clean lubricating oil to the No. 2 idler stubshaft and to the turbocharger drive gear.
6. Lift the turbocharger and remove covering from all openings, except the exhaust stack and exhaust inlet duct.
7. Align the turbocharger, guiding it onto the No. 2 idler stubshaft and into position. Care must be taken to ensure proper mesh of the turbocharger idler gear and the turbocharger drive gear on the engine.
8. Use hardened washers under the 3/4" bolts, and apply all the turbocharger to camshaft drive housing bolts before removing the lifting device. Snug up bolts, but do not tighten.
9. When the correct backlash is obtained, torque the 1/2" turbocharger mounting bolts to 65 ft-lbs, the 3/4" bolts to 175 ft-lbs, and the 3/8" bolts to 24 ft-lbs.

AIR DUCT AND AFTERCOOLER APPLICATION

If a different aftercooler core is to be installed, proper core alignment to the duct must be ensured before application can be made. The air ducts must be re- ¾moved from the engine to accomplish alignment. Remove the lockwire from the support pad bolts at the rear of the duct, and loosen the bolts. Position the core in the duct until the dowels on the core align with the dowel holes in the support pad. Tighten support pad bolts, torque to 130 ft-lbs, and lockwire. Remove the core and proceed as follows with application.

1. Apply the gaskets to the air duct assemblies.

2. Carefully maneuver the right bank air duct into position and apply the bolts at the engine and turbocharger flanges. One bolt at the engine flange must be installed from inside the duct. Make sure that air duct flange on the engine side is not touching the cam- shaft drive housing. Snug the bolts only at the turbocharger end, but torque the bolts at the engine end to 65 ft-lbs. Then remove the bolts from the turbocharger end of the air duct, and with the gasket in place, and using a .008" feeler gauge, determine the clearance at the mating flanges. If a .008" feeler gauge can be entered between the turbocharger and the air duct, the duct must be relocated. If necessary, the holes in the engine flange may be enlarged so as to position the duct properly.
3. Apply the left bank air duct using the same procedure as used on the application of the right bank air duct.
4. Tighten the air duct to turbocharger bolts to 35 ft-lbs.
5. Using a .u01" feeler gauge, check that no clearance exists between the gasket and turbocharger flange, and the gasket and air duct flange.
6. Apply gaskets to air ducts, and using a lifting device, install aftercoolers in air ducts. Apply attaching bolts and torque to 35 ft-lbs.

7. Attach water pipe to aftercoolers and torque bolts to 75 ft-lbs.
8. Attach water pipe to engine and torque bolts to 75 ft-lbs.
9. Clamp soak back oil line to tapping pad on right aftercooler air duct. Connect soak back line to check valve on turbocharger housing.

FINAL ASSEMBLY

1. Apply gaskets and install oil separator assembly.

2. Install the expansion joint between the turbine inlet scroll and the engine exhaust manifold. When assembling the expansion joint, the tapered end of the interior liner should be facing toward the front of the engine. This taper will not be evidenced by external viewing of the expansion joint.

3. Coat the threads of the expansion joint bolts with high temperature thread lubricant, apply, and torque to 80 ft-lbs.

4. In bolting the expansion joint to the manifold, it is recommended that one flange of the expansion joint be securely bolted to the manifold before attempting to bolt the other flange. If the holes of the second flange do not align with the flange of the inlet scroll, do not pry into alignment. This will result in undue stress placed on the expansion joint and will also reduce the internal liner clearance required for trouble-free operation. If alignment can not be acquired through repositioning the expansion joint, en- large the holes in the flange until bolts can be freely inserted and tightened.
5. Lower the exhaust stack through the roof hatch and attach to the top of the turbine exhaust duct with bolts coated with high temperature thread lubricant.
6. Check the impeller eye clearance as previously done in step 2 of "Installation" to see if the measurements can be duplicated. If the clearances cannot be duplicated, it indicates that the turbocharger has been distorted in installation. In this event, the air ducts should be removed and eye clearance rechecked. If turbocharger is still distorted, the turbocharger mounting bolts must be loosened and the turbocharger realigned so that no stresses or distortion are introduced during installation.
7. Install the air inlet assembly and air duct assembly on turbocharger.

8. Replace rod hatch.

STARTING THE ENGINE

1. Make sure the turbo lube oil circulating pump is running.

2. Make the necessary preparations and start the engine.
3. Load test the engine.

EXHAUST MANIFOLD

DESCRIPTION

The exhaust gases from the engine cylinders are discharged from the cylinder heads into the exhaust manifold, Fig.7-3, and to the turbocharger turbine. Going through the turbine, the gases expand to atmospheric pressure, pass through the turbocharger ducting, and are then expelled from the engine.

The exhaust manifold is made up of chamber assemblies, expansion joints, and adapter assembly. The expansion joints, which are used between chamber

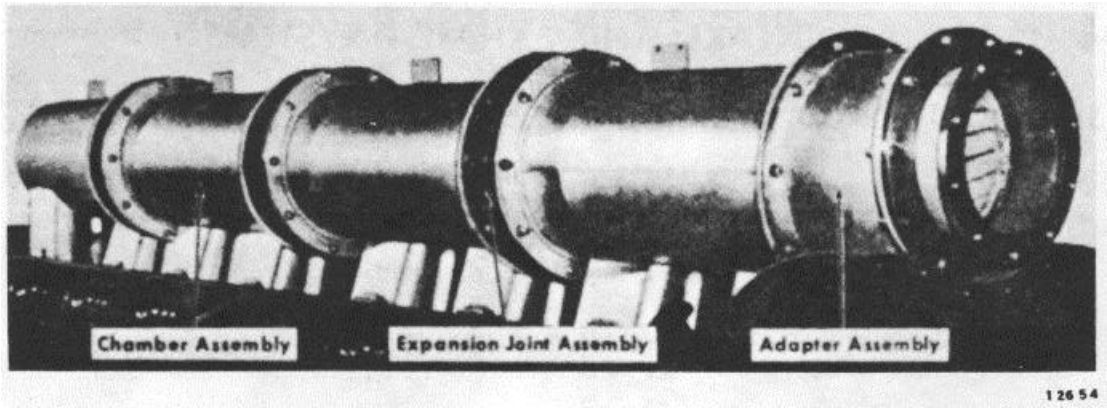


Fig. 7-3. Exhaust Manifold

assemblies and between the adapter and screen assembly and the turbocharger, provide the necessary flexibility to compensate for expansion and contraction of the manifold due to temperature changes. The adapter assembly contains a stainless steel screen to prevent the entry of foreign objects into the turbocharger.

MAINTENANCE

Inspect the adapter and screen assembly between rear expansion joint and chamber assembly for condition of screen. If foreign material is present in the exhaust manifold, it is recommended that the screen be Magnaflux inspected.

The exhaust manifold is essentially "maintenance free, " but should the manifold be disassembled for any reason, the following assembly provisions should be observed.

When assembling the expansion joints, the tapered end of the interior liner should be facing toward the front of the engine. This taper will not be evidenced by external viewing of the expansion joint.

In bolting the expansion joints to the chamber assemblies, it is recommended that one flange of the expansion joint be securely bolted to the chamber assembly before attempting to bolt the other flange. If the holes of the second flange do not align with the flange of the turbocharger inlet scroll, do not pry into alignment. This will result in undue stress being placed on the expansion joint and will also reduce the internal liner clearance required for trouble-free operation. If alignment can not be acquired through repositioning the expansion joint, enlarge the holes in the flange until bolts can be freely inserted and tightened.

567E4 SERVICE DATA

AIR INTAKE AND EXHAUST SYSTEMS

SPECIFICATIONS

Clearances And Backlash

Impeller eye clearance (check at 3 and 9 o'clock positions at same time, and at 6 and 12 o'clock positions at same time) ..... .012" - .026"

Clearance between turbocharger and turbocharger end of air duct (with turbocharger to duct bolts removed) ..... Less than .008"

Clearance between gasket and turbocharger flange (bolts installed and torqued, and using a .001" feeler gauge) ..... .000"

Clearance between gasket and air duct flange (same conditions as step above) ..... .000"

Torque Values

(Renew all washers on turbocharger at assembly)

	Bolt Size	Torque
Turbocharger to Crankcase	3/4"-16	175 ft-lbs
Turbocharger to Camshaft Housing	1/2"-20	65 ft-lbs
Turbocharger to Air Duct	3/8"-16	35 ft-lbs
Air Duct to Crankcase	1/2"-20	65 ft-lbs
Aftercooler to Air Duct	3/8"-24	35 ft-lbs
Water Pipe to Aftercooler	1/2"-13	75 ft-lbs
Water Pipe to Engine	1/2"-13	75 ft-lbs
Turbocharger to Manifold Self Lock Nuts, Oiled	1/2"-20	80 ft-lbs
Exhaust Manifolds to Crankcase	5/8"-18	130 ft-lbs

LUBRICATING OIL SYSTEM

DESCRIPTION

The complete engine lubricating oil system is a combination of three separate systems. These are the main lubricating system, the piston cooling system and the scavenging oil system. Each system has its own oil pump. The main lube oil pump and piston cooling oil pump, although individual pumps, are both contained in one housing and driven from a common drive shaft. The scavenging oil pump is a separate pump. All the pumps are driven from the accessory gear train at the front of the engine. Parts of the complete oil system and a schematic arrangement of oil circulation are shown in Fig. 8-1.

MAIN LUBRICATING SYSTEM

The main lubricating system supplies oil under pressure to most of the moving parts of the engine. The main lube oil pump takes oil from the strainer housing at the right front of the engine. Oil from the pump goes into the main oil manifold which is located above the crankshaft, and extends the length of the engine. Maximum oil pressure is limited by a relief valve in the passage between the pump and the main oil manifold.

Oil tubes at the center of each main bearing "A" frame conduct oil from the main manifold to the upper half of the main crankshaft bearings. Drilled passages in the crankshaft supply oil to the connecting rod bearings and to the harmonic balancer and accessory drive gear at the front of the crankshaft. Leak-off oil from the adjacent main bearings lubricates the crankshaft thrust bearings.

Oil from the manifold enters the gear train at the rear of the engine, at the idler gear stubshaft. Oil passages in the base of the stubshaft distribute the oil. One passage conducts oil upward to the left bank camshaft drive gear stubshaft bracket through a jumper, and downward to the lower idler gear stubshaft and bearing. Another passage conducts oil to the right bank camshaft drive stubshaft bracket and on to the turbocharger oil filter supply line. After passing through the filter, the oil enters the return line, returning to the upper idler gear stubshaft bore and bearing. Filtered oil enters the turbocharger oil system from the upper idler gear stubshaft.

Oil enters the hollow bore camshafts from the camshaft drive stubshafts. Radial holes in the camshaft conduct oil to each camshaft bearing. An oil line from one camshaft bearing at each cylinder supplies oil to the rocker arm shaft, rocker arm cam follower assemblies, hydraulic lash adjusters, and the injector rocker arm button. Leak-off oil returns to the oil pan.

Passages in the turbocharger conduct oil to the turbocharger bearings, idler gears, planet gear assembly, and through a connecting line to the governor low oil pressure connection on the camshaft drive

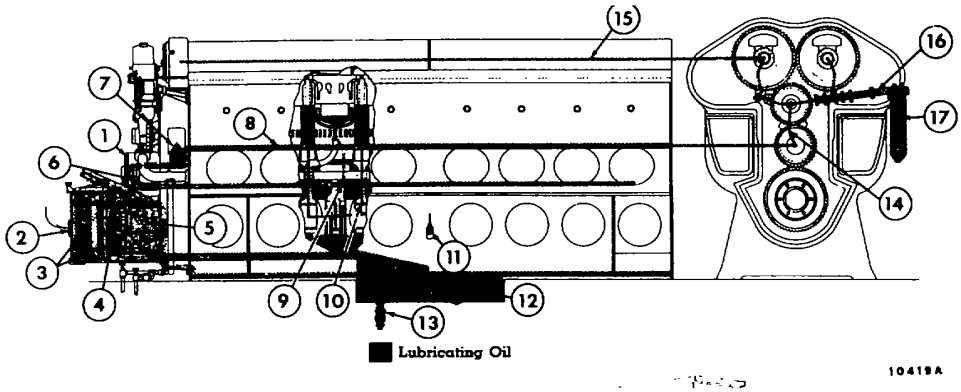
housing. Considerable heat will remain in the metal parts of the turbine when the engine is shut down and if the oil supply to the turbocharger was shut off suddenly, this heat would penetrate the turbocharger bearing area. To prevent possible overheating of the bearings, oil is automatically supplied to the bearings after stopping the engine by the auxiliary oil circulating pump.

PISTON COOLING OIL SYSTEM

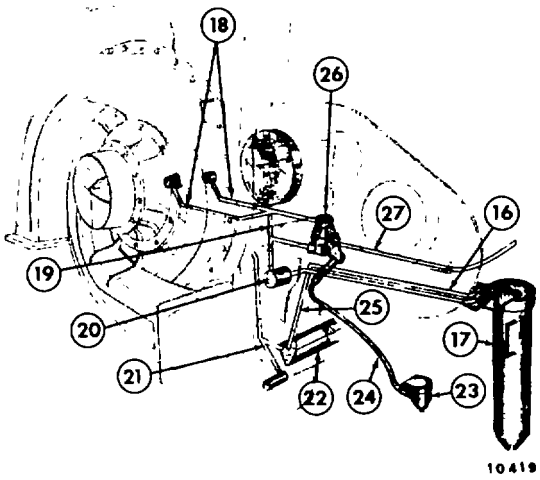
The piston cooling oil system pump receives its oil from a common suction with the main lube oil pump and delivers oil to the two piston cooling oil manifolds ex- tending the length of the engine, one on each side. A piston cooling oil pipe at each cylinder directs a stream of oil through the carrier to cool the underside of the piston crown and the ring belt. Some of this oil enters the oil grooves in the piston pin bearing and the remainder drains out through holes in the carrier skirt to the sump.

SCAVENGING OIL SYSTEM

The scavenging oil system pump, Fig. 8-1, takes oil through the scavenging oil



1. Piston Cooling Oil And Lubricating Oil Pump
2. Lube Oil Inlet To Strainer Housing
3. Lube Oil Strainers
4. Scavenging Oil Strainer
5. Scavenging Oil Pump
6. Piston Cooling Oil Discharge
7. Oil Pressure Relief Valve
8. Lube Oil Manifold
9. Piston Cooling Oil Line
10. Oil Supply To Crankshaft And Bearings
11. Oil Gauge (On Right Bank)
12. Oil Pan Sump
13. Oil Sump Drain Valve
14. Gear Train Oil Lines
15. Camshaft Oil Passage (To Camshaft Bearings And Cylinder Rocker Arms)
16. Turbocharger Filter Oil Supply And Return Manifold
17. Turbocharger Oil Filter
18. Turbocharger Bearing Oil Supply Lines
19. Main Oil Supply Line To Turbocharger
20. No. 2 Idler Gear Stubshaft
21. Oil Line To Left Bank Camshaft Drive And No. 1 Idler Gear Stubshaft
22. Main Lube Oil Manifold
23. Soak Back Oil Filter



24. Soak Back Oil Line
25. Oil Line To Right Bank Camshaft Drive And To Turbo Filter
26. Check Valve
27. Low Oil Pressure Line To Governor

Fig. 8-1. Lubricating Oil System

strainer from the oil pan sump or reservoir. The pump then forces the oil through the oil filters and oil cooler which are located near the engine. Oil then returns to the strainer housing to supply the main lube oil pump and piston cooling oil pump with cooled and filtered oil. Excess oil spills over a dam in the strainer housing and returns to the oil pan.

OIL GAUGE

An oil level gauge, Fig. 8-2, extends from the side of the oil pan into the oil pan sump. The oil level should be maintained between the low and full marks on the gauge, with the reading taken when the engine is at idle speed and the oil is hot.

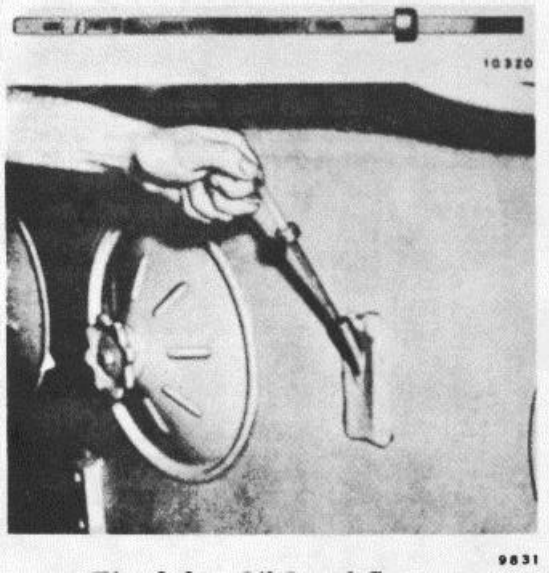


Fig. 8-2. Oil Level Gauge

MAINTENANCE

LUBRICATING OIL PRESSURE

Adequate lubricating oil pressure must be maintained at all times when the engine is running. Upon starting and idling an engine, it should be noted that the oil pressure builds up almost immediately. In the event of cold oil, the pressure may rise to the relief valve setting of approximately 125 psi.

Lubricating oil pressure is not adjustable. The operating pressure range is deter- mined by such things as manufacturing tolerances, oil temperature, oil dilution, wear, and engine speed. Thus no specific operating pressures can be given.

The minimum oil pressure is approximately 8-12 psi at idle and 25-29 psi at full speed. In the event of insufficient oil pressure, a shutdown feature built into the governor will automatically protect the engine by shutting it down. Maximum pressure is determined by the relief valve setting of 125 psi.

PISTON COOLING OIL PRESSURE

No gauge is provided for piston cooling oil pressure. Piston cooling oil pressure can be determined by connecting a gauge at the 3/4" plugged opening at the pump discharge elbow. Pressure of the piston cooling oil will be governed by oil viscosity, speed of engine, temperature of oil, and wear of pump parts. The minimum piston cooling oil pressure at idle engine speed is 10 psi and at full speed 45 psi.

POSSIBLE LUBRICATION TROUBLES

NO OIL IN STRAINER CHAMBER

This may be caused by inoperative scavenging system or open drain valve. Failure of scavenging system may be due to a broken or loose oil line connection, scavenging strainer not properly seated causing an air leak, a faulty scavenging pump, clogged strainer, or low oil level.

LOW OIL PRESSURE

This may be due to a stuck oil relief valve, foreign material on valve seat holding valve open, broken oil lines, clogged strainers, excessive bearing wear, low oil viscosity, faulty pump,

diluted oil, or insufficient oil in strainer housing.

PUMP FAILURE

This may be due to sheared pump gear keys, broken housing, or damaged gears.

OIL DILUTION

It is possible for fuel oil to get into the lubricating oil if a fuel line connecting the injector to the fuel manifold is loose or broken, or an injector is defective. If this occurs, the lube oil viscosity should be checked, The lube oil may also be contaminated by water. This can be checked visually on top of the cylinder heads or in the oil pan, also by taking test sample of oil. See Checking Oil Viscosity.

EXCESSIVE OIL CONSUMPTION

This may be caused by oil leaks, broken or stuck piston rings, worn cylinder liners, clogged oil separator screen, improper grade of oil, or clogged oil drain holes under piston oil control rings.

UNUSUALLY LOW OIL CONSUMPTION

This may be due to water or fuel leaking into the oil.

LUBE OIL PRESSURE RELIEF VALVE

DESCRIPTION

The lube oil pressure relief valve, Fig. 8-3, is installed on the lube oil crossover manifold, inside the accessory gear train housing on the left side of the engine, Fig. 8-1. A cover plate provides access to the valve for inspection and adjustment.

The purpose of the valve is to limit the maximum pressure of the lube oil entering the engine oil system. When the lube oil pump pressure exceeds the spring tension on the valve, the valve will be lifted off its seat and relieve the excess pressure. This oil drains into the accessory housing and then into the oil pan.

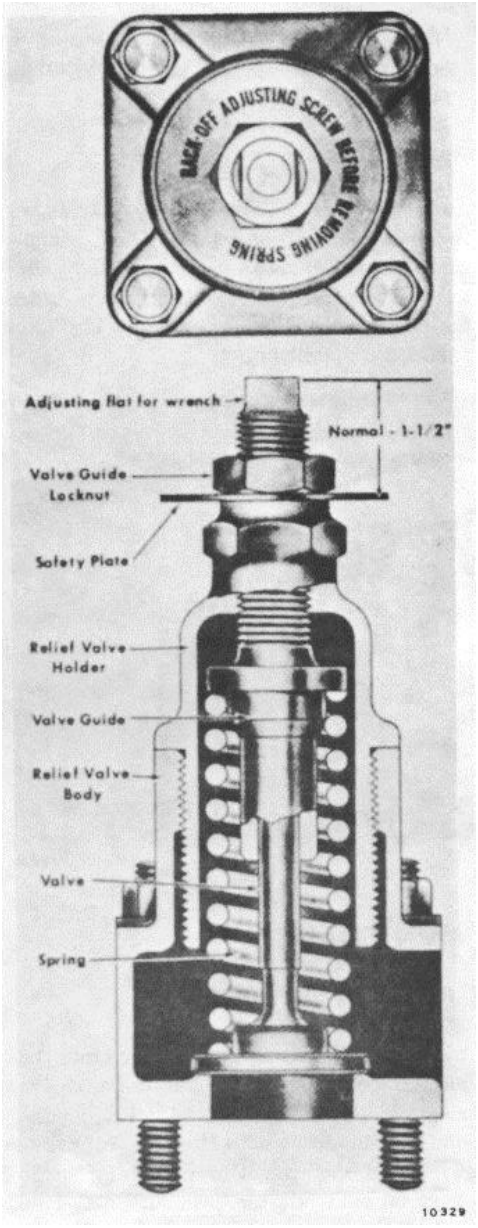


Fig. 8-3. Lube Oil Pressure Relief Valve

MAINTENANCE

The oil pressure relief valve should be removed and the parts inspected at intervals specified in the Scheduled Maintenance Program.

Disassemble the valve and wash all the parts thoroughly. As stated on the safety plate on the valve, back off on the valve guide all the way before removing the valve holder and spring. Inspect the parts as follows to determine their condition for reuse.

VALVE SPRING

Check the valve spring for any nicks which could cause subsequent spring failure.

Test the valve spring by applying a load of 310 lbs. Under this load the spring length should not be less than 4-1/2".

VALVE GUIDE

Using a telescoping gauge, check the valve guide inside diameter.

If the inside diameter is rough or lightly scuffed, clean up the bore but do not exceed the maximum diameter.

VALVE

Examine the valve stem for roughness and light scuffing. The stem maybe hand- stoned and buffed to remove high spots. Replace the valve if the stem is badly galled.

Check that the outside diameter of the valve stem is not less than the minimum limit.

Also, check for a possible bent valve or distorted face by checking the squareness of the valve face to the stem, measuring from the outer edge of the valve face. Total indicator reading should be as specified.

INSTALLATION

When installing relief valve on engine, make sure that the bypass port is positioned away from crankcase end plate.

SETTING OIL PRESSURE RELIEF VALVE

The setting of the oil pressure relief valve connected to the lube oil manifold determines the maximum oil pressure at the main lube oil pump. It is not set by pressure gauges, but by a specific dimension from the top of the valve guide to the top of the valve holder. To set the valve, loosen the locknut, Fig. 8-3, and position the valve guide so that it extends 1-1/2" above the safety plate.

This setting will permit a maximum oil pressure of about 125 psi under cold oil conditions, and allow an adequate pressure for normal operation and hot oil. Lubricating oil manifold pressure or pressure at the valve can be determined by applying a pressure gauge at the main lube oil pump discharge elbow.

PISTON COOLING OIL PIPE

DESCRIPTION

The piston cooling oil pipe is bolted at one end to a flange on the piston cooling oil manifold, and at the other end to the bottom of the cylinder liner. A pipe is specifically located at each cylinder to direct a stream of oil through the piston carrier to the top of the piston. This cooling oil is very important to the function of the piston, as without piston cooling oil of a sufficient quantity, the piston would be overheated in a short time and damage would occur to the piston and subsequently to the other engine parts. Alignment of the piston cooling oil pipe is very important.

MAINTENANCE

The alignment of the piston cooling oil pipe to the inlet hole in the piston carrier is checked with an alignment gauge as shown in Fig. 8-4.

The small end of the gauge fits into the nozzle of the pipe and by bringing the piston to bottom center the gauge should enter the inlet hole in the piston carrier and turn freely in this position. This gauge is not to be used for bending the pipe in case of misalignment. If the gauge will not freely enter the carrier hole, the pipe should be removed and replaced with a new or correctly aligned one.

In addition to the alignment check covered in the preceding paragraph, the piston cooling pipe nozzle should be examined for ragged edges which might cause the oil to spray out instead of shoot out in a stream.

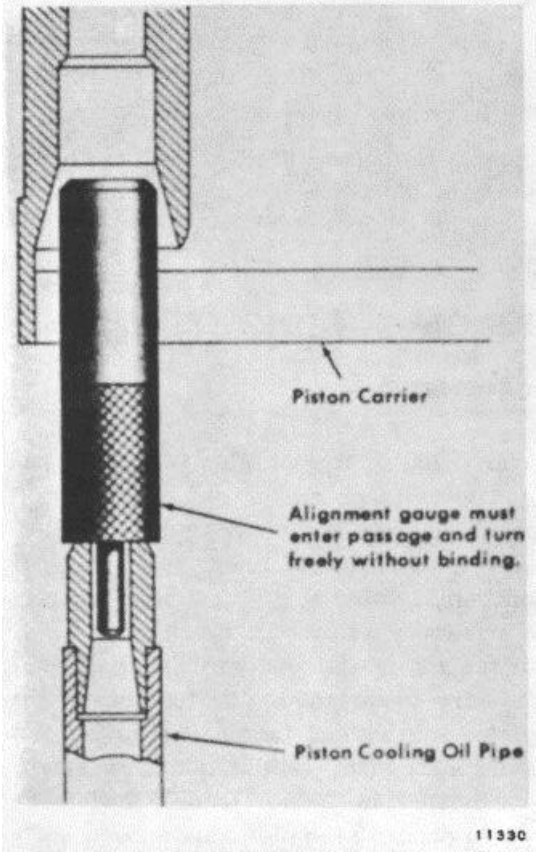


Fig. 8-4. Piston Cooling Oil Pipe Alignment

A piston cooling oil pipe cleaner is available from the EMD Parts Center.

CHECKING OIL VISCOSITY

Oil viscosity should be checked at intervals as specified in the Scheduled Maintenance Program. By comparing the viscosity at different intervals taken at the same temperature, excessive fuel dilution may be detected by an unusual drop in viscosity and excessive oxidation of the oil may be detected by an unusual rise in viscosity within the recommended oil drain periods. The viscosity limits are directly related to the type of oil being used and the type of viscosity measurements being made. The oil suppliers will furnish these values, which should correspond to a maximum of 5% fuel dilution and a 35% viscosity rise.

Operating an engine with badly oxidized oil or poor oil filtration will result in oil cooler core plugging, carbon buildup on piston undercrowns, ring grooves, oil rings, and piston pin bearing grooves, and limitation of oil flow to the main and connecting rod bearings with subsequent engine damage.

Therefore, to provide protection to the engine, the oil and system components should be carefully observed for proper functioning and corrective steps taken where necessary. Oil and filter change periods should be followed closely since the oil is not only oxidizing but contaminants are coming into the engine from the process of fuel combustion, as well as the normal air borne contaminants which are not caught by the air filters. It is therefore beneficial to drain the oil and eliminate these contaminants as specified in the Scheduled Maintenance Program.

CHANGING OIL

Engine lube oil should be drained, filters replaced, and strainers and screens cleaned at intervals outlined in the Scheduled Maintenance Program. Before the oil is drained, its viscosity should be checked for any indication of fuel dilution. If fuel leakage is indicated, the leak should be corrected before charging the engine with new oil.

GENERAL PROCEDURE

1. Shut down the engine.

2. Open drain valves in the oil strainer housing to drain oil into the engine oil pan sump.

3. Provide a container or oil runoff line for drained oil.

4. Remove pipe plug from oil drain valve and open valve to drain all the oil from the engine oil pan sump.

5. Remove pump strainers from strainer housing, and remove the oil filters from the filter housing.

6. Clean the strainers using a suitable cleaner, and rinse thoroughly.

7. Wash down top deck, oil pan and filter housings using fuel oil or kerosene. Drain off cleaning fluid and wipe areas free of excess fluid, using bound edge absorbent towels.

8. Replace pipe plugs in drain lines, where required, and close valves. Where necessary, renew gaskets.

9. Install clean strainers and screens. Install new elements in filter containers. Prepare system to receive new oil.

10. Recharge engine with new lubricating oil qualified for use as specified in Maintenance Instruction 1752. Add oil through square filler opening in strainer housing.

NOTE: Be sure strainer housing internal drain valves are closed.

Sufficient oil will be retained in the housing to supply main lube and piston cooling oil pumps on starting. Engine oil level is shown on the oil gauge. Pour a liberal quantity of oil over cylinder heads and top deck components before starting.

11. Inspect engine prior to starting, then start engine. Check oil level with engine at idle speed. If oil level is not to "full" mark on gauge, add oil to bring level to "full" mark; with engine at idle speed and with hot oil.

NOTE: Under some conditions the oil level may be above the bottom of the oil pan handholes, so care must be taken when the oil pan handhole covers are removed.

OIL STRAINER HOUSING

DESCRIPTION

The oil strainer housing, Fig. 8-5, is a large box-shaped cast aluminum: housing which is mounted on the right front side of the engine on the accessory drive cover, Fig. 8-1. It contains independent strainers for the main oil pump supply and scavenging oil pump. There are two strainers for the main lube pump oil and one strainer screen for scavenging pump oil, with a separate oil inlet and discharge for each of the systems.

The two main lube oil pump strainers, Fig. 8-6, each consists of a replaceable

element made of a pleated perforated metal core covered with mesh screening, and a metal cylinder which encloses the element. The cylinder prevents collapse of the element in the event of a high pressure drop. The element is attached to the cylinder by a through bolt in the cylinder f which runs through the base of the element and is secured with a locknut. The unperforated outer cylinder provides a constant head of oil since suction is from the bottom only and not through the entire length of the screen. The flow of oil is from the bottom of the strainer between the cylinder and the mesh screen, through the mesh screen and the perforated metal core into the center of the element, then out the top of the strainer.

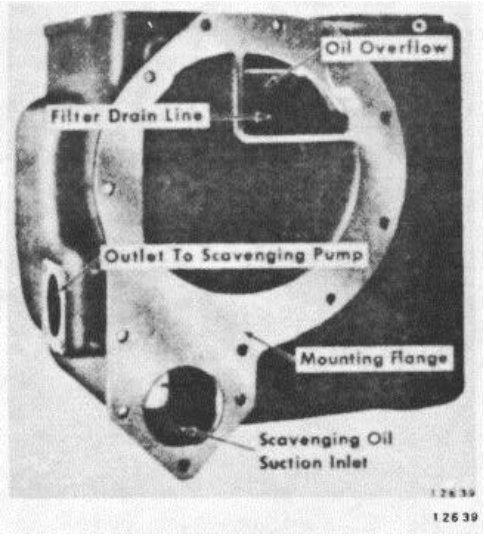


Fig. 8-5. Oil Strainer Housing

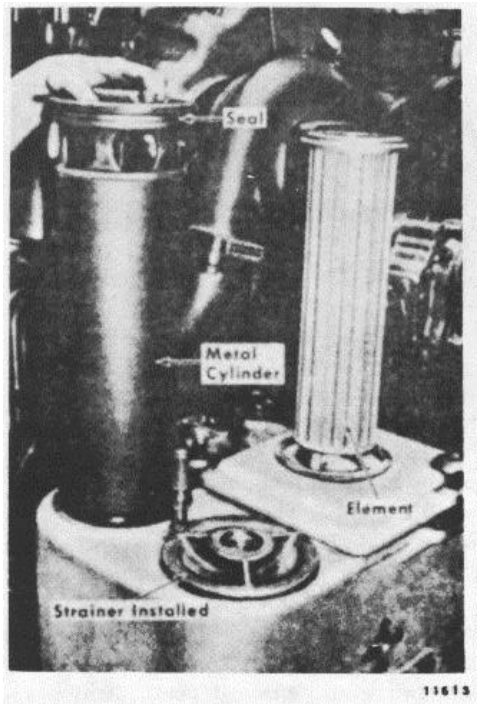


Fig. 8-6. Main and Piston Cooling Oil Pump Strainers

The scavenging oil pump strainer, Fig. 8-7, has a rigid perforated metal screen which retains its shape and is easily cleaned.

Fig. 8-6 shows one of the main lube oil pump strainers removed from the housing.

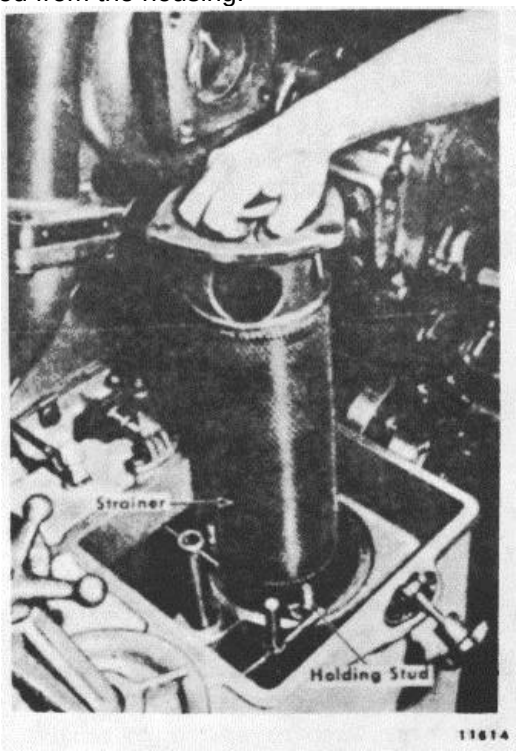


Fig. 8-7. Scavenging Oil Pump Strainer

When in place, they are held by a crab and handwheel on the stud between the holes. Each strainer is sealed at the top by a seal ring. Also, oil under pump pressure is admitted to a groove around each strainer, just below the seal, to prevent air entry in event of a leaky seal. A partition adjacent to the strainers, open at the bottom, separates them from the oil inlet area of the housing. Oil enters the strainers at the partition bottom and is taken up by the pump through a cast passage in the housing.

The scavenging oil pump strainer is shown removed in Fig. 8-7. When the strainer is installed in the housing, it is held in position with three nuts. The scavenging oil strainer inlet and outlet openings are shown in Fig. 8-5.

An oil level is maintained in the strainer housing up to the bottom of the overflow opening, Fig. 8-5. Excess oil returns to the oil pan sump. A spring-loaded valve, Fig. 8-8, is provided to drain the oil from the strainer housing into the oil pan sump, at the time of an oil change. An additional valve, Fig. 8-8, is used to drain the oil filter housing. Both valves are located under the filler cover and must be kept closed at all times except for the period of draining.

MAINTENANCE

Lube oil strainers should be removed at each oil change and strainers and housing thoroughly cleaned, using a petroleum solvent.

As previously described, the engine lube oil strainers have a seal of oil under pressure in addition to the seal rings. The oil under pressure will leak out under the strainer flanges if the seal rings are not seated properly or are damaged. When strainers are replaced, care should be taken to see that the sealing surfaces are free from nicks and scratches and seal

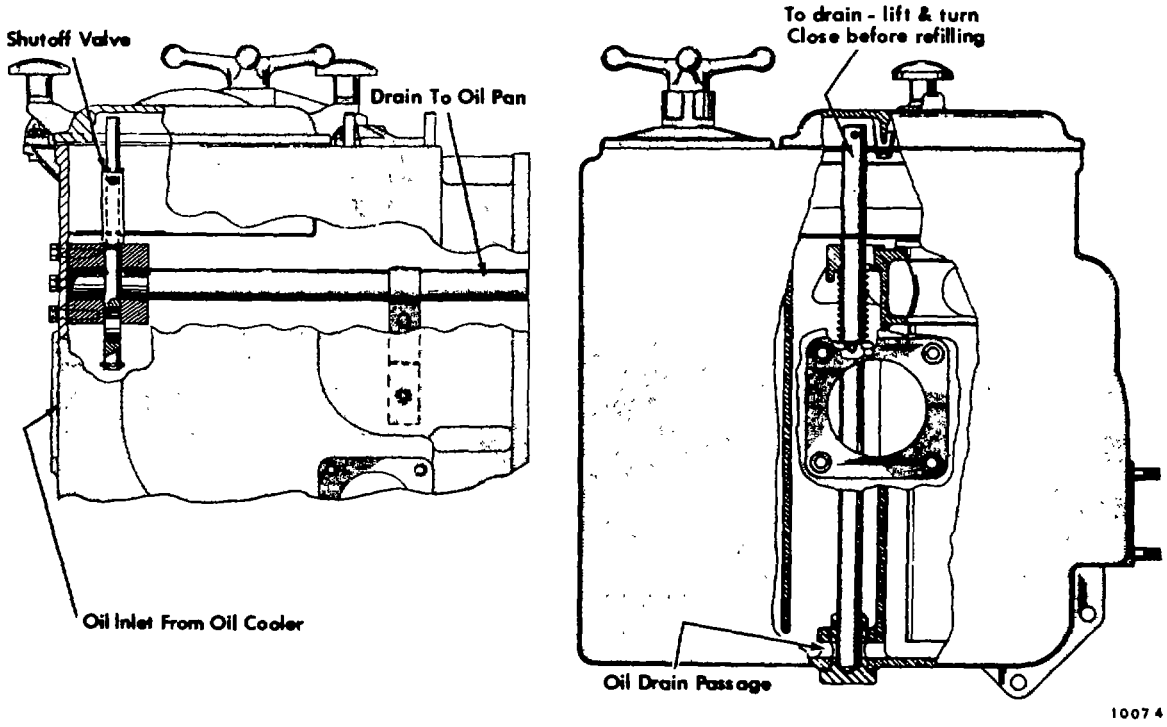


Fig. 8-8. Strainer Housing Drain Valves

rings are in good condition. Also, that the oil passages to the seals are open and clear.

The pressure oil seal maybe checked, with the engine at idle speed, by loosening the large handwheel until the seal ring of the furthest strainer from the engine is free of the housing. Oil should leak out around the strainer flange. If no oil appears, the engine should be shut down and the oil supply passages inspected and cleaned.

Any air which might enter system at this location will be discharged with the lubricating oil and may cause damage, even though normal oil pressure is indicated.

LUBE OIL SEPARATOR

DESCRIPTION

The oil separator, Fig. 8-9, which is mounted on the turbocharger housing, is an elbow-shaped cylindrical housing containing a wire mesh screen element. The crankcase ejector assembly is mounted on top of the separator.

An air line connected into the air duct (50 cycle unit) passes through the ejector assembly creating a suction which draws oily vapor from the engine up through the separator element. An air box drain line is used on the 60 cycle unit. The oil collects on the element and drains back to the engine. The remaining gaseous vapor is discharged into the exhaust and vented to atmosphere

MAINTENANCE

The screen should be removed from the oil separator and cleaned at intervals specified in the Scheduled Maintenance Program.

1. Shut the engine down.

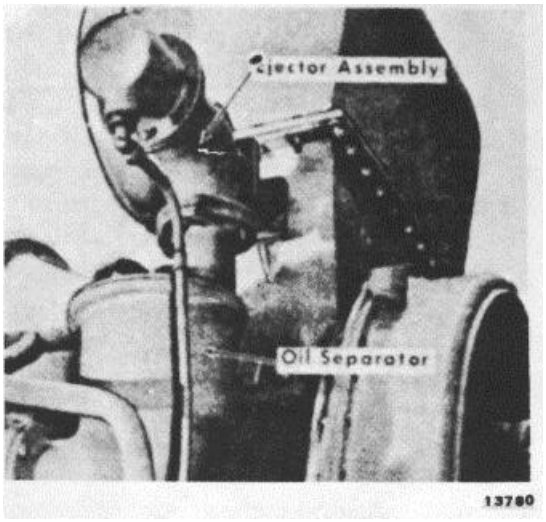


Fig. 8-9. Lube Oil Separator

2. Disconnect the ejector assembly from the exhaust duct and remove it from the separator.
3. Remove the separator cover and element and wash it in a petroleum solvent. Then rinse the element with hot water and blow dry with air.
4. Replace the element and the cover and elbow assembly.

MAIN LUBE OIL AND PISTON COOLING OIL PUMPS

DESCRIPTION

The main lube oil and piston cooling oil pumps, Fig. 8-10, are contained in one housing a spacer plate between the sections of the pump body. Each has its individual oil inlet and discharge opening. The piston cooling pump gears at the end are narrower than the lube oil pump gears. The lube oil and piston cooling oil pump assembly is mounted in the center of the accessory drive housing, Fig. 8-1, and is driven by the accessory drive gear.

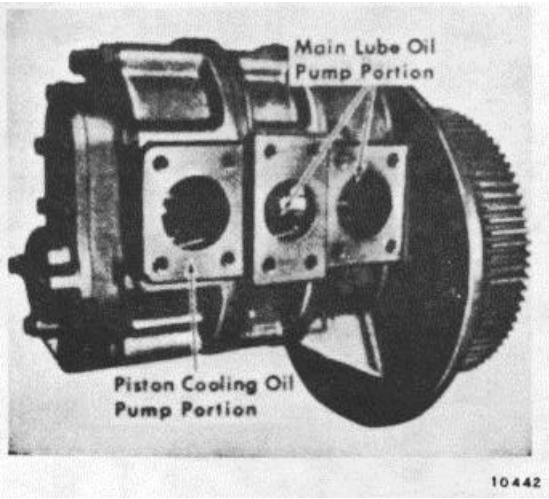


Fig. 8-10. Main Lube Oil And Piston Cooling Oil Pumps

MAINTENANCE

DISASSEMBLY (Refer to Fig. 8-11)

1. Clean the pump externally before disassembly.
2. Hold the pump in a suitable vise.

   As a safety precaution, provide an additional support at the center of the pump until the front body and bushing and piston cooling pump gears are removed.

3. Remove the long bolts holding the front body to the center body.
4. Using a rawhide mallet, tap the front body at the inlet and outlet openings, to remove the front body, cover, idler shaft, and outer driven gear as an assembly.
5. Remove the cotter pin, (60 cycle unit only), drive shaft nut and washer.
6. Support pump on its flange, pump drive gear down, so that gear is free to move downward.
7. Apply pressure to shoulder of drive shaft and press the shaft down a maximum of 1/2".

   CAUTION: If shaft is pressed down too far, the piston cooling pump gear key will shear the collar in the spacer plate.

8. Manually raise pump drive gear and drive shaft until a 1/2" clearance is obtained between the drive shaft sleeve and the piston cooling pump drive gear.
9. Attach a puller to the drive shaft sleeve and remove sleeve from the drive shaft.
10. Remove the piston cooling pump drive gear and its drive key.
11. Remove the spacer plate and collar.
12. Remove the lube oil pump center driven gear, drive gear, and key.
13. Using a rawhide mallet, remove the center body portion of the pump.
14. Remove the lube oil pump inner driven gear, drive gear, and key.
15. The pump drive gear and shaft assembly is then removed.
16. Keep all parts of the one pump assembly together.

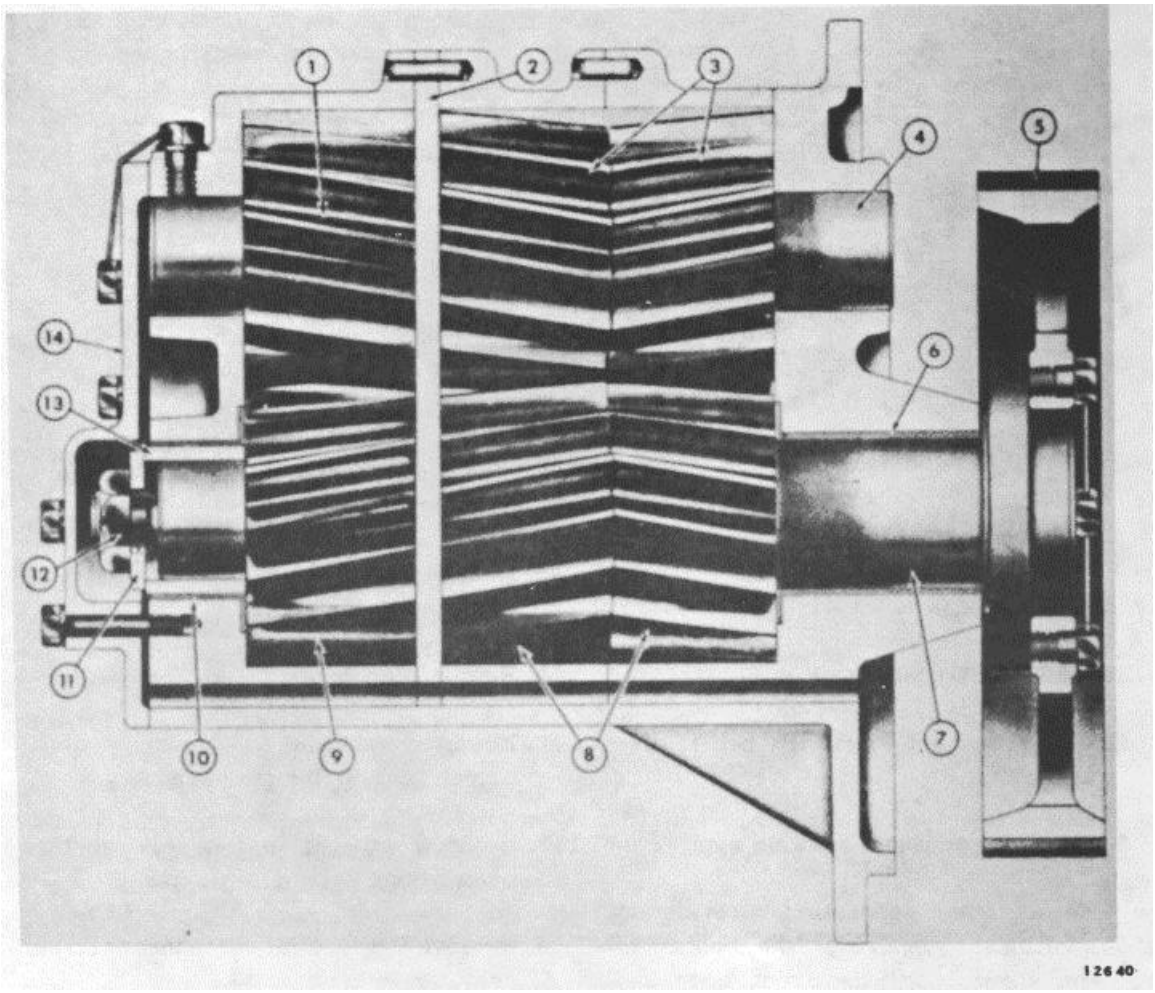
CLEANING

Clean all the individual parts of the pump using a petroleum solvent. After cleaning, dry the parts with compressed air.

INSPECTION

Pump Bodies

1. Check the surface of the pump bodies for nicks, dents or scratches which



1. Piston Cooling Driven Gear
2. Spacer Plate
3. Lube Oil Pump Driven Gears
4. Idler Shaft
5. Drive Gear
6. Inner Bushing
7. Drive Shaft
8. Lube Oil Pump Drive Gears
9. Piston Cooling Drive Gear
10. Front Bushing
11. Washer
12. Shaft Nut
13. Shaft Sleeve
14. Cover

Fig. 8-11. Main Lube Oil And Piston Cooling Oil Pumps, Cross-Section

may have protrusions above the normal surface. Smooth down any evidence of roughness.

2. Inspect the drive shaft bushings for imbedded dirt, metallic particles, flaking and pitting. Bushings with light scratches and small quantities of imbedded dirt may be reused after smoothing up, provided bore sizes are within the maximum limits.
3. Replace the bushings if any other adverse conditions exist. Details of construction and application of bushing installation and removal tools are shown in Fig. 8-12.
4. Using fine abrasive cloth on a smooth surfaced tool, clean off the gasket face of the pump bodies.

Spacer

Inspect the sides of the spacer for smoothness. If necessary, smooth the sides using fine abrasive cloth held flat on a flat surfaced tool.

Gears

1. Inspect the gear teeth for nicks, pitting and excessive wear. Light nicks are permissible provided they are blended by filing and stoning.
2. Gears having tooth faces pitted in excess of 30% of tooth contact area should not be reused.
3. Inspect the driven gear bushing inside diameter for wear and possible dam-age.
4. Driven gear bushing installation and removal tool construction and application is shown in Fig. 8-13.
5. Inspect the key ways in the drive gears for any damage which would interfere with the key application.

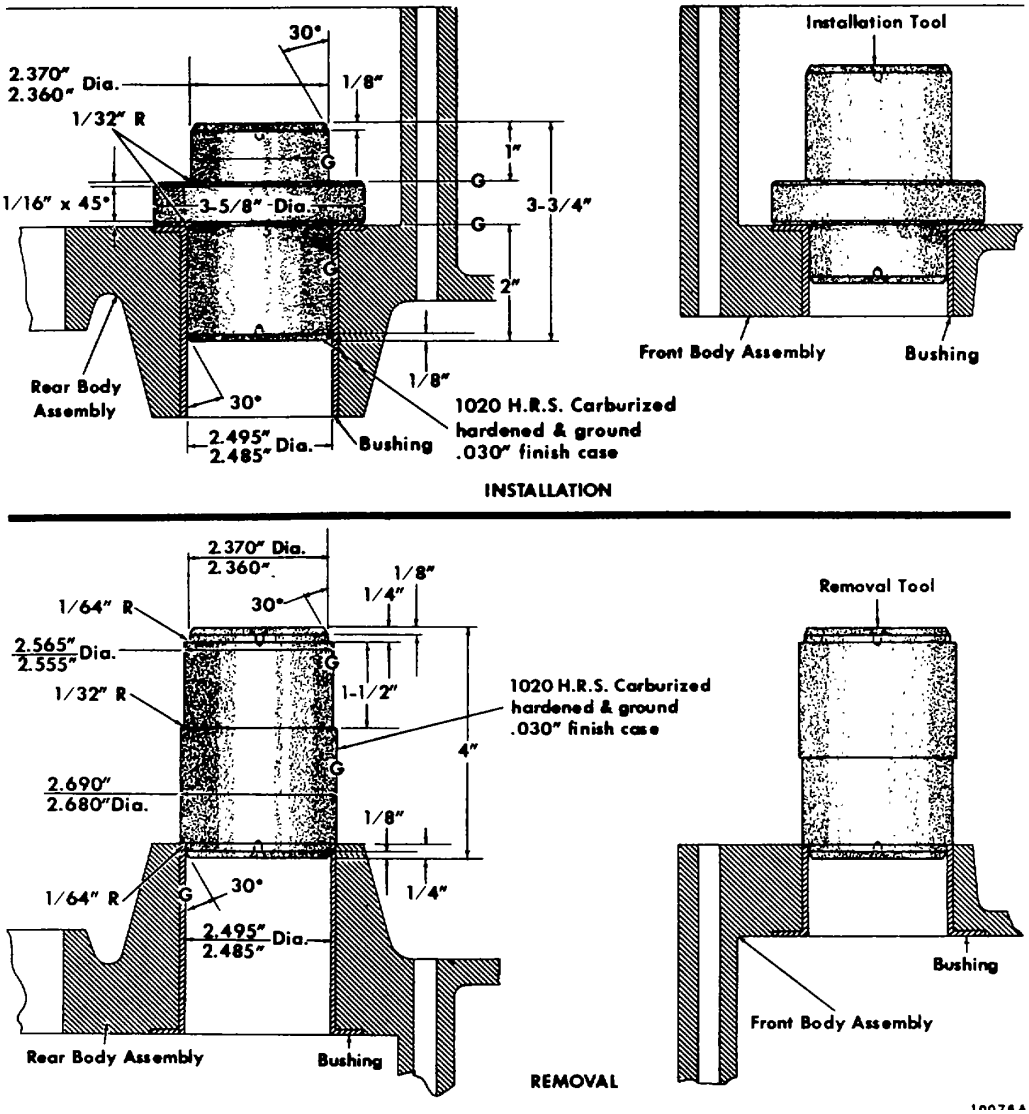


Fig. 8-12. - Oil Pump Body Bushing Tools

6. The drive shaft gear may be Magnaflux inspected in accordance with procedures in Maintenance Instruction 1754.

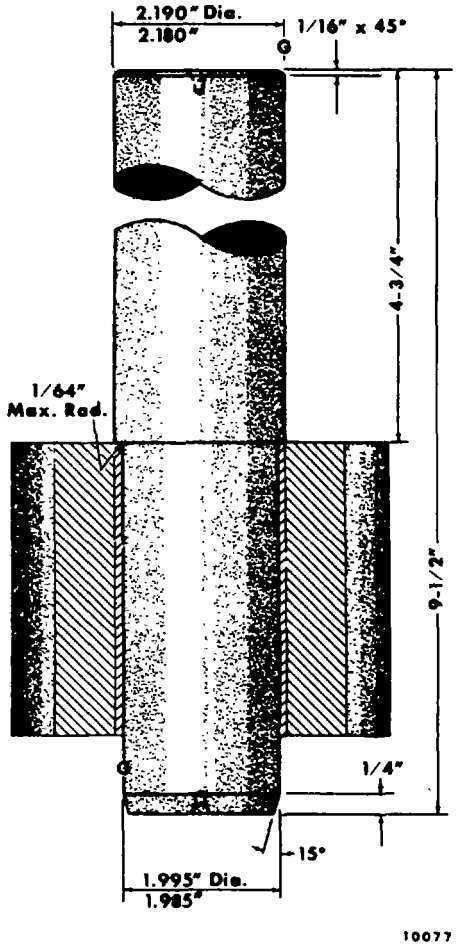


Fig. 8-13. - Oil Pump Driven Gear Bushing Tool

Drive Shaft, Keys, And Idler Shaft

1. Inspect the shafts for any roughness. Check the drive shaft key ways and key fit, making sure the keys fit snugly in the shaft.

2. Check the drive shaft diameter to determine whether the drive shaft to body bushing clearance is within maximum limits.

3. Also check the Idler shaft to make 2-122 certain that the shaft to bushing clearance is within maximum limits.

ASSEMBLY

1. Place the mounting flange of the cleaned and inspected rear body in the bench vise with the drive shaft bore uppermost. Refer to Fig. 8-11 for assembly.

2. With the pump drive gear applied to the drive shaft, lightly oil the shaft journal and insert the shaft in the rear body bushing.

3. Place the inner drive gear key in the drive shaft and install the inner drive gear on the shaft. (Refer to Fig. 8-11.)

4. Next after oiling the bushing, apply the mating driven gear, meshing it with the top gear in the pump body.

5. Fit the center drive gear key in the drive shaft.

6. Oil the pump rear body to center body gasket and apply it to the gasket face of the rear body, being careful to align the bolt and dowel holes.

7. Apply the center body to the rear body.

8. Install the center drive gear and its *I* mating driven gear.

9. Oil the body gasket and apply it to the center body.

10 Apply the spacer plate to the center body and apply the collar to the drive shaft.

11. Install the piston cooling drive gear key in the drive shaft and apply the drive gear. Make sure that the identification groove on the outer gears are facing the spacer plate.

12. Make sure that sleeve and drive shaft are free of dirt, oil, and grease. Spray cleaner activator on the I. D. of the sleeve and the O. D. of the shaft and wipe off. (50 cycle unit)

13. Re-spray sleeve and shaft and allow to dry for about 10 minutes. Do <u>not</u> wipe off. (50 cycle unit)

14. Coat entire surface of shaft which is covered by the sleeve by applying retaining compound in small amounts. (50 cycle unit)

15. Apply sleeve and wipe off excess compound at each end of sleeve. Apply heavy duty washer and nut and tighten nut to 325-350 ft-lbs torque. (50 cycle unit)

NOTE: Apply the sleeve, washer and nut to the drive shaft. Tighten the nut, align-ing the cotter pin passage and apply the cotter pin. (60 cycle unit)

16. Check that all excess compound is removed before proceeding with assembly. (50 cycle unit)

17. Oil the spacer plate gasket and apply it to the spacer.

18. Completely coat the bushing in the front body with oil.

19. Apply the piston cooling pump driven gear to the idler shaft which was left assembled to the front pump body and cover, and apply this assembly to the pump. Make sure that the identification groove on the outer gears are facing the spacer plate. If the front body, cover, and idler shaft were disassembled, apply these parts individually using a new oiled gasket between the cover and the front body.

20. Complete assembly of the pump by installing the long bolts through the cover. Tighten securely.

21. If possible, allow pump to remain unused for approximately 24 hrs. after torquing to ensure sleeve to shaft retention.(50 cycle unit)

ASSEMBLY INSPECTION

1. After pump assembly, rotate the pump drive gear to check for gear noise or tight assembly.

2. Check the thrust of the drive gears. This may be done by securing an indicator on the pump flange with the indicator button contacting the rim of the pump drive gear, Fig. 8-14. Push Section 8 the drive gear inward so that all clearance is located at one end, then set the indicator to zero. Pull the drive gear outward to determine the amount of thrust clearance.

3. Leaving the indicator button on the outside of the pump drive gear rim, rotate the drive gear to check the gear runout. Drive gear runout should not exceed specified total indicator read-ing, with thrust in one direction.

4. Check the pump flange runout. Mount the indicator clamp on the drive gear and place the indicator button to con-tact the pump flange. Set the indicator to zero, and with the thrust held in one direction, rotate the drive gear. The runout of the pump flange face should not exceed specified total indicator reading.

5. Check the pump gears to body radial clearance. Clearance should be within the specified limits.

6. Additional clearances and limits are listed in the “Service Data” at the end of the section. Some of these clearances must be obtained by comparing the individual mating parts, or by

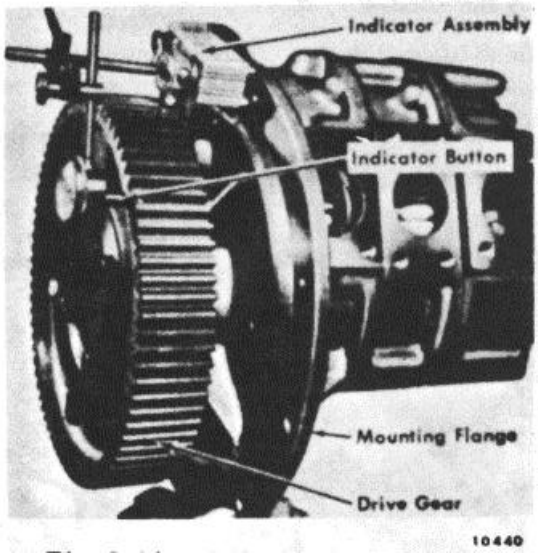


Fig. 8-14. - Checking Pump Drive Gear End Thrust

assembly and disassembly using lead wire or other suitable means to obtain the part to part clearance.

7. After pump inspection, seal off the pump body openings, and provide protection for the teeth of the pump drive gears.

SCAVENGING OIL PUMP

DESCRIPTION

The scavenging oil pump, Fig. 8-15, is a positive displacement, helical gear type pump. The pump body, split transversely for ease of maintenance, contains sets of mated pumping gears. The driving gears are retained on the pump drive gear shaft by Woodruff keys. The idler shaft is held stationary in the housing by a set screw, and the driven pump gears rotate on this shaft on bushings pressed into the gear bores. The drive shaft turns in bushings pressed into the pump body. These bushings are made with thrust collars which protrude slightly above the pump body and absorb the thrust of the drive gears. The scavenging pump is mounted on the accessory housing, Fig. 8-1, in line with and to the left of the crankshaft, and is driven by the accessory drive gear.

In addition, the scavenging oil pump drives the engine fuel pump through an extension and coupling at the end of the drive shaft as shown in Fig. 8-15.

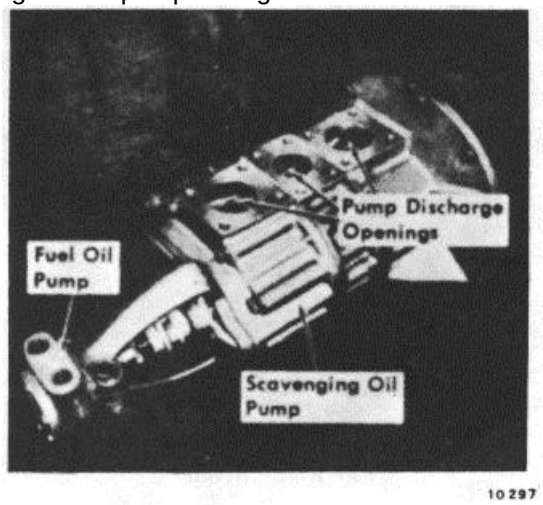


Fig. 8-15. - Scavenging Oil Pump

MAINTENANCE

Construction and maintenance of the scavenging oil pump is similar to the main lube oil and piston cooling oil pump, except for the fuel pump drive extension and the spacer in the main lube oil pump.

DISASSEMBLY

1. Clean the external surfaces of the pump before disassembly.
2. Hold the pump in a suitable vise. As a safety precaution, provide additional support until the rear body is removed.
3. Remove the nut and bolt holding the fuel pump in the bracket and loosen the set screws in the fuel pump to drive shaft extension coupling, then remove the coupling.
4. Remove the long bolts holding the pump bodies together.
5. Using a rawhide mallet, tap the front body at the oil inlet and outlet openings to remove the front body, idler shaft, and fuel pump bracket as an assembly.
6. Remove the drive shaft nut, washer, and sleeve from the drive shaft.
7. Remove the front drive gear, key, and driven gear.
8. Remove the center body.
9. Remove the center drive gear, key, and the mating driven gear.
10. Remove the rear drive gear, key, and driven gear.
11. Remove the pump drive gear and shaft as an assembly from the rear pump body.
12. Keep all parts of the same pump together.

CLEANING

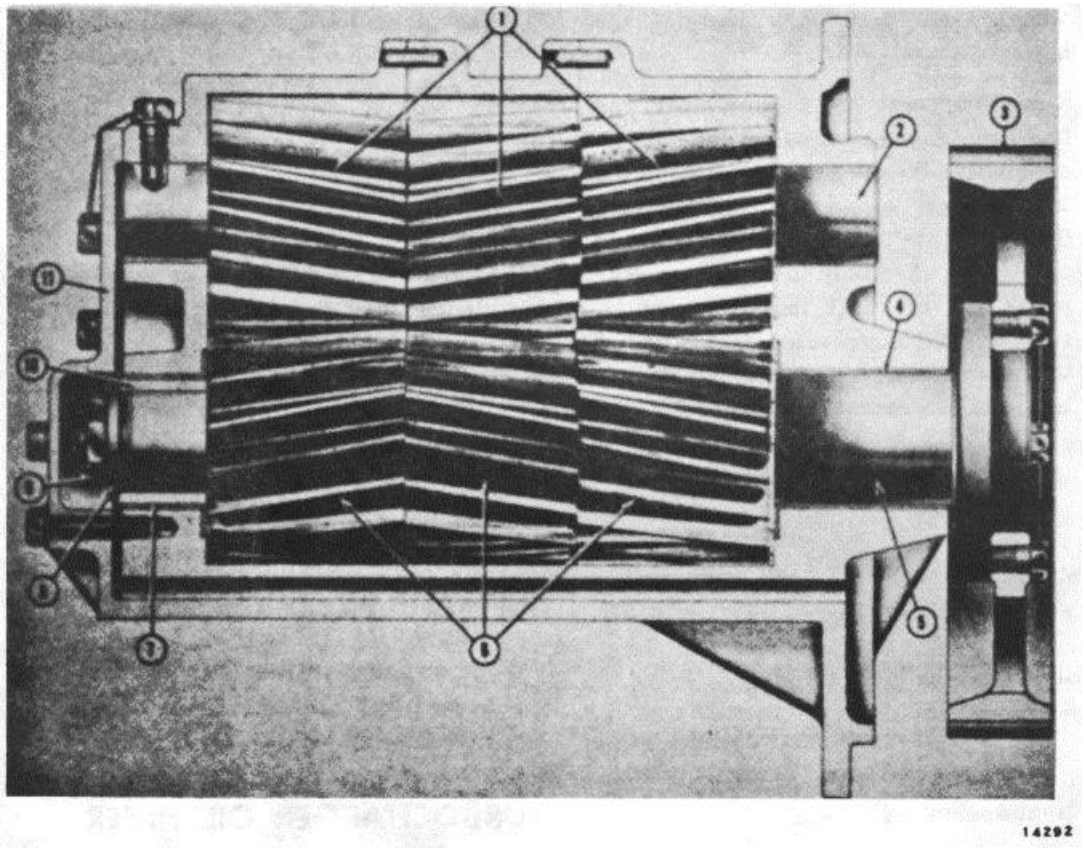
Clean all the individual parts of the pump using a petroleum solvent and rinse in hot water. Dry the parts, using compressed air.

INSPECTION

Refer to the corresponding procedures in the preceding "Main Lube Oil And Piston Cooling Oil Pumps" coverage. Also, refer to "Service Data" at the end of the section.

ASSEMBLY

1. Place the cleaned and inspected rear body in the vise with the drive shaft bore uppermost. Refer to Fig. 8-16 for pump assembly.
2. Oil the drive shaft journal sparingly, and apply the pump drive gear and shaft as an assembly to the rear-body.
3. Apply the drive gear key to the drive shaft and apply the inner drive gear. Apply the mating driven gear.
4. Fit the center drive gear key to the shaft.
5. Oil the body gasket and apply it to the rear body.
6. Apply the center body to the rear housing.
7. Install the center drive gear to the drive shaft.
8. Place the center driven gear in the body in mesh with its drive gear.



1.	Driven Gears	4.	Inner Bushing	7.	Front Bushing	10.	Sleeve
2.	Idler Shaft	5.	Drive Shaft	8.	Washer	11.	Cover
3.	Pump Drive Gear	6.	Drive Gears	9.	Drive Shaft Nut		

Fig. 8-16. - Scavenging Oil Pump, Cross-Section

9. Apply an oiled gasket to the face of the center body.

10. Apply the outer drive gear key to the drive shaft and install the outer drive gear.

11. Apply the sleeve, heavy duty washer, and nut to the drive shaft. Torque the nut to 325-350 ft-lbs.

12. If the seal was removed from the fuel pump bracket, clean the seal bore and press in a new seal. Make sure the lip of the seal is toward the mounting side of the pump bracket.

13. Before applying the fuel pump bracket assembly, place the tapered sleeve oil seal installer tool on the pump shaft extension. This tool will aid in protecting the seal when applying the pump bracket.

14. Since the front body, idler shaft, and fuel pump bracket were left as an assembly, these parts may be applied to the pump together. Apply the outer driven gear to the idler shaft and apply this assembly to the pump. Remove the oil seal installer tool. A tapped hole is provided in the end of the seal installer for a ¼"-20 bolt to aid in the removal of the tool.

15. Install the long bolts through the fuel pump bracket and tighten securely.

16. Apply the fuel pump and couplings as shown in Fig. 8-15.

ASSEMBLY INSPECTION

1. After pump assembly, rotate the pump drive gear to check for gear noise or tight assembly.
2. Check the thrust of the pump drive gears. This is done using the same indicator arrangement shown in Fig. 8-14 for the main lube oil pump. Attach the indicator holder to the pump flange with the indicator button contacting the rim of the pump drive gear. Push the drive gear inward to take up all thrust in one direction. Set the indicator button to zero and pull the drive gear outward to deter-mine clearance. Thrust clearance using new parts should be within the specified limits.
3. With the indicator button on the out-side of the pump drive gear rim, as when checking thrust clearance, rotate the gear with the thrust held in one direction to check drive gear runout. Drive gear runout should not exceed specified total indicator reading.
4. Check the pump flange runout. Mount the indicator clamp on the drive gear and place the indicator button to con-tact the pump flange. Set the indicator to zero, and with the thrust held in one direction, rotate the drive gear. The runout of the pump flange face should not exceed specified total indicator reading.
5. Check the pump gears to body radial clearance. Clearance should be within the specified limits.
6. Additional clearances and limits are listed in the "Service Data" at the end of the section. Some of the clearances must be obtained by comparing the individual mating parts, or by assembly and disassembly using lead wire of other suitable means to obtain the part to part clearance.
7. After pump inspection, seal off the pump body openings and provide protection for the drive gear teeth.

TURBOCHARGER OIL FILTER

DESCRIPTION

The turbocharger oil filter, Fig. 8-17, provides additional protection for the

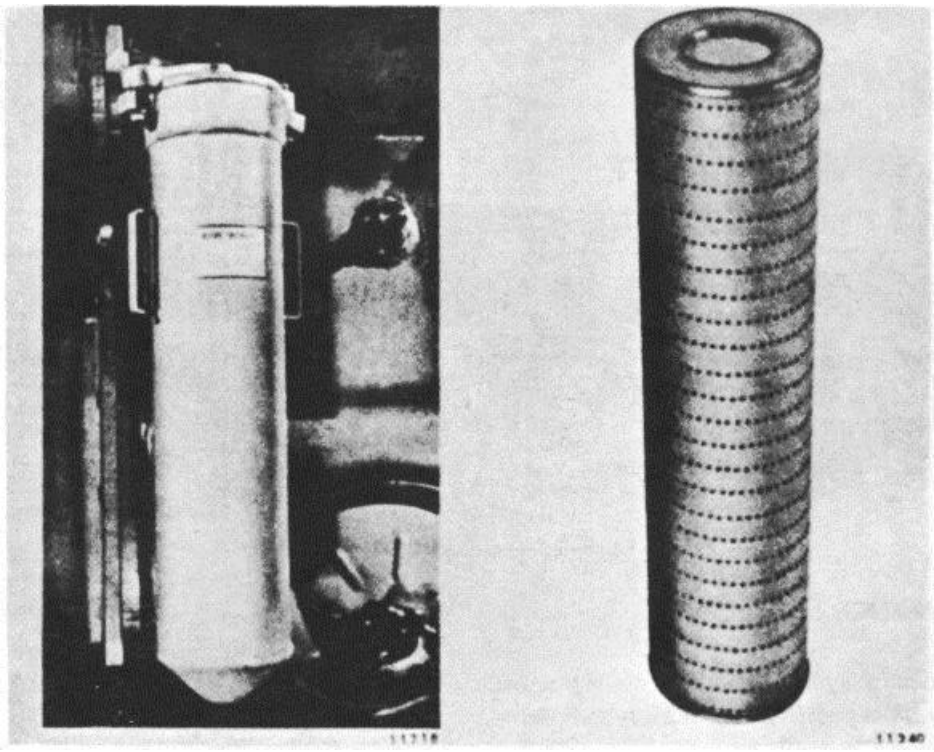


Fig. 8-17. -Turbocharger Oil Filter

high speed bearings and other lubricated areas of the turbocharger, by filtering the oil just before it is admitted to the turbocharger. Oil enters the filter through a cast manifold and, after passing through the filter, returns to the upper idler gear stub shaft and into the turbocharger. The filter element is of pleated paper construction, and is disposable. The filter is mounted on the camshaft drive housing at the right bank of the engine.

MAINTENANCE

The turbocharger filter should be serviced at intervals as specified in the Scheduled Maintenance Program or more frequently if experience indicates it is necessary.

To remove turbocharger filter assembly, loosen the two nuts holding the container to the upper housing until, using the handles on each side of the container, the container can be rotated to disengage from the upper housing. Remove the paper element and dispose of it. Thoroughly clean the container, install a new element, check the seal and replace, if required. Fill the container with clean oil and reassemble to the upper housing. Do not over-tighten attaching bolts as the seal may be damaged.

SOAK BACK OIL FILTER

DESCRIPTION

The soak back oil filter, Fig. 8-18, is a part of the system to supply oil to the turbocharger immediately after the engine has been shut down. This prevents residual heat in the turbine from possibly damaging the turbocharger bearings. The filter purifies the oil being supplied by the lube oil circulating pump. The system also ensures positive lubrication of the turbocharger when the engine is started and until the oil from the engine driven pump reaches operating pressure.

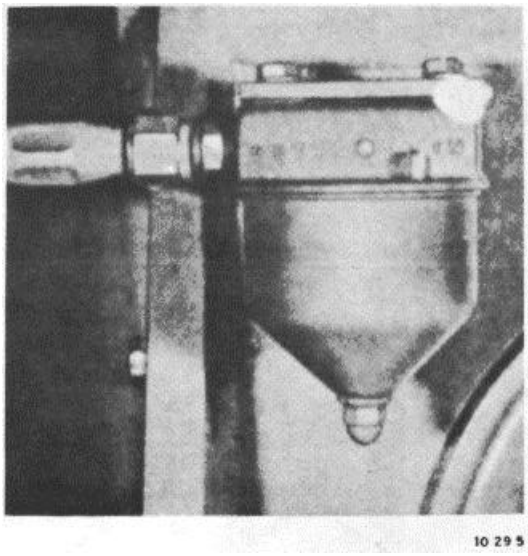


Fig. 8-18. - Soak Back Oil Filter

MAINTENANCE

The soak back system should be serviced at intervals specified in the Scheduled Maintenance Program or more frequently if experience indicates it is necessary.
To remove the cartridge discs for clean-ing, remove the acorn nut from the bottom of the bowl and separate the bowl from the upper housing. Remove the two nuts securing the cartridge on the center stud and remove the cartridge. It is not necessary to further disassemble the cartridge for cleaning.
A special tool, Fig. 8-19, is used for cleaning the disc cartridge.

1. Install the cartridge on the cleaning fixture, as shown in Fig. 8-19.
2. Connect an air hose to the fixture and immerse the fixture and filter in an open 50 gallon drum containing 20 gallons of cleaning solution (one part heavy LIX and two parts fuel oil).
3. For effective cleaning, the solution must flow both directions through the cartridge. This can be done by apply-ing air pressure to the element for one minute and then shutting off the air for one minute.
4. When the cartridge is clean, rinse for five minutes in a container of clean fuel oil.
5. Clean the filter bowl thoroughly.
6. Remove fixture from cartridge, and install a new seal on the upper housing.
7. Install the cartridge on the center stud and apply the two holding nuts.
8. Install the filter bowl to the center stud and install the acorn nut.

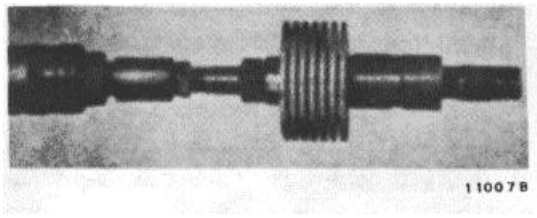


Fig. 8-19. - Cleaning Fixture Installation

PRELUBRICATION OF ENGINES

The prelubrication of newly installed over-hauled engines or engines which have been in storage a considerable length of time, is a necessary and important practice.

This procedure alleviates loading of unlubricated engine parts during the interval when the lube oil pump is filling the passages with oil. Also, it offers protection by giving visual evidence that oil distribution in the engine is satisfactory. The oil supply from an external pump should be warm. Oil pressure need not exceed 35 psi.

When pumping the oil through the engine, inspection should be made at the rocker arms, camshaft bearings, and main bearings to see that oil is reaching these parts. The crankshaft should be rotated at least one revolution so as to distribute oil over various moving parts. Sufficient oil should be pumped to ensure oil reaching all parts of the engine.

Before starting the engine, pour a liberal quantity of oil over the cylinder mechanism of each bank. This applies also to new engines.

NOTE: When an engine is replaced due to mechanical breakdown, it is important that the entire oil system, such as oil coolers, filters, and strainers, be thoroughly cleaned before a replacement engine or the reconditioned engine is put in service. A recurrence of trouble may be experienced in the clean engine, if other system components have been neglected.

In some cases engines have been removed from service and stored in the “as is” condition by draining the oil and applying anti-rust compound. When these engines are returned to service, care must be taken to see that any loose deposits are flushed out before adding a new oil charge. The entire engine should be sprayed with fuel, to break up any sludge deposits, and then drained, being careful that the drains are not plugged. Fuel should not be sprayed directly on the valve mechanism or bearings, as lubrication will be removed or dirt forced into these areas. The surfaces should then be wiped dry before the new oil is added to the engine.

OIL SYSTEM INFORMATION

Additional information on the oil system and components is given in the latest revisions of Maintenance Instruction bulletins. These instructions cover important items such as the Scheduled Maintenance Pro-gram, which outlines maintenance intervals, flushing instructions, and cleaning information. Engine lubricating oil should be qualified for use as specified in Maintenance Instruction 1752.

567E4 SERVICE DATA
LUBRICATING OIL SYSTEM

SPECIFICATIONS

Lube Off Pressure Relief Valve

Valve guide inside diameter - *Max*	.5025"
Valve stem outside diameter - Min.	.4925"
Valve face to stem squareness (outer edge of valve face) - T.L.R. Limit	.002"

Oil Pumps

	600 RPM	720 RPM
Capacity (approximate GPM)		
Scavenging pump	260	311
Piston cooling pump	61	59
Lube oil pump	123	149
Drive shaft to rear housing bushing clearance - New	.0015" -	.0045"
Limit		.007"
Sleeve to bushing clearance - New	.015" -	.0050"
Limit		.007"
Idler shaft to gear bushing clearance - New	.0015" -	.0051"
Limit		.007"
* Driven gear to body thrust clearance (front or rear) - New	.016" -	.024"
Limit		.000"
** Outer driven gear to front body or to spacer plate thrust clearance - New	.019" -	.023"
Limit		.000"
** Center driven gear to spacer plate and inner driven gear to rear body thrust clearance - New	.016" -	.003"
Limit		.000"
* Drive gear to body bushing thrust clearance (front or rear) - New	.008" -	.016"
Limit		.022"
** Outer drive gear to spacer plate thrust clearance - New	.001" -	.019"
Limit		.022"
** Inner drive gear to rear body bushing thrust clearance - New	.004" -	.018"
Limit		.022"

Thrust face of bushing to body clearance (front and rear) - New	.001" - .007"
Limit	.000"
Drive and driven gear backlash - New	.012" - .016"
Limit	.030"
Radial clearance of drive and driven gear to body - Min	.0015"
Max.	.010
Pump drive gear backlash - New	.008" - .016"
Limit	.025"
Front body bushing diameter - New	2.3745" - 2.3765"
Max.	2.3790"
Rear body bushing diameter - New	2.4995" - 2.5015"
Max.	2.5040
Driven gear bushing diameter - New	1.9995" - 2.0021"
Max	2.0040"
Pump drive gear face runout - T.L.R. Limit	.003"
Pump flange face runout - T.LR. Limit	.005"
Pump flange pilot concentricity - T.LR. Limit	.002"

NOTE: * Scavenging pump only
** Lube and piston cooling pump only

EQUIPMENT LIST

	Part No.
Gauge - piston cooling pipe alignment	8071720
Cleaner - piston cooling oil pipe	8087086
Spray gun	8193041
Oil seal installer tool	8301543
Soak back filter cartridge cleaning tool	8315754
Cleaner activator (6 oz.)	8352873
Retaining compound (50 cc.)	8366781
Testing device - lube oil suction	File 110
Lube oil system - pretest diagram (includes diagram for fuel and water system)	File 294

COOLING SYSTEM

DESCRIPTION

The engine cooling system consists of **engine driven centrifugal** water pumps, replaceable inlet water manifolds with an individual jumper line to each liner, cylinder head discharge elbows, and an outlet manifold through which cooling water is circulated. The centrifugal water pumps are mounted on the accessory drive housing and are driven by the governor drive gear. A representative illustration of the engine cooling system is shown in Fig. 9-1.

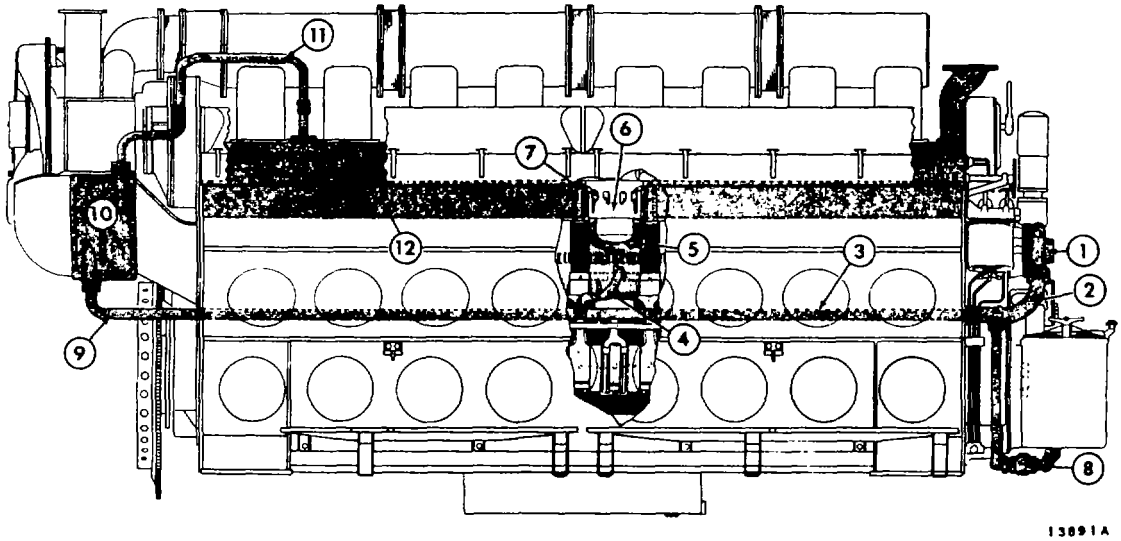
Engine water is also circulated through each after cooler, Fig. 9-1, located in the turbocharger air discharge duct, to cool the air before it enters the engine air box.

The engine discharge water flows through an external cooling system to dispel the heat taken up in the engine. This system consists of a water tank, water level gauges, temperature gauges, radiators and connecting piping.

MAINTENANCE

ENGINE WATER TEMPERATURE

Temperature gauges are provided in the cooling system to visually check that the engine water temperature is within the



1. Water Pump
2. Water Inlet Elbow
3. Water Inlet Manifold
4. Water Inlet Tube
5. Liner Water Passage
6. Cylinder Head
7. Cylinder Head Outlet Elbow
8. System Drain Valve
9. Water Line To After coolers
10. Right Bank Aftercooler
11. After cooler Water Discharge
12. Water Discharge Manifold

Fig. 9-1. - Cooling System Schematic 2-132

recommended range of about 160 - 190° F. Automatic temperature controls are set to maintain the water temperature within set limits. It should be noted, however, that the engine should not be run above 500 RPM until the water temperature is above 130° F.

A hot engine alarm indicates excessively high water discharge temperature. Hot engine water could result from faulty water cooling equipment or excessive loss of cooling water. In the event of a hot engine alarm, engine load should be re-moved and speed reduced in an attempt to obtain normal temperature. Before resuming operation, the cause of the hot engine water should be found and the condition corrected.

ENGINE COOLANT SOLUTION

Coolant solutions are composed of water, corrosion inhibitor and, if necessary, antifreeze. The selection and maintenance of a proper coolant solution are necessary for efficient cooling system opera tion. Failure to recognize the importance of these factors can result in cooling system damage, increased maintenance costs, and unnecessary equipment down time. Refer to Maintenance Instruction 1748 for detailed information regarding coolant solutions.

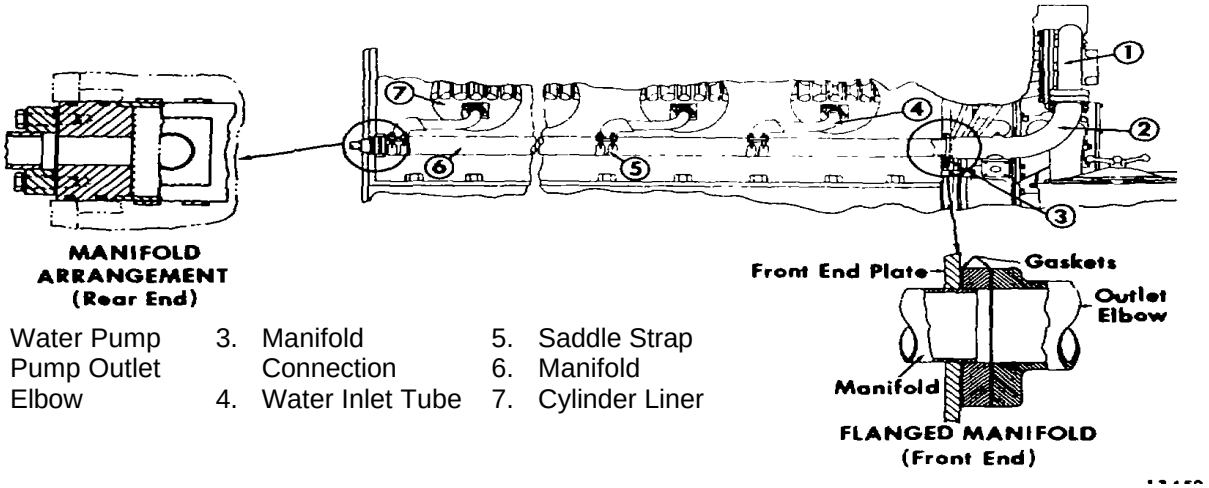
Coolant samples should be taken from the cooling system for analysis at intervals as specified in the Scheduled Maintenance Program.

COOLING SYSTEM PIPING

DESCRIPTION

Refer to Fig. 9-2 for piping details. Pump outlet elbows conduct water from the pumps to the removable water inlet manifolds located in each air box. Each manifold is connected at the rear end plate to an after cooler water inlet pipe. The rear end flange of the manifold is equipped with two seals, which prevent the leakage of air from the air box. A flange at the front end of the manifold contacts the outer face of the front end plate when the manifold is installed. One gasket is used between the manifold flange and end plate, and one between the manifold flange and water pump outlet elbow.

Each liner is individually supplied with coolant from the water manifold through a water inlet tube assembly. The inlet



1. Water Pump
2. Pump Outlet Elbow
3. Manifold Connection
4. Water Inlet Tube
5. Saddle Strap
6. Manifold
7. Cylinder Liner

tube is bolted to the liner and connected to the manifold by saddle strap assemblies around the manifold. A gasket is used at the saddle connection while a synthetic rubber seal ring is used at the liner. A deflector is used at each liner water inlet to divert the water and prevent direct impingement on the inner liner wall. Water enters the cylinder head through 12 discharge holes at the top of the liner. A counterbore around each hole accommodates a water seal ring. A water discharge elbow bolted to each cylinder head provides water passage to the water discharge manifold extending along the top of the crankcase. The cylinder head water discharge elbows are applied to each cylinder head before installation, and act to properly position each cylinder head. Seal rings are used at the elbow connections. The seals may be replaced if required, by removing the elbow, after first removing the crab above it, without disturbing the cylinder head. The crankcase has two “built-in” siphon tubes inside the water discharge manifold. One is located at the second cylinder from the rear end on the right bank, and the other at the second cylinder from the front end on the left bank. When engine water is drained, this will provide for engine cooling water draining in the event the engine is not level.

MAINTENANCE

PIPING INSTALLATION

After the cylinder head and liner are properly installed in the engine, the water inlet manifold and liner water inlet tube may be applied.

1. Inspect the water manifold for any dirt or roughness in the area of the discharge holes and at the front end plate flange, and correct if necessary. Clean off the end plate flange area for the flange gasket.
2. Place the manifold flange gasket over the manifold and insert the manifold- into the air box.
3. Carefully guide the end of the water manifold into the rear end plate so that seals are not damaged. When positioned correctly, the manifold should be quite firmly supported at the end.
4. Apply and tighten the manifold flange to front end plate bolts. Temporary bolts may be used if the water dis-charge elbow is not ready to be applied.
5. Apply the seal to the liner water inlet tube, and apply the tube to the liner, leaving the bolts loose. (The seal used on the liner water inlet tube is the same as that used at the cylinder head water discharge elbow.)
6. Apply the saddle strap and tighten the nuts finger tight, leaving sufficient space between the saddle and manifold for the gasket. #
7. Bend the manifold to inlet tube gasket slightly to conform to the manifold and insert the gasket between the manifold and the saddle.
8. Tighten the liner to water tube bolts to 30 ft-lbs torque and the saddle strap nuts to 15 ft-lbs torque.
9. After all liner water inlet tubes are properly applied, the manifold will be securely held and the temporary bolts, if applied, should be removed and the water pump discharge elbow connected.

WATER LEAKS

If loss of water in the cooling system is noticed, check for leakage at piping, pump seals, jumper tube connections, cylinder head outlet elbow, junction of head to liner, and check for liner or cylinder head cracks.

Unless very obvious the location of a crack in the cylinder head or liner is very difficult to find, and requires careful examination. Any indication of a water leak in the head or liner requires removal and thorough inspection. inspect cylinder interior through liner ports.

Water may leak and enter the lube oil at the cylinder head outlet elbow seals. These seals can be replaced without disturbing the cylinder head, provided a crab nut and crab are removed and the water is drained. Water contamination of lubricating oil will necessitate draining the oil. Before the oil is renewed, the system should be flushed as outlined in Maintenance Instruction 1757.

Lube oil contamination is best determined by laboratory analysis, but in the absence of such means, the following method of checking for water in the oil may be used.

Draw or dip a gallon of lube oil from the bottom of the engine lube oil sump. Let it stand for about 10 minutes, then spill about ¾ of the oil from the container. Place the remaining ¼ in a glass bottle and allow sample to stand another 10 minutes. If any water is indicated in the bottom of the bottle, it is recommended that the lube oil system be drained and flushed. Replace with new oil after source of contamination is eliminated.

AFTERCOOLER

DESCRIPTION

An aftercooler is located on each side of the turbocharger to cool the air entering each bank of the engine. Cooling the air compressed in the turbocharger reduces the temperature of the air thereby increasing air density and improving engine operating efficiency.

The aftercoolers are heat exchangers of box-like construction consisting of a tube nest, through which the water is circulated, and fins to aid the transfer of heat from the compressed air entering the engine air box. The aftercoolers receive water directly from the discharge side of the engine water pumps, and water leaving the aftercoolers is piped to the engine discharge manifold. No valves are located in the aftercooler piping, so cool-ing water is provided whenever the engine is running.

MAINTENANCE

Any evidence of water leakage in the core of the aftercooler will necessitate removal of the aftercooler assembly. Leakage can usually be detected by inspecting the interior of the air duct assembly at the air box side when the engine is shut down.

REMOVAL

1. After draining the engine water, dis-connect the water discharge or vent line flange at the top of the aftercooler.

2. Loosen the water inlet line at the bottom of the aftercooler.

3. Remove the mounting bolts securing the aftercooler to the air duct both at the front and at the back, and free the assembly. Jacking screw holes in the aftercooler flange will receive screws to aid in breaking the joint between the air duct and aftercooler.

4. When the aftercooler is sufficiently free apply an aftercooler lifting tool, Fig. 9-3, and using a suitable hoist, remove the entire assembly from the air duct.

INSTALLATION

1. Check the air duct and aftercooler mounting surfaces to make certain that there are no nicks, dirt or roughness on these areas.

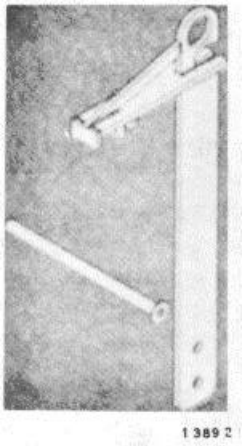


Fig. 9-3. - Aftercooler Lifting Tool

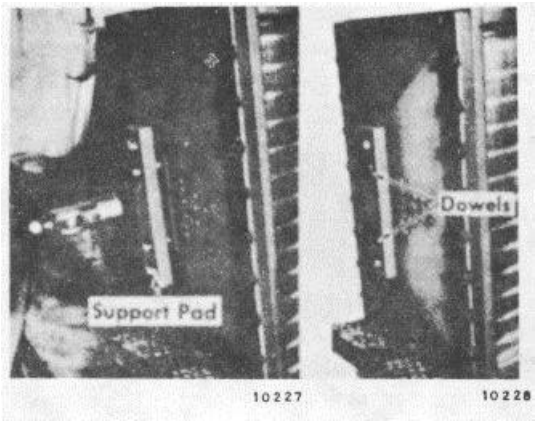


Fig. 9-4. - Support Pad To Dowel

2. Apply the support pad to the back plate dowels of the aftercooler, Fig. 9-4, with the gasket in position at the out-side so as to contact the air duct.

3. Apply the aftercooler to air duct gasket over two guide dowels and using the aftercooler lifting tool and hoist, install the aftercooler in the air duct.

4. Line up the support pad bolt holes, Fig. 9-5, at the back of the air duct Installation and apply, but do not tighten the support pad bolts.

5. Correctly position the aftercooler flange over the air duct gasket and flange holes, apply and tighten the bolts holding the aftercooler to the air duct.

6. When the aftercooler flange bolts have been tightened, tighten the support pad

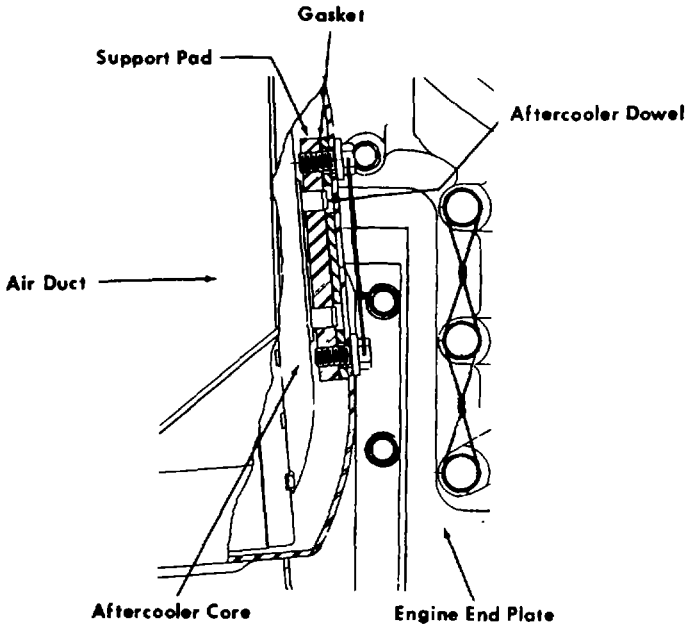


Fig. 9-5. - Air Duct Support Pad Application

bolts at the back of the air duct, Fig. 9-5, to 130 ft-lbs and lockwire.

CORE REPLACEMENT

In the event that an aftercooler is removed due to a leaking core, the core may be replaced using the following procedure.

1. Gaskets used in the aftercooler assembly should be prepared in advance of assembly by being soaked in ASTM (American Society For Testing Materials) No. 3 oil for 15 minutes at a temperature of 160° F. After soaking, the gaskets should be removed and permitted to drain before using.

2. Place the core on the work bench and apply the cover gasket and cover.

3. Apply the cover bolts and tighten to 35 ft-lbs. Tighten from the center bolt out to the end bolts.

4. Invert the assembly and apply the header to core gasket and header.

5. Apply the header to core bolts and tighten from the center bolt out to the end bolts. Tighten the bolts to 35 ft-lbs.

6. After the assembly has been completed, blank off all flanges except one, and apply an air test arrangement on the remaining flange.

7. With 50 psi air pressure in the water passage of the core, submerge the assembly in water and check for leaks.

8. After water test, recheck the torque of the header and cover bolts to 35 ft-lbs.

WATER PUMPS

DESCRIPTION

The two engine cooling water pumps, Fig. 9-6, are high capacity centrifugal pumps, which rotate counterclockwise. The components of the water pump are identified

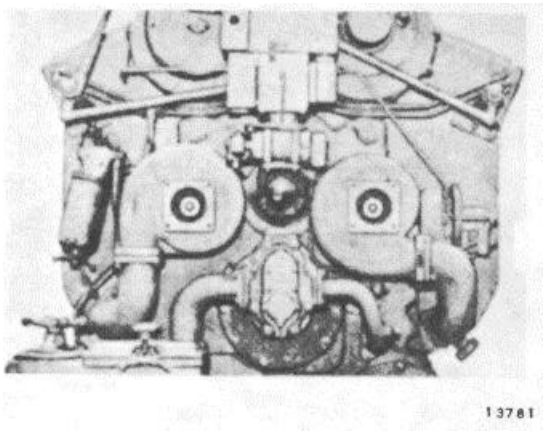


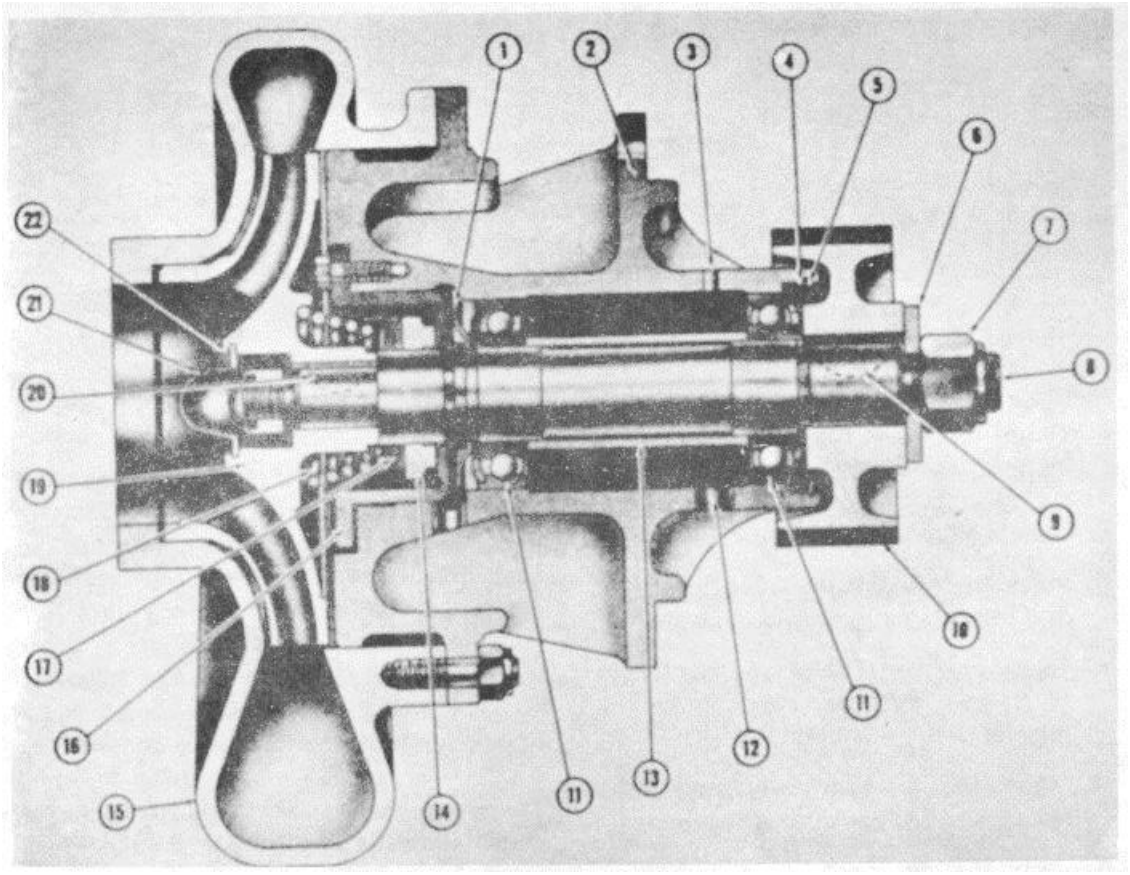
Fig. 9-6. - Water Pump Installation

in Fig. 9-7. The pumps are carried under two part numbers to identify the right and the left bank pumps. The only difference between right and left bank pumps is the position of the impeller housing in relation to the pump shaft housing. The position of the impeller housing may be changed on either pump to permit its use on the opposite bank.

The pump drive shaft is supported in the main pump housing by two ball bearings separated by a steel spacer. The bearings receive lubricating oil from the engine oil system through a drilled passage in the pump housing. The outer bearing ad-joins a water slinger which bears against a shoulder on the shaft. The inner bearing is held in place by a retainer and snap ring to absorb any thrust in the shaft. The pump drive gear is keyed to the pump shaft abutting the inner bearing and is held on the shaft by a washer and nut.

The stationary bushing, Fig. 9-7, is applied to the drive shaft housing. The carbon of the seal assembly, Fig. 9-8, faces against the smooth inner surface and is held by a spring. Any water leakage past the seal is indicated at a tell-tale drain in the drive shaft housing, which permits runoff, and prevents water from reaching the engine side of the pump.

The impeller is keyed to the pump shaft and is secured to the shaft by a washer



1. Water Slinger
2. Support Housing
3. Oil Inlet
4. Bearing Retainer Ring
5. Snap Ring
6. Gear Retainer Washer
7. Retaining Nut
8. Water Pump Shat
9. Drive Gear Key
10. Drive Gear
11. Bearing Assembly
12. Oil Outlet
13. Bearing Spacer
14. Carbon Seal
15. Impeller Housing
16. Stationary Bushing
17. Outer Seal
18. Seal Retainer Spring
19. Impeller
20. Impeller Retainer Key
21. Impeller Cap
21. Impeller Cap
22. Snap Ring

NOTE: Callouts 21 and 22 apply to 60 cycle unit only.

Fig. 9-7. ***--*** *Water Pump, Cross-Section*

and capped nut. It is enclosed by the impeller housing, which is assembled to the main pump housing by eight studs and nuts.

MAINTENANCE

PUMP REMOVAL

1. Drain cooling system.
2. Remove water pump inlet flexible connection.

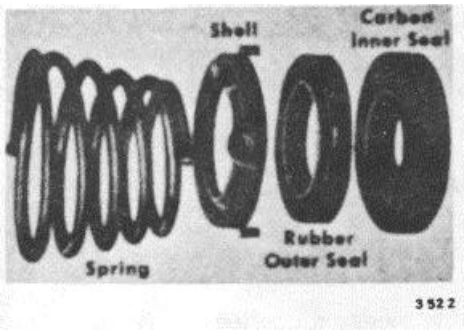


Fig. 9-8. - Spring And Seal Assembly

3. Disconnect pump discharge flange connection.
4. Remove pump mounting bolts and pump from engine.

HOUSING AND IMPELLER REMOVAL

1. Some pumps have two lockwired bolts in the bottom of the housing which must be removed prior to pump dis-assembly.

2. Remove nuts holding impeller housing and remove the housing. The impeller housing can be more easily removed if the pump is held suspended slightly above the work bench by a hoist, impeller end down, while tapping on the housing with a rawhide or wooden mallet.

3. Remove impeller shaft nut and washer. Place the extension tip of the impeller puller, Fig.--9, on the pump drive shaft. Apply the puller to the pump and remove impeller.

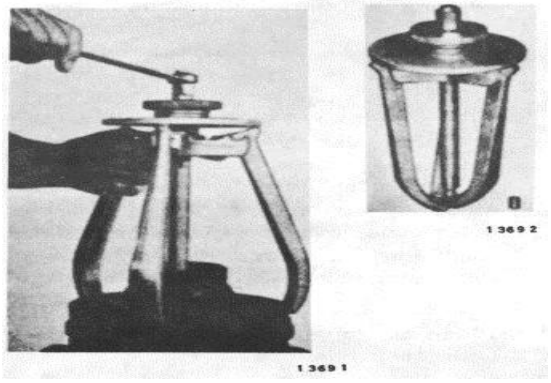


Fig. 9-9.-Removing Pump Impeller

REMOVAL AND APPLICATION OF PUMP SEALS

Seal Removal

1. After impeller removal, remove spring and seal assembly, Fig. 9-10. Use care to prevent damage to the stationary bushing seal surface. Some seal assemblies offer little resistance to removal, but some are quite firm on the shaft. Seal assemblies tight on the shaft may be removed with the stationary bushing.

2. Remove the bolts from the stationary bushing. In the event the bushing is not easily removed, insert 3/8" x 2" bolts in the puller holes provided in the bushing, Fig. 9-10, and force the bushing out from the housing. Some-times the bushing may be loosened by tapping on the bushing flange with a rawhide mallet, a 11 o w i n g removal without using puller bolts.

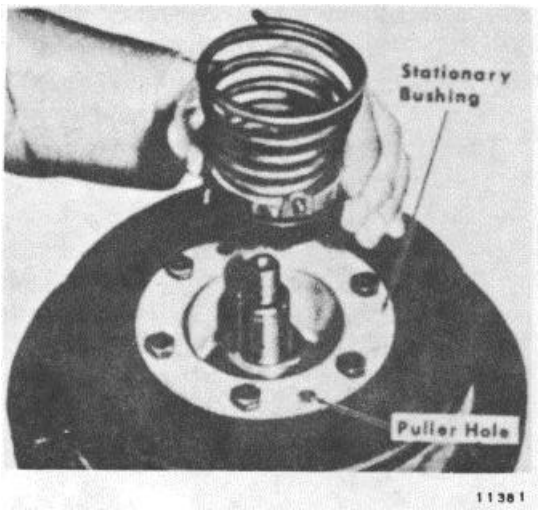


Fig. 9-10. - Seal And Bushing Removal

Seal Application

1. Clean the stationary bushing and pump shaft.

CAUTION: The sealing surface of the stationary bushing must be absolutely smooth and flat to

prevent wear of the carbon washer. A stationary bushing having a rough surface must be refinished or be replaced with a new bushing.

2. Before applying the stationary bush-ing, be sure the bushing and mounting surfaces are clean. Foreign material can cause the bushing to cock and interfere with effective sealing. Also, be sure that the smooth and flat carbon seal surface of the bushing is clean and dry. Apply new stationary bushing gasket and bushing. Tighten the bolts evenly and torque to 90-100 in.-lbs.

After applying the stationary bushing, check runout of the carbon seal surface using an indicator mounted on the end of the pump shaft. If runout limit is exceeded, reposition bushing 180° and/or scrape off mounting surface in area of high reading.

3. Install the new seal assembly, refer to Fig. 9-8. Apply carbon inner seal with the narrow end contacting the stationary bushing. Check carbon face for cleanliness. Apply rubber outer seal to shell, and apply to carbon seal so ears of shell fit into the slots in the carbon seal. One end of the drive spring fits into the shell while the other end must be fitted into a slot at the bottom of the impeller when it is assembled.

DRIVE GEAR, BEARING, AND

SHAFT REMOVAL

1. Support drive shaft housing in a vise with jaw protectors and remove drive gear retaining nut and washer.
2. Remove drive gear and key from shaft.

3. Remove snap ring and bearing retainer.

4. Using a rawhide mallet, tap shaft at impeller end of housing until shaft and bearing assembly can be removed from the gear end of housing.

5. Place shaft and bearing assembly in arbor press and remove bearings.

6. Clean and inspect parts for defects and replace damaged parts.

Bearings with seals or shields on both sides should be wiped clean but not washed. Inspect bearings for excessive end play, roughness, seizing, galled, worn or abraded surfaces, broken or bent seals or shields, and fractured outer races.
Pump shaft seal contact surfaces must be smooth. See Service Data at end of section for wear limits.

SHAFT, BEARING, AND DRIVE GEAR ASSEMBLY

1. Assemble water slinger, outer bear-ing, spacer, and inner bearing to the pump shaft, making sure that the rear bearing with the retainer ring is positioned correctly with the retainer ring to the outside. These parts are assembled, Fig. 9-7, first with the slinger next to the shoulder on the shaft, con-cave side toward the impeller end, followed by the outer bearing (without retainer), spacer and inner bearing, abutting each other snugly. The seal sides of the bearings go toward the outer ends of the assembly, being distinguished by the seal side of the bear-ing protruding slightly beyond the outer race.

2. Place the drive shaft housing in a vise with jaw protectors.

3. Insert the shaft and bearing assembly, slinger end first, from the drive gear

end of the housing. Using a rawhide mallet, lightly tap the assembly until it aligns with and enters the first bearing bore and continue tapping the assembly until it is properly seated in the housing.

4. Apply the bearing-retainer and snap ring back of the rear bearing.
5. Place key in shaft and assemble drive gear to shaft, using a rawhide mallet. Check shaft key and keyway fit. Check that pump shaft diameter to gear bore fit is within the maximum limit. Inspect gear nut insert for any signs of disintegration. Nuts may be reused if fiber collar drag is 92 in.-lbs. Gear nut (1" - 14) torque is 265 ft-lbs.
6. Replace seal assembly as previously described.

INSTALLING IMPELLER

1. Fig. 9-11 shows the impeller installer being used to assemble the impeller to the drive shaft housing. The threaded bushing is screwed on pump shaft threads and then by turning outer portion of installer tool, the impeller is pressed into position. Care must be taken to start the impeller straight on the shaft and to see that the key and keyway are aligned. Before the impeller is brought all the way down, check the underside to see that the seal spring is in the spring slot under the impeller and then finish the impeller application.
2. Check the insert in the impeller shaft nut to see that it is free from tears and disintegration. Nuts may be re-used if the fiber collar drag is 32 in.-lbs. Apply the impeller retaining washer and nut. Torque value of the impeller nut is 80 ft-lbs.

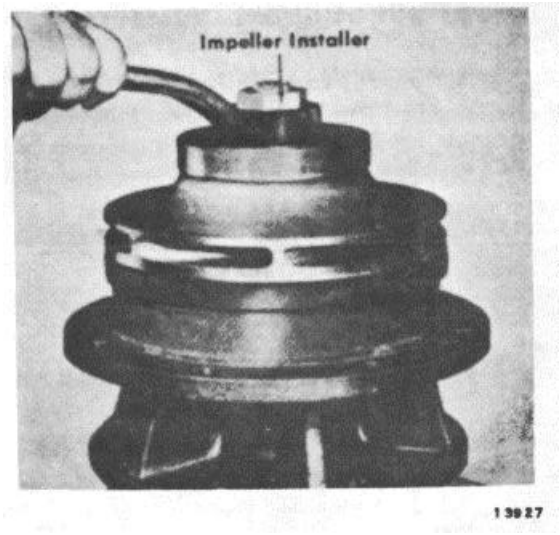


Fig. 9-11. - Installing Pump Impeller

INSTALLING IMPELLER HOUSING

1. Check that drilled drain passage is free of obstruction.
2. Determine whether the pump is to be used on the right or left bank of the engine since the impeller housing is positioned differently in each case.
3. An arrow is cast at the bottom of the pump shaft housing and the impeller housing has a letter "R" and "L." *For* a right bank pump assemble the impeller housing so that the "R" is opposite the arrow on the shaft housing or for a left bank pump the "L" is opposite the arrow, as shown in Fig. 9-12.
4. Install housing in the correct position, using new gasket between the impeller and shaft housing. Apply housing nuts to studs and carefully tighten.
5. If applicable, put the two bolts in the bottom of the housing and lockwire.

INSTALLING PUMP

1. The pumps are installed in the position shown in Fig. 9-12 for the right or left bank. Torque value for the pump

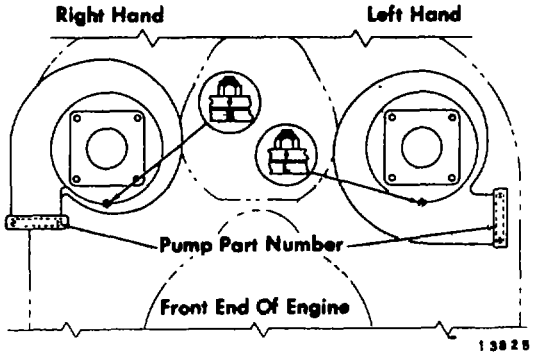


Fig. 9-12. - Pump Housing Positioning

accessory cover mounting bolts is 65 ft-lbs.

2. The part number of the pump is located on a plate attached to the pump dis-charge flange, as shown in Fig. 9-12. It should be noted also on pump installation that the water inlet elbow is the proper one as listed in the parts book for the engine installation.

3. When installing a water pump, care should be taken with the application of the flexible water inlet connection. This connection consists of a sleeve, synthetic rubber seals, seal retainers and bolted clamps. See Maintenance Instruction 1800 for information on the application of flexible pipe couplings.

567E4 SERVICE DATA

COOLING SYSTEM

SPECIFICATIONS

Pump drive gear backlash -	New	.008" - .016"
	Limit	.030"

Bearing bores in support housing may be oversize or bearing outer diameter undersize. The limits governing the fit are:	Interference - Max.	.0001"
	Clearance - Max.	.0025"
Pump shaft bearing mounting diameters to bearing bores. No wear allowed. The limits governing the fit are:	Interference - Max	.0009"
	Clearance - Max	.0001"
Pump shaft drive gear mounting diameter to gear bore. The limits governing the fit are:	Interference - Max.	.0005"
	Clearance - Max	.001"
Pump shaft impeller mounting diameter to impeller bore. The limits governing the fit are:	Interference - Max.	.0025"
	Interference - Min.	.0005"

Stationary bushing seal seat squareness with drive shaft - T.I.R. ..... .001"

EQUIPMENT LIST

	Part No.
Impeller installer	8052959
Water pump collar puller	8220578
Water pump impeller puller	8354367
Engine cooling system water test (schematic pumping diagram)	File 292
Aftercooler lifting tool	File 690

FUEL SYSTEM

DESCRIPTION

The engine fuel system, Fig. 10-1, consists of the fuel injectors, the engine mounted fuel filter, and fuel supply and return manifolds, and the engine driven fuel pump mounted on the scavenging oil pump.

Components external to the engine such as the fuel tank, flame arrester, fuel suction filter, single cartridge filter, and connecting lines complete the fuel system.
]
In operation, fuel from the fuel tank is drawn up by the fuel pump through a suction strainer and is delivered to the engine mounted filter. It then passes through the filter elements to the fuel manifold supply line and from there through a jumper line and injector inlet filter at each cylinder into the injector. A small portion of this fuel supplied to each injector is pumped into the cylinder, at a very high pressure, through the needle valve and spray tip of the injector. The quantity of fuel injected depends upon the rotative position of the plunger as set by the injector rack and governor. The excess fuel not used by the injector, flows through the injector, serving to lubricate and cool the working parts.

The fuel leaves the injector through the return fuel filter. This filter protects the injector in the event of a backward flow of fuel into the injector from the return fuel line. From the return fuel filter in the Injector, the excess fuel passes through the fuel return line in the manifold to the relief valve inlet of the “return fuel” sight glass on the engine mounted fuel filter.

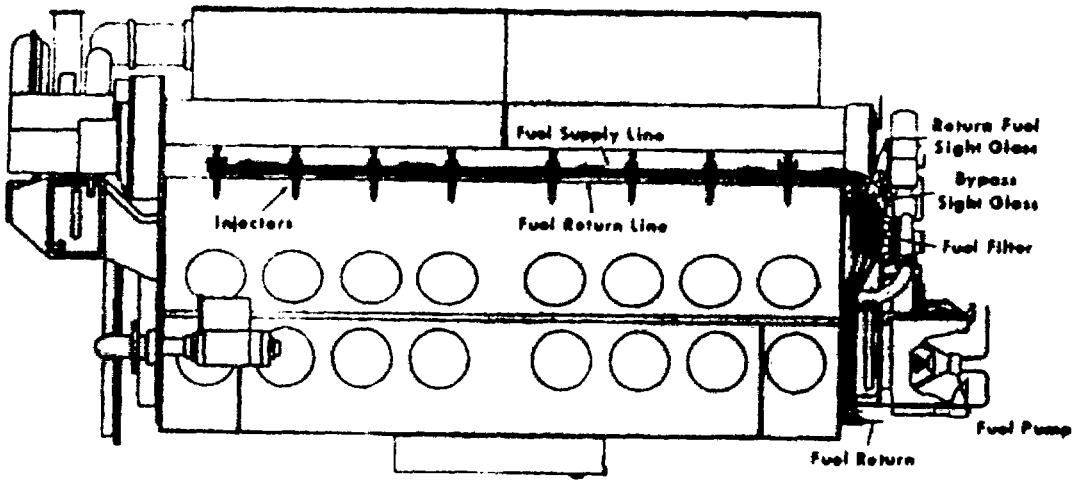


Fig. 10-1. - Typical Fuel System

This valve restricts the return fuel, maintaining a back pressure on the injectors. The fuel continues into the "return fuel" sight glass, filling the glass, down through the standpipe under the glass and through the return line to the fuel supply tank.

FUEL INJECTORS

DESCRIPTION

An injector, Fig. 102, is located and seated in a tapered hole in the center of each cylinder head, with the spray tip protruding slightly below the bottom of the head. It is positioned in the head by a dowel and held in place by an injector holddown crab and nut.

The external working parts of the injector are lubricated by oil from the end of the injector rocker arm adjusting screw. The internal working parts are lubricated and cooled by the flow of fuel oil through the injector.

A cross-section of the unit injector and names of the various parts are shown in Fig. 10-3.

The plunger is given a constant stroke reciprocating motion by the injector cam acting through the rocker arm and plunger follower. The timing of the injection period during the plunger stroke is set by an adjusting screw at the end of the rocker arm. Fig. 10-4 shows flow of fuel through the injector during one downward stroke.

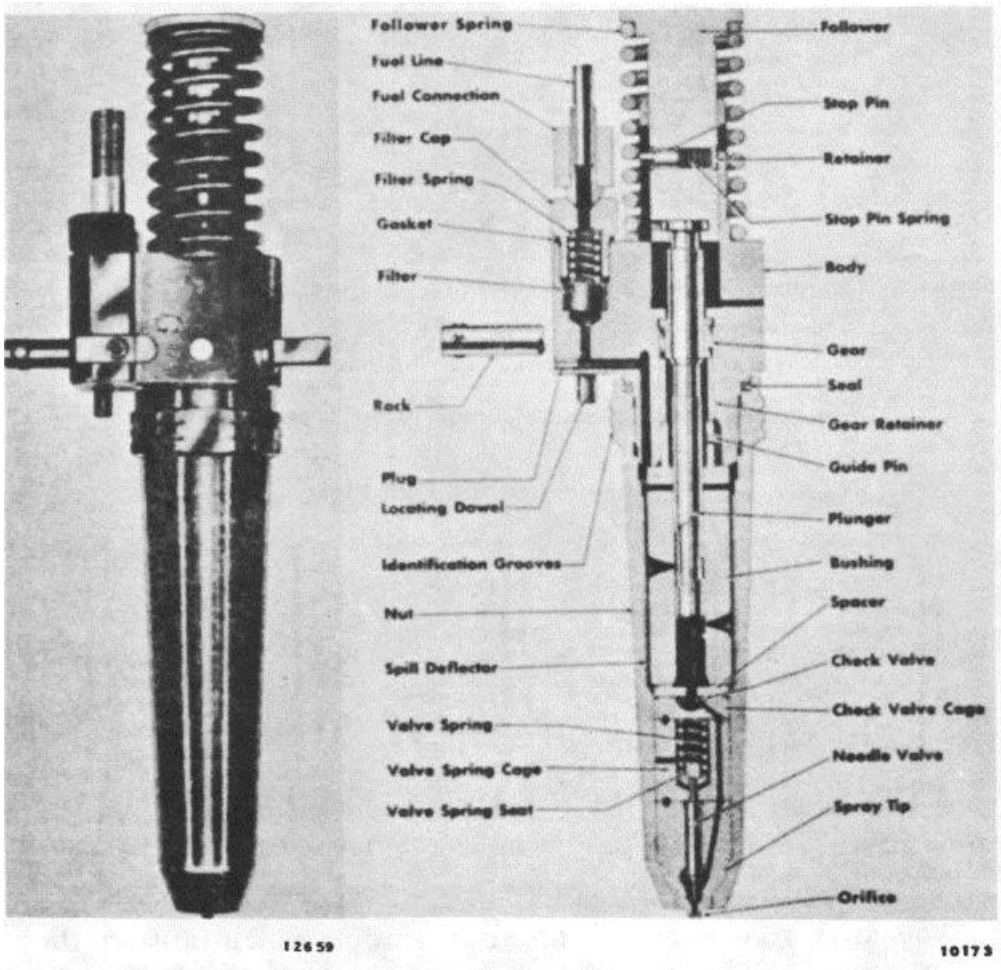


Fig. 10-2. - Fuel Injector

Fig. 10-3 - Fuel Injector, Cross-Section

Rotation of the plunger, by means of the rack and gear, controls the quantity of fuel injected into the cylinder during each stroke. Rack position is controlled by the governor through the injector lay shaft and linkage. The gear is keyed to and is a sliding fit on the plunger to allow plunger vertical movement.

The helices near the bottom of the plunger control the opening and closing of both fuel ports of the plunger bushing. Rotation of the plunger regulates the time that both ports are closed during the downward stroke, thus controlling the quantity of fuel injected into the cylinder as shown in Fig. 10-5. As the plunger is rotated from idling position to full load position, the pumping part of the stroke is lengthened, injection is started earlier, and more fuel is injected.

Proper atomization of the fuel is accomplished by the high pressure created during the downward stroke of the plunger, which forces fuel past the needle valve and out through the spray holes in the tip of the injector.

The injectors have an adjustable calibrating slide mounted on the side of the injector body, adjacent to the rack. This

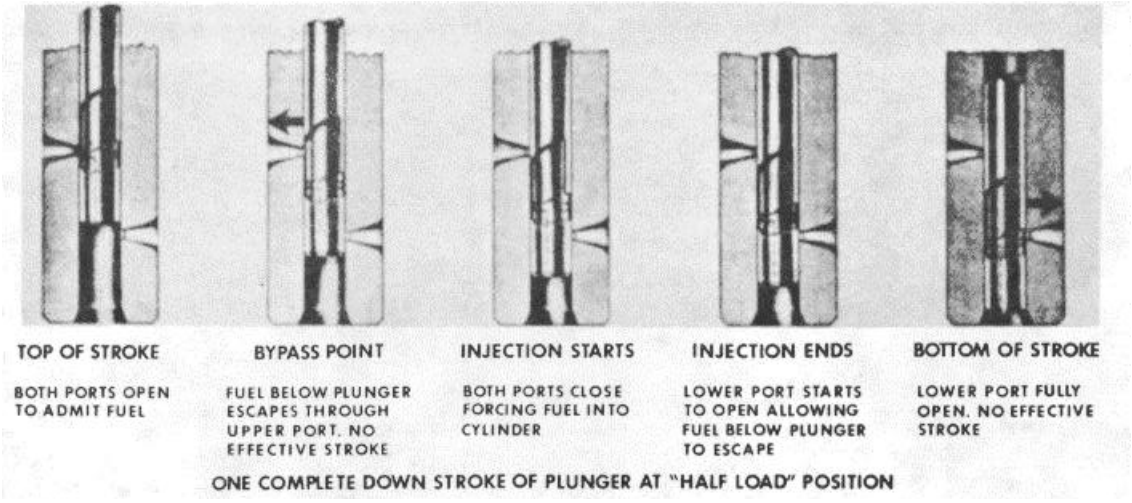


Fig. 10-4.- Injector Fuel Flow

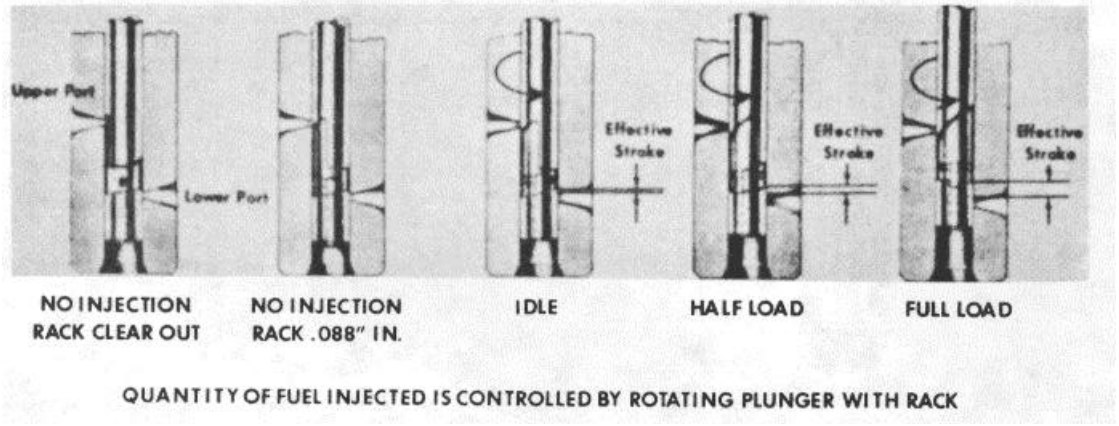


Fig. 10-5. - Plunger Fuel Control

slide is incorporated solely as a means of adjusting injector output on a calibrating stand.

Filters at the fuel inlet and outlet connections protect the working parts of the injector.

MAINTENANCE

INSTALLATION

1. When installing an injector in an engine, make sure it is the correct injector for the engine in which it is to be applied.

2. See that injector body and tapered hole in cylinder head are clean.

3. Install injector and apply injector hold down crab, spherical washer and nut. Torque nut to 40-50 ft-lbs.

4. Connect injector rack to lever assembly.

5. Install and tighten fuel supply and return lines to injector and engine fuel manifold.

6. Install rocker arm shaft and rocker arms. Loosen injector rocker arm locknut and back off on adjusting screw before tightening rocker arm shaft nuts. Injector is now ready for timing.

TIMING THE INJECTOR

With the injector installed, make timing adjustment as follows:

1. Set the flywheel at 0° top dead center of the cylinder being timed.

2. Insert injector timing gauge into the hole provided for it in the injector body, Fig. 10-6.

3. Loosen locknut and turn the rocker arm adjusting screw until the shoulder of the gauge just passes over the injector follower guide.

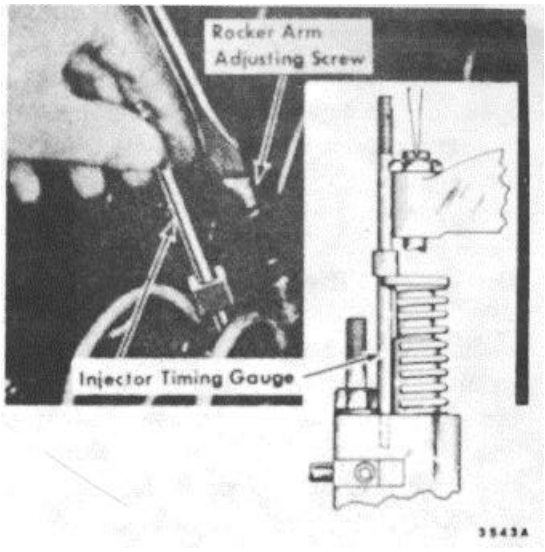


Fig. 10-6. - Timing Injector

NOTE: Injectors cannot be timed if the overspeed has been tripped. It must first be reset and the engine crankshaft barred over at least one revolution.

4. Tighten adjusting screw locknut, hold-ing adjusting screw in position with a screwdriver.

5. Recheck setting.

STICKING INJECTORS

Engines may encounter sticking injectors due to fuel, lube oil, or filter maintenance conditions. Since these conditions very often are momentary, injector removal may be minimized by utilizing alcohol to free up injectors while installed. This is done by applying ordinary commercial methanol to the injectors through a hole opposite the timing tool hole, and “popping” the injectors or motoring the engine. This sticking condition usually occurs on injectors which are held with the plungers down when the engine is stopped. Should injector racks show signs of sticking, they should be checked for gum or varnish deposits. If present, the rack should be cleaned with alcohol and rechecked. If sticking persists, the injectors should be

removed and replaced with operational injectors. In no case should injectors be "crutched out" or cut out and the engine operated. If injectors operating unsatisfactorily cannot be remedied or replaced, the engine should be shut down until corrective action has been taken.

SERVICING INJECTORS

When servicing injectors, clean working conditions must be maintained. Dust or dirt in any form is a frequent cause of injector failure. When an injector is in an engine it is protected against dirt, dust, and other foreign materials by the various filters employed. When an injector is in storage, it is protected against harmful material by the filters sealing the body openings, which are in turn protected by shipping blocks.
However, an entirely different set of conditions is encountered when it becomes necessary to disassemble an injector for repair or overhaul. These conditions necessitate special shops, equipment, and trained personnel. Adequate maintenance facilities are expensive, and in most cases the customer would not be warranted in the expense. Electro-Motive maintains this service for our customers and recommends that injectors be returned to their nearest factory branch for rebuild or unit exchange. For particulars on this service, see Factory Rebuild Bulletin No. 302.

INJECTOR TEST STAND
In order to ensure efficient engine performance, injectors should be tested when ever removed from an engine, regardless of the reason for removal. In addition, it is advisable to test all injectors in an engine during each annual inspection. It is recommended that injectors be tested with the same oil used for protection against rust as given under "Storing Injectors."

It is important that the individual doing the testing understands the basic principles of injector operation and testing procedures in order to prevent acceptance of defective injectors and rejection of good ones. Instructions in the use of the injector test stand and an outline of each separate test procedure along with a basic explanation of operation follows.
These instructions cover the testing of all needle valve injectors using the test stand shown in Fig. 10-7. The procedures are not applicable to other types of testing equipment, since injector leak off rates vary greatly in proportion to the volume of fuel contained in the high pressure portion of the test stand.

SETTING UP TEST STAND

Basically, the stand consists of a fuel reservoir, filter, high pressure pump, pressure gauge, and necessary connecting lines and fittings to supply fuel to the injector under test. The test stand should be set up as instructed by the manufacturer. Inspect carefully for dirt or foreign material in the tank and lines. Fill the tank with clean fuel and operate the pump to purge all free air from the system.

Investigation has shown that the viscosity of the fuel oil used in the test stand has a

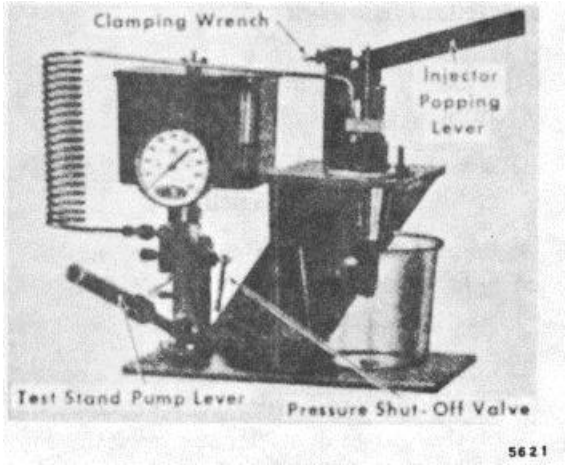


Fig. 10-7. - Injector Test Stand

marked effect on the test results obtained. Regular fuel oil may be used provided the viscosity is not less than 32 S.S.U. at 100° F. Do not reuse fuel oil which has been pumped through the injectors into the plastic bowl.

CHECKING TEST STAND

Install the test block in place of an injector in the stand and pump up pressure to 2000 psi, as indicated by the gauge. After five minutes, the pressure should not have dropped below 1975 lbs. Release the block and recheck at 500 and 1000 psi. These pressures should hold one minute with no apparent gauge drop. Make these tests with the pressure shutoff valve, Fig. 10-7, open all the way. If the tests are satisfactory, all injector tests may be made without using the shutoff valve. If the preceding tests indicate leakage in the stand, repeat the tests, closing the shutoff valve before timing the leak off rates. If the tests are satisfactory with the shutoff valve closed, it will be necessary to use the shutoff valve when making the injector holding pressure test.
When placing a new test stand in operation, or after removing and replacing the gauge, fuel tank, filter, or pump, for any reason, the test block should be installed and pressure raised to 2500 psi and vented at least six times before making an operational check.

TEST STAND OPERATION

The operator must consider the test stand as an instrument, rather than a tool. Every effort should be made to make the manual operation of repeated tests the same. The following general information is provided to help in obtaining uniform operation:
General Information

1. When operating the pump, use a rate of 40 strokes per minute. This provides a fuel rate to operate the check valve smoothly and to circulate fuel within the injector.
2. When using the popping lever, do not use such force as to damage either the injector or the lever. Do not permit the lever to fly up freely.
3. In making holding tests, do not pump the stand above 2500 psi.
4. Test stands regularly in use should be checked daily for leaks, using the test blocks.
5. Fuel oil used for testing should not be reused.

INJECTOR TESTS

Preparation

1. Install the injector in the test stand.
2. Fill the injector with fuel oil, but do not connect the fuel line from pump to injector at this time.
3. Set the injector rack at maximum fuel output position (minimum rack length).
4. “Pop” the injector with the popping lever, Fig. 10-7, using approximately 40 smooth even strokes per minute. A finely atomized spray should show at each of the holes in the tip. Rapid closing of the needle valve should produce a sharp “chatter.”

If the valve opens without producing a finely atomized spray or the valve seats without producing the sharp “chatter, “ make several rapid strokes with the lever to dislodge any foreign material on the valve seat. If the needle valve still fails to function properly, a stuck needle, dirt on the valve seat, or a defective valve seat may be the cause.

Holding Pressure And Leak Test

1. All injectors lose pressure due to leakage at any of several points, but this leakage must be controlled during

injector manufacture to prevent engine lube oil dilution. The holding pressure test will qualify injectors having specified leak off rates, providing this leakage is at the proper point and is satisfactorily controlled.

2. Manually hold the test stand fuel line block on the injector. Pump until fuel is discharged from filter cap on opposite side, to remove air. Apply 1800 to 2000 psi pressure to the injector. No leakage is permitted at the nut to body seal, filter cap gasket, body plugs, or between spray tip and injector nut.

3. Injectors should be qualified on the pressure holding test by timing the interval for a drop in pressure from 2000 psi to 1500 psi. If this interval is less than 20 seconds (used) or 30 seconds (new or reconditioned), repeat the test, but close the pressure shutoff valve on the test stand immediately after establishing the 2000 psi pressure. This is to ensure that the leak down time is not being affected by possible leakage in the test stand itself. If the timed interval for the pressure drop from 2000 psi to 1500 psi is still less than 20 seconds (used) or 30 seconds (new or reconditioned), the injector should be rejected. Do not attempt to “pop” the injector, except with the popping lever.

Rack Freeness Test

1. The rack engages with a small pinion on the injector plunger and serves to rotate the plunger with respect to two ports in the injector bushing, which regulates the amount of fuel injected with each stroke of the plunger. Bind-ing of the rack is generally caused by damaged gear teeth, scored plunger and bushing, or galling of rack itself. A binding rack may cause sluggish or erratic speed changes and overspeed trip action.

2. To be considered satisfactory, the rack must fall in and out through full travel by its own weight when injector is held horizontally and rotated about its axis.

Binding Plunger Test

1. Failure of the inject or plunger to move up and down freely indicates scoring of the plunger and bushing or weak or broken spring. A binding plunger will cause erratic cylinder firing and, in extreme cases, overspeed trip action.

2. Place injector in test stand but do not attach the fuel line. Place rack in the full fuel position and pump all the fuel out of the injector with injector popping lever, Fig. 10-7. When all of the fuel has been removed, depress the injector plunger to full extent of its travel and release popping lever. Plunger should return to the top of its stroke with a definite snap action. Repeat this test with the rack in the half fuel and no fuel positions. Care should be used in the test to prevent the plunger from snap-ping back so violently that the plunger stop pin is broken.

REPLACING INJECTOR FILTERS

Injector filters should not be disturbed or removed except during injector reconditioning (when all parts are completely washed), or in the event of fuel stoppage to the injector.

STORING INJECTORS

When injectors are not to be used for a considerable length of time, they should be protected against rust by using a stable, non-corrosive straight-run petroleum distillate in the kerosene volatility range. It is also recommended that injectors be tested using this oil. If this is done, treatment will be taken care of at time of injector test.

After treatment, the injectors should be stored in a protective container until needed.

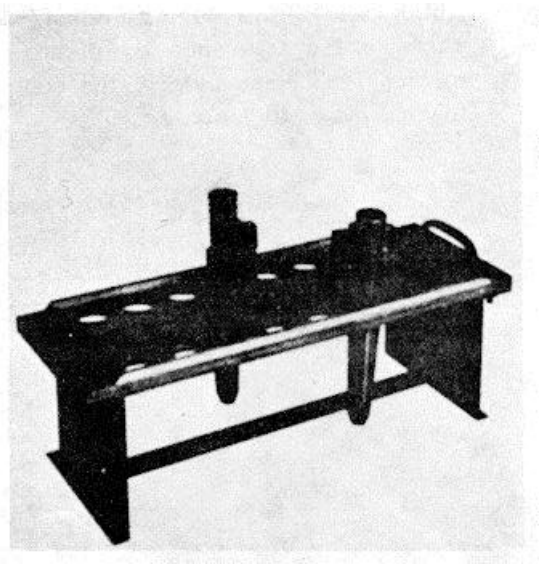


Fig. 10-8. - Injector Holding Rack

INJECTOR LINKAGE

DESCRIPTION

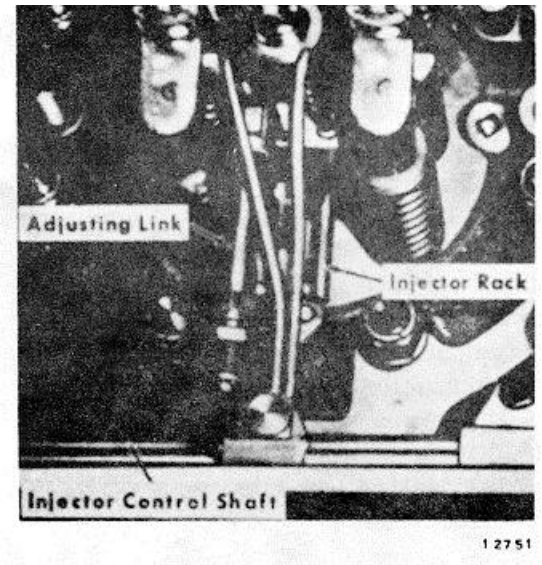
The injector linkage, Fig. 10-9, consists of the mechanical arrangement between the governor and the injector permitting all injector rack positions to be changed simultaneously when the governor terminal shaft is rotated. Two injector control rods connect the lever on the governor terminal shaft to the injector control shafts. The injector control shafts, one for each bank, extend the length of the cylinder banks under the cylinder head cover frames. At each cylinder location, a lever is pinned to the control shaft. An adjusting link connects the control shaft lever to an injector control lever mounted on the cylinder head, one end of which straddles the ball at the end of the injector rack.

MAINTENANCE

Before attempting to set injector racks, all racks and linkage should be checked for binding, sticking, or wear which would affect operation.

SETTING INJECTOR RACKS

Injector racks should be set with the engine at operating temperature. If racks are set when engine is not at operating temperature, the settings should be rechecked when operating temperature is reached. As engine temperature increases, the right



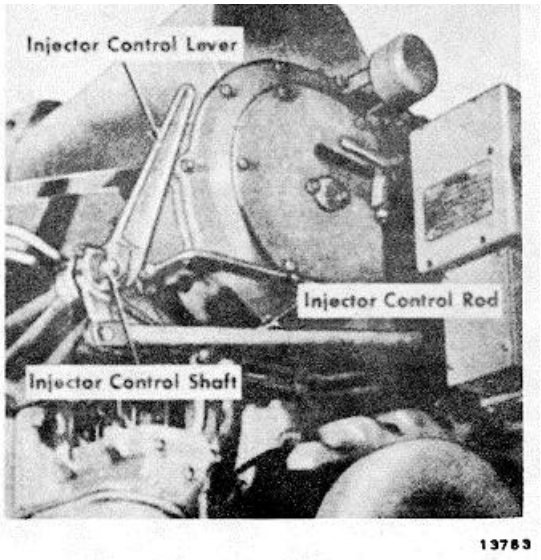


Fig. 10-9. - Injector Linkage

bank rack length shortens and the left bank rack length increases. The change on the left bank is insignificant, but the change on right bank may shorten the racks beyond the minus 1/64" tolerance.

NOTE: Every time a governor is installed on an engine the injector rack setting should be checked.

Set the injector rack on the engine as follows:

1. Position the load indicator on the governor at approximately the full or 100 per cent load, approaching from the no load side, using the control shaft lever. Apply the governor terminal shaft holding tool, Fig. 10-10.

2. Adjust the load indicator to the 100 per cent full load by loosening one adjusting screw on the terminal shaft holding tool and tightening the other. Be sure to adjust the load indicator to the full load position by approaching from the no load side, so the play in the linkage will be taken up in the direction of fuel increase. After the4 load indicator is adjusted correctly, the terminal shaft holding tool will prevent movement of the linkage while the injector racks are being set.

3. After the injector control shaft has been properly positioned, the injector

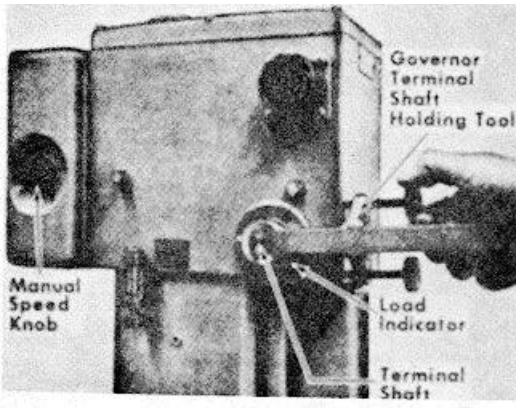


Fig. 10-10. - Load Indicator Positioning

rack is set at 58/64", using a rack gauge, Fig. 10-11. The rack setting gauges are 8 to 1 multiplying gauges which indicate the plus or minus 1/64" rack setting tolerance by means of marks 1/8" each side of the center mark on the gauge scale.

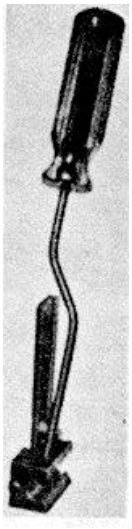


Fig. 10-11. - Injector Rack Gauge

4. Place the gauge over the injector rack and hold the gauge firmly against the face of the adjustable calibrating slide on the injector, Fig. 10-12, and check the gauge pointer. If the pointer is to the short ("S") end of the gauge scale center mark, the rack is not extending out far enough from the injector. Loosen the locknut on the adjusting link, Fig. 10-12, and turn adjusting nut on link until pointer is at long:("L") end of the scale; then reverse pointer travel until it aligns within 1/64" of the "58" mark on the scale. Hold adjusting nut and tighten locknut. The reason for exceeding the "58" scale mark when making adjustment is so that in setting all of the racks, the backlash will be taken up in the same direction.

When pointer is at long ("L") end of scale, loosen locknut and turn the

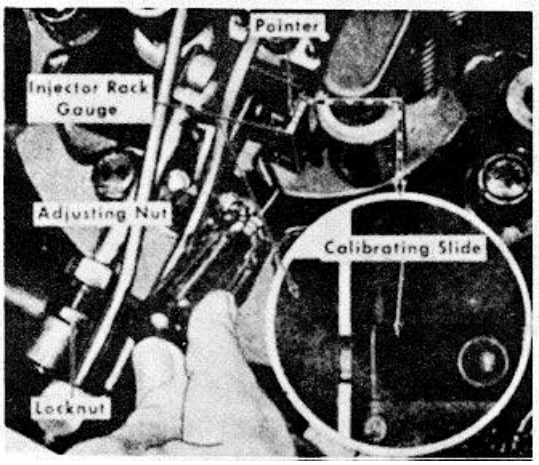


Fig. 10-12. - Injector Rack Gauge Application

adjusting nut until pointer is within ± 1/64 of the "58" mark. The accuracy of the injector rack gauge can be checked by inserting the master block in the gauge body. The pointer should align with the "58" mark on the scale.

5. After completion of adjustments to all injector racks, remove the governor terminal shaft holding tool.

FUEL PUMP

DESCRIPTION

The single unit fuel pump, Figs. 10-13 and 10-14, is mounted on and directly driven by the lubricating oil scavenging pump. It is an "internal" gear pump. Fuel is drawn into the inlet portion to fill a space created by the gear teeth coming out of mesh, Fig. 10-15. The fuel is then trapped in the space between the gear teeth and carried to the outlet side of the pump. There the gears mesh, which forces the fuel from between the gear teeth to flow through the outlet.

The seal is a device to prevent leakage between the stationary pump body and the rotating drive shaft. This is done by providing a perfectly smooth surface on the

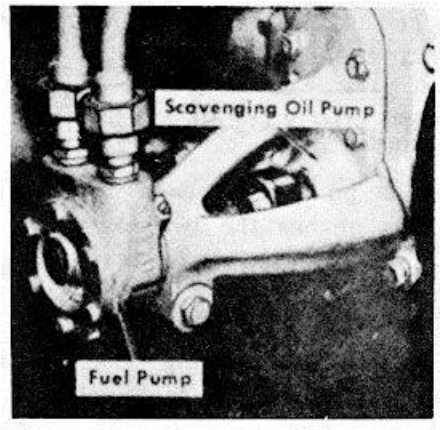


Figure 10-13. - Fuel Pump Installation

pump body against which a perfectly smooth surface on the shaft can turn with such small clearance that resistance to fuel flow is great enough that fuel will not leak out and air will not leak in.

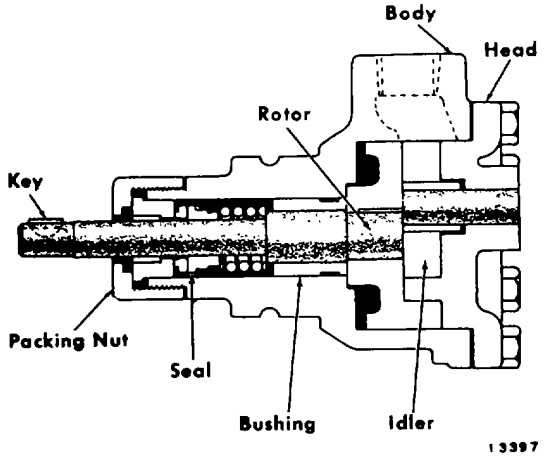


Fig. 10-14. - Fuel Pump, Cross-Section

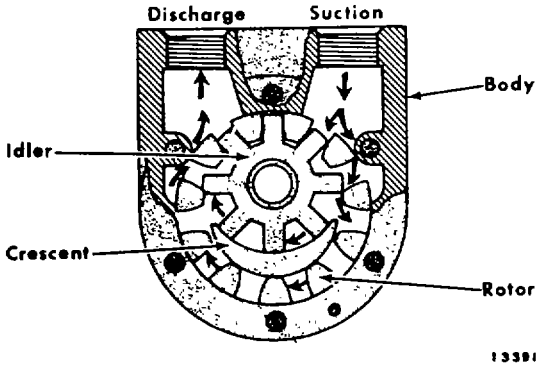


Fig. 10-15. - Fuel Pump Operation

One face of the seal is spring-loaded to maintain the closest possible fit.

DISASSEMBLY OF SEAL

1. Place pump in vise so that one jaw grips across the two ports. Do not tighten excessively as pump housing may be distorted.

2. Remove seal nut using a hook spanner wrench and remove seal assembly.

DISASSEMBLY OF PUMP

1. Place matching marks on cover and body of pump for proper reassembly.

2. Remove pump cover.

3. Remove rotor and idler.

4. Inspect pump for wear and scored surfaces.

ASSEMBLY OF PUMP

1. Install idler and rotor in pump body.

2. Install cover gasket. If pump has had a loss of capacity, a thinner body gasket may be used to reduce excessive clearance.

3. Install cover on pump (align matching marks).

ASSEMBLY OF SEAL

1. Clean seal faces thoroughly, using great care to eliminate all dirt.

2. Install seal. With seal faces touching, it should be necessary to compress the seal approximately 3/16" to bottom the taper seat of the seal in the pump body.

3. Apply a thin coating of fuel resistant sealing compound to the taper seat, install the seal nut and tighten securely.

TESTING PUMP

In order to provide the required fuel to the engine, the fuel pump should be checked after servicing.

FUEL FILTER

DESCRIPTION

There is only one fuel filter, Fig. 10-16, mounted on the engine. However, other filters which vary in design depending on the engine installation and are not a part of the engine, are used in the fuel system.

The engine mounted fuel filter is located at the right front of the engine. Two sight glasses are provided on top of the filter housing to provide a visual indication of the condition of the fuel system. The flow diagram, Fig. 10-17, indicates fuel flow through the filter.

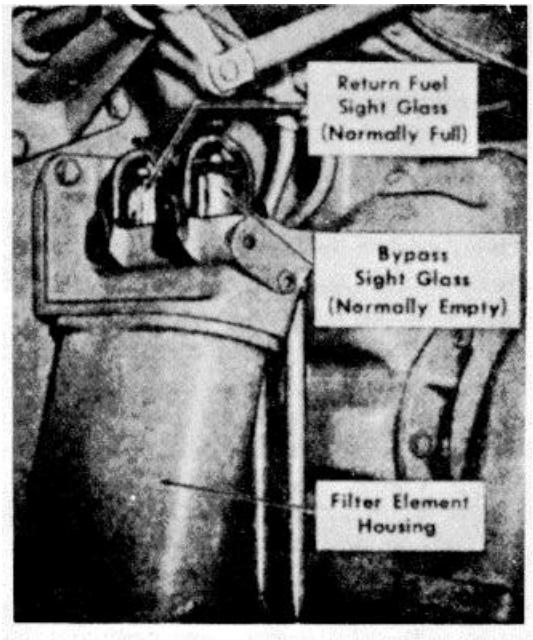


Fig. 10-16. - Fuel Filter

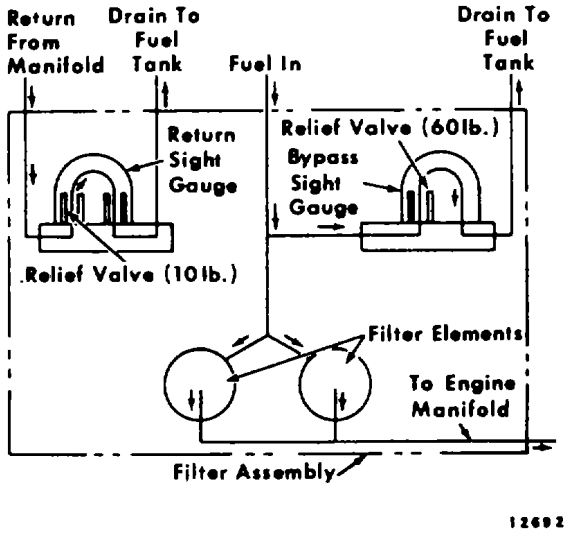


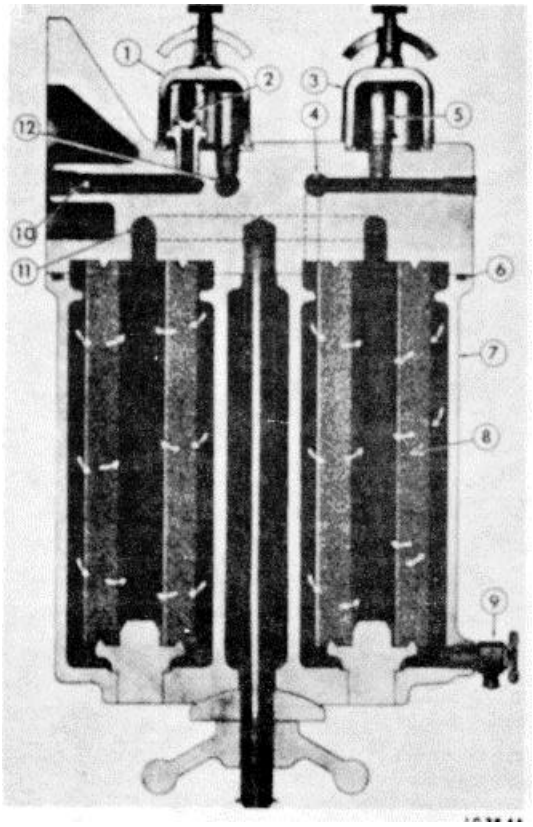
Fig. 10-17. - Fuel Flow Through Filter

Fuel returning from the injectors passes through the "return fuel" sight glass nearest the engine and returns to the fuel tank. Under normal operation this glass is full of fuel. A relief valve (10 psi) at the inlet to the "return fuel" sight glass establishes a fuel back pressure at the injectors for improved operation.

Air or gas in the fuel system will appear in the "return fuel" sight glass as bubbles. Air entering the fuel at any place in the suction line may cause the engine to misfire or stop. Bubbles in the "return fuel" sight glass with the fuel pump running and the engine stopped, indicates air entering the suction side of the fuel pump. If bubbles appear only when the engine is running, it indicates leaky valves in the fuel injectors, allowing combustion gases to get into the fuel. Little or no fuel in the "return fuel" sight glass, with the bypass sight glass empty, indicates insufficient fuel supply to the engine.

Under normal operation, the "bypass" sight glass farthest from the engine should be empty of fuel. As the elements of the filter become dirty, the fuel pressure in the filter will increase. When fuel pressure in the element housing is approximately 60 psi, the relief valve under the glass will open, fuel will enter and fill the "bypass" sight glass, and then return to the fuel tank, starving the engine.

As shown in the cross-section view, Fig. 10-18, two filter elements are positioned by bosses in the housing and the housing is held against the filter body by the center bolt assembly. The filters are large wound elements to provide adequate filter surface and ensure protection against foreign material reaching the fuel injectors.



1. Return Fuel Sight Glass
2. Relief Valve (10 psi)*
3. Bypass Sight Glass
4. Fuel Inlet11.
5. Relief Valve (60 psi)*
6. Seal
7. Housing
8. Filter Element
9. Drain Cock
10. Fuel from Engine Manifold Fuel to Engine Manifold
12. Return Fuel to Tank

*Relieving pressure and Part No. Are stamped on these valves to avoid misapplication.

Fig. 10-18. - Fuel Filter Cross-Section

MAINTENANCE

The filter elements should be removed and new ones installed at intervals specified in the Scheduled Maintenance Program.

At the time of element replacement, the housing and sight glasses should be cleaned.

1. Shut down the engine and the engine fuel supply.

2. Open housing drain valve to empty fuel from the housing.

3. Loosen the filter housing handwheel to permit the housing to be tilted from the filter body for element removal.

4. Remove the used filter elements and discard them.

5. Clean the_ housing with fuel oil and wipe clean, using lint-free cloths.

6. Check the condition of the sight glasses, and clean.

7. Check the filter housing to body seals and replace, if necessary.

8. Carefully place the new filter elements in the housing, and reapply the housing to the filter body.

For information on fuel oil specifications and recommendations for the engine, see Maintenance Instruction 1750.

567E4 SERVICE DATA

FUEL SYSTEM

EQUIPMENT LIST

	Part No.
Injector timing gauge	8034638
Injector pry bar	8041183
Injector holding rack (16 injectors)	8159228
Plastic spray cup (extra - used with 8202944)	8171780
Injector test stand (complete)	8202944
Oil (injector test, storage, and rust prevention - 50 gal. drum)	8203258
Governor jack	8291936
Governor terminal shaft holding tool	8295586
Injector rack gauge	8295982
Injector storage box	File 207
Fuel system, pre-test (including water and oil system piping, for checking systems)	File 294

GOVERNOR

DESCRIPTION

The Woodward Model LSG-10 governor, Fig. 11-1, is installed at the front of the engine on the governor drive housing, and is driven by the engine through right angle drive gears. A fuel lever mounted on the governor terminal shaft is connected to each injector control shaft on the engine by a link and lever on the control shaft. Movement of the governor fuel lever results in proportional movement of each cylinder fuel injector rack. By controlling the fuel injector racks, the governor maintains the same engine speed for all loads within the engine rating.

The governor is an isochronous mechanical-hydraulic speed sensing, and electro-hydraulic load sensing governor with steady state speed regulation (speed droop). When the generating units are tied to an infinite bus, the load sensing portion of the governor is not used and the governor will operate at fixed load as a conventional speed droop governor. Units using the load sensing portion of the governor will also, in effect, parallel with

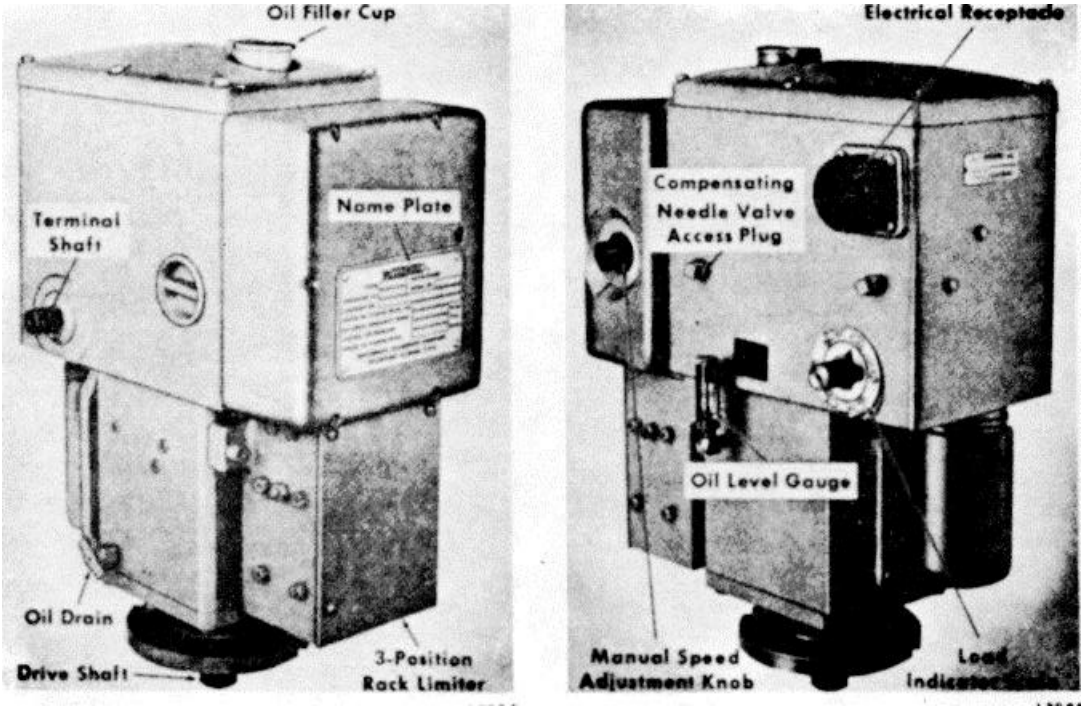


Fig. 11-1. - LSG -10 Engine Speed Governor

zero steady state speed regulation and divide the load proportionately. When the governor employs load sensing as well as speed sensing, additional electrical devices are used in conjunction with the governor, but are located away from the governor.

The speed sensing arrangement of the governor is shown schematically in Fig. 11-5.

model governor. The speed droop, adjustable from zero to approximately 7%, is in the speed sensing portion of the governor and is actuated by the speed servo. The function of the speed governor is to provide the basic speed reference and to provide accelerating torque during speed transients within the engine rating.

The load sensing section, or "load governor, " is an electro-hydraulic transducer. It consists of a polarized solenoid mechanically connected to a pilot valve which controls flow of oil from the pump to the load servo, Fig. 11-5, in such a manner that a proportional relationship exists between the force motor coil current and the load servo position. The coil current varies linearly with generator load. The governor to engine connecting linkage is arranged so that the governor terminal shaft will move the necessary distance required to exactly correct the fuel for any load change which occurs.

Other than the primary governor parts, such as the hydraulic system and the electrical load sensing (where used), the governor has additional built in functions to aid operation when used in the power unit. These additional items are: a governor rack switch, upper limit switch, rack stop, idle speed solenoid, full speed solenoid, governor motor and the gear box and clutch assembly.

The governor rack switch (Gov-RS), Fig. 11-2, is actuated by the terminal shaft and is set to trip the main circuit breaker when the load has decreased to approximately 400 KW.

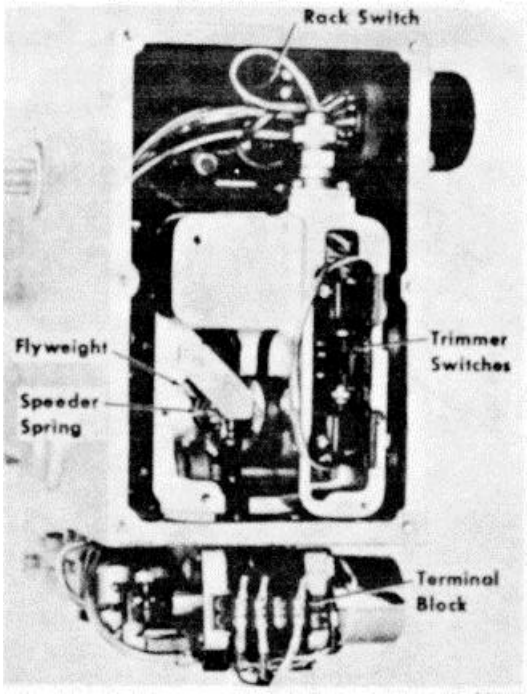


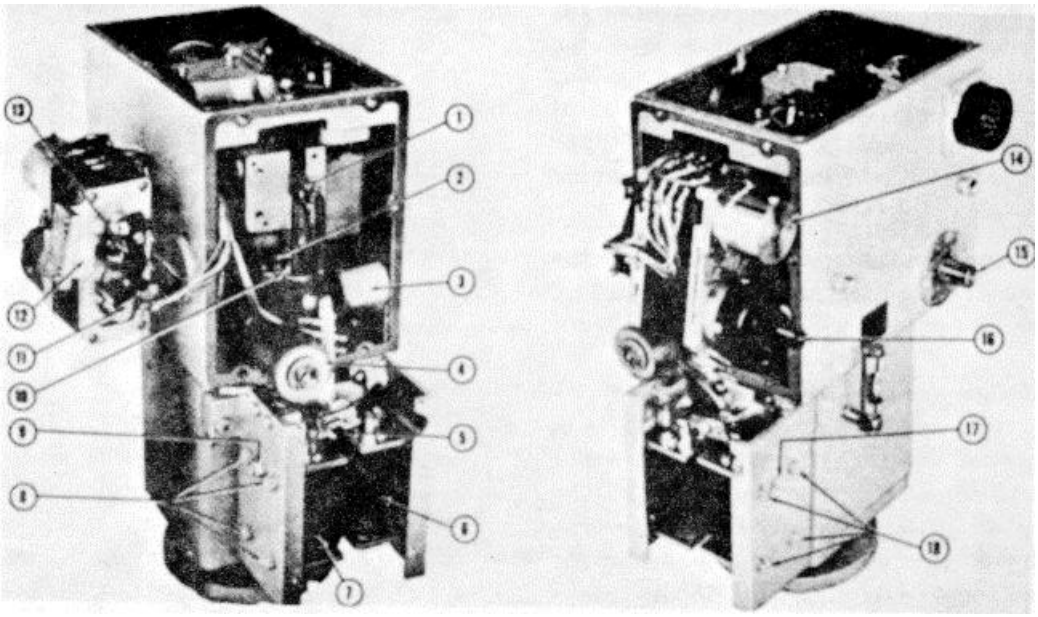
Fig. 11-2. - Top View Of Governor With Cover Removed

The upper limit switch (Gov-95), Fig. 11-3, enables the governor speeder spring to be compressed corresponding to 650 RPM (50-cycle) or 720 RPM (60-cycle) engine speed so that the engine will assume its correct load, and disconnects the speed motor after loading is completed.

The rack stop, Fig. 11-3, is a mechanical stop, to limit the maximum engine output. The rack stop should be adjusted as outlined under Maintenance, so as to limit the maximum fuel injection.

The speed solenoids GS-1 and GS-2 perform the main speed change functions, instead of running the governor speed motor. This results in a faster speed setting in the governor.

The idle speed solenoid GS-1, Fig. 11-3, when energized, permits engine starting



1. Speeder Spring Adjustment Lever
2. Full Speed Adjustment Screw
3. Full Speed Solenoid
4. Idle Speed Solenoid
5. Rack Stop Adjustment
6. Loading Solenoid, LS
7. Starting Solenoid, GSS
8. Starting Solenoid Mounting Bolts
9. Starting Solenoid Adjusting Screw And Locknut
10. Idle Speed Adjusting Screw
11. Gov. 95 Switch
12. Gear Case
13. Gov. 95 Switch Lever
14. Synchronizing Motor
15. Load Indicator Scale
16. Manual Speed Adjustment Knob
17. Loading Solenoid Adjusting Screw And Locknut
18. Loading Solenoid Mounting Screws

Fig. 11-3. - Front And Side Views Of Governor With Covers Removed

by causing oil to push the idle speed piston up and give the desired idle engine speed. If the idle speed solenoid is not energized, the engine will be shut down. An internal stop in the idle speed piston cylinder limits the maximum travel of the idle speed piston. The idle speed adjustment is made by using the Allen screw in the full speed piston, Fig. 11-3, located above the idle speed piston.

The full speed solenoid GS-2, Fig. 11-3, when energized, immediately raises the full speed piston to its stop. This action causes the engine speed to increase to an approximate synchronous speed of 600 RPM (50-cycle) or 720 RPM (60-cycle). The governor synchronizing motor, Fig. 11-3, acting through a gear train and clutch, is used to adjust engine speed for synchronizing and loading, by changing speeder spring tension until correct engine output is reached. The clutch, contained in the gear box, engages the governor motor and gear drive.

When the engine starting motor is engaged, the accumulator booster pump, Fig. 11-4, which is an external motor driven oil pump mounted in front of the governor on the engine, takes oil from the governor under pressure to provide more rapid governor response than would be available if the governor only was relied upon to build up its own oil pressure.

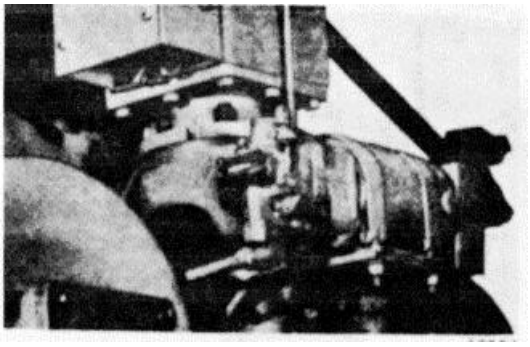


Fig. 11-4. - Accumulator Booster Pump

OPERATION

A schematic diagram of the LSG-10 governor operation is shown in Fig. 11-5.

The main oil pump draws oil from the governor sump and supplies it to the spring-loaded accumulators where it is stored under a pressure of 100 psi. Very rapid servo movements are then possible as the accumulators supply the necessary oil faster than the pump alone could supply it. As the accumulator pistons move against the force of the accumulator springs, one of the pistons uncovers a port leading back to the sump. This serves as a relief valve and limits the pressure to slightly more than 100 psi. This pressure is applied directly to the power piston pilot valve, and also to the pump of the pilot governor where the pressure is increased to 150 psi.

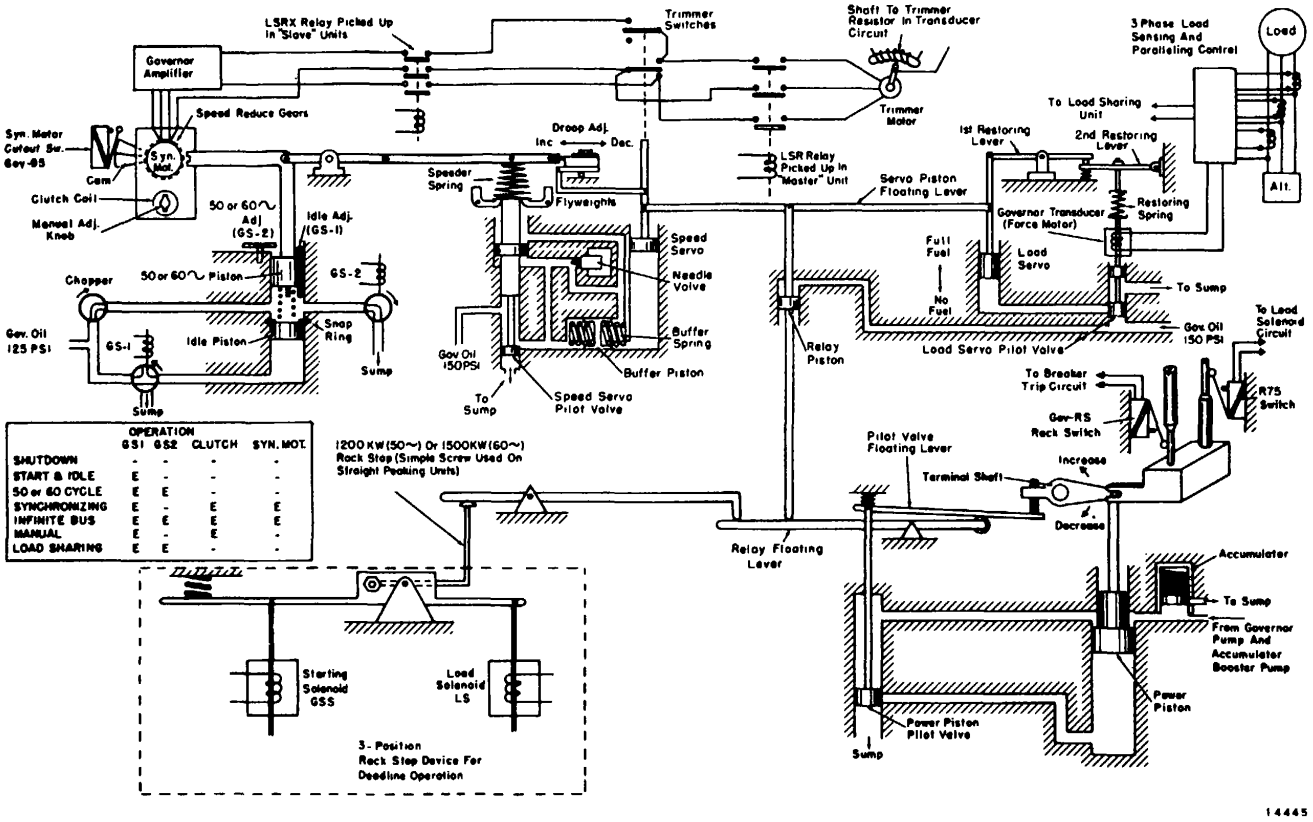
SPEED GOVERNOR OPERATION

In the operating description of the speed governor, assume that the right-hand end of the servo floating lever remains fixed and the generator load is increased. The resulting decrease in governor speed below the set value will permit the speeder spring to force the flyweights, which are driven by the engine, to move inward. This lowers the speed servo pilot valve and permits the pressure oil supplied by the pump to flow into the buffer piston bore. This causes the buffer piston to move to the right in the schematic drawing. As the oil trapped on the right side of the buffer piston is displaced, the speed servo is moved upward.

The speed servo moving upward against the force of the relay piston can do less than one-half ft-lb of work, so its power is amplified by the power piston portion of the governor. Movement of the relay piston is transmitted. to the pilot valve floating lever which uncenters the power piston pilot valve and admits oil under 100 psi pressure to the space below the power piston. The upward movement of the piston moves the governor terminal shaft and engine fuel injector racks in a direction to increase fuel. Movement of the power piston recenters the pilot valve through the pilot valve floating lever.

Oil pressure on the left side of the buffer piston is greater than oil pressure on the right of the piston since the buffer piston was moved to the right to raise the speed servo. These unbalanced oil pressures are transmitted to the upper and lower sides of the compensating land on the speed servo pilot valve. This produces an upward force on the pilot valve opposing the decrease in flyweight force which had permitted the speeder spring to move the pilot valve down. When the speed servo has moved far enough to supply the fuel now required, the unbalanced pressures on the compensating land will have recentered the speed servo pilot valve, which closes the valve port and stops any further speed servo motion.

An increase of speed to normal does not cause the flyweights to move outward and open the pilot valve port in the opposite direction, because leakage of oil through the compensating needle valve equalizes the pressures above and below the compensating land at the same rate that the speed returns to normal. As the pressures are equalized, the springs return the buffer piston to its normal central position. Movement of the speed servo is



OPERATION	GS1	GS2	CLUTCH	SYN. MOT.
SHUTDOWN	-	-	-	-
START & IDLE	E	-	-	-
50 or 60 CYCLE	E	E	-	-
SYNCHRONIZING	E	-	E	E
INFINITE BUS	E	E	E	E
MANUAL	E	-	E	-
LOAD SHARING	E	E	-	-

Fig. 11-5. -- LSG-10 Governor Simplified Schematic Diagram

opposed by the relay piston, which possessing less effective force, moves with it.

When the generator load is decreased, the resulting increase in governor speed causes the flyweights to move outward, raising the speed servo pilot valve. The relay piston, which is under constant pressure from the governor pump, is now able to force the speed servo downward, because oil at the left of the buffer piston can now discharge to the sump. Also, downward movement of the relay piston raises the power piston pilot valve, permitting oil under the power piston to go to the sump, and the power piston to be forced downward to decrease fuel. The power piston pilot valve is moved downward to close its port as the power piston is moved downward again, and differential pressure across the compensating land recenters the speed servo pilot valve and keeps the pilot valve ports closed while speed decreases to normal.

LOAD GOVERNOR OPERATION

If the load governor portion is used in conjunction with the speed governor, additional electrical components adjusted and calibrated at the factory, are also used. The general operation of this load system is described in the following paragraphs.

In the preceding description of the speed governor it was assumed that the right-hand end of the servo floating lever remained fixed during the load change and the subsequent speed change, and return to normal. In following the operating description of the load governor, it should be assumed that the left end of the servo floating lever remains fixed. The load governor mechanism moves the right-hand end accurately and extremely rapidly in response to a change in electrical load on the generator, to bring the fuel control to a new position required to carry the new value of the load.

In using the load governor portion, connections are made from the potential and current transformers associated with the generator output leads, to a load computer which forms a part of the load governing equipment. The load computer, sensing the current and voltage in each phase, supplies a variable current to the coil of the polarized solenoid, Fig. 11-5. This current varies from 25 milliamperes DC with no load on the generator to 300 at full rated load.

An increase in current through the coil of the polarized solenoid will cause the permanent magnet armature of the solenoid to move upward carrying with it the load servo pilot valve. This uncovers the valve port, and oil from the high pressure oil supply flows very rapidly under the load servo. This piston moves upward, overcoming the force of the relay piston. This initiates an increase in fuel supply to the engine as occurred when the relay piston was raised by the speed servo.

Upward movement of the load servo causes a downward movement of the right end of the second restoring lever, Fig. 11-5. This continues until the increased compression of the restoring spring balances the increase in solenoid force that initiated the action, and the load servo pilot valve moves down so that the ports are again closed. The result of this operation is that the load always assumes a position corresponding to the current of the solenoid coil, which is in turn proportional to the kilowatt load on the generator.

TRIMMER SWITCHES

The trimmer switches, Fig. 11-5, are used in conjunction with the load governor system.

Internal mechanical adjustments of the governor are such that when there is a current of 25 milliamperes applied to the polarized solenoid, the speed servo has to be in its midposition to bring the load indicator mark on the side of the governor to the zero load position. These same adjustments also require that the speed

servo remains at its midposition to bring the load indicator to 100% when the coil current is 300 milliamperes.

If the speed servo is required to move above its midposition because for some reason unit speed is below the value for which the governor is set, the increase load signal contacts are closed. If the piston moves below center because speed is high, the decrease signal contacts are closed.

A small error in frequency will cause the speed servo to move above or below its midposition and close one or the other of the trimmer switches. The trimmer switches in the selected master governor will, through external governor components, cause a proportionate increase or decrease in coil current of the polarized solenoids of all governors in the system and therefore a change in energy input to all units. This gradually eliminates the small speed error that existed, and when the speed is back to normal, the speed servos will be back in midposition and the trimmer switch contacts in the master governor will be open.

TRIMMER CUTOUT SWITCH

The trimmer cutout switch opens when load on the units drops below approximately 5% of normal load. Variations in engine fuel supply will probably be much greater at very small loads than at the loads normally carried, so the trimmer apparatus might easily go to one extreme or the other. There is no harm in this, except that the trimmer motor would require a certain amount of time to travel back to the necessary position should a large load increase occur. Since generator units would never be run at such small load as 5% of full load, except possibly very briefly under most abnormal conditions, it is considered acceptable to eliminate the trimming and tolerate a possible small speed error at very small loads.

MAINTENANCE

Service work on the governor at the installation other than the following three position rack stop adjustments or compensating adjustment should not be attempted by operating personnel, since even minor adjustments on the governor would alter other operating apparatus not adaptable to general adjustment in the field. If other adjustments or operations are required, we suggest that the customer obtain the services of an authorized factory representative.

Before making any governor settings apply full load to the unit for one hour to make sure all components are at operating temperature.

THREE POSITION RACK STOP

DESCRIPTION

The three position rack stop is an extra used on applications requiring maximum deadload pickup or minimum time to reach peak load.

It consists of two solenoids, GSS and IS, and connecting linkage that limit the rotation of the governor terminal shaft. The starting solenoid, GSS, is energized during starting and limits the rack travel to approximately 1/3 rated load to prevent overfueling. This solenoid is de-energized when the engine speed reaches about 200 RPM. The engine comes up to synchronous speed and loads to approximately 35% rated load with both solenoids de-energized. At that point, the R25 switch, which is operated by the governor terminal shaft, closes the circuit to the loading solenoid, LS, through an externally located time delay relay, RLTD. The time delay relay keeps the loading solenoid energized for 30 seconds while the injector rack is allowed to go to full fuel. When RLTD drops out the loading solenoid, the rack stop returns to the peak load limit.

MAINTENANCE

STARTING SOLENOID ADJUSTMENT

With the unit in peaking mode, load it to about 50% of full load. Loosen the four starting solenoid mounting bolts, Fig. 11-3, just enough so the solenoid can be moved up or down with the starting solenoid adjusting screw. Disconnect a lead at the No. 17 terminal at the terminal board on the engine control panel to prevent the ST contactor from being energized when the starting solenoid is energized. Jumper the starting solenoid to energize it. After loosening the locknut on the starting solenoid adjusting screw, move the solenoid up or down by turning the adjusting screw until the unit is limiting at 30 to 35% full load. Tighten the mounting bolts and check the setting, then remove the jumper and reconnect the lead at the No. 17 terminal.

LOADING SOLENOID ADJUSTMENT

With the unit in automatic peaking mode, bring it to full load. Loosen the four loading solenoid mounting bolts, Fig. 11-3, so the loading solenoid can be moved up or down with the loading solenoid adjusting screw. Energize the loading solenoid and adjust the coil up or down until the load indicator pointer on the governor terminal shaft is positioned half way between the 100% and maximum fuel marks. Tighten the mounting bolts and check the setting, then de-energize the loading solenoid.

GOVERNOR COMPENSATION

DESCRIPTION

The compensating mechanism prevents the engine from racing or hunting by arresting the movement of the speed servo after it has traveled a sufficient amount to give the desired speed. The compensating mechanism includes the buffer piston and springs, and compensating needle valve.

When the engine is started the first time or after installation of a new or reconditioned governor or one that has been drained and cleaned and new oil added, the governor will require compensation adjustment. This is necessary to purge the governor oil system of trapped air.

MAINTENANCE

COMPENSATION ADJUSTMENT

1. See that the governor oil is at the proper level in the sight glass. Then start the engine, operating at idle speed.

2. Remove the access plug, Fig. 11-1, and open the compensating needle valve several turns.

3. The engine will hunt and surge, and air will bleed from the oil passages. After about 30 seconds, close the compensating needle valve slowly until the hunting condition stops or is lessened. Allow the engine to run until normal operating temperature is reached. If necessary, add oil to obtain the proper level in the governor.

4. After normal temperature has been reached, again open the compensating needle valve and allow the engine to hunt. Then close the needle valve until hunting stops. The needle valve will be open approximately one-quarter to three turns depending upon the engine characteristics.

5. Test the governor stability by manually changing the engine speed to observe governor recovery. If the engine returns to a steady speed, the compensating adjustment is satisfactory. If

hunting is resumed, close the compensating needle valve slightly and test again.

6. Keep the compensating needle valve open as far as possible to prevent sluggishness and still maintain even engine operation. After compensation is made, it should not require another adjustment, unless a permanent temperature change effects the viscosity of the governor oil. Be sure the compensating needle valve access plug is replaced.

FLUSHING GOVERNOR

Governor flushing is not recommended as a regular maintenance item. Instead, the governor should be disassembled and cleaned if operation is impaired due to dirt or other foreign particles in the governor.

In cases of necessity where the governor is suspected of being dirty and it would not be practical to remove the governor from the engine, it may be flushed on the engine as follows:

1. The engine should be shut down and the drain plug removed from the governor case, or petcock opened. Close valve or replace plug and add two pints of filtered kerosene to governor and start engine. Using the layshaft lever, vary the speed of the engine from 400 to 500 RPM, for about five minutes. Shut the engine down and drain kerosene from the governor. Repeat this operation several times until the kerosene drained from the governor appears clean.

2. Add two pints of recommended oil to the governor and repeat the above procedure and drain. This will remove any kerosene trapped in the governor.

3. Fill the governor with recommended oil to the proper level and start the engine. Adjust the governor compensation as previously described. The oil level should then be checked and oil added, if necessary.

GOVERNOR OIL SUPPLY

The oil capacity of the governor is three pints. Use new oil which will meet the specifications for governor oil listed in M.I. 1752 or a low additive type oil having rust and oxidation protection. The oil level should be maintained between the marks on the sight glass. The vent at the top of the sight glass must be open to ensure correct readings. The governor oil need only be changed once a year, using care that the oil and its container are clean.

GOVERNOR STORAGE

In the event the governor is to be stored for a considerable length of time, it should be protected against rust. Governors using a low additive type oil having rust and oxidation protection require no further protection. However, if other oil lacking these properties is used, the oil should be drained and the governor flushed with kerosene and drained. The governor should then be filled with oil providing protection against rust. After filling with this oil, the governor should be run several minutes if possible. When the governor is again put in service the recommended governor oil should be used.

GOVERNOR DRIVE ASSEMBLY

DESCRIPTION

The governor drive assembly, Fig. 11-6, is mounted at the front of the engine on the accessory drive cover adjacent to the water pumps. The governor is mounted on the housing and driven through the 90° bevel gear drive. The serrated end of the drive shaft is mated into a drive plate on the governor drive gear in the accessory

gear train. Lubrication of the governor drive bearings and gears is provided through drilled passages in the drive housing.

MAINTENANCE

The governor drive assembly normally does not require servicing except at the time of general engine overhaul or reconditioning. At this time or when conditions warrant, the governor drive assembly should be removed and the parts inspected and checked. After removal of the governor, the governor drive assembly can be easily removed. A mounting dowel correctly positions the governor drive housing on the accessory drive cover.

After the governor drive assembly has been removed and disassembled, visually inspect the bushing bores and thrust faces for flaking, imbedded dirt, chipping or scoring. Bushings that are chipped or flaked or have large quantities of imbedded dirt should be replaced with new bushings. Check oil passages in the housing to be sure they are free of restrictions. Inspect bevel gears for nicks, pitting or visible wear on the loaded tooth faces. Nicks, burrs or any high spots should be stoned out or the gears replaced. If it is necessary to replace a gear, it is recommended that both gears be replaced as a set. Check individual parts and assembly to be sure dimensions are within limits given in Service Data at the end of this section.

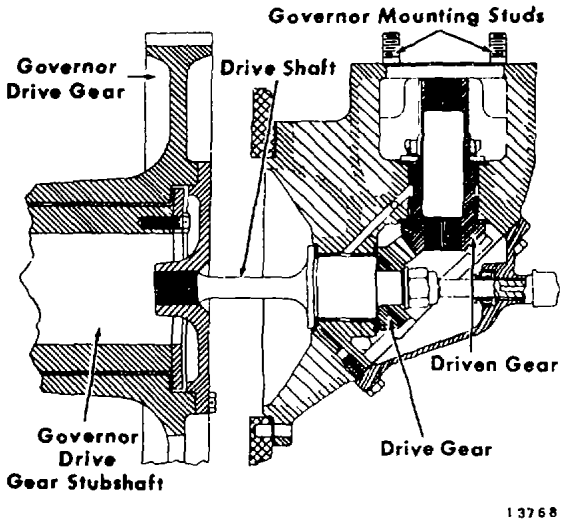


Fig. 11-6. - Governor Drive Application

567E4 SERVICE DATA

GOVERNOR

SETTING AND ADJUSTMENT

R25 Switch (Hi)	Approximately 35% of full load in the increase fuel direction
Gov-RS Switch (Lo)	25 to 27% of full load in the reduce fuel direction
Gov-95	Closed at 16 ± 4 cycles to 64 ± 4 cycles
Time Delay Relay (RLTD)	60 ± 5 seconds
Starting Solenoid (GSS)	Limit at 30 to 35% of full load
Loading Solenoid (LS)	Limit at 100% to Max. Fuel

SPECIFICATIONS

Bushing bore diameter (as assembled in housing) - Max.	1.8795"
Distance between bushing thrust faces - Min.	1.867"
Diameter of drive shaft journal - Min.	1.8715"
Governor drive shaft thrust face to shoulder - Max.	1.879"
Driven gear thrust face to shoulder - Max.	1.881"
Diameter of driven shaft journal - Min.	1.8715"
Bevel gear backlash - Max.	013"
Thrust clearance	Limit is governed by gear backlash

EQUIPMENT LIST

	Part No.
Hand tachometer	8107967
Rotary shaft bearing remover- installer	8225658
Rotary shaft oil seal driving rod	8225659
Rotary shaft oil seal remover	8225660

PROTECTIVE DEVICES

GENERAL

This section contains the description and maintenance information for engine protective devices. These devices are designed to, in most instances, shut down the engine in the event of a malfunction occurring during engine operation.

LOW WATER AND CRANKCASE PRESSURE DETECTOR ASSEMBLY

DESCRIPTION

The low water and crankcase pressure detector assembly, Figs. 12-1 and 12-2, is a compact device for detecting loss10 DS or lack of engine cooling water as well as any change in the normal negative crankcase pressure to a positive pressure. If either of these conditions exists, the device will cause the engine to be shut down.

The low water pressure portion balances water pressure into the engine against the air box pressure plus a light spring to hold an oil relief valve in a latched position. In the event water pressure into the engine falls below the pressure in the air box plus the force of the light spring, the oil relief valve is released and lube oil pressure to the oil pressure switches is relieved, Fig. 12-3. The oil pressure switches sense low oil pressure and initiate engine shutdown. The low water pressure portion of the device will trip whenever the cooling system is drained. Tripping should occur if water pressure does not exceed the limit specified in Service Data.

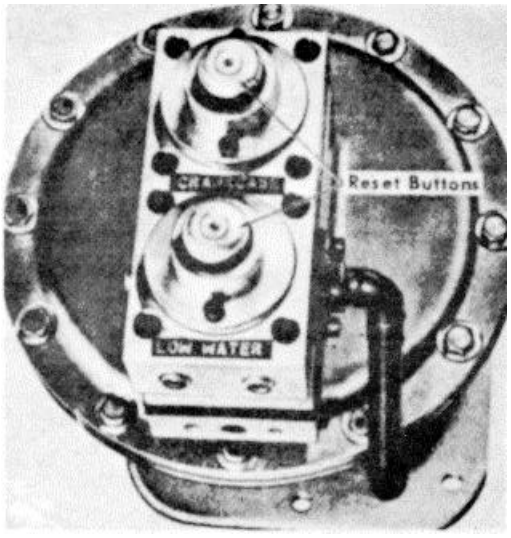


Fig. 12-1. - Low Water and Crackcase Pressure Detector Assembly

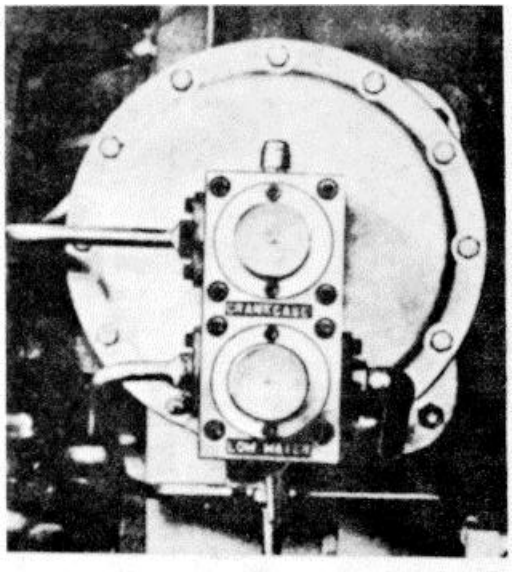


Fig. 12-2. - Detector Assembly Installation

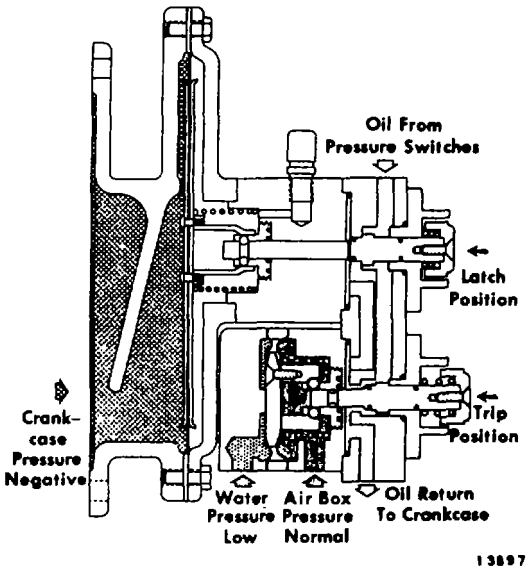


Fig. 12-3. - Low Water Pressure Condition

The crankcase pressure portion of the device consists of an oil relief valve, comparable to the one in the low water portion, held in a latched position until a positive pressure is built up in the crankcase. The oil relief valve is released and lube oil pressure to the oil pressure switches is relieved, Fig. 12-4. As in the

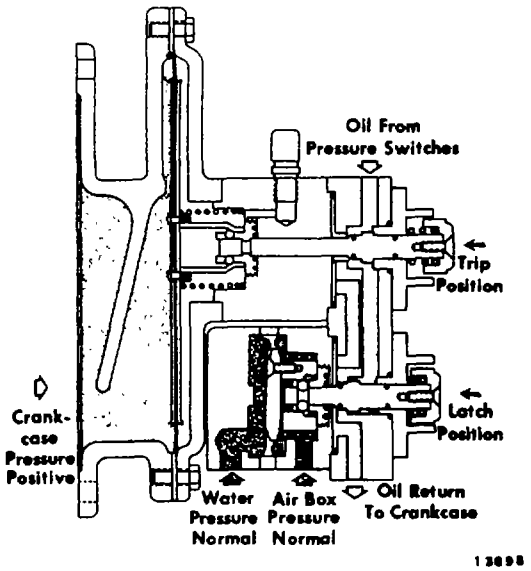


Fig. 12-4. - Positive Crankcase Pressure Condition

low water portion, the oil pressure switches sense low oil pressure and initiate engine shutdown.

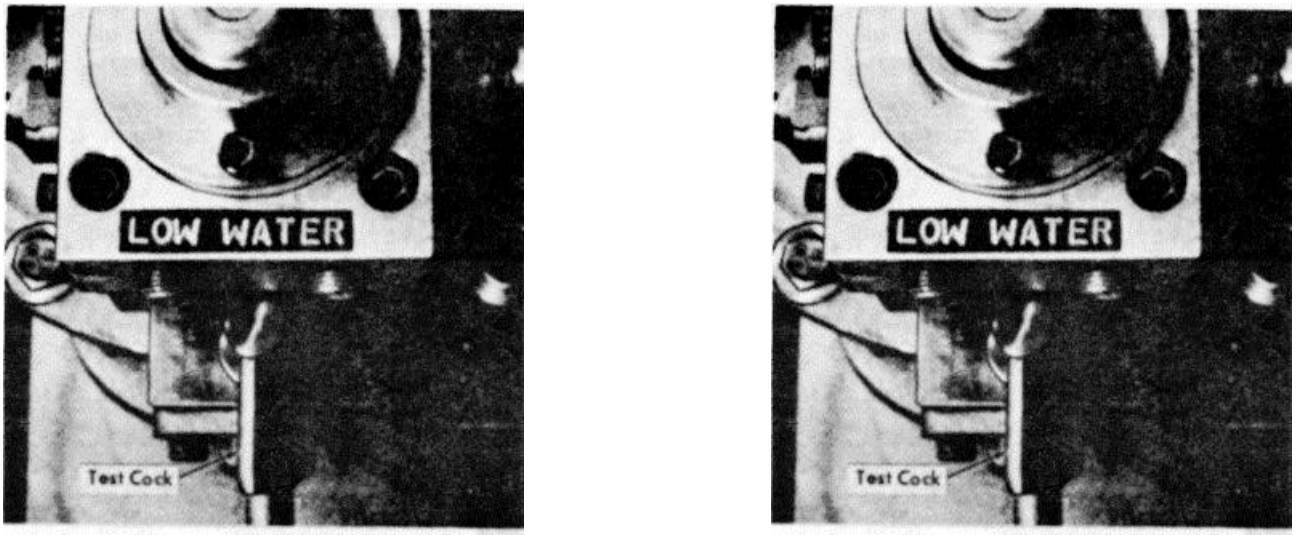
When a shutdown occurs, the reset button, Fig. 12-1, for that portion of the device responsible for the shutdown must be manually reset.

A 1/8" bleed hole is provided in the space between the water pressure and crankcase diaphragms to visually indicate a leaking diaphragm.

MAINTENANCE

The low water and crankcase pressure detector should be tested periodically to ensure proper operation.

A test cock, Fig. 12-5, is installed in the cooling water line to the low water safety portion and provides a means of manually dumping the water pressure on the diaphragm and, in turn, provides a check on the tripping action of the low water detector. By rotating the test cock handle to the horizontal position, the discharge of water from the small orifice hole in the cock should be a steady flow. Because of contaminants in the cooling water, the small orifice in the cock may become plugged, reducing or restricting the bleed off of water pressure on the water diaphragm. In most cases, rapidly opening and closing the test cock a few times will dislodge the obstruction and allow the low water detector to trip. Plugging of the test cock in no way affects the operation of the low water device. With the engine running at idle speed, opening the test cock and obtaining a free flow of water, should trip the device on the first or second try. If the device does not trip, the device should be taken off and checked on a test panel to determine the cause of malfunction. It is recommended that the operation of the low water detector be checked monthly with the test cock. Test



NORMAL POSITION TEST POSITION

Fig. 12-5. - Test Cock Positions

cock handle must be returned to vertical position, Fig. 12-5, and button must be manually reset before starting engine.

Without starting the engine the crankcase pressure portion of the device can be tested by creating a suction on the vent tube at the top of the device, using a hydrometer bulb. Tripping pressure should be .04 to .05 psi.

If tests prove unsatisfactory, replace the device.

OVERSPEED TRIP

DESCRIPTION

An overspeed trip mechanism is provided as a safety feature to prevent the injection of fuel into the cylinders if the engine speed becomes excessive. An electric solenoid tripping device is also applied to the engine, which will operate the overspeed trip. This provides engine shutdown when an off-engine system malfunction occurs which otherwise would not affect engine operation. When the solenoid device brings about an engine shutdown, the overspeed trip must be manually reset before the engine can be started.

Fig. 12-6 shows the mechanical overspeed trip mechanism. If the engine speed should increase to the specified limits, the overspeed mechanism will shut down the engine.

A trip shaft extending the length of each engine bank under the camshaft has a cam at each cylinder, which when rotated, contacts a spring-loaded catch pawl mounted on each cylinder head, under the injector rocker arm. In the overspeed trip housing the trip shafts are connected to spring operated links and a lever mechanism. A reset lever on the spring lever shaft, when rotated counterclockwise, puts tension on an actuating spring. The spring tension is retained by a trip lever engaging a notch in the reset lever shaft. This holds the cams on the trip shaft away from the rocker arm catch pawls.

The overspeed trip release mechanism is incorporated in the right bank front

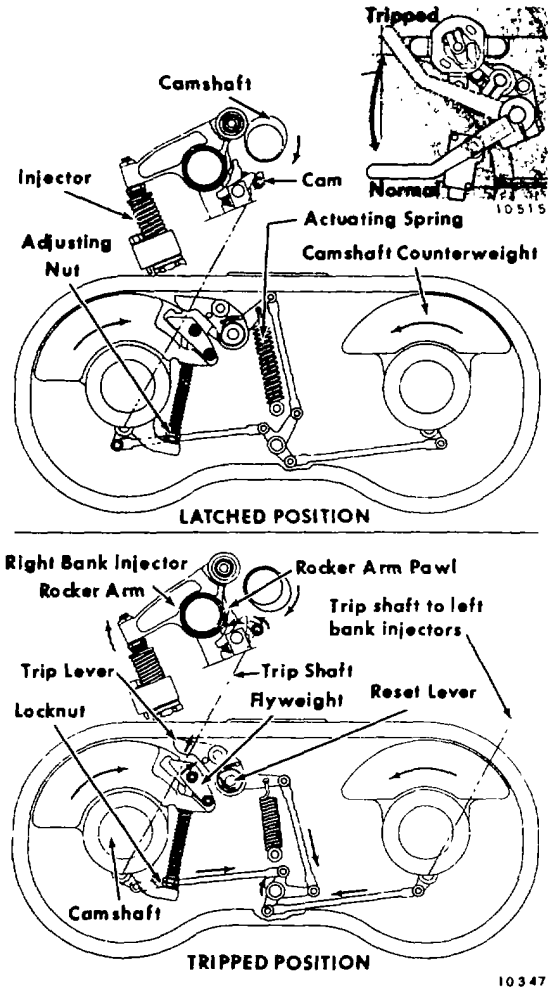


Fig. 12-6. - Overspeed Trip

camshaft counterweight. It consists of a flyweight held by an adjustable tension spring. When engine speed exceeds the set limit, the tension of the spring is overcome by the centrifugal force acting on the flyweight, causing the flyweight to move outward to contact the trip lever. This allows the actuating spring, acting through connecting links, to rotate the trip shafts. Consequently, the trip shaft cams contact and raise the injector rocker arm pawls preventing full effective injector rocker arm roller contact on its cam. This prevents fuel injection and stops the engine.

After manually resetting, by counterclockwise movement of the reset lever, the trip shaft cams release the injector rocker arm catches. Rotation of the camshafts on starting the engine lift the rocker arms slightly allowing the catch pawls to resume unlatched position, releasing the injector rocker arm for normal operation.

MAINTENANCE

ADJUSTING MECHANICAL OVERSPEED TRIP

To adjust the overspeed trip, shut the engine down, and remove the cover from right side of overspeed trip housing. Turn adjusting nut to increase or decrease spring tension as required. To increase engine speed at which overspeed trip operates, increase spring tension.

After the adjusting nut has been moved, the locknut must be tightened and the engine run to test speed at which trip operates. The speed rise of the engine from idle to trip should be made in 20 to 30 seconds. Several adjustments may be required before final setting of tripping speed is reached.

See Scheduled Maintenance Program for frequency of checking the overspeed trip.

ADJUSTING ELECTRIC SOLENOID OVERSPEED TRIP

The only adjustment of the electric solenoid overspeed trip is the positioning of the solenoid and bracket to provide the specified clearance between the solenoid cam and the trip lever, Fig. 12-7. This is done by positioning the solenoid bracket until the correct clearance is obtained.

After any adjustment, the solenoid circuit should be energized to check operation of the cam and trip lever, and the trip lever reset to the normal position.

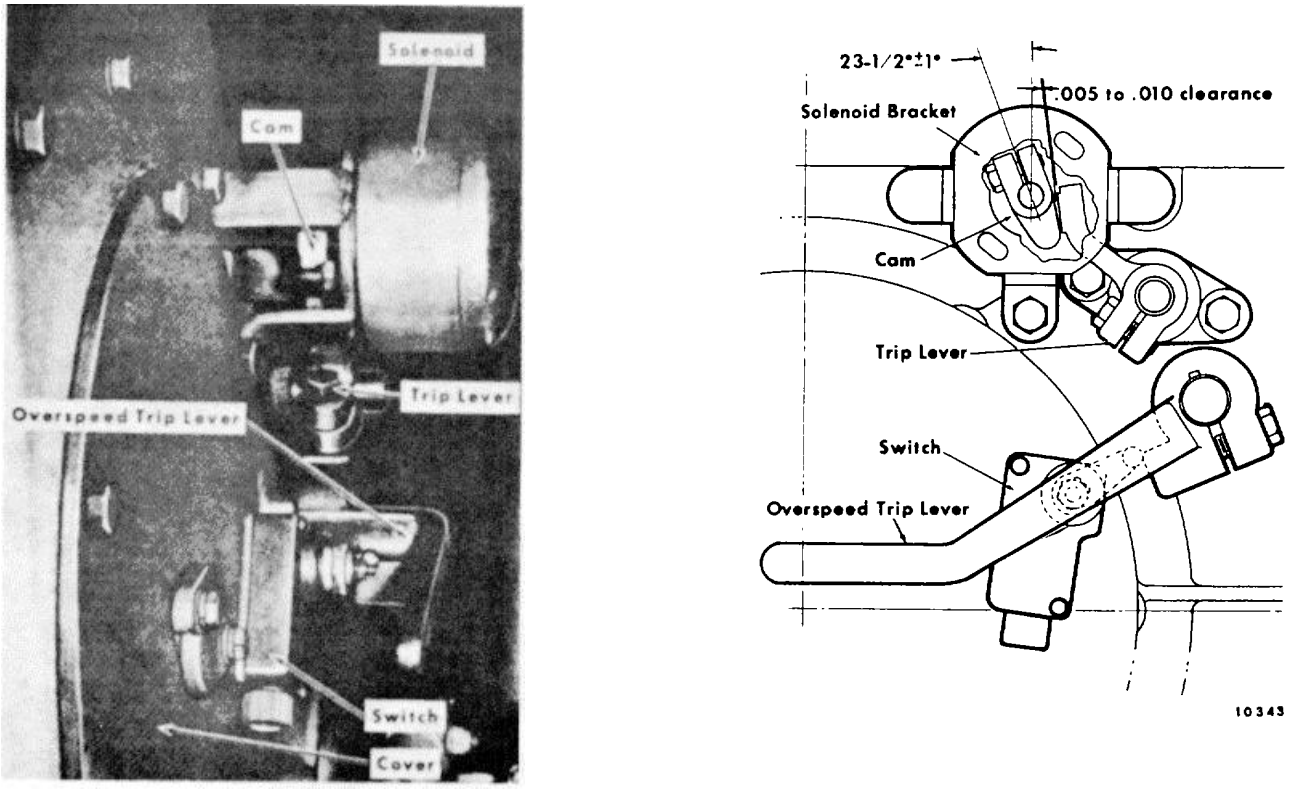


Fig. 12-7. - Electric Solenoid Overspeed Tripping Device

567E4 SERVICE DATA
PROTECTIVE DEVICES

SPECIFICATIONS

LOW WATER AND CRANKCASE
PRESSURE DETECTOR

Low water tripping pressure -- Min. ..... 10" H_20

Crankcase tripping pressure ..... .8" -1.5" H_20

OVERSPEED TRIP

Clearance, trip latch to flyweight - Min. ..... .010"

Trip setting - RPM..... (50-cycle) - 695-710
(60-cycle) - 855-870

Solenoid cam to trip lever clearance ..... .005" -.010"

EQUIPMENT LIST

	Part No.
Hydrometer bulb	8140866
Test panel	8349113

STARTING SYSTEM

DESCRIPTION

The electric starting motor assembly, Fig. 13-1, is mounted at the rear of the engine at the right bank, and is held securely in a bracket bolted to the engine oil pan end plate. The assembly is made up of three major parts, consisting of the electric motor, the drive housing containing the Dyer drive mechanism, and the actuating solenoid mounted on the electric motor. Individual parts of the assembly are identified in Fig. 13-2.

When the starting sequence is initiated the actuating solenoid is energized. The solenoid plunger is drawn into the solenoid and this operates the engagement mechanism lever which pushes the drive pinion into mesh with the ring gear mounted on the engine flywheel. If the pinion to ring gear engagement is properly made, the solenoid plunger will have moved to the full extent of its travel. Near the end of its travel or stroke, the solenoid plunger actuates the starting magnet limit switch shown in Fig. 13-5, which initiates control circuits to energize the starting contactors and de-energize the starter motor solenoid. Energizing the starting contactors permits the motor to crank the engine. When the engine starts, the drive pinion is thrown clear of the ring gear and as engine speed is increased, the engine start circuits are de-energized.

The Dyer drive is a special type of mechanism which provides for positive engagement of the cranking motor drive pinion with the engine flywheel ring gear, before the motor contactor is closed and thus before the armature starts to rotate. This eliminates clashing and

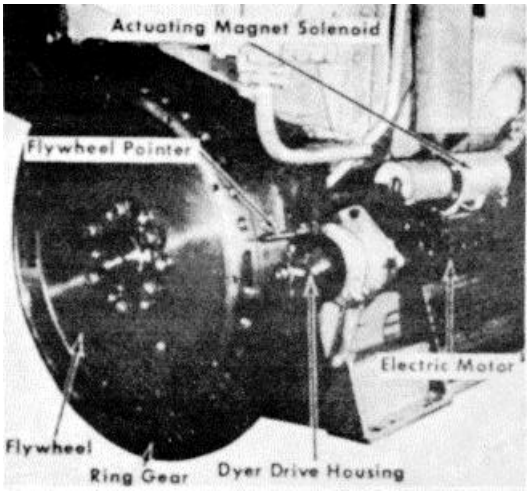


Fig. 13-1. - Starting Motor Application

the possibility of broken or burred teeth on either the pinion or ring gear. As soon as the engine starts, the pinion is automatically disengaged by the reversal of torque, so that the armature will not be subjected to excessive speeds.

The Dyer drive is assembled on the armature shaft spiral spline, as shown in Fig. 13-2, and consists of thrust washers, a shift sleeve assembly, pinion guide, spring, pinion, and pinion stop.

When the shift lever is moved by the solenoid, it forces the shift sleeve toward the flywheel or pinion, as indicated in Fig. 13-2. As the shift sleeve contacts the pinion guide it unlocks it from the undercut on the spiral splines on the armature

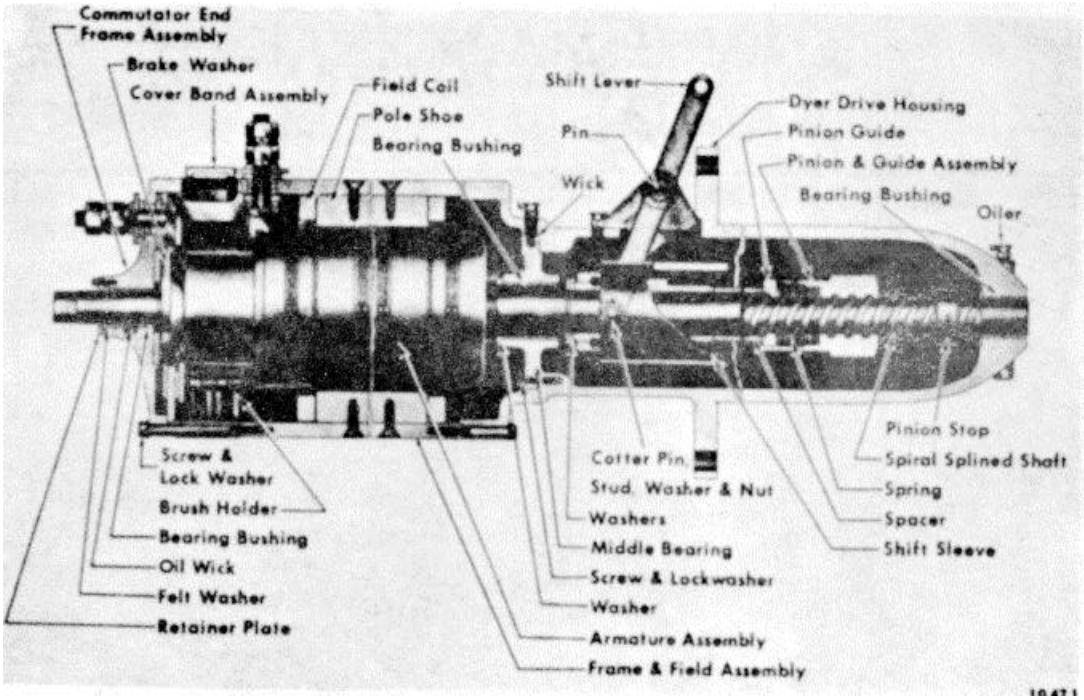


Fig. 13-2. - Starting Motor, Cross-Section

shaft. As the pinion guide is moved endwise, it presses against the pinion spring, forcing the pinion toward the flywheel. When the pinion reaches the flywheel, and the flywheel and pinion teeth are in alignment, meshing of the gears takes place immediately. if the teeth butt, meshing cannot take place. However, as the lever continues to push the assembly, the pinion guide is caused to rotate on the shaft splines. Since lugs on the pinion guide are in slots on the pinion, the pinion is caused to rotate even though its forward motion has been stopped. There is sufficient clearance between the pinion and the shaft splines so that it can rotate enough to permit pinion engagement with the flywheel.

As full engagement is made between the pinion and the flywheel, solenoid travel, as is likewise completed. As previously mentioned, the solenoid is then de-energized and the spring returns the actuating lever an shift sleeve back to their original positions. When the engine fires, the pinion guide, spring, and pinion will be spun back, until the pinion guide is again locked by the undercut in the armature shaft splines.

MAINTENANCE

LUBRICATION

The four hinge cap oilers should be filled with a light engine oil every 200 hours of engine operation. However, the grade of oil and frequency of lubrication may be varied according to the usage of the starting motor and the operation temperature.

The only lubrication required on the Dyer drive unit is that of the pinion and shaft splines. These parts should be lubricated with a few drops of SAE 10-W oil or, at low temperatures, SAE 5-W oil. A very small amount of powdered graphite also may be used on the screw shaft. Normally it is only necessary to apply lubricant to these parts when the assembly s removed for servicing.

Excess lubrication should be avoided because dust and foreign material will be

absorbed by the oil and result in a gummy condition that will prevent satisfactory operation. If necessary, the pinion gear and shaft threads may be washed, using kerosene or a good commercial solvent. Gasoline should not be used as a cleaning agent. After washing, lubricate the parts sparingly.

PERIODIC INSPECTION

At periodic intervals the starting motor should be inspected to determine its condition. The frequency of use and other conditions will determine the inspection intervals. Starting motor action is indicative of the condition of the assembly. That is, a starter motor that responds actively is usually considered in good condition. However, the inspection procedure should include more than a check of the operation. The following items should also be checked.

1. Check the starter solenoid mounting to see that it is secure and the connecting linkage is free from any binding.

2. Remove the cover band at the commutator end and inspect the commutator, brushes and internal wiring. Check the cover band for evidence of thrown solder from the commutator.

Inspect the commutator for roughness, or high mica and thrown solder. Any of these items will require removal of the assembly for reconditioning. If the commutator is glazed it can be cleaned by holding a strip of "00" sandpaper against it with a piece of wood while operating the motor a few seconds.

Inspect the brushes to make sure that they are not binding in their guide, and that they are resting against the commutator with sufficient tension to give good firm contact. Check the brush leads and screws to see that they are tight. If the brushes are worn down to one-half their original length (as compared to a new brush), they should be replaced.

Check the main connections of the starter assembly to see that they are tight. Also check the bracket mounting bolts to see that they are secure.

ADJUSTING SOLENOID LINKAGE

The solenoid linkage consists of a tang end clevis stud, a link having slotted ends to receive the tang end stud and shift lever, and pins with cotter keys to hold the assembled linkage. The tang end clevis stud screws into a tapped bolt in the end of the solenoid plunger. The clevis stud should be a free fit in the bolt.

The current supply to the solenoid and starter motor should be disconnected while adjusting the solenoid linkage. This will prevent starter operation when the solenoid plunger is in the engaged position and will prevent overheating and burnout of the solenoid coil. The solenoid should not be energized to "hold in" while adjusting the linkage, but should be manually positioned during adjustment.

LINKAGE CENTERLINE ALIGNMENT

The solenoid assembly should be mounted on the starter motor so that the centerline of the solenoid is aligned with the shift lever centerline within 1/64", as indicated in Fig. 13-3. The linkage should move freely without any binding throughout the linkage travel. Recheck the alignment after tightening of the solenoid mounting bracket.

LINKAGE ADJUSTMENT TO PROVIDE PINION FREE TRAVEL

Correct linear adjustment of the linkage is indicated when the required pinion free travel is obtained. The pinion free travel is the distance that the pinion can be

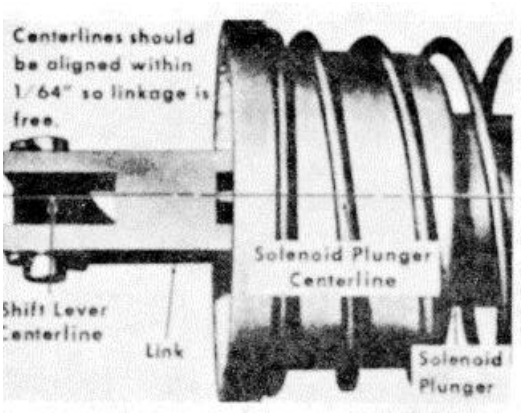


Fig. 13-3. - Solenoid Linkage Alignment

pushed back against the pressure of the pinion spring when the solenoid is in the energized position. The pinion free travel should be 3/8" to 7/16", as indicated in Fig. 13-4.

1. Place a 13/32" spacer block between the pinion gear and pinion stop. Screw the clevis stud "in" or "out" of the bolt in the plunger, until the spring retainer is solid against the end of the solenoid (no gap) when the linkage is connected to the shift lever.

2. Check the adjustment with 3/8" and 7/16" spacer blocks. The plunger should be against the end of the solenoid with the 3/8" block inserted between the pinion and pinion stop, but the 3/8" spacer block will not be tight between the gear and pinion stop. With the 7/16" spacer block in place between the pinion gear and pinion stop the plunger will not contact the end of the solenoid and the 7/16" spacer block will be held tight.

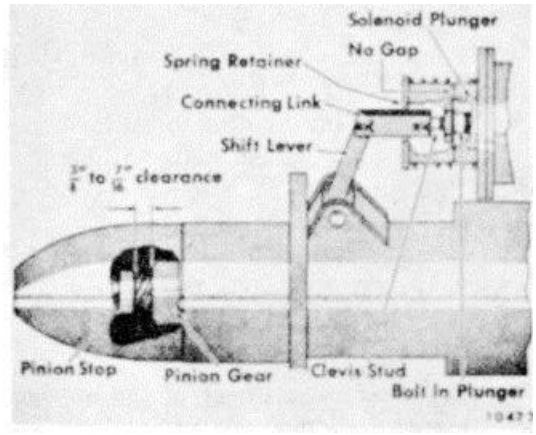


Fig. 13-4. - Dyer Drive Pinion Free Travel

STARTER MAGNET LIMIT SWITCH SETTING

The starter magnet and limit switch assembly is shown in Fig. 13-5. The magnet solenoid is energized to actuate the mechanism of the Dyer drive and engage the starter motor pinion with the ring gear on the engine. The starting magnet limit switch detects this engagement and initiates a circuit to energize the starting motor, and to de-energize the starter magnet solenoid when full engagement of the pinion and ring gear is made. As the plunger nears the end of the stroke it pushes the bar assembly to release the switch and make the switch contacts.

The starter magnet limit switch can be set as follows:

1. Remove the cover plate at the switch end of the magnet assembly.

2. Apply the clip ends of a test light circuit to interlock connections "C" and "D" as shown on the switch cover, Fig. 13-5. When C-D interlocks are made, the test light should be "on".

3. Manually force the plunger into the solenoid. When the plunger is 1/16" short of full stroke or with a 1/16" shim between the plunger retainer and solenoid bobbin flange, the test light should be "on," indicating that interlocks C-D are made.

4. If the test light comes on before 1/16" of full plunger stroke, screw "in" on the switch adjustment screw, or "out" on the screw if the light does not come on at 1/16" short of full plunger travel.

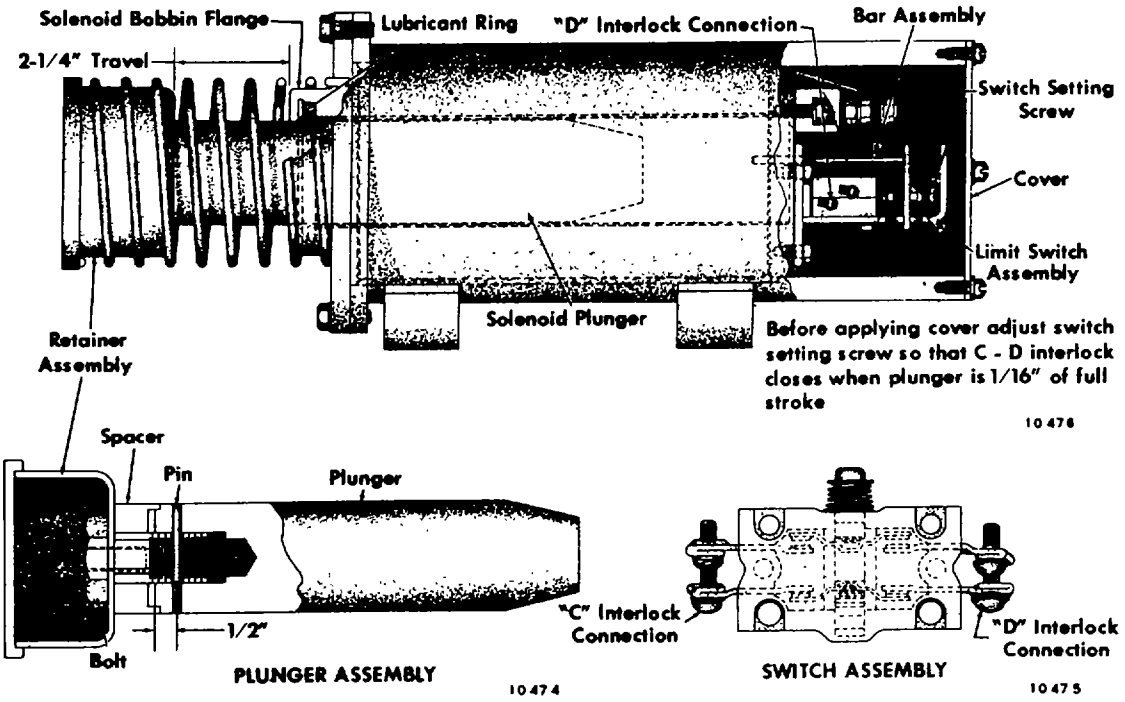


Fig. 13-5. - Starter Magnet And Limit Switch

STARTER MOTOR RECONDITIONING

The starter motor should be removed, disassembled and the parts inspected at the recommended intervals outlined in the Scheduled Maintenance Program. Defective parts should be replaced and the starter motor reassembled. For the location of the parts given in the following procedure, see Fig. 13-2.

DISASSEMBLY

1. Place the motor in a suitable position for disassembly. Remove the cover band and disconnect all brush leads and field leads from brush holders. Remove all brushes.

2. Mark field frame, commutator end frame, and drive housing to establish relationship for reassembly. This may be done by using a hammer and punch making a small mark adjacent to the parting lines do the mating parts.

3. Clean the portion of the shaft extending from the commutator end frame. Remove all high spots, paint or dirt to prevent damage to the bearing bushings as the commutator end housing is removed from the shaft.

4. Remove the three screws, lockwasher, retaining plate and felt washer from the commutator end housing being careful not to damage the felt seal.

5. Remove the five commutator end housing attaching screws. Slip the housing off the shaft.

6. Remove the eight screws attaching the stator to the drive housing.

7. Remove the stator from the drive housing by tapping lightly to free it from the pilot fit.

8. Remove the stator from the armature, being careful not to damage the armature.

9. Remove the four attaching screws from the middle bearing assembly.

10. Remove the pin holding the lever shaft and remove the shaft. The end of the lever can then be removed from the shift sleeve and the lever removed from the housing.

11. After the lever is removed, the motor drive housing can be removed, exposing the parts on the shaft.

12. Remove the pinion stop cotter key and remove the pinion assembly and other parts from the shaft. Keep the pinion, pinion spring and pinion guide together as an assembly.

PARTS INSPECTION

BRUSH HOLDER

Check brush holders and see that they are not deformed or bent, but will properly hold the brushes against the commutator. Check pressure arm tension by using a brush spring tension scale, holding the tension arm 1/8" above the stop in brush holder. Tension should be as stated in Service Data.

If the spring does not meet the required tension, the spring should be replaced. This can be done by removing the cotter pin from the end of the brush spring pin, removing the spring stop washer, and removing spring and pressure arm. Using a new spring, assemble parts in reverse order. After reassembly, and with the proper spring tension the straight end of the spring must extend at least 1/16" under edge of holder when the pressure arm is raised 90°.

Check the brush holder assembly, using 400 volts for 10 seconds. If grounded, repair as necessary. Replace the brushes if they are chipped or worn more than half their original length compared to a new brush.

ARMATURE BUSHINGS

Check the fit of the armature shaft journals to their respective bushings. Shafts should fit snugly in bushings. If bushings are excessively worn, they should be replaced.

ARMATURE

Make an insulation check on the armature using an insulation resistance tester. If the reading is less than 1 megohm, it may be due to moisture in the armature. To dry the armature, place it in a hot oven, at about 3500 F. for three hours. After drying, remove, cool, and recheck. If the reading is still less than 1 megohm, the armature will have to be repaired or replaced. If the reading is 1 megohm or higher, proceed as follows:

1. Inspect points where armature wires join commutator bars to make sure a good firm connection is formed. A burned commutator bar is usually evidence of a poor connection. If poor connections are evident, clean connection area and hand solder, using pure tin solder. Be careful to keep solder away from armature windings behind commutator.

2. If the commutator bars are rough or burned, turn down in lathe until thoroughly cleaned. See Service Data for limits on the diameter of the commutator. Maximum eccentricity of the commutator to the shaft at the bearing seats is .002". Total indicator reading for shaft eccentricity is .001".

3. After machining and polishing the commutator, the mica between the bars should be undercut as stated in Service Data. Then smooth commutator surface with #00 grade sandpaper. Make certain all copper chips are removed from the slots.

4. Check armature for shorts in windings by using a "Ductor" ohmmeter and checking from bar to bar on the commutator. Any irregularity in readings, as shown on the ductor meter, will indicate bad solder connections or shorts in the windings of the armature. These conditions will have to be repaired before the armature can be used.

5. Hy-pot armature at 500 volts AC for 10 seconds. If the armature fails to pass the hy-pot test, further inspection will be necessary to determine if the armature can be repaired.

6. Check armature bands. They should be tight with no evidence of overheating. The insulation on the armature should be free from flakes and blisters.

ASSEMBLY

DRIVE END ASSEMBLY

1. Place the armature in a suitable stand and place the first drive end washer on the armature shaft.

2. Lubricate the middle bearing bushing using a small amount of light oil and apply the bearing assembly to the armature shaft.

3. Apply the two washer just ahead of the middle bearing assembly.

4. Saturate the felt oiler within the shift sleeve and apply the sleeve to the armature shaft. After the sleeve is installed, apply the spacer to the armature shaft.

5. Apply the pinion guide to the armature shaft and position it about 3" from the end of the shaft, so as to be at the inward side of the undercut toward the end of the shaft.

   Insert the pinion spring inside the pinion bore and apply this assembly to the armature shaft. While applying the pinion and pinion spring, hold the pinion guide stationary, so that the lugs enter the slots in the pinion and the pinion spring is compressed. Then, with the pinion guide free, complete the pinion assembly application by screwing the pinion and pinion guide toward the armature.

6. Apply the pinion stop to the shaft, positioning it at the shaft undercut area. Insert the cotter pin that holds the pinion stop on the shaft.

7. Apply a small quantity of light oil to the bushing at the end of the drive housing. Install the housing over the previously installed parts on the shaft so that the bushing end of the housing is just supported by the end of the shaft.

8. Rotate the shift sleeve on the shaft so as to permit application of the actuating lever. Insert the lever into the housing so that the pin in the end of the lever is engaged in the hole provided for it in the shift sleeve. Then install the lever shaft and shaft pin.

9. Apply the middle bearing assembly to the housing, using the four screws and lockwashers.

COMMUTATOR END ASSEMBLY

Before proceeding with the assembly of the commutator end it will be necessary to sand the brushes. This can be done in the following manner:

1. Place the inner thrust washer on the shaft.

2. Place a strip of #00 grade sandpaper, rough side up, around the commutator, holding it in place with a small piece of tape.

3. Apply a few drops of engine oil to the commutator end housing bushing and assemble housing on the shaft.

4. Install brushes in holders and secure brush leads.

5. With the pressure arm holding the brushes against the sandpaper, rotate the end housing to seat the brushes to the curvature of the commutator.

6. When the brushes are properly seated, lift the brushes and cock in their holders to keep them off the commutator.

7. Remove the housing assembly from the armature and blow off all carbon dust.

8. Remove the sandpaper from the commutator and blow off all carbon dust from the armature.

COMPLETION OF ASSEMBLY

1. Attach stator to drive housing by carefully moving stator over the armature up to the drive housing. Line up punch marks, made at disassembly, and fasten stator in place with eight attaching screws and lockwashers.

2. Assemble the commutator end housing to the armature. Line up punch marks made at disassembly.

3. Apply five attaching screws and lock-washers to secure end housing to stator.

4. The brushes can now be lowered into their holders.

5. Attach field lead to its proper brush holder as indicated in Fig. 13-6.

6. Assemble the felt washer, retainer plate, three screws and lock washers to the commutator end housing.

7. Replace commutator cover band.

8. Check the insulation resistance of the completed assembly. The insulation resistance should be at least one megohm or more.

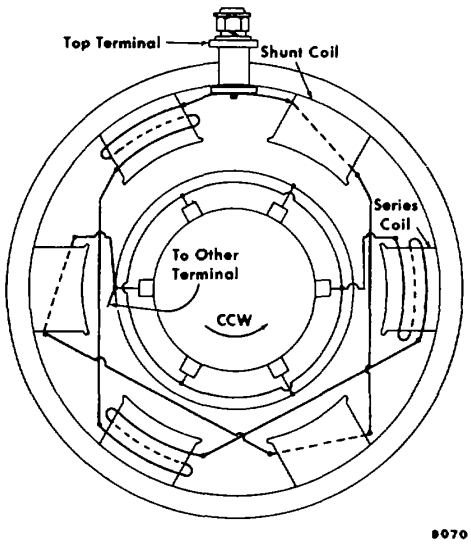


Fig. 13-6.-Schematic Wiring Diagram

567E4 SERVICE DATA
STARTING SYSTEM

SPECIFICATIONS

Commutator

Diameter - New	3.802" -3.812"
Min	3.677"
Mica groove depth	.025"-.032"
Mica groove width	.030"
Pinion free travel	3/8"-7/16"
Brush spring tension	4 - 4-1/2 lbs.

EQUIPMENT LIST

	Part No.
Brush spring tension scale	8068027
Ductor ohmmeter	8068118
Insulation resistance tester	8174880

STARTER WILL NOT CRANK ENGINE

1. Check automatic starting circuit.
2. Check for water or oil in cylinders.
3. Inspect starter motor.

ENGINE WILL NOT START WHEN TURNED OVER AT PROPER SPEED

1. Check fuel supply to cylinders by opening test valves and cranking engine with injector control lever in the starting position. A dense spray of fuel oil should be emitted from each cylinder test valve discharge hole.
2. Inspect exhaust valves to determine if some of them are stuck open or have improper clearance. Loss of compression causes misfiring in the affected cylinders.
3. Injectors may be incorrectly timed.
4. Check to see that overspeed trip is not tripped.
5. Check that engine protector reset buttons are not tripped.

LOW LUBRICATING OIL PRESSURE

1. Check oil supply in oil pan.
2. Check for oil dilution or low oil viscosity.
3. Gauge lines clogged, valve shut off, or broken oil lines.
4. Supply line strainer or cooler may be clogged. Check and clean.
5. Spring-loaded relief valve, mounted inside accessory gear train cover, may be bypassing lubricating oil due to sticking or foreign material on valve seat holding valve open. Check, clean and readjust.
6. Lubricating oil pump worn. Check and renew parts if necessary.
7. Excessive bearing wear.

ABSENCE OF OIL PRESSURE AT PUMP INLET

This may be caused by inoperative scavenging system or open drain valve. Failure of scavenging system may be due to a broken or loose oil line connection causing an air leak, a faulty scavenging pump or clogged suction screen, low oil level, or defective bypass relief valve.

LITTLE OR NO LUBE OIL CONSUMPTION

This may be due to water or fuel leaking into the oil.

EXCESSIVE USE OF LUBRICATING OIL

1. Check for broken or stuck piston rings and clogged oil drain holes under oil control rings.
2. Check for worn pistons, piston rings, or liners.
3. Check for clogged oil separator screen.

4. Oil leaking into water side of cooler.

5. Check for external oil leaks.

6. Improper grade of oil.

DILUTION OF LUBRICATING OIL

1. Check to see that fuel jumper tubes to injectors are not cracked and are seated properly.

2. Check injector filter cap gaskets for leaks.

3. Check for stuck piston rings.

4. Check injector for leaks.

5. Check for leaking valves in fuel lines.

6. The lube oil may also be contaminated by water. This can be checked visually on top of the cylinder heads or in oil pan; also by taking test sample of oil.

HIGH LUBRICATING OIL TEMPERATURE

1. Check oil pressure and level.

2. High water temperature.

3. Low water flow. Check water pressure.

4. Oil cooler may be clogged. Check and clean.

HIGH WATER TEMPERATURE

1. Check level in expansion tank.

2. Low water flow. Check water pressure.

3. Check thermostatic bypass valve operation.

4. Check water flow through radiators.

LOW WATER PRESSURE

1. Stop engine and vent engine driven pump.

2. Check all flanges on the suction side of the pump. Air admitted to the system will reduce the efficiency of the pump.

3. Check radiators for obstructions or clogging.

LOW FUEL OIL PRESSURE

1. Check supply.

2. Check filters for dirt or obstructions.

3. Check fuel oil relief valve for dirt.

ENGINE WILL NOT SHUT DOWN WITH INJECTOR CONTROL LEVER IN "STOP" POSITION

1. Injector linkage may be improperly adjusted.

2. Injector rack may be stuck or incorrectly meshed with injector gear. In order to stop engine, manually trip overspeed trip.

EXCESSIVE VIBRATION

1. Check cylinders for valve blow and/or leaking injectors.

2. Check for loose main bearing or connecting rod caps.

3. Check camshaft counterweight timing'

4. Check generator alignment.

LOSS OF POWER

1. Injectors or racks may be stuck.

2. Fuel pump may be air bound or filters clogged.

3. Check fuel oil pressure.

4. Scavenging air intake ports in liners may be partially closed with carbon deposits.

5. Exhaust valves may be stuck.

6. Check for obstructions in exhaust.

ENGINE KNOCKS

1. Check exhaust valve lash adjustment.
2. Injector may be stuck causing rocker lever to pound.
3. Injector timing incorrect.
4. Engine overloaded or overheated.

ENGINE STOPS

1. Fuel supply may have been shut off.
2. Fuel oil filters may be clogged.
3. Check fuel pump.
4. Overspeed trip may be tripped.
5. Engine protector may be tripped.

SMOKY EXHAUST

1. Engine may be overloaded.
2. Check injector timing.
3. Injector may be stuck or spray tips burned.
4. Check for stuck piston rings which may cause excessive burning of lubricating oil.
5. Check for dirty air intake filters.
6. Check for exhaust obstruction.

CYLINDER MISFIRE

1. Check for stuck exhaust valves.
2. Check for stuck injectors.
3. Check for air bound fuel lines or clogged filters.

TRACING A DEFECTIVE OR NOISY CYLINDER

A cylinder that is not firing properly will have a cooler exhaust stack, compared to one that is firing properly (engine at idle). This is caused by:

1. Badly leaking exhaust valves.
2. Defective injector.
3. Improper injector timing or control rack setting.
4. Dirty injector filter.
5. Air bound injector.
6. Excessive ring blow-by.
7. Cracked piston.

To determine if injector is at fault, disconnect injector adjustment link on the suspected cylinder and, with engine running at idle, push control rack open slowly and return to idle position as soon as observation has been made. If injector is operating properly a pronounced laboring of the cylinder will have been detected.

An exhaust valve leak can be detected, when standing beside an engine, by a pronounced blow in the exhaust stack, with engine idling.

To locate the leaking cylinder, shut down the engine and remove the cylinder test valve from the cylinder to be checked. Using an exhaust valve tester, Fig. 14-1,

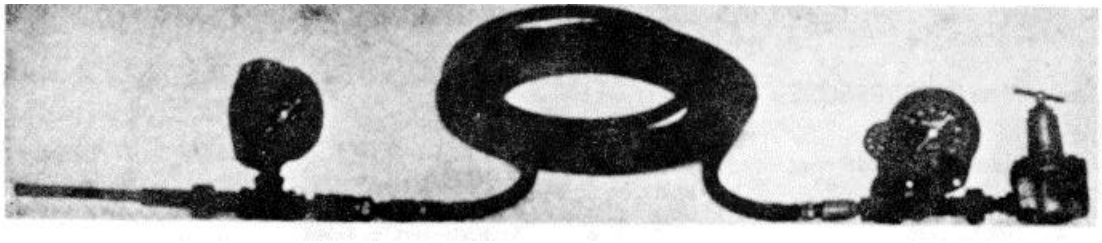


Fig. 14-1.-Exhaust Valve Tester

install the adapter and air gauge assembly in the test valve hole in the crankcase. Before attaching the air line to the adapter, turn on the air valve and regulate the air pressure to read 60 psi on the line air gauge. Rotate crankshaft until piston of cylinder being checked is at approximately top dead center. Attach air line coupling to adapter and note adapter gauge pressure. Valve leakage is indicated if gauge reads below 56 psi. Repeat check on remaining cylinders.

PART III

SUPPORT DATA

3-1

ELECTRIC STARTING MOTOR MODELS 910 AND 911

DESCRIPTION

The Model 910 and 911 starting motors, Fig. 1, are used on stationary and mobile power units. They are identical in appearance and operation. The only difference between the units is their operating voltage. Model 910 is designed for 120 volt DC current, the Model 911 is for 64 volt DC current.

The motor is equipped with a Bendix drive mechanism consisting of a drive pinion, return spring, a spiral drive shaft, and a friction clutch torque limiting device.

OPERATION

By pressing the start button, battery current flows into the starting motor causing the armature to rotate. This motion is transmitted through the friction clutch to the spiral drive shaft forcing the pinion along the spiral drive shaft, compressing the return spring, and meshing the pinion with the ring gear on the engine flywheel.

As the engine begins to run, it spins the pinion at a higher rate of speed than that of the starter motor. This causes the pinion to rotate in a direction opposite to the spiral drive shaft so that the pinion, aided by the return spring, moves back out of mesh with the ring gear.

Caution should be used in making a second starting attempt in the event the engine runs for a short while then stops. If a second starting attempt is made before the engine rotation is completely

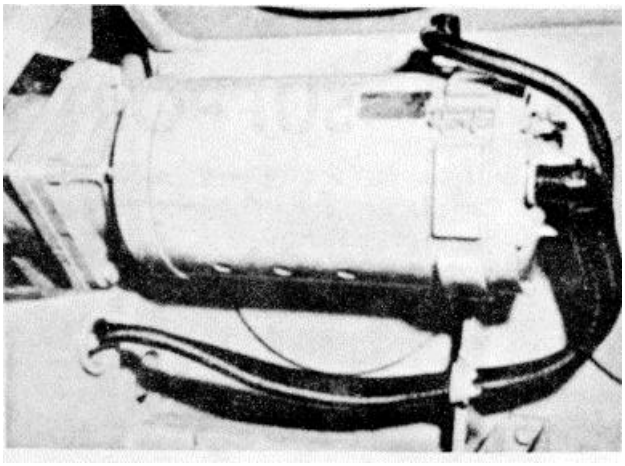


Fig. 1. - Starting Motor

stopped, serious damage could result to the starting motor. It is advisable to wait at least 15 seconds between starting attempts.

CAUTION: Never operate a starting motor continuously for more than 30 seconds without pausing to allow the motor to cool for at least 2 minutes. Overheating, caused by excessively long cranking periods, can seriously damage the starting motor.

ROUTINE MAINTENANCE

Periodically the cover band should be removed and the brushes, brush leads and commutator examined. The brushes should be making good, clean contact with the commutator and there should be sufficient brush length to last until the next inspection period. Brushes should not be allowed to wear to the extent that the

pressure arms are resting on the brush holder support. Brushes should move freely in the holder slots. Any brush that might be sticking should be removed and cause of sticking corrected. Coil leads and brush lead screws should be tight.

Inspect commutator for evidence of burning, thrown solder, roughness, being out-of-round, having excessive wear, or high mica between bars. Any such conditions will require motor removal and disassembly for correction.

The Bendix drive spiral shaft should be cleaned thoroughly with a suitable solvent before periodic lubrication to prevent sticking between the pinion and shaft.

The starter motor is lubricated by filling the three oilers and applying a few drops of oil on the Bendix engaging
spiral gear shaft,

CAUTION: Never put oil on the commutator or brushes.

The main stator terminals should be tight and the starter mounting bolts secure. Frequent starting, operation in dusty or very moist climates, or sub-zero temperatures, all put added strain on the equipment and tend to wear parts more rapidly.

Under such conditions, the frequency of the starter motor inspection should be increased.

OVERHAUL

At periodic intervals outlined in the Scheduled Maintenance Program, Maintenance Instruction 1704, the starter motor should be removed from the engine for overhaul.

Due to the similarity in design and construction of the two models, the instructions listed apply to both.

Using Fig. 2 as a reference for position of parts, disassemble in the suggested sequence outlined below.

DISASSEMBLY

1. Place motor in a suitable position for disassembly. Remove the cover band and disconnect all brush leads and field leads from brush holders. Remove all brushes.

2. Mark field frame, commutator end frame, and drive housing to establish relationship for reassembly. This may be done by using a hammer and punch making a small mark adjacent to the parting lines of the mating parts.

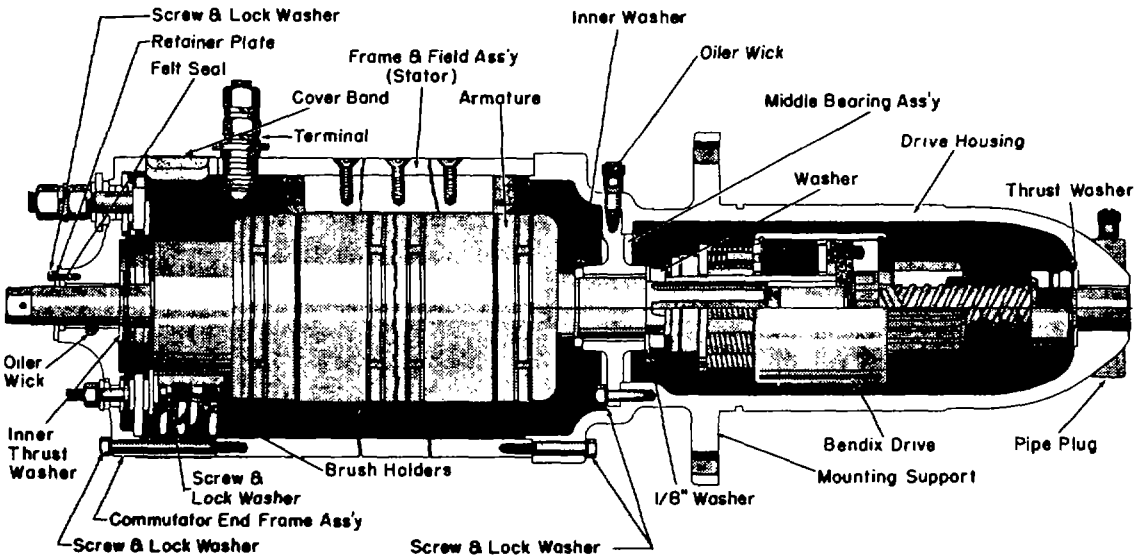


Fig. 2. - Cross-Section Of Starting Motor

3. Clean the portion of the shaft extending from the commutator end frame. Re-move all high spots, paint or dirt to prevent damage to the bearing bushings as the commutator end housing is re-moved from the shaft.

4. Remove the three screws, lock washer, retaining plate and felt seal from the commutator end housing being careful not to damage the felt seal.

5. Remove the five commutator end housing attaching screws. Slip the housing off the shaft. Remove the thrust washer from the shaft.

6. Remove the eight screws attaching the stator to the drive housing.

7. Remove the stator from the drive housing by tapping lightly to free it from the pilot fit.

8. Remove the stator from the armature, being careful not to damage the armature.

9. Remove the six attaching screws from the middle bearing assembly. The armature, middle bearing assembly, and Bendix drive can then be removed from the drive housing as an assembly.

10. The Bendix drive, spacers, and middle bearing housing can be removed from the armature in the order of their assembly.

CLEANING AND INSPECTION OF PARTS

All parts should be cleaned and inspected for wear. Never use grease dissolving solvents for cleaning the Bendix drive since this would dissolve the lubricant packed in the clutch mechanism. It is only necessary to clean the spiral shaft to give the engaging pinion free movement. The drive clutch is set at time of assembly for 350 ft-lbs. and should not be disturbed.

Check the pinion teeth, spline and spiral shaft for cracks, chips, or excessive wear. Replace Bendix as a complete assembly if found defective.

Check all spacers and washers for wear. If there are signs of wear replace with new parts.

BRUSH HOLDER

Check brush holders and see that they are not deformed or bent, but will properly hold brushes against commutator. Check pressure arm tension by using scale 8068027, holding the tension arm 1/8" above the stop in brush holder. Tension should be between 4 to 4-1/2 lbs.

If the spring does not meet the required tension, the spring should be re-placed. This can be done by (1) removing the cotter pin from the end of the pressure arm support, (2) removing the spring stop washer, (3) removing spring and pressure arm. Using a new spring, assemble parts in reverse order. After reassembly and with the proper spring tension the straight end of the spring must extend at least 1/16" under edge of holder when the pressure arm is raised 90°.

Check brush holder assembly, using 400 volts for 10 seconds. If grounded, repair as necessary. Check the condition of the brushes, if chipped or worn, replace.

ARMATURE BUSHINGS

Check the fit of the armature shaft and Bendix drive shaft to their respective bushings. Shafts should fit snugly in bushings. (See Maintenance Data for bushing and shaft sizes.) If bushings are worn .004"-.005" over tolerance they should be replaced.

ARMATURE

Make an insulation check on the armature using megger 8174880.

If the reading is less than 1 megohm, it may be due to moisture in the armature. To dry the armature, place it in hot oven, set at 160° C. for 3 hours. After drying, remove, cool, and recheck. If the reading is still less than 1 megohm, armature

will have to be repaired or replaced. If the reading is 1 megohm or higher, proceed as follows:

1. Inspect points where armature wires join commutator bars to make sure a good firm connection is formed. A burned commutator bar is usually evidence of a poor connection. If poor connections are evident, clean connection area and hand solder, using pure tin solder. Be careful to keep solder away from armature windings behind commutator.

2. If the commutator bars are rough or burned, turn down in lathe until thoroughly cleaned up. Minimum diameter is 3.677" (original diameter is 3.802"-3.812"). Maximum eccentricity of commutator to shaft at bearing seats is .002". Total indicator reading for shaft eccentricity is .001".

3. After machining and polishing the commutator, the mica between the bars should be undercut .025"-.032" deep and .030" wide. Then smooth commutator surface with #00 grade sandpaper. Make certain all copper chips are removed from the slots.

4. Check armature for shorts in windings by using a "Ductor" 8068118 and checking from bar to bar on the commutator. Any irregularity in readings, as shown on the ductor meter, will indicate bad solder connections or shorts in the windings of the armature. These conditions will have to be repaired before armature can be used.

5. Hy-pot armature at 500 volts AC for 10 seconds. If the armature fails to pass the hy-pot test, further inspection will be necessary to determine if the armature can be repaired.

6. Check armature bands. They should be tight with no evidence of overheating.

The insulation on the armature should be free from flakes and blisters.

VARNISH TREATMENT OF ARMATURE

The armature should be given a varnish treatment to seal and rejuvenate the insulation. Treatment should be given in the following sequence:

1. Preheat armature to 130° C.

2. While hot, dip in clear baking varnish 8136692 for 5 minutes, being careful not to get varnish on the commutator.

NOTE: Baking varnish viscosity, using a #4 Ford cup, should be between 40 and 50 seconds at 21.1° C. Average varnish temperature should be maintained between 20° C. And 50° C. Varnish should be thinned using Xylol 8089758(or equal).

3. Remove armature from the varnish, let drain for 3 minutes.

4. Clean varnish from shaft with Xylol.

5. Place armature in a hot oven, set at 160° C. and bake for 4 hours.

FIELD COILS

Field coils should be given a megger test and hy-pot as outlined under "Armature." If the coils fail, or examination indicates coil insulation is charred or brittle, the coils should be removed, and repaired, or renewed. Any coils re-moved should be replaced in the same relative position from which they were removed in order to maintain the proper polarity. See wiring diagram outline in Fig. 3.

Coil leads and connections must be secure and all taping intact.

VARNISH TREATMENT OF STATOR

When necessary, varnish treat stator as outlined under "Varnish Treatment of Armature." Make certain that all connection areas, tapped holes, and machined surfaces are protected from varnish.

ASSEMBLY OF STARTING MOTOR

Referring to Fig. 2 for location and identification of parts, assemble motor in sequence listed:

A. Drive End Assembly

1. Place armature in a suitable stand and place inner washer on shaft.

2. Apply a few drops of engine oil to bushing of the middle bearing assembly and place assembly on shaft. Be careful not to damage bushing when placing it on shaft.

3. Next assemble the two thrust washers in position on the shaft, placing the 1/8" washer next to the bushing face.

4. Apply a few drops of engine oil on the shaft spline and assemble Bendix drive to the shaft.

5. Place thrust washer on end of shaft. Apply a few drops of engine oil on the drive housing bushing.

6. Insert armature and drive assembly into drive housing. Secure middle bearing housing to drive housing with six screws and lock washers.

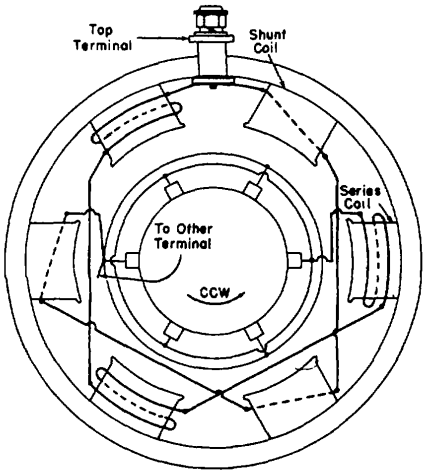


Fig. 3. - Wiring Schematic

B. Commutator End Assembly

Before proceeding with the assembly of the commutator end it will be necessary to sand the brushes. This can be done in the following manner:

1. Place the inner thrust washer on the shaft.

2. Place a strip of #00 grade sandpaper, rough side up, around the commutator holding it in place with a small piece of tape.

3. Apply a few drops of engine oil to the commutator end housing bushing and assemble housing on the shaft.

4. Install brushes in holders and secure brush leads.

5. With the pressure arm holding the brushes against the sandpaper, rotate the end housing to seat the brushes to the curvature of the commutator.

6. When the brushes are properly seated, lift the brushes and cock in their holders to keep them off the commutator.

7. Remove the housing assembly from the armature and blow off all carbon dust.

8. Remove the sandpaper from the commutator and blow off all carbon dust from the armature.

C. Completion Of Assembly

1. Attach stator to drive housing by carefully moving stator over the armature up to the drive housing. Line up punch marks, made at disassembly, and hold in place with five attaching screws and lock washers.

2. Assemble the commutator end housing to the armature. Line up punch marks made at disassembly.

3. Apply five attaching screws and lock washers to secure housing to stator.

4. The brushes can now be lowered into their holders.

5. Attach field lead to its proper brush holder.

6. Assemble the felt seal, retainer plate, three screws and lock washers to the commutator end housing.

7. Replace communtator cover band.

8. Give the completed assembly a megger check; should be 1 megohm or better. Hy-pot assembly at 500 volts for 10 seconds.

MAINTENANCE DATA

Bushing Tolerance

	Armature Shaft O.D.	Bushing I.D.
Commutator end	1.121"-1.222"	1.235"-1.1255"
Center bearing	1.737"-1.738"	1.7485"-1.7505"
Drive housing end	1.121"-1.122"	1.1275"-1.1295"

NOTE: Listed bushing sizes are after reaming or machining to size. For service tolerance add .004"-.005" between listed shaft and bushing sizes.

Brush holders pressure arm tension---------- 4 to 4-1/2 lbs.

Commutator dimensions ---------- Minimum neck width 1/8"
Minimum diameter 3.677"

Hy-Pot Data

Complete assembly ----------500 volts AC, 60 cycle

Stator----------500 volts AC, 60 cycle

Armature ----------500 volts AC, 60 cycle

Brush holder rigging----------400 volts AC, 60 cycle

RECONDITIONING NEEDLE VALVE INJECTORS

DESCRIPTION

The most important part of the fuel system is the unit injector, which is a high pressure fuel metering pump and spray valve combined in one housing.

It is located and seated in a tapered hole in the center of the cylinder head, with the spray tip protruding slightly below the bottom of the head. It is positioned in the head by a dowel and held in place by an injector hold-down crab and nut. A cross-section of the unit injector and names of the various parts is shown in Fig. 1.

The external working parts of the injector are lubricated by oil from the end of the injector rocker arm adjusting screw. The internal working parts are lubricated and cooled by the flow of fuel oil through the injector.

The main working parts of the injector are: rack, gear, plunger, follower, spring, and needle valve.

The plunger is given a constant stroke reciprocating motion by the injector cam acting through the rocker arm and plunger follower. The timing of the injection period during the plunger stroke is set by an adjusting screw at the end of rocker arm. Fig. 2 shows flow of fuel during one downward stroke.

Rotation of the plunger by means of the rack and gear, controls the quantity of fuel injected into the cylinder during each stroke. Rack position is controlled by the governor through the injector layshaft and linkage. The gear is keyed with a sliding fit to the plunger to allow plunger vertical movement.

The helices near the bottom of the plunger control the opening and closing of both fuel ports of the plunger bushing. Rotation of the plunger regulates the time that both

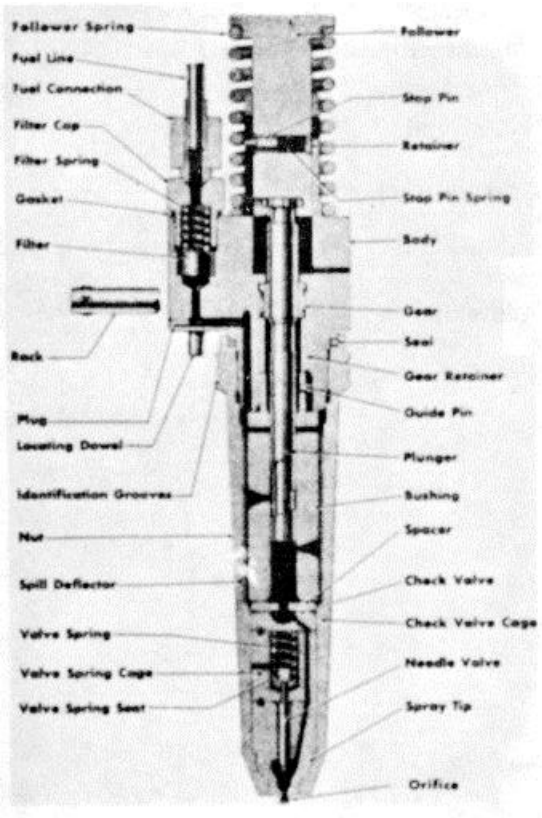


Fig. 1.-Unit Injector, Cross-Section

ports are closed during the downward stroke, thus controlling the quantity of fuel injected into the cylinder as shown in Fig. 3. As the plunger is rotated from idling position to full load position, the pumping part of the stroke is lengthened, injection is started earlier, and more fuel is injected.

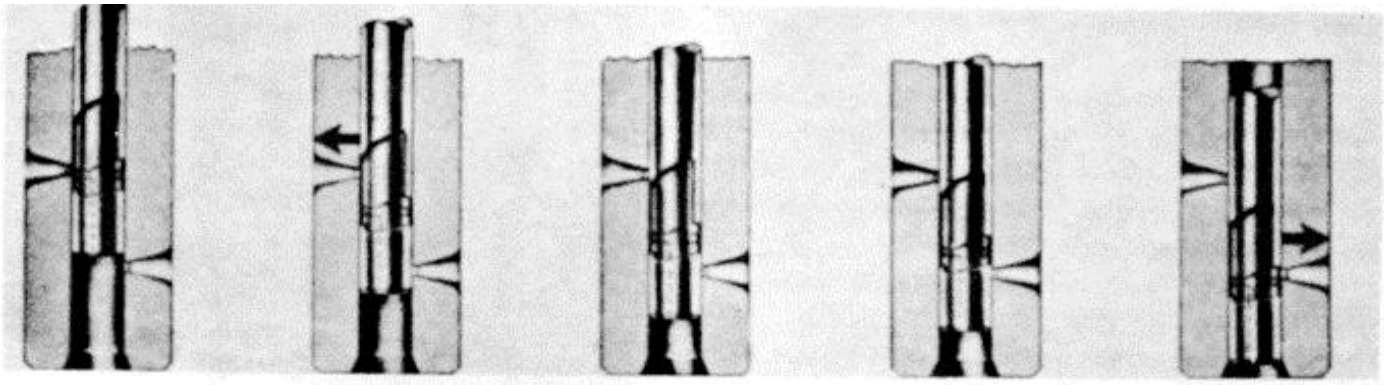
Proper atomization of the fuel is accomplished by the high pressure created by the downward stroke of the plunger, which forces fuel past the needle valve and out through the spray holes in the tip of the injector.

Filters at the fuel inlet and outlet connections protect the working parts of the injector.

MAINTENANCE

Special equipment, tools, fixtures, and gauges called out in the maintenance procedures are listed at the end of the M.L with their part number.

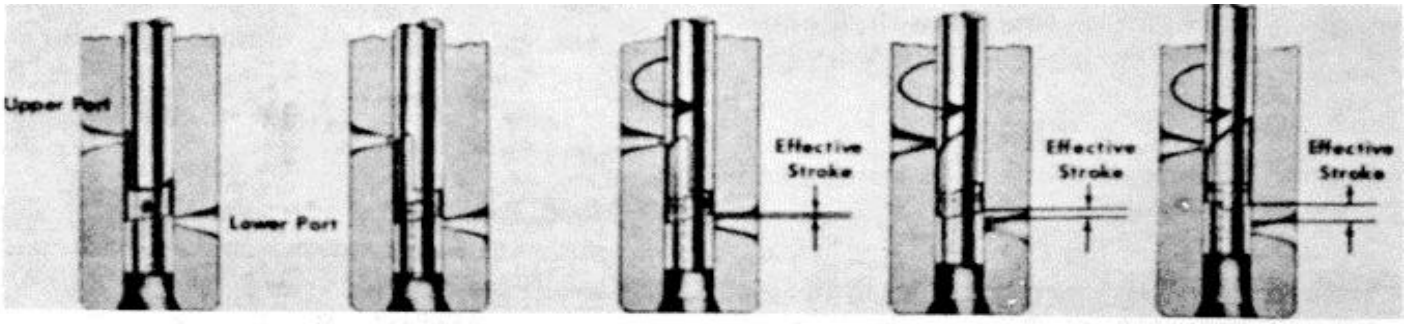
When servicing the injectors, clean conditions must be maintained. Foreign material in any form is the most common cause of injector failure. When an injector



TOP OF STROKE	BYPASS POINT	INJECTION STARTS	INJECTION ENDS	BOTTOM OF STROKE
BOTH PORTS OPEN TO ADMIT FUEL	FUEL BELOW PLUNGER ESCAPES THROUGH UPPER PORT. NO EFFECTIVE STROKE	BOTH PORTS CLOSE FORCING FUEL INTO CYLINDER	LOWER PORTS STARTS TO OPEN ALLOWING FUEL BELOW PLUNGER TO ESCAPE	LOWER PORTS FULLY OPEN. NO EFFECTIVE STROKE

ONE COMPLETE DOWN STROKE OF PLUNGER AT "HALF LOAD" POSTION

Fig. 2.-Pumping Action Of Injector Plunger



NO INJECTION RACK CLEAR OUT	NO INJECTION RACK .088"	ILDE	HALF LOAD	FULL LOAD

Fig. 3. - Fuel Control Plunger Rotation

is in an engine it is protected against dirt, dust and other foreign materials by the various filters employed. When an injector is in storage it is protected by the filters which seal the body openings, which in turn are protected by a shipping block or plastic caps.

However, an entirely different set of conditions is encountered when it becomes necessary to disassemble an injector for repair or overhaul. Under these conditions, care should be exercised for proper handling of the parts and to provide the cleanest possible working facilities.

The mechanics working on the injectors must protect the parts by careful handling, as some parts are so finely finished that the slightest burr or scratch can make them unfit for use. It is important also, that the hands and the apparel of the mechanic be clean.

DISASSEMBLY

When disassembling an injector, care must be taken not to damage any of the parts. As parts are removed, place them in a parts pan and keep them separate from other injector parts. Many of the components are matched and are not usable with other injectors.

1. Clamp injector in vise in upright position, Fig. 4, and remove the shipping block or plastic caps, if installed.

2. Remove the fuel filter caps using a 3/4" socket. Remove and discard gasket and filter elements.

3. While manually compressing the follower spring, insert a small rod between coils of spring and push "stop pin" in to release the follower. The spring can now be unloaded by gradually allowing the follower to move upward.

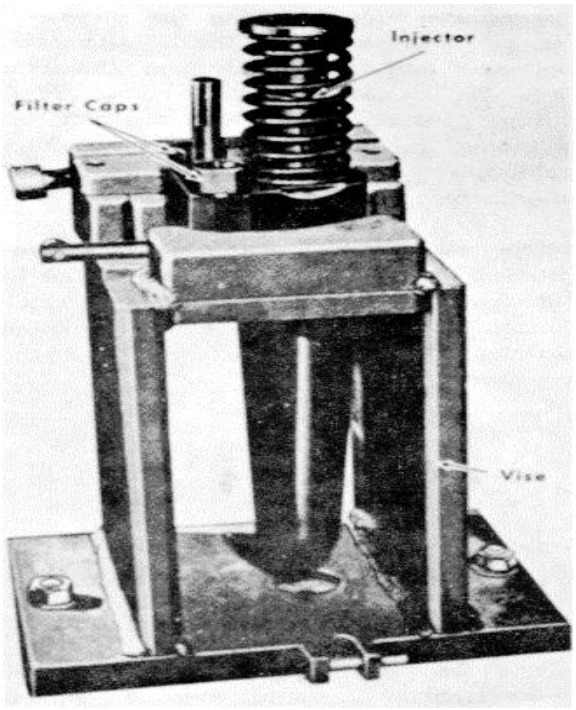


Fig. 4. - Preparation For Disassembly

4. Carefully lift the follower and plunger from the injector, Fig. 5. Disengage the plunger from the follower and remove the follower spring.

5. Invert the injector in the vise. Using wrench, loosen the injector nut, Fig. 6. Unscrew the nut by hand and lift it straight up so as not to disturb the parts underneath.

6. After the nut is removed, Fig. 7, the exposed stacked parts can be removed.

NOTE: Occasionally the spray tip sticks in the nut and is removed with the nut. If the spray tip cannot be pressed out with the fingers, it can be removed by setting the nut on a block of wood and using a short

length of brass tubing to drive out the spray tip. The inside diameter of the brass tubing must be large enough so that only the outer edge of the spray tip is contacted by the tubing.

7. Remove the spill deflector and plunger bushing by lifting them straight up. Insert the previously removed plunger into its mating bushing, but in a reversed position so that plunger enters bushing at the end of bushing opposite end with guide pin.

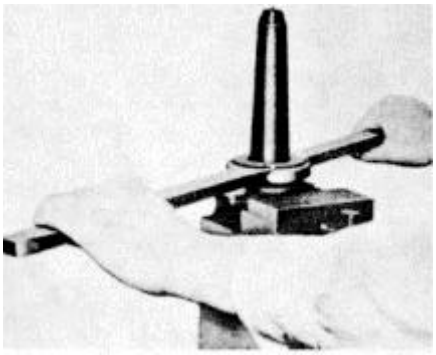


Fig. 6. - Loosening Injector Nut

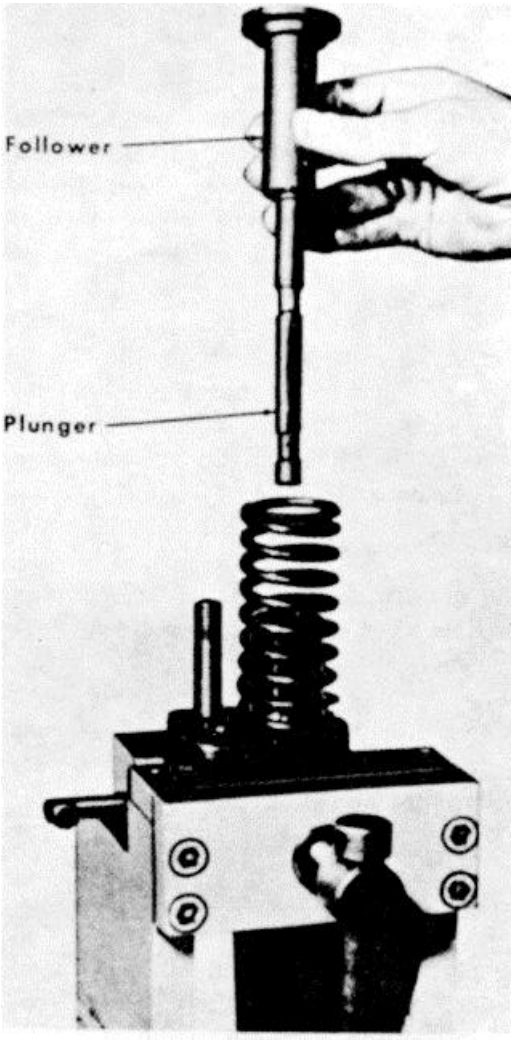


Fig. 5.- Removing Follower And Plunger

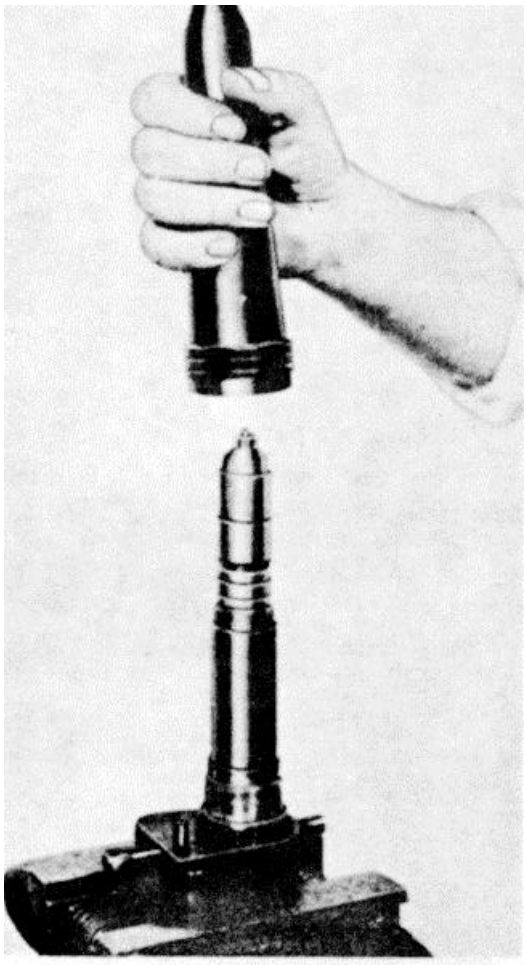


Fig. 7. - Removing Injector

8. Remove and discard the body to nut seal ring.

9. Release the injector body from the vise and holding free hand at bottom, invert the body to remove the gear retainer and gear. After the gear is removed, the injector rack can be withdrawn from the body, Fig. 8.

CLEANING

In preparation for cleaning the parts of the disassembled injector, a perforated carrying basket should be provided for each injector. The cleaning containers may be conventional baking pans made of rust proof material of such size to accommodate all parts of one injector, or a large cleaning tank is available which is divided into four large cleaning compartments.

The physical dimensions of the cleaning tank are approximately 5' long by 2' wide and each compartment is 12" deep and equally spaced the length of the tank. The hood of the tank has provisions for an air filter and exhaust fan.

The parts of each injector can remain in the perforated carrying basket and be placed into either the cleaning tank or pan. This will allow the cleaning solution to drain when the basket is removed. The cleaning containers should also have a removable screened or perforated frame at the bottom to keep injector parts above the contaminants which settle in the cleaning containers.

The four cleaning containers should contain the following solutions:

Container No. 1

This container holds a non-phenolic, non-chlorinated, oil-soluble, water-miscible, liquid-type soap solution which when diluted with four parts of a petroleum distillate-type solvent forms a solvent-emulsion cleaner.

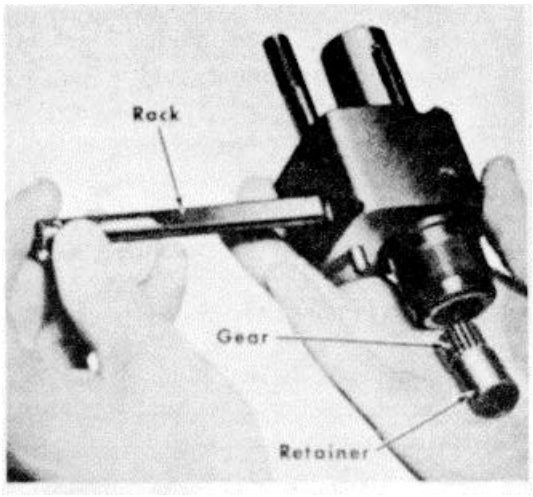


Fig. 8. - Removing Injector Rack, Gear And Retainer

Sufficient liquid should be added to cover all parts. Leave disassembled parts in this container about fifteen minutes. Carbon and lacquer must be completely removed from all parts.

Container No. 2

The second container is filled with clean solvent or mineral spirits. This is used for rinsing parts after removal from the first container and after secondary cleaning.

Container No. 3

The third container is used for storing parts after they have been cleaned and inspected, until they are ready for reassembly. Fill container with enough fuel oil or injector testing-rust proofing oil to completely cover all the injector parts.

Container No. 4

The fourth container is filled with the same kind of oil as used in No. 3. The solution in this container is not used until reassembly of the injector parts is about to begin. Just prior to assembly, the part is removed from container No. 3 and blown off with filtered compressed air. Immediately after

blowing off, the part is dipped into container No. 4 solution and assembled in the injector without further drying. The oil that adheres to the part after dipping provides rust proofing and/or initial lubrication.

After the parts have soaked in container No. 1 and rinsed in container No. 2, they should be dried with compressed air, and cleaned further as outlined in the following procedure.

NOTE: Care must be taken while wire brushing the following parts, not to wire brush their lapped surfaces.

BODIES

1. Apply abrasive disc (11/16" diameter - 60 grit emery disc) to seating tool. Mount the seating tool in a motor driven chuck and remove any carbon from inside diameter flat on gear side of the body.

2. Apply abrasive disc (13/16" diameter - 60 grit emery disc) to seating tool and apply seating tool in motor driven chuck. Remove any carbon from the inside diameter flat on follower side of body, Fig. 9.

3. Using magnetized reamer, Fig. 10, clean out oil passages in the body. A pin vise may be used to hold the reamer. There are two other passages besides the two fuel passages at the bottom of the body namely: the vent passage at the back, and the passage whose entrance is opposite the shallow timing gauge hole.

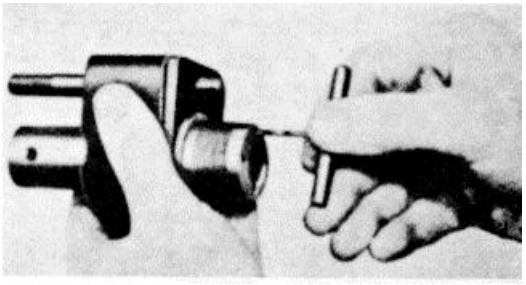


Fig. 10. - Reaming Body Fuel Passages

4. Buff external surfaces (except bottom) on a soft wire buffing wheel.

5. Wash off entire body being sure that all carbon particles are removed. Use brush (1" diameter china bristle) to clean the body. Using compressed air, blow out fuel passages and dry the body.

6. Place body on a clean surface or pan for inspection.

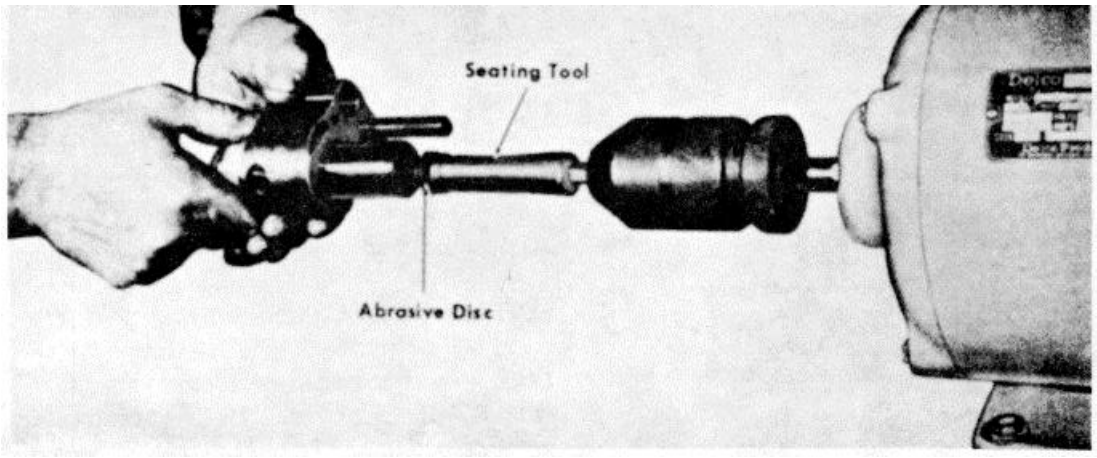


Fig. 9. - Cleaning Flat, Gear Side Of Body

INJECTOR NUT

1. Clean external surface of the nut by buffing on the soft wire buffing wheel.

2. Using nut reamer, Fig. 11, clean carbon from inside diameter of the nut, and spray tip seating surface.

3. Wash nut inside and out using brush and solvent. Dry nut with compressed air and place with body for inspection.

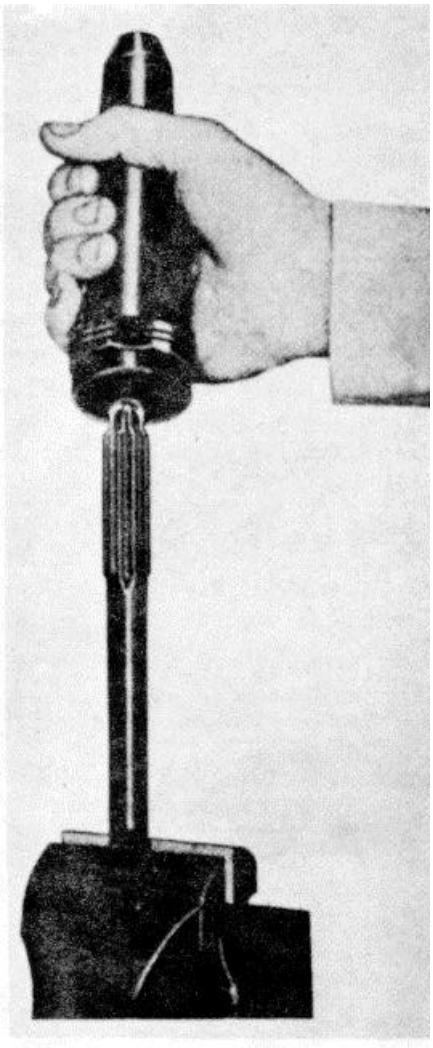


Fig. 11. - Reaming Injector Nut

INJECTOR RACK

Buff the rack on soft wire wheel, being careful to clean thoroughly between rack teeth. Wash the rack in solvent and blow dry.

INJECTOR GEAR

1. Clean gear teeth and outside surface by buffing. Clean inside using 7/16" diameter wire brush mounted in a motor driven chuck.

2. Wash gear in solvent, then dry and place with other items.

PLUNGER BUSHING

1. If required, lightly buff the external surface of the bushing, taking care to avoid the lapped end.

2. Using soft bristle brush and solvent, wash bushing bore and external surface. Dry with compressed air.

PLUNGER

1. If required, lightly buff only the upper half of the plunger. Do not buff on the lapped lower portion of the plunger.

2. Wash the plunger using solvent and brush, paying careful attention to the helical grooves. Dry with compressed air and clean tissue.

NOTE: After plunger and bushing are cleaned, insert plunger in its mating bushing with the plunger placed into the end of bushing opposite the end containing the guide pin.

SPILL DEFLECTOR

Lightly buff the spill deflector to remove carbon, if required. Using brush and solvent, wash entire part. Dry with compressed air.

SPRAY TIP

1. Buff external surface of spray tip on the soft wire buffing wheel, taking care to avoid the lapped surface.

2. Clean spray tip bore, valve seat, and the guide O.D. on the valve with solvent to remove lacquer and carbon.

3. Clean out spray holes in tip, Fig. 12.

   a. Apply short length of 011" wire to pin vise. About 1/4" of wire should extend beyond vise jaws.

   b. Hone wire end to a point to remove any burrs, using abrasive stone.

   c. After cleaning holes with wire, wash spray tip in solvent and blow dry.

GEAR RETAINER

1. Buff external surface of gear retainer on soft wire buffing wheel. Remove any carbon from the inside diameter, using 1/2" diameter wire brush mounted in motor driven chuck.

2. Using solvent, wash the retainer and blow dry with compressed air.

SPRING CAGE

1. Buff outside surface, except lapped surface, using soft wire wheel.

2. Remove any carbon from the inside diameter, using 7/16" diameter wire brush mounted in a motor driven chuck.

3. Wash in solvent and blow dry with compressed air.

SPACER

1. Using magnetized reamer, ream out fuel passage in the spacer.

2. Buff spacer surface, except lapped surfaces, on soft wire buffing wheel.

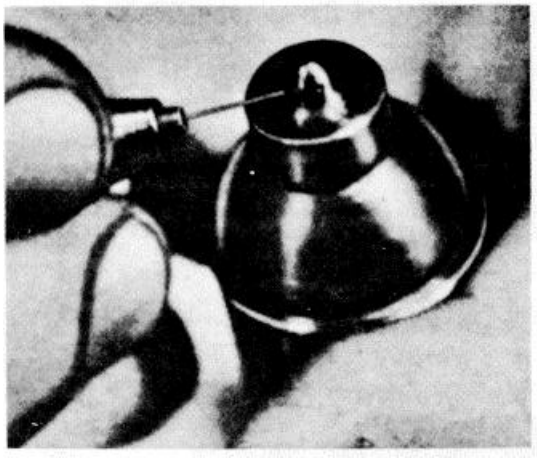


Fig. 12. - Checking Spray Tip Orifice

3. Wash in solvent and dry with compressed air.

REMAINING PARTS

1. Clean the parts listed below by buffing on soft wire wheel:

Follower	Filter Caps
Follower Spring	Filter Springs
Valve Spring	

2. Wash each in solvent and dry with compressed air.

EMERGENCY MEASURES

1. Filters - The old filters should be discarded when-reconditioning injectors. However, if it is necessary due to parts shortage to reuse old filters, they should only be cleaned by gentle sloshing in the cleaning solvent.

CAUTION: Do not use a brush or compressed air on these filters.

2. Copper Gaskets - Copper gaskets often become hard and lose their sealing ability, so they should be discarded after use. However, if it is necessary to reuse them, they should be cleaned and annealed.

To anneal copper gaskets, heat them to a dull cherry color, 1200° F. (649° C.) to 1500° F. (816° C.) and quench them quickly in water.

INSPECTION

BODIES

The injector bodies should be carefully inspected for any burrs, metal slivers or bad threads. The body and all drilled passages should be clean. On injectors equipped with calibrating slides, remove slide from body before inspecting. Check slide for same conditions as body.

PLUNGER AND BUSHING

Plunger should be closely examined for scores and scratches on the lapped surface. The helices should be inspected for chipping or eroding. Scored surface on the plunger is easily seen, but the bushing requires a good light such as provided by an otoscope, Fig. 13, to see evidence of scoring. For any of these defects, reject the plunger and bushing. Refer to Fig. 14 for examples of plunger defects which are cause for rejection. It may be necessary to remove light lacquer buildup or oil stains from the plunger and bushing by polishing. Procedure for polishing these parts is given under "Lapping of Injector Parts."

In addition to being free from burrs, scratches, scores, or other imperfections, the plunger and bushing must be absolutely clean. To test for cleanliness, insert the plunger in its bushing and spin the bushing. If both the plunger and bushing have been properly cleaned, the bushing will spin freely.

NOTE: The plunger and bushing must be absolutely dry while making this test. If the bushing does not spin freely, the cleaning operations should be repeated, or the parts replaced.

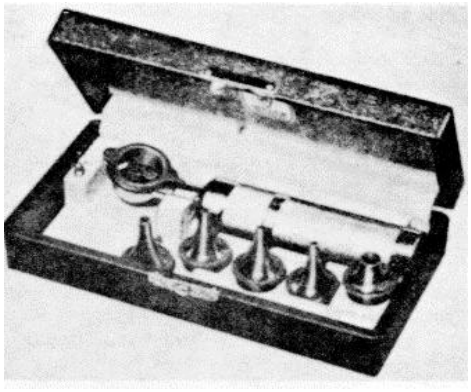


Fig. 13. - Otoscope

Plunger and bushing should always be kept together as they are manufactured only in matched sets. If these parts should become mixed, due to error in handling, lightly etched identification numbers will be found in the undercut below the head of the plunger and on the outside surface of the bushings. The same number will be etched on each mating piece. This number will be different on each assembly and has no meaning except to identify the parts as being matched sets.

NUT

Inspect the outside of the nut for deep scratches or gouges on the seating surfaces, or pits around the spray tip end. Any of the above defects, that appear on the flat surface adjacent to the spray tip, may be removed by refinishing to 6.870" overall length. The inside spray tip seating surface must be free of scratches or burrs and be clean. Discard nut if imperfections are present on inside of nut.

CONTROL RACK AND GEAR

These parts should be free from burrs and rough spots so that the rack will move

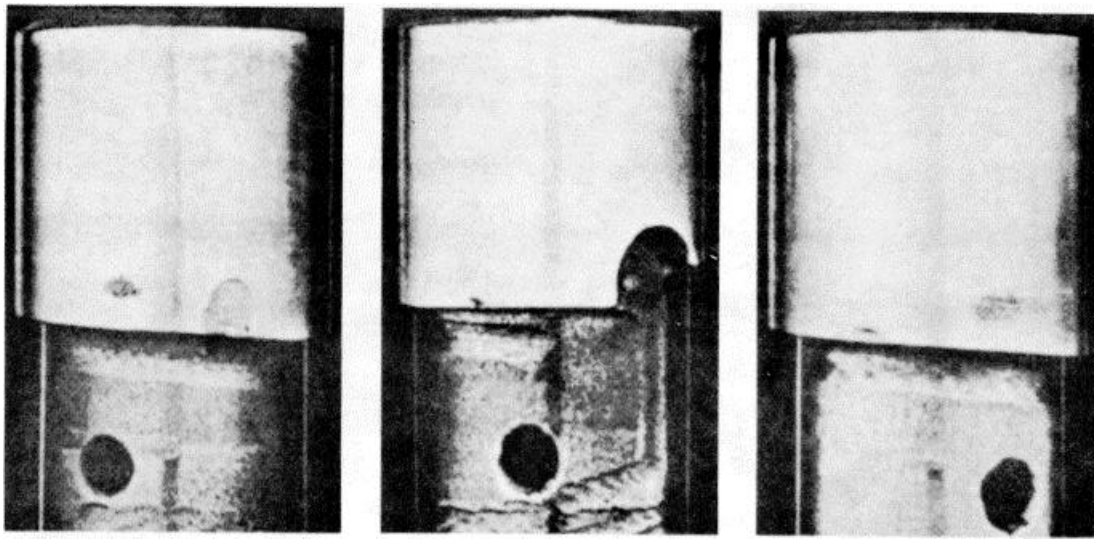


Fig. 14.-Examples of Chipped And Scored Plungers

freely when the injector is assembled. Make sure that the rack is straight by checking against a straight edge. The rack must be straight so as not to bind in the injector during operation.

SPRAY TIP ASSEMBLY

1. Replace needle valve in spray tip, if removed, and check valve action. If movement of valve is sticky, remove valve from spray tip and check guide O.D. on valve and spray tip bore for scoring and pitting. Reject assembly if either condition is observed.

2. Check valve and valve seat for spalling, nicks, and scratches. Reject badly spalled valves. Refer to Fig. 15 for an example of spalling on needle valve. If the spray tip condition is satisfactory, but the valve is not, the spray tip can be reworked and a new valve installed.

3. Inspect center hole and spray orifices for cleanliness and burrs.

4. Inspect the three fuel supply holes for obstructions and burrs. Inspect the lapped surface for a high mirror finish, and for scratches or cracks.

5. Check each spray tip orifice with a .014" wire. Reject any spray tip which will accept the wire in any orifice.

6. Place spray tip in air flow gauge, Fig. 16, set air pressure to 30 psi as indicated at bottom right side of gauge, and check air flow through orifices in tip. Air flow should register within

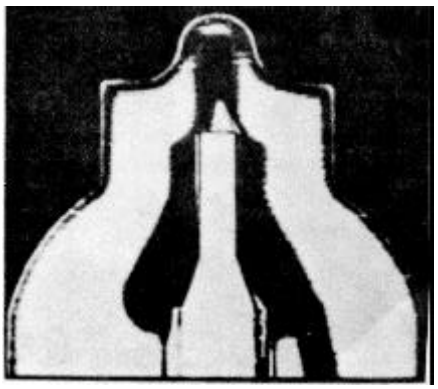
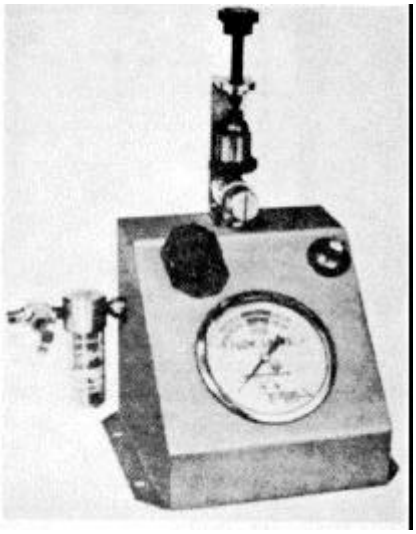


Fig. 15. Example Of Spalling On Needle Valve



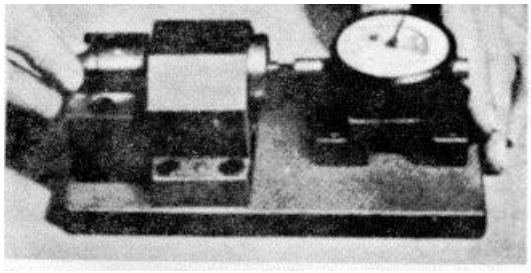
13172

Fig. 16. - Injector Tip Air Flow Gauge

the green area on gauge to indicate acceptable tip. Instructions for gauge operation are provided with the gauge.

7. Assemble needle valve to spray tip making sure that the needle is seated in the tip.

8. Place the spray tip assembly in the dial indicator gauge, Fig. 17, and measure the valve lift. The lift being the difference in height between the upper lapped surface of the spray tip and the shoulder of the needle valve. If the lift exceeds .020", replace the spray tip assembly.



13173

Fig. 17. - Dial Indicator Gauge

SPRING CAGE

Check that the wear on the bottom of the spring cage, where the needle valve shoulder makes contact, does not exceed .002". A new spring cage is required if wear exceeds limit.

VALVE SPRING

New valve springs should be used when the injectors are rebuilt. However, if due to parts shortage it is necessary to reuse springs, they should be inspected as follows:

1. Determine if the spring has taken a set or shortened. This is done by comparing spring length with an unused spring of the same part number. If there is a noticeable difference in length, do not use the old spring.

2. The outside of the spring should be examined for bright marks which would indicate that the coils have rubbed hard against the wall of the spring cage. Also check spring for pitting or erosion. A valve spring in either condition should not be used except in extreme emergency.

RECONDITIONING PROCEDURES

LAPPING OF INJECTOR PARTS

As previously stated, the injector valve assemblies and their related parts are subjected to full injector fuel pressure. Each of these parts has at least one surface making contact (sealing) with an adjacent part. These sealing surfaces must be clean, brightly polished and absolutely flat, so that when the injector is assembled and operated, each joint will withstand full injection pressure with-out leaking.

The required high polish and flatness is attained by hand lapping the parts on suitably prepared "lapping plates". This is an operation that requires some degree of skill. Since this skill can only be attained by actually lapping parts, it is recommended that some time be spent in practicing the lapping operations, using scrap parts before lapping parts intended for use in injectors.

To ensure the best quality of finished lapping work requires use of correct lap-ping plates that are kept in proper condition. The lapping plate set consists of three lapping plates, 8" x 8" x 1", in a covered wooden box. The lapping surface of each plate is grooved into 1/8" squares separated by 1/64" grooves. The plates should be kept covered in the box when not in use.

Continued use of the lapping plates tends to cause worn or low spots to develop, and sometimes the plates become scratched. Imperfections of this kind are evident when a plate is held under a strong light. When such defects are present, the lapping surfaces of the plates must be refinished.

Refinishing Lapping Plates

To refinish the lapping plates, sprinkle some lapping powder (600X), or equivalent, on one of the plates and add sufficient light machine oil to make a lapping paste. Place another plate on top of this plate face to face, and work them together. Alternate the plates from time to time. For example, assuming the plates are numbered 1, 2, and 3, work No. 1 and No. 2 together, then No. 1 and No. 3, and finally No. 2 and No. 3 together. Continue this procedure until all plates are perfectly flat and free of imperfections. After the surfaces have been refinished, clean all lapping paste from the plates by rinsing in fuel oil and washing, using a soft bristle brush.

It is good practice where considerable lapping work is done to devote some time each day to refinishing the plates. This procedure ensures the plates being in first class condition at all times.

Lapping Procedure

Avoid unnecessary lapping of injector parts. It frequently happens that when an injector is disassembled for repairs, many of the lapped surfaces still retain their mirror finish. When parts are found to be in good condition, set them aside and lap only the parts which require cleaning or removal of mirror defects. New re-placement parts also should be polished by lapping.

1. Lap following parts on the lapping plates:

Body assembly seat	Spring cage
Plunger bushing	Spacer
Flat check valve	Spray tip

2. Clean off lapping plate using compressed air. Do not use a cloth or other material for this purpose.

3. Sprinkle some lapping powder on one of the lapping plates. (A common salt shaker is good for this purpose.)

4. Place the part to be lapped flat on the plate, as shown in Fig. 18, moving it back and forth across the plate using a figure "8" motion. Do not exert too much pressure on the part, but sufficient to keep the part flat. Rotate the part in hand 10 to 30 degrees every few seconds to produce an even smooth surface. When the part is flat and clean, wash it in solvent and dry with compressed air.

5. To provide a mirror finish on the lapped surface, lap the part on the second plate dry. Do not use any lap-ping powder. Make several figure "8" passes with part.

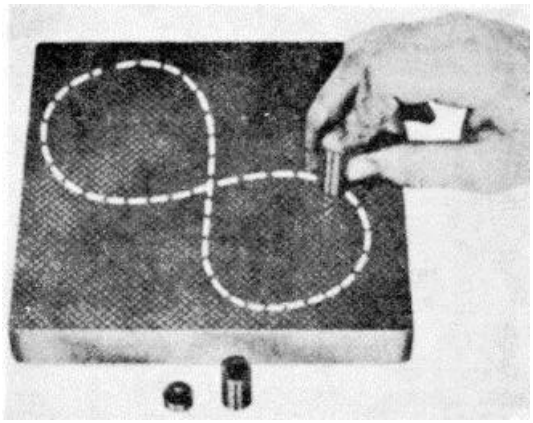


Fig. 18. - Lapping Injector Parts

NOTE: if the body assembly seat has a nick or low spot which cannot be removed through normal lapping, place No. 320 grit aluminum oxide cloth on lapping plate and make as many figure "8" passes with the body assembly as required to remove defect. Then lap to required finish.

Polishing Bushing And Plunger

The bushing and plunger are polished using jewelers rouge paste and toilet tissue. The paste is made by mixing a small amount of jewelers rouge and mineral spirits.

1. Polishing Bushing

   To polish the injector bushing, wrap a sufficient amount of toilet tissue around a small diameter rod so that it may be inserted into the bushing bore. Apply a small amount of the jewelers rouge paste to the toilet tissue and insert into the bushing bore, Fig. 19. Work bushing back and forth over tissue, using a rotary motion.

2. Polishing Plunger

   The plunger is polished using some of the jewelers rouge paste on toilet

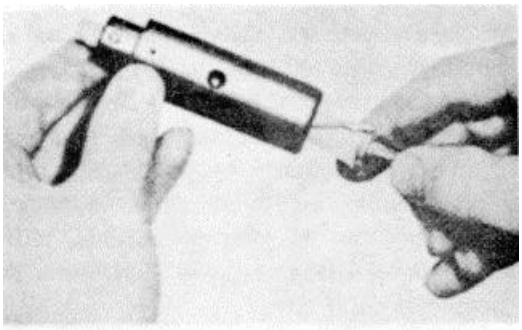


Fig. 19. - Polishing Injector Bushing Bore

tissue held in the hand, Fig. 20. The plunger is then worked back and forth through the tissue using a rotary motion. When the plunger and mating bushing have been thoroughly cleaned and polished, the bushing should be able to be spun around the inserted plunger. It is important in making this check that both the plunger and bushing are absolutely dry and clean.

After the injector parts have been lapped and polished, they should be washed in solvent to remove all compound. They then should be blown dry with clean compressed air. Place them in cleaning container No. 3 in preparation for assembly of the injector.

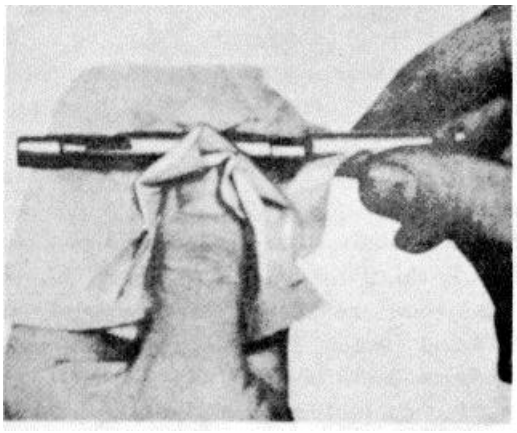


Fig. 20.-Polishing Injector Plunger

Lapping Spray Tip

Lap needle valve spray tip, if required. Improper seating is indicated by drip or poor spray pattern at the "pop" test or when under pressure, and lack of chatter during the "pop" test.

1. Flush spray tip clean and dry with air hose.

2. Select the proper lapping tool from set.

NOTE: The 21 lapping tools are graduated in increments of .0001" from .2170" through .2190" diameters. Select the tool which has a light wring fit with the spray tip in order to maintain seat-to-bore concentricity of .0001".

3. Place a small amount of 800 grit lapping compound on the 60° lap seat of the lapping tool. Place tool into spray tip. Use extreme caution to prevent the tool with compound from touching the side walls of the .2170" - .2190" diameter since this will destroy the selective fit of the plunger and spray tip and will be cause for rejection.

4. With the lapping tool properly positioned in the spray tip, revolve the lapping tool between the thumb and index finger, applying a light pressure while revolving. Lift the tool slightly each turn to permit the compound to be drawn under the lap. Three or four complete revolutions should reseat the tip.

5. Carefully remove the lapping tool from the tip making sure to wash all of the compound from the tool. Wipe dry and replace in box. Flush all compound from the internal passages of the spray tip, and dry with air hose.

6. Visually inspect seat, using otoscope.

NOTE: The spray tip has a 60° seat angle while the needle plunger is 62°. Therefore, the assembly will show only a hairline bearing area. When reworking, consider the lift dimension of .012" - .018".

7. If bright rubbing marks are on the shank, lap the pilot diameter of the needle valve as follows. Insert upper stem of needle valve into chuck and spin at 350 RPM maximum. Do not chuck needle on lapped pilot diameter. Apply a very small quantity of lapping compound to the spinning valve with the tip of the finger. Rub back and forth across the lapped diameter with the tip of the finger just long enough to remove any bright rubbing marks on the needle valve shank. If needle valve seat has soft deposits or lacquer, touch with finger and clean the same as described for the pilot diameter.

CHECKING VALVE OPENING PRESSURE

1. Assemble needle valve to test fixture, Fig. 21, and connect test pump fuel line.



Fig. 21.-Injector Valve Test Fixture

2. Actuate pump handle at approximately 40 smooth even strokes per minute, observing pressure gauge until opening pressure is obtained. The opening pressure should be between 2200 - 3400 psi.

   A finely atomized spray at the tip will result. Rapid closing of the needle valve will produce a sharp "chatter".

3. if the valve opens without producing a finely atomized spray or the valve seats without producing the sharp "chatter", make several rapid strokes with the pump to dislodge any foreign material from the needle valve seat. If the needle valve fails to function properly, dirt on the seat or a defective seat may be the cause. Misalignment can also cause sluggish valve action. To correct misalignment, loosen injector nut and rotate the tip 180° with finger tips. Repeat Step 2.

ASSEMBLY

In preparation for the assembly of the injector, remove the parts which have been previously cleaned, inspected, and re-conditioned, from cleaning container No. 3. Blow the individual parts off with compressed air, and place them in a clean dry parts pan or on clean paper.

As each injector part is selected for assembly as subsequently outlined, dip the part in container No. 4, containing the injector test and rust proofing oil or fuel oil. After dipping the part in container No. 4, do not blow off, but leave it wet. The liquid retained on the part will provide rust protection and/or lubrication during assembly.

The assembly sequence is as follows:

1. Insert the injector rack into the body. Position the rack so the two marked teeth are centrally located in the body bore as viewed from the thread end (bottom) of the body.

   On injectors equipped with calibrating slides, assemble the slide so that the end of the slide is flush with the face of the injector body.

2. Apply rack gear to mesh with the rack so timing mark on the one gear tooth is between the marked teeth of the rack. Timing markings should be facing the assembler when looking down at the parts from the thread end of the body, as shown in Fig. 22. The use of a flashlight or illuminated magnifying glass greatly facilitates the timing of rack and gear, as otherwise it is difficult to see the markings.

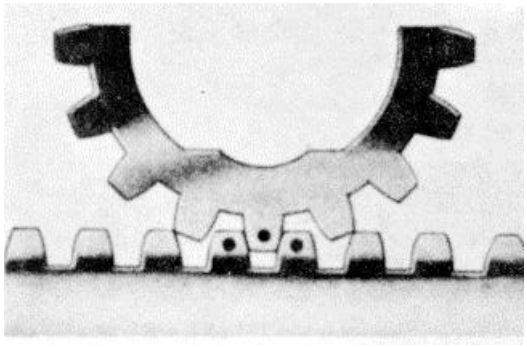


Fig. 22. - Location Of Timing Marks On Rack And Gear

   After gear is correctly applied to the rack, clamp the body, thread end up, in the injector vise.

   Apply gear retainer on top of the gear.

3. Position the bushing on the body so locating pin enters the slot in the body. Place spill deflector over the bushing.

   Apply new body seal as shown in Fig. 23.

4. After dipping each part into container No. 4, assemble the spacer, check valve, check valve cage, valve spring, valve spring seat, and valve spring cage, see Fig. 24. Carefully position this assembly with spacer end on bushing.

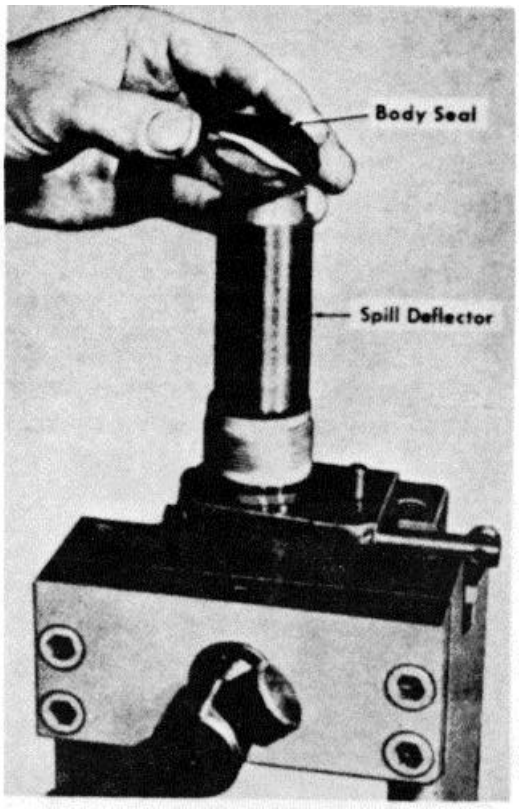


Fig. 23. - Applying New Body Seal

5. After dipping the spray tip assembly, Fig. 25, place it in position so that needle valve enters valve spring cage and rests on valve spring seat.

6. Place the injector nut carefully over the stacked parts, Fig. 26. Screw nut down by hand, then finally tighten to 120 ft-lbs using special injector nut socket and torque wrench.

7. Invert the injector in the vise, nut end down and reclamp in the vise.

8. Apply two new fuel filters in place in the body. Then apply filter springs and filter caps, using new filter cap gaskets. Torque filter caps to 40 ft-lbs with torque wrench.

9. Apply follower spring in place on injector body.

10. Install stop pin, spring, and their retainer in the follower. Slide the plunger into the cutout at the bottom of the follower.

11. With the roller end of the rack to the left side of the injector, position the rack so that the circumscribed groove on the rack (1" from end) is approximately flush with the face of the injector body.

12. Position the flat side of the plunger to the right side and align the stop pin with the stop pin slot in the body.

13. Place the follower and plunger assembly into the body, Fig. 27.

14. Depress the stop pin and press down on top of the follower. If necessary,

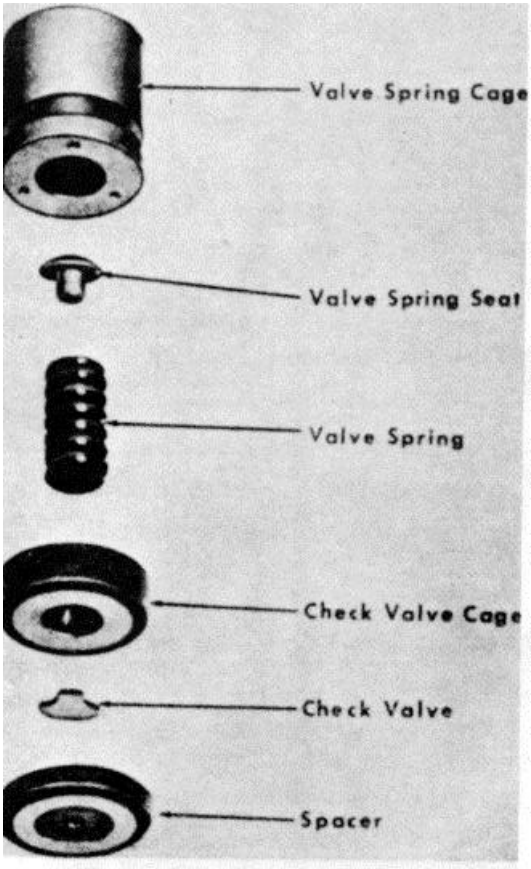


Fig. 24.--Injector Sub-Assembly

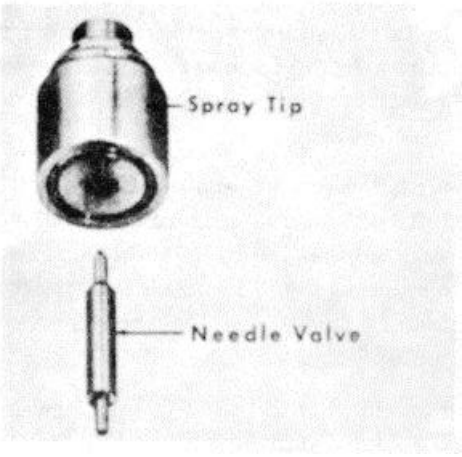


Fig. 25. - Spray Tip Assembly

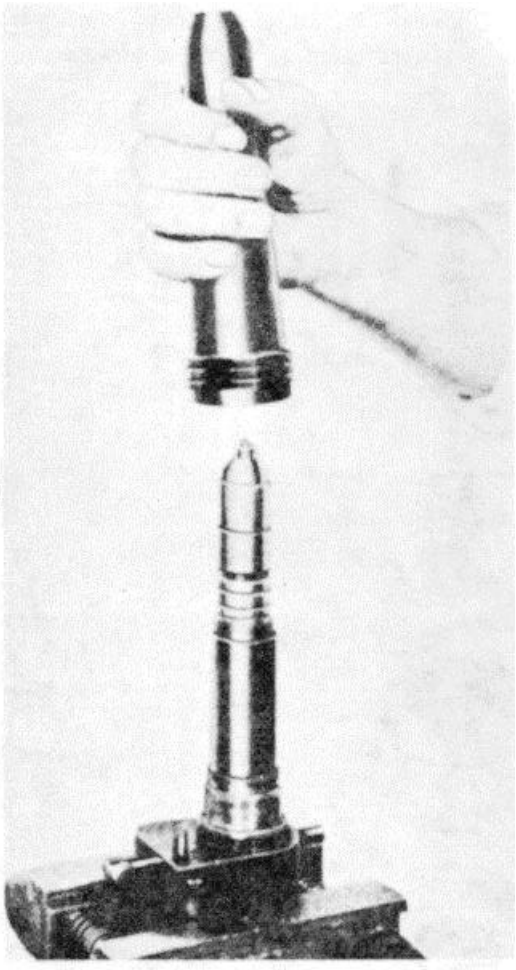


Fig. 26. - Installing Injector Nut

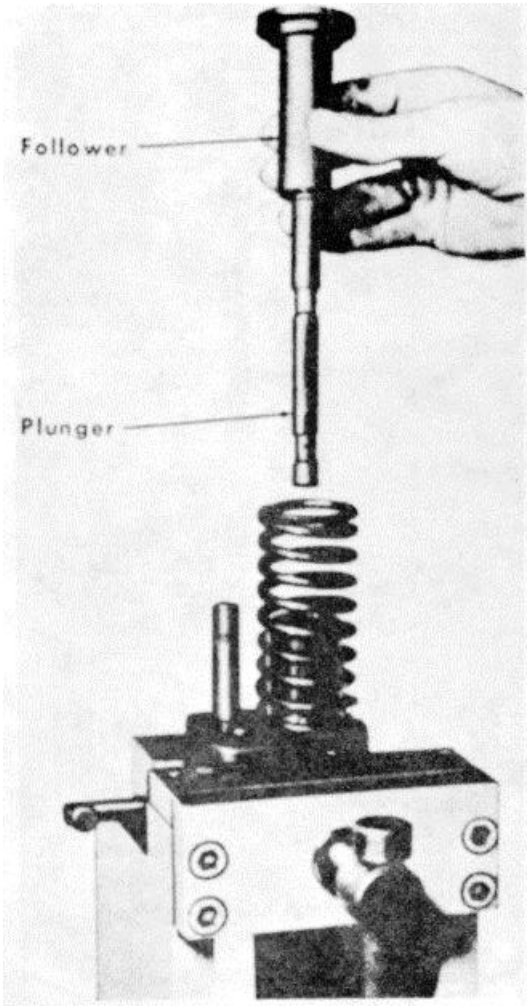


Fig. 27. - Plunger And Follower Installation

move rack slightly in or out until plunger engages with rack gear.

15. Continue pressing on follower until stop pin enters slot.
16. Apply the shipping block or plastic caps over the body stud to protect the open filter caps.
17. Place injectors in holding rack, Fig. 28, in preparation for testing.

TESTING

In order to ensure efficient engine performance, injectors should be tested whenever removed from an engine, regardless

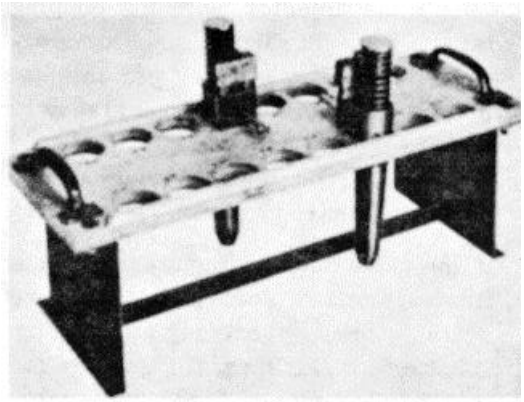


Fig. 28. -Injector Holding Rack

of the reason for removal. In addition, it is advisable to test all injectors in an engine during each annual inspection. It is recommended that injectors be tested with the same oil used for protection against rust as given under "Storing Injectors."

It is important that the individual doing the testing understands the basic principles of in j e c to r operation and testing procedures in order to prevent acceptance of defective injectors and rejection of good ones. Instructions in the use of the injector test stand and an outline of each separate test procedure along with a basic explanation of operation follows.

These instructions cover the testing of all needle valve injectors using the test stand shown in Fig. 29. The procedures are not applicable to other types of testing equipment, since injector leakoff rates vary greatly in proportion to the volume of fuel contained in the high pressure portion of the test stand.

SETTING UP TEST STAND

Basically, the stand consists of a fuel reservoir, filter, high pressure pump, pressure gauge, and necessary connecting lines and fittings to supply fuel to the injector under test. The test stand should be set up as instructed by the manufacturer. Inspect carefully for dirt or foreign material in the tank and lines. Fill the tank with clean fuel and operate the pump to purge all free air from the system. Investigation has shown that the viscosity of the fuel oil used in the test stand has a marked effect on the test results obtained. Regular fuel oil may be used provided the viscosity is not less than 32 S.S.U. at 100° F. Do not reuse fuel oil which has been pumped through the injectors into the plastic bowl.

CHECKING TEST STAND

Install the test block in place of an injector in the stand and pump up pressure to 2000 psi, as indicated by the gauge. After five minutes, the pressure should not have dropped below 1975 lbs. Release the block and recheck at 500 and 1000 psi. These pressures should hold one minute with no apparent gauge drop. Make these tests with the pressure shutoff valve, Fig. 29, open all the way. If the tests are satisfactory, all injector tests may be made without using the shutoff valve. If the preceding tests indicate leakage in the stand, repeat the tests, closing the shutoff valve before timing the leakoff rates. If the tests are satisfactory with the shutoff valve closed, it will be necessary to use the shutoff valve when making the injector holding pressure test.

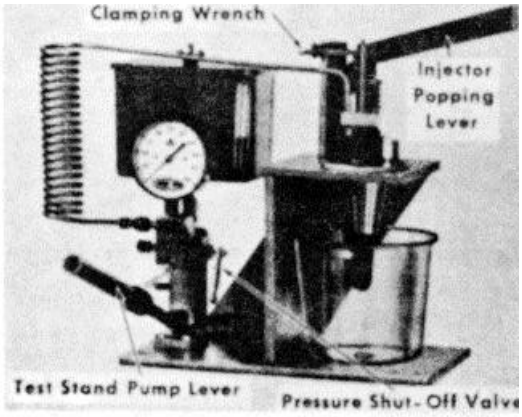


Fig. 29. Injector Test Stand

When placing a new test stand in operation, or after removing and replacing the gauge, fuel tank, filter, or pump, for any reason, the test block should be installed and pressure raised to 2500 psi and vented at least six times before making an operational check.

TEST STAND OPERATION

The operator must consider the test stand as an instrument, rather than a tool. Every effort should be made to make the manual operation of repeated tests the same. The following general information is provided to help in obtaining uniform operation:

General Information

1. When operating the pump, use a rate of approximately 40 smooth strokes per minute. This provides a fuel rate to operate the check valve smoothly and to circulate fuel within the injector.

2. When using the popping lever, do not use such force as to damage either the injector or the lever. Do not permit the lever to fly up freely.

3. In making holding tests, do not pump the stand above 2500 psi.

4. Test stands regularly in use should be checked daily for leaks, using the test blocks.

5. Fuel oil used for testing should not be reused.

INJECTOR TESTS

Preparation

1. Install the injector in the test stand.

2. Fill the injector with fuel oil, but do not connect the fuel line from pump to injector at this time.

3. Set the injector rack at maximum fuel output position (minimum rack length).

4. "Pop" the injector with the popping lever, Fig. 29, using approximately 40 smooth even strokes per minute. A finely atomized spray should show at each of the six holes in the tip. Rapid closing of the needle valve should produce a sharp "chatter".

   If the valve opens without producing a finely atomized spray, or the valve seats without producing the sharp "chatter", make several rapid strokes with the lever to dislodge any foreign material on the valve seat. If the needle valve still fails to function properly, a stuck needle, dirt on the valve seat, or a defective valve seat may be the cause.

Holding Pressure and Leak Test

1. All injectors lose pressure due to leakage at any of several points, but this leakage must be controlled during injector manufacture to prevent engine lube oil dilution. The holding pressure test will qualify injectors having specified leakoff rates, providing this leakage is at the proper point and is satisfactorily controlled.

2. Manually hold the test stand fuel line block on the injector. Pump until fuel is discharged from filter cap on opposite side, to remove air. Tighten block securely to injector. Apply 1800 to 2000 psi pressure to the injector. No leakage is permitted at the nut to body seal, filter cap gasket, body plugs, or between spray tip and injector nut.

3. Used injectors should be qualified on the pressure holding test by timing the interval for a drop in pressure from 2000 psi to 1500 psi. If this interval is less than 20 seconds, repeat the test, but close the pressure shutoff valve on the test stand immediately after establishing the 2000 psi pressure. This is to ensure that the leak-down time is not being affected by possible leakage

in the test stand itself. If the timed interval for the pressure drop from 2000 psi to 1500 psi is still less than 20 seconds, the injector should be rejected. Do not attempt to "pop" the injector, except with the popping lever.

Rack Freeness Test

1. The rack engages with a small pinion on the injector plunger and serves to rotate the plunger with respect to two ports in the injector bushing, which regulates the amount of fuel injected with each stroke of the plunger. Binding of the rack is generally caused by damaged gear teeth, scored plunger and bushing, or galling of rack itself. A binding rack may cause sluggish or erratic speed changes and overspeed trip action.

2. To be considered satisfactory, the rack must fall in and out through full travel, by its own weight, when injector is held horizontally and rotated about its axis.

Binding Plunger Test

1. Failure of the injector plunger to move up and down freely indicates scoring of the plunger and bushing, or weak or broken spring. A binding plunger will cause erratic cylinder firing and, in extreme cases, overspeed trip action.

2. Place injector in test stand but do not attach the fuel line. Place rack in the full fuel position and pump all the fuel out of the injector with injector popping lever, Fig. 29. When all of the fuel has been removed, depress the injector plunger to full extent of its travel and release popping lever. Plunger should return to the top of its stroke with a definite snap action. Repeat this test with the rack in the half fuel and no fuel positions. Care should be used in the test to prevent the plunger from snapping back so violently that the plunger stop pin is broken.

CALIBRATING INJECTOR OUTPUT

If it is desired to calibrate the output of the injectors after reconditioning, it will be necessary to use a calibration stand such as shown in Fig. 30.

The calibration stand will enable the user to:

1. Check all injectors for output.

2. Obtain specified output by interchanging components of injectors not equipped with calibrating slides.

The data for checking output on the referenced stand is listed on the following page. Procedures for setting up and operating the calibration stand are included with the stand.

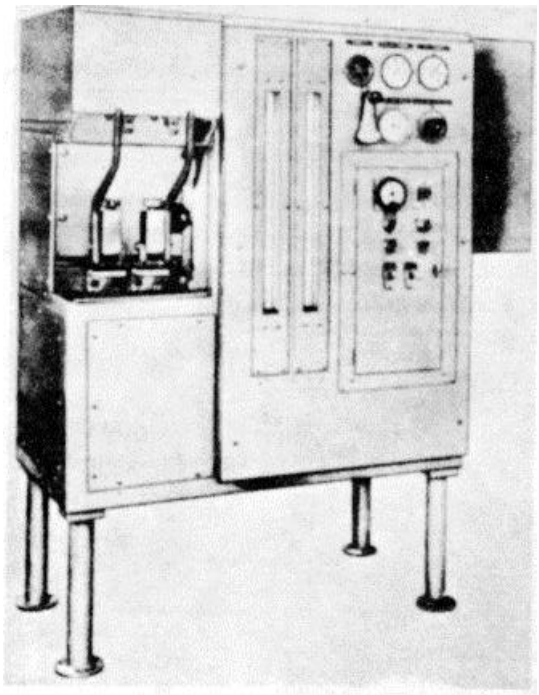


Fig. 30. - Injector Calibration Stand

INJECTOR OUTPUT CALIBRATION DATA

Calibration	Part No. 8332467
Test Oil	EMD Test and Storage Oil Part No. 8203258 - 50 gallons Part No. 8219007 - 5 gallons or Fuel Oil with viscosity of 32-34 sec. Saybolt at 100° F.
Test Oil Temperature	95 F - 1050 F.
Test Oil Pressure	35 psi
Test Stand Speed	835 RPM
Injector Output	
Low Output Injectors 5228565 Needle Valve 5228810 Needle Valve with Calibrating Slide	183-197 CC/400 strokes at .875" rack length
Medium Output Injectors 5228540 Needle Valve 5228800 Needle Valve with Calibrating Slide	219-230 CC/400 strokes at .875" rack length
High Output Injectors 5228605 Needle Valve 5228750 Needle Valve with Calibrating Slide	184-195 CC/300 strokes at 1.00" rack length

REPLACING INJECTOR FILTERS

Injector filters should not be disturbed or removed except during injector reconditioning (when all parts are completely washed), or in the event of fuel stoppage to the injector.

STORING INJECTORS

When injectors are not to be used for a considerable length of time, they should be protected against rust by using a stable, noncorrosive straight-run petroleum distillate in the kerosene volatility range. It is also recommended that injectors be tested using this oil. If this is done, treatment will be taken care of at time of injector test. After treatment, the injectors should be stored in the protective holding rack, Fig. 28, until needed.

EQUIPMENT LIST

	Part No.
Wrench, Nut	8032655
Brush, Body	8069986
Brush, Plunger bushing,	8069987
Vise, Pin	8069988
Vise, Spray tip cleaning wire	8069989
Stone, Spray tip wire abrasive	8070961

Part No.

Wire, Spray tip cleaning	8122519
Wrench, Torque (100 ft-lbs)	8157120
Rack, Injector holding	8159228
Wrench, Torque (200 ft-lbs)	8173332
Plate Set, Lapping	8191188
Reamer, Body fuel oil passage	8194040
Tool, Body seating	8201443
Disc, Abrasive (use with 8201443)	8201444
Socket, Nut	8201445
Tool, Body burring	8201446
Disc, Abrasive (use with 8201446)	8201447
Vise, Injector	8201448
Rouge, Jewelers (1 lb. can)	8201456
Powder, Lapping (600X)	8201459
Cleaner, Liquid (55 gal. bbl.)	8201460
Solvent, Liquid (55 gal. bbl.)	8201461
Stand, Test	8202944
Tank, Cleaning (drawing available on request)	8204639
Oil, Test (5 gal. can) (50 gal. drum - 8203258)	8219007
Brush, Spring cage and gear	8236901
Fixture, Valve test	8276319
Reamer, Nut	8291642
Bulb, Light (use in 8330339)	8330338
Otoscope	8330339
Stand, Injector calibration	8332467
Gauge, Spray tip air flow	8360398
Gauge, Dial indicator	8360447
Injector reconditioning room construction drawing	File #470
Injector storage box construction drawing	File #207
Set, Lapping tool	File #687

PANEL TYPE OIL BATH AIR FILTERS

DESCRIPTION

An abundance of clean air is essential for efficient, trouble-free operation of the diesel engine and long life of its internal components. Roots type blowers or a turbocharger provide the volume of air necessary for complete cylinder scavenging and combustion. The air is cleaned by means of filters installed on the intake side of the blowers or turbocharger.

Flat or panel type filters, Fig. 1, are designed to operate on the oil bath principle and provide efficient air cleaning action. As shown, the air is drawn in through an opening in the front cover of the panel. Here it strikes against an air deflector which divides the air so that a portion is diverted downward to the oil supply chamber. The air that has been diverted downward picks up oil out of the sump and is redirected upward by the baffle. This air deposits the oil on the filter media before entering the engine. The balance of the incoming air supply goes through the oil wetted media where air-borne contaminants are deposited by impingement.

The constant flow of oil droplets down through the filter media carries dirt particles to the sump where they can settle and be subsequently drained away. This type filter, therefore, provides a self-cleaning action during operation.

MAINTENANCE

By their design and operating principle, panel type oil bath filters provide efficient air filtration with a minimum of maintenance. They should however be inspected, drained and cleaned at intervals recommended in the applicable Scheduled Maintenance Program. The specific items to be given attention are as follows:

1. Oil Level

   The oil level may be observed on the sight glass provided at the lower front portion of the filter.

   With engine shut down for at least 1/2 hour (to permit draining of oil from filter media) oil level should be at midpoint on glass. When checking with engine running, oil level should be visible in lower portion of glass.

2. Adding Oil

   In instances where the preceding oil level check indicates the need for oil, it may be added through the opening provided in the front cover.

   The viscosity of the oil to be used depends upon the brand of filter and ambient temperature or only to brand of filter. To meet specific operating conditions, the filter manufacturer recommends the following oils:

Farr Panel Type Filter
- Above 90°F..... SAE 40
- Between 32°F and 90°F..... SAE 20
- Below 32°F..... SAE 10

Air Maze Type Filter
- Normally above 10°F..... SAE 40
- Consistently below 10°F..... SAE 20

Take care when adding oil to prevent overfilling.

3. Draining

At prescribed intervals, the drain plugs should be removed and the filter sump drained of all oil and sludge.

After draining and replacing plugs, refill with oil to proper level as indicated above. Oil capacity is approximately 6 quarts.

4. Filter Cleaning

The entire filter panel assembly should be removed from the adapter for thorough cleaning.

With the front cover removed, the filter media is exposed and should be washed with hot water. It should then be totally immersed in an alkaline or solvent type cleaner to loosen imbedded dirt from the filter media and oil sump.

After cleaning, again wash with hot water to remove all traces of cleaning solution. Then dry with air, inspect carefully and reinstall using a new filter to adapter gasket. Fill with oil and the filter is ready for another service cycle.

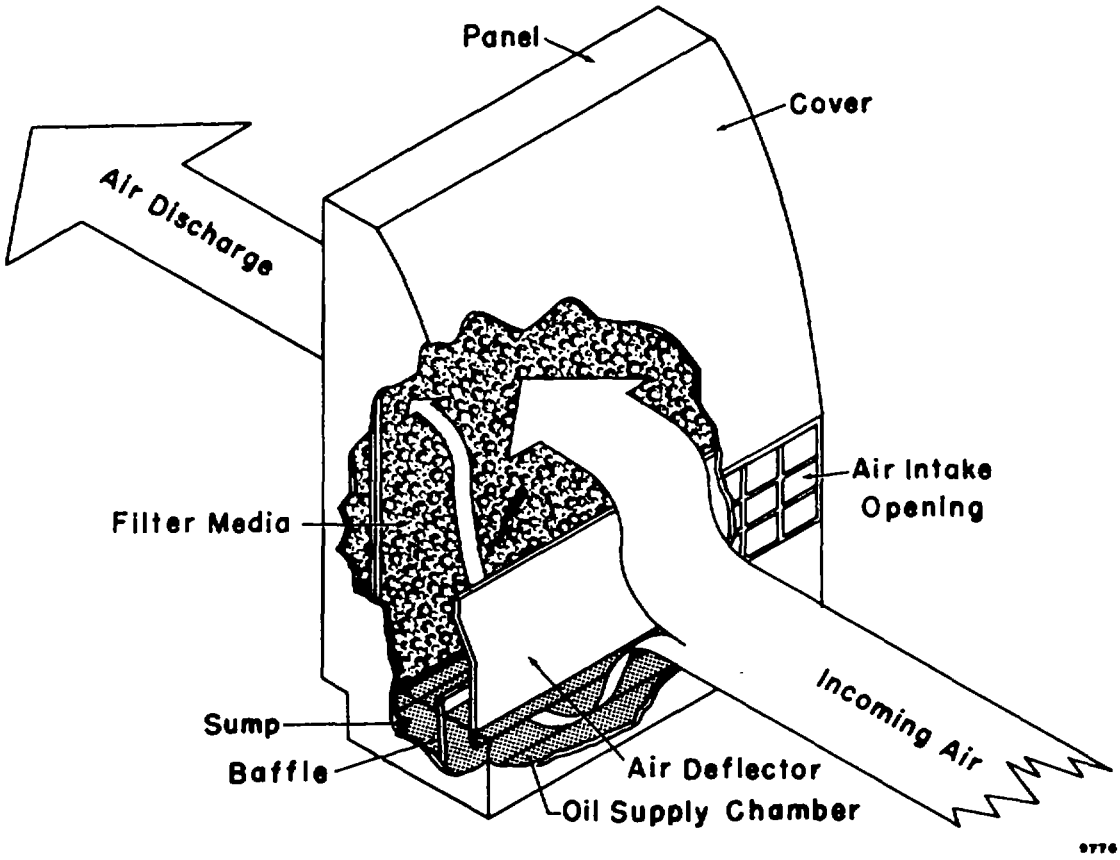


Fig. 1. - Typical Panel Type Oil Bath Filter

THERMOSTATIC VALVE
8224544, 8261223, 8307024

DESCRIPTION

The thermostatic valves covered in this instruction are all similar in construction to the model shown in Fig. 1. Differences between models involve dimensions and the number of thermostatic elements within the valve, but operation is the same for each model. The description and instructions given apply to all models.

The thermostatic valve is a diverting valve that is used to maintain a constant temperature at the diesel engine water outlet. When an engine is started and cold, the valve causes all water to bypass the heat exchanger in the engine cooling system. After warmup, part of the heated water bypasses and part is directed to the heat exchanger. The bypassed water is then mixed with the cold water returning from the heat exchanger before re-entering the engine. Valve action and mixing of water maintains the desired engine water temperature. However, if water from the engine reaches a nominal temperature of 170° F. (77° C.), the valve will close the bypass side entirely, and all water will flow to the heat exchanger.

The valve is self-contained and self-powered. It contains thermostatic element assemblies that hold valve sleeves in the bypass position by spring tension when cold water from the engine outlet passes over the elements. As water temperature increases, a thermostatic material that is highly sensitive to temperature changes

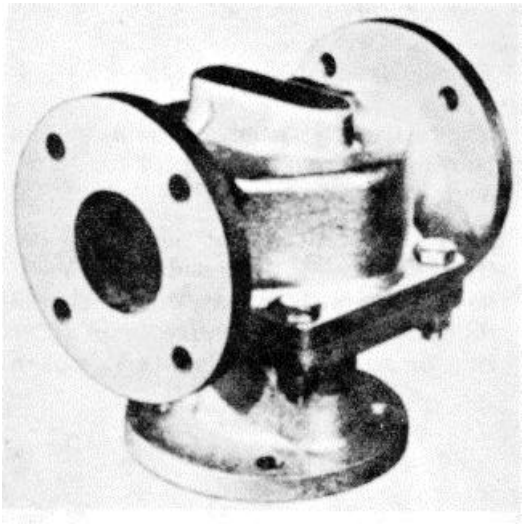


Fig. 1. - Thermostatic Valve

expands to develop pressure that overcomes the force of the return spring. The thermostatic material drives a molded synthetic rubber plug into a reduced diameter piston guide that by extruding action multiplies the travel of the plug. The plug drives a piston that forces the valve sleeves to open the valve outlet to the heat exchanger and at the same time constrict the bypass opening. This action is illustrated in Fig. 2.

MAINTENANCE

Disassembly and, inspection of the thermostatic valve should be performed at intervals prescribed in the applicable Scheduled Maintenance Instruction or at any time improper cooling of the engine is evident. Improper cooling may be due

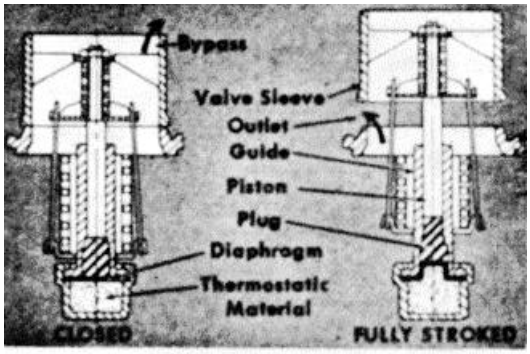


Fig. 2. - Thermostatic Element Assembly

to O-ring deterioration or malfunctioning thermostatic elements.

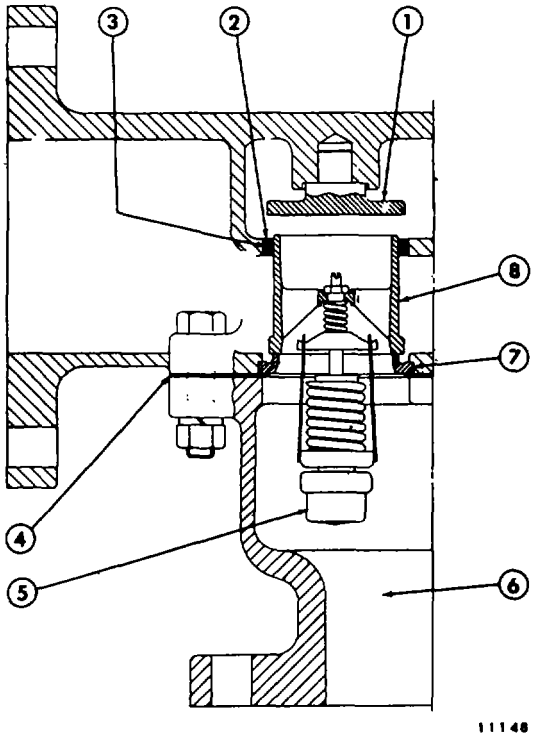
To perform an inspection on the thermostatic valve, it may be necessary to remove the entire valve from the cooling system piping. However, on some installations and under some circumstances it may be easier to remove only the bolted housing and its attached piping from the valve. If the entire valve is to be removed, it is advisable to tag or otherwise mark the pipe flanges with the letter appearing at the adjacent valve flange. The letter "A" identifies the valve inlet flange. The letter appears on the bolted housing. The letter "B" identifies the outlet to the bypass piping. The letter "C" identifies the outlet to the heat exchanger.

Referring to Fig. 3, perform the inspection as follows:

1. Unbolt the housing (6) from the valve body, being careful not to drop or otherwise damage the thermostatic elements within the valve.

2. Remove the housing gasket (4) and discard it.

3. Remove the thermostatic element assemblies (5) from the valve. Ascertain that the nominal temperature rating stamped on the side strap is the correct rating.



1. Upper Seat
2. Channel Type O-Ring Sleeve
3. O-Ring
4. Gasket
5. Thermostatic Element Assembly
6. Element Housing
7. Lower Seat
8. Valve Sleeve

Fig. 3. - Thermostatic Valve Cutaway View

4. Visually inspect the O-rings (3) for deterioration, and replace if necessary.

5. Under exceptional circumstances pitting of brass parts may occur. If the valve sleeve (8) or lower seat (7) is pitted, the thermostatic element assembly should be scrapped. If the press fitted upper valve seat (1) is lightly pitted, a light touch-up is permissible. However, if deep pitting has occurred, consult General Motors Overseas Organization or ElectroMotive Division of General Motors Corporation regarding replacement of the valve seat.

NOTE: The presence of corrosion may indicate the need for treatment of engine cooling water. For in-

formation regarding water treatment, refer to the cooling system section of the applicable Engine Maintenance Manual.

6. Place the thermostatic elements in a container of water at a temperature 10 degrees F. (5.5° C.) lower than the nominal rating indicated on the side strap. Use the element to stir the water for three to five minutes. The valve sleeve (8) should remain seated tightly against the lower seat (7).

7. Fabricate a support that will allow the thermostatic element to be submerged in water while a dial indicator is mounted to obtain a reading of valve sleeve travel.

8. Place the thermostatic element in a container of water at a temperature 15 degrees F. (8.3° C.) higher than the nominal rating of the element and stir the water. Make certain that the movement of the dial indicator pointer is smooth. If the valve slider rises with decided jerks, the element can be expected to malfunction completely within a short time, therefore should be scrapped.

9. After 3 to 5 minutes, observe the reading on the dial indicator. If travel (gap between valve sleeve and lower seat) is less than 0.375 inch (9.525 millimeters), the element should be scrapped.

10. Place the thermostatic element assembly in cool water to verify that it will return to its seated position.

ASSEMBLY

To reassemble the thermostatic valve, perform the following:

1. Insert O-rings in the channel type O-ring *sleeves.*

2. Place the thermostatic element assembly valve sleeves in through the O-rings. A small amount of grease at the leading edge of the valve sleeves will allow them to enter more easily.

3. Obtain a new housing gasket and place it in position before bolting down the housing.

4. Replace the valve in the cooling system piping (if removed), using new gaskets at each flanged connection.

5. Tighten 1/2" bolts to a torque of 50 ft-lbs (6.9 Kg. M.), 5/8" bolts to a torque of 85 ft-lbs (11.7 Kg. M.)

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LEAD-ACID BATTERIES

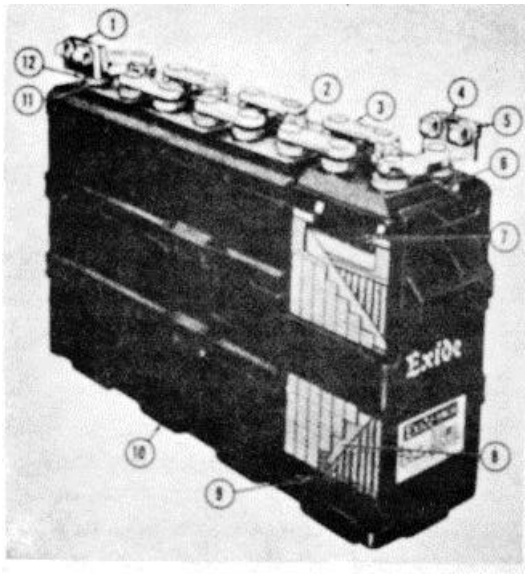
OPERATION

The storage battery, Fig. 1, provides the source of electrical energy necessary for starting, switchgear and relay operation, and lighting.

In a fully charged battery all of the active material of the positive plates is lead peroxide, and that of the negative plates is pure sponge lead. The active material of both the positive and negative plates is porous so that it has absorption qualities similar to a sponge, and the pores are therefore filled with some of the battery solution. The battery solution, properly called electrolyte, is a mixture of sulphuric acid and water.

The strength of the electrolyte is measured in terms of specific gravity (frequently referred to merely as "gravity"), which is the ratio of the weight of a given volume of electrolyte to an equal volume of water. Concentrated sulphuric acid has a specific gravity of about 1.835 and water 1.000. The acid and water are mixed in a proportion to give the specific gravity desired. For example, electrolyte of 1.250 specific gravity is about 25% concentrated acid and 75% water, by volume.

In a fully charged battery, all the acid is in the electrolyte and the specific gravity is at maximum. As the battery discharges, some of the acid separates from the electrolyte which is in the pores of the plates, forming a chemical combination with the active material of both the positive and negative plates, changing it to lead sulphate and producing water. As



1. Negative Terminal
2. Vent Plug
3. Cell Connector
4. Positive Terminal
5. Connector Bolt
6. Cell Cover
7. Protector (Splash Cover)
8. Separator
9. Bridge Insert
10. Container
11. Seal Nut Gasket
12. Seal Nut

Fig. 1. - Typical Four Cell Battery, Partial Cutaway

the discharge continues, additional acid is drawn from the electrolyte and further sulphate and water is formed. As this process continues, it can be readily understood that the specific gravity of the electrolyte will gradually decrease, because the proportion of acid is decreasing and the water is increasing.

When a battery is placed on charge, the reverse action takes place. The acid in the sulphated active material is driven out and back into the electrolyte. This

return of the acid to the electrolyte reduces the sulphate in the plates and increases the specific gravity of the electrolyte. The specific gravity will continue to rise until all the acid is driven out of the plates and back into the electrolyte. There will then be no sulphate in the plates.

After all the acid is returned to the electrolyte, additional charging will not raise the gravity any higher. All of the acid in the cells is in the electrolyte, and the battery is fully, charged regardless of the actual value of the specific gravity. The material of the positives is again lead peroxide, the negatives are sponge lead and the specific gravity is at a maximum. Practically speaking, on discharge, the plates absorb acid from the electrolyte, and on charge, they return the acid absorbed back to the electrolyte.

As the cells approach full charge they cannot absorb all of the energy from the charging current, and the excess acts to break up water from the electrolyte into its two components, hydrogen and oxygen, which are liberated from the cells as gases. This is the primary reason for the required addition of water to battery cells.

The decrease in specific gravity on discharge is proportional to the amount in ampere hours discharged. This is shown by the straight line in Fig. 2 which indicates the approximate gravity readings taken during a discharge. On recharge, however, as shown by the curved line, the rise in specific gravity as indicated by a hydrometer is not uniform or proportional to the amount of charge (in ampere hours). During the early part of the charge there is nothing to mix or stir the electrolyte and some of the heavier acid coming from the plates does not rise to the top of the cell and cannot be reached or read by the hydrometer. During this part of the charge, therefore, the hydrometer reading does not represent the true state of charge of the battery. Later in the charge, when gassing begins, all of the electrolyte becomes more completely mixed and the gravity, as read at the top of the cell, rises rapidly to its full charge value. The dotted line indicates ampere hours returned, and (up to where it nears the gravity line) what the gravity would read if it were possible to keep the electrolyte completely mixed throughout the charge. This "lag"' in gravity rise as read at the top of the cell does not mean that the battery is not taking the charge and does not reduce the discharge capacity available.

It will also be noted from Fig. 2 that the cell voltage decreases somewhat during discharge to a final end value (in this case 1.75 volts). At high rates of discharge the final voltage may be carried much lower. On charge, the voltage rises almost immediately to 2.10 volts or higher and then more slowly in a distinctive pattern to its full charge value (in this case 2.6 volts) depending on the charging rate.

As a matter of general principle, a battery may be discharged at any rate of current it will deliver without harm to the plates. No discharge should be continued, however, beyond the point where the cell voltage becomes ineffective for the application, or to where an abnormal amount

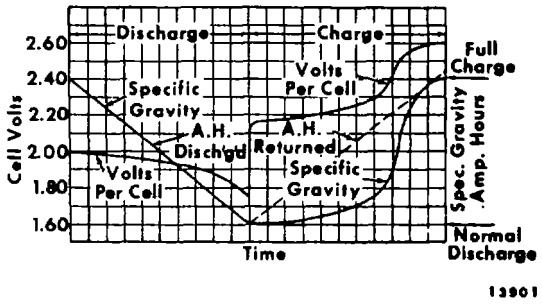


Fig. 2. - Typical Voltage And Gravity Characteristics, And Constant Rate Discharge And Recharge

of lead sulphate is formed in the cell. When this point is exceeded, more than a normal amount of charge is required to completely restore the cell to a fully charged condition.

In charging, any current rate may be used which does not produce excessive gassing or raise the cell temperature beyond a safe value, this being nominally 110° F. or possibly 1250 F. for short periods.

In all normal applications, of course, the routine operation of the battery is designed to be well within these limits.

INSTALLATION

WET BATTERIES

Exide Batteries are normally shipped with electrolyte in the cells and fully charged. If for special reasons, they are shipped without electrolyte, see "Dry-Charged Batteries."

Upon receiving a new battery, examine for any possible loss or spillage of electrolyte during shipment. Remove the vent plugs and note the height of the electrolyte in all cells. The electrolyte level of all cells should be about 1/8 inch below the bottom of the filling tubes, unless some has been spilled during shipment. if there is evidence of spillage but only a small amount has been lost and plates are still wet, restore the level by adding electrolyte of the same specific gravity as in the other cells. If no electrolyte is on hand, fill with approved water. If, after charging, the specific gravity of such cells is more than 15 points below the average of the other cells, arrange to have it adjusted to normal value.

In case of severe damage in transit, or spillage which results in partial or complete exposure of the elements to the air, the cells will require repairs or replacement.

Trays should be identified by number and plainly marked by stencil or other means. Tray numbers should start with #1 at the positive terminal of the battery and follow the electrical circuit, thus the highest tray number will be at the negative battery terminal. If a "set number" is assigned to the battery as a whole, this should also appear on each tray.

The individual cells are not normally numbered, but for reference and record purposes, the positive terminal cell is considered as #1 and the numbers follow the circuit, reaching the highest number at the negative terminal cell.

During transit the battery may have lost some of its charge and should be given a freshening charge. if the specific gravity is within 20 points of its average full charge value, such a charge is optional but still desirable. If the specific gravity is more than 20 points below its full charge value, a freshening charge is definitely necessary. This may be done either before or after installation but should be done from an external charging source so that the current may be better controlled.

All references to specific gravity are to its "corrected value, " equivalent to normal temperature and level. Refer to "Specific Gravity Corrections."
A freshening charge is given by continuing the charge, preferably at the finish charge rate shown in Maintenance Data as long as the hourly specific gravity readings of the lowest gravity cell show any increase, and continuing for three hours after the last increase is shown. If the charge rate used is considerably below the rate given this three hour period should be lengthened in proportion. This specific gravity at the end of this charge should be within the limits shown on the nameplate when corrected for temperature and level.

When the freshening charge is complete, make a written record of the specific gravity of each cell and note the temperature and level of ectrolyte in two or three cells for future comparison.

If the battery is to stand idle for some time, refer to "Storage of Batteries-Wet."

DRY-CHARGED BATTERIES

Some batteries are shipped dry-charged, without electrolyte. Until ready for use they must be stored in a cool, dry place with vent plugs tightly closed. To prepare for use obtain sufficient electrolyte of the specific gravity shown below. (This is dilute sulphuric acid, pure and of "storage battery grade.") When filling, the electrolyte should be cool, not over 90^0F.

For a Full Charge Gravity of:	Use a Filling Gravity of:
1.265-1.285	1.265
1.250-1.270	1.250
1.240-1.250	1.230

1. Fill each cell with electrolyte, bringing the level to 1/8" below the bottom of the filling tube. Allow to stand several hours or overnight, and if level has dropped in any cells refill to original point. Replace or close vent plugs and remove any spilt acid with a damp cloth. A mild solution of bicarbonate of soda may be used to neutralize any acid on the battery, clothing or skin.

2. Give battery a freshening charge as described above. At least 12 hours and possibly longer, will be required if the applicable charge rate in Maintenance Data is used. If a lower rate is used, increase time proportionately.

If necessary to restore electrolyte level during charge, use water only.

If temperature rises above 110° F., stop charge and allow battery to cool.

3. After completion of charge the gravity of all cells should be within the specified full charge gravity range corrected for temperature and level. If not, adjust by removing some electrolyte and replacing with water or acid as required. Charge for another hour to mix solution before testing again. Repeat if necessary.

Battery is then ready for service.

TRAY BLOCKING

All battery trays should be properly blocked in place, Fig. 3, to avoid movement and damage. There should be an

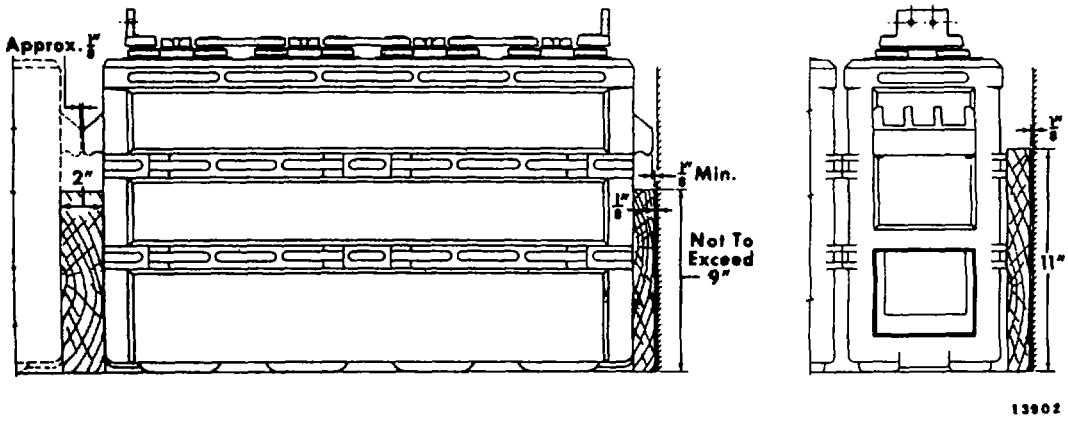


Fig. 3. - Recommended Blocking For Batteries

overall clearance of about 1/8". Do not wedge trays as this may cause breakage or distortion.

Where wood blocking is required at the tray sides, it should be of sufficient height to support the upper portion of the tray to prevent "rocking." End blocking should be sufficiently thick that the tray handles do not touch those of adjacent trays or the compartment sides.

All such blocking should be of sound hard wood and painted with two coats of black asphaltum paint.

CONNECTIONS

Connections between all trays in series should be from the negative terminal of one tray to the positive terminal of the next throughout the circuit. Positive terminals are marked POS or + or painted red; negative terminals NEG or - or painted black. The positive terminal of the battery should be connected to the positive of the system and charger, and the negative battery terminal to the negative of the system and charger.

After connections are completed, check each cell with a voltmeter to insure that all trays have been connected with proper polarity.

Terminal and inter-tray cables should be quite flexible and so arranged and of such length that they will not put a strain on the cell posts, or rest on the intercell connectors.

Before connecting up the battery, scrape the contact surfaces of the solid lead terminal posts or clean with a wire brush. Wipe lead-plated connector lugs or intertray connectors clean, but do not scrape them or clean with a wire brush as the lead coating may be removed. Apply a thin coat of No-Ox-Id grease or vaseline to all contact surfaces and connector bolts.

Tighten with two wrenches (preferably box type) to avoid strain on the cell terminals. After all connections are made, surplus grease should be wiped off.

Make sure that all connections are snug and tight. The nuts should be gone over a second time, to insure good connections.

NOTE: No intermediate taps or connections should be made at other than the main terminals of the battery. Any lower voltage device should be supplied through a series resistor or from a separate source. Any such device connected to an intermediate point of a battery results in overworking one section of the battery and/or overcharging the remainder. Avoid prolonged use of extension cords with lamps of less than total battery voltage.

MAINTENANCE

INSPECTION

Lead acid storage batteries should receive inspections during the intervals specified in the Scheduled Maintenance Program in addition to any other attention, which the user may desire to give or which may be found necessary based on operating conditions. In regular service these are a must.

MONTHLY INSPECTION

This inspection should be made while all equipment is normally "warm." It should include the following:

1. Make a general check of the battery as to proper blocking, clean and tight connections at all points, and any

unusual appearance or condition. Remedy anything requiring it.

2. Read and record the specific gravity, Fig. 4, of one or more pilot cells in each 16-cell battery or section. Record temperature and height of electrolyte in these cells also. Be sure all vent plugs are replaced and tight. For accuracy, always read hydrometer with eye at same level as electrolyte.

   The pilot cells should be "rotated" in order to cover all cells of the battery within a reasonable time. These cells can readily be identified by distinctive vent plugs (or marking standard ones) and following a regular routine of moving them. For example, start with the pilot vent plug in cell #1 of each 16-cell section. On the next inspection that cell will be read and the vent plug moved to #2. This is continued until it goes back to #1 again to repeat the cycle.

3. Measure electrolyte height and add water if required. Water should be added if the level has dropped one



third of the available height. For example, on cells with a 1-1/2" electrolyte height above the splash cover, add water when this level is found at 1" or lower. Electrolyte height is most readily measured with a rubber or plastic rod or "stick." If the surface is too smooth, give it a soft finish with very fine sandpaper. Add water with a suitable filler, Fig. 5.

Fig. 4. - Checking Specific Gravity

4. Clean the battery as required. If there is just a small amount of dry dust or dirt on it, this may be blown off with air. If there is any large accumulation of dirt and/or any moisture, it should be washed with water from a hose. Make sure vent plugs are tight and use only a moderate water pressure so that water is not forced in through the vent openings in the plugs. Wash out the compartment also and blow off any excess water that remains, with air.

NOTE: Do not use hot water or steam, or allow a high pressure air nozzle to get close to battery covers, as the grease in the seal nuts may be washed or blown out.

ANNUAL INSPECTION

1. Read and record the specific gravity of all cells with the temperature and electrolyte level of several. Scan these readings carefully for any irregularities or indications of trouble

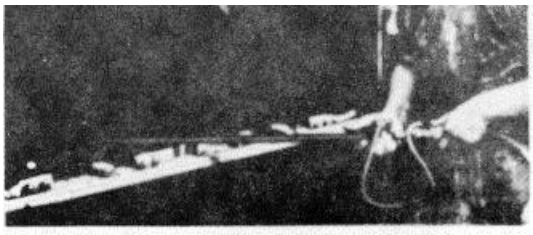


Fig. 5. - Adding Water With Exide Cell Filler

Investigate and remedy any that are found.

2. Add water as required.

3. Clean battery thoroughly. Give preliminary cleaning as in Monthly Inspection. Then wash top of battery with soda solution (1 lb. bicarbonate of soda to 1 gallon of water) making sure to get under connectors to remove all traces of acid. Rinse thoroughly with clear water and blow off excess with air.

4. If there are any indications of corrosion in the battery compartment, remove the battery and thoroughly clean and repaint the compartment.

5. Make sure all battery connections are free of corrosion and re-tighten them.

EMERGENCY INSPECTION

In the event of reported battery failure or other difficulty, include the following checks or tests in the sequence shown:

1. Read total battery voltage on open circuit and under load. If this is normal, the actual failure is elsewhere than in the battery.

2. Check all battery connections to make sure they are clean and tight.

3. Read battery gravity. If it is low as a whole, the battery has become discharged due either to connected loads when idle or to some failure of the battery charger. Recharge the battery with whatever facilities are available and be sure to locate and remedy the cause of the discharged condition.

4. Read voltage of individual cells (using 3.0 voltmeter scale), Fig. 6, at the same time looking for any hot cells or any other unusual conditions.

If one or more low cells are found, read their voltage under load and if it is quite low in comparison with other cells, that is probably the immediate cause of trouble. Replace the tray or trays containing the low cells with spare trays to get the unit in service promptly.

Send the tray with the low cells to the shop for complete inspection and repair. If the condition found at such inspection is one which may affect or be found in the remainder of the battery, the entire battery should be shopped.

SPECIFIC GRAVITY OF ELECTROLYTE

The specific gravity of the electrolyte at 77°F., with the cells fully charged and the level 1/8" below the bottom of the filling tube, should be as shown on the nameplate. It is adjusted within these limits at the factory and will not require adjusting during the life of the battery unless electrolyte is actually lost out of the battery. If, however, electrolyte is lost it should be replaced with electrolyte of about the same specific gravity as in the surrounding cells.

SPECIFIC GRAVITY CORRECTIONS

The specific gravity varies, however, with changes in temperature. This is not due to any characteristic of the battery but merely to the fact that the electrolyte expands as the temperature rises and

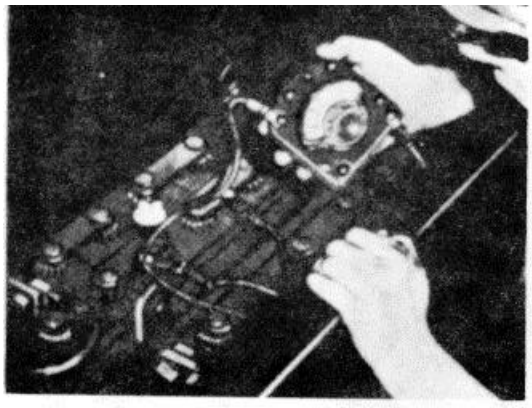


Fig. 6. - Reading Cell Voltage

thus becomes less dense, resulting in a lower gravity reading. Conversely, as the temperature is lowered the gravity rises. This change is equal to one point (.001) in gravity for every 3° F. change in temperature.

Likewise the gravity will vary as the electrolyte level falls and rises with the use and addition of water. This results in a change of about 15 points in gravity for each 1/2" change in level in "M" type cells and 25 points for each 1/2" change in level for "K" and "L" type cells.

In order to accurately compare specific gravity readings taken at different times and at different temperatures and electrolyte levels, such readings are "corrected" to the normal temperature of 77° F. And the normal level at 1/8" below the bottom of the filling tube. Such "corrected specific gravity" readings indicate what the gravity would be if the temperature and level were at the above normal values. To make this correction of the types listed in Maintenance Data the following steps should be performed:

1. Add one point of gravity for each 3^0F. above 770 F. Subtract one point of gravity for each 30 F. below 770 F.

2. Subtract 8 points of gravity for each 1/4" below normal level of "M" cells. Subtract 12 points of gravity for each 1/4" below normal level of "K" and "L" cells.

EXAMPLE: Specific gravity of MGD cell reads 1.235 at 89^0F. And 1/2" low level.

89 - 77 = $12^0 \div 3 = 4$ points to be added 1/2" low level = 16 pointed to be subtracted.

Net result: subtract 12 points: corrected gravity is 1.223.

The full charge specific gravity will decrease in value as the battery ages. No definite value can be given, but this decrease is very small, not over a few points per year at the most. The change is mentioned so that it will be understood as it occurs.

SPECIFIC GRAVITY DROP

The approximate state of charge of a battery can be determined by reading the specific gravity and comparing it with the "specific gravity drop, " as shown in Maintenance Data, which represents the approximate total decrease in gravity between full charge and normal discharge.

EXAMPLE: A certain type of cell reads 1.195, corrected (if necessary) for temperature and level. Assume this type has an average full charge gravity of 1.245 and a gravity drop of 125 points (8 hour rate). It is now 50 points below full charge and is therefore about 50/125 or 40% discharged. (If battery is, or has recently been, on charge, some allowance must be made for "lag" in in gravity rise as described in "Operation.")

ADJUSTING SPECIFIC GRAVITY

The specific gravity requires adjusting only if electrolyte is actually lost from the cells, and is normally a shop job where proper equipment and facilities are available. Adding "acid" is not a remedy for necessary charging or for internal trouble in the cell. It merely makes it worse.

USE OF HYDROMETER

To obtain accurate and comparable specific gravity readings, the above corrections for temperature and level should be applied and the hydrometer carefully read. Keep the following points in mind:

1. Be sure the hydrometer is clean and clear. A dirty float or barrel will not read correctly. It should be disassembled frequently and all parts washed with soap and water.

2. Draw sufficient electrolyte into the hydrometer syringe so that the hydrometer floats freely, midway of the barrel. It must not touch either top or bottom.

3. Do not tilt the barrel allowing the hydrometer to stick to the side. Shake slightly to make sure it is floating free.

4. Hold the syringe at eye level. The point where the electrolyte level meets the scale in the hydrometer stem indicates the specific gravity.

5. Empty the syringe completely making certain the electrolyte is returned to the same cell.

EXTREME TEMPERATURES

There is little danger of freezing of the battery electrolyte in temperate climates unless the battery is completely discharged. At the freezing point shown in the following table the electrolyte will become slushy, but will not solidify until the temperature goes still lower:

Specific Gravity Corrected to 600 F.	Freezing Point
1.275	- 850 F.
1.250	-620 F.
1.225	- 350 F.
1.200	-160 F.
1.175	-4^0F.
1.150	$+5^0$F.

The capacity of a storage battery is reduced at low temperatures due to the increased resistance and viscosity of the electrolyte but no permanent harm results if freezing is avoided.

High temperatures, particularly continuous operation above 110°F., will considerable shorten the life of a storage battery.

CHARGING

WARNING: Do not bring any type of flame or lighted cigarette near the battery. Gas formed while the battery is charging is highly explosive. This gas remains in the cells long after charging has stopped.

Do not lay tools, or anything which might cause a short circuit, on the battery.

Do not allow electrolyte to come in contact with the skin, clothing or any other material which it might damage. If some should be spilled on the skin, rinse promptly with clear water and wash with soap. Bicarbonate of soda solution (one pound to one gallon of water) will neutralize acid spilled on clothing or other material, Apply until bubbling stops and rinse with clear water.

In general, a storage battery may be charged at any current rate that does not produce excessive gassing or bubbling of the electrolyte or result in temperatures above 110° F. (1250 F. For short periods). Another guide is that any current is safe which does not produce a voltage higher than 2.40 volts per cell when the current itself is above the finish-charge rate. The finish rate, or less, may be used at any time that charging is required as long as the temperature does not exceed the above limits, regardless of the cell voltage.

In practice, however, it is seldom necessary to use a current of more than 4 or 5 times the finish-charge rate even at the start of charge and this should be reduced to the finish rate whenever the battery is more than three-quarters charged. The entire charge may be given at the finish rate or less if sufficient time is available.

When the battery becomes fully charged, the charge should be stopped or reduced to a low "floating" or "trickle" value.

The proper operation and correct adjustment of the battery charger means more than any other one thing in the trouble-free operation and life of the battery. It determines the rate and amount of charge received, and thus indirectly its temperature and water requirements.

Correct charger adjustment means:

1. Proper amount of charge, -no appreciable overcharge.
2. Minimum water requirements.
3. Safe operating temperature.
4. Minimum shopping or repairs.
5. Long life.

High voltage adjustment means:

1. Overcharging the battery.
2. High water requirement and possibly low electrolyte level in the cells.
3. High temperature which in turn increases (1) and (2).
4. Possible repairs.
5. Shortened life.

Low voltage adjustment means:

1. Insufficient charge and possibly a discharged battery with an operating failure.
2. Possible damage to the battery from over-discharge, and shopping for repairs.
3. Shortened life.

The charging rate should be checked by the following indications, preferably on a weekly basis, until the proper value for existing conditions is determined.

If the gravity is within 10 or 15 points of its "corrected" full charge value and the water requirements are normal, the adjustment may be considered nominally correct.

If the gravity shows a steady decline or is usually 20 or more points below full charge, and the battery uses less than a normal amount of water, it indicates a low setting which should be raised.

If the gravity is usually at or near full charge, and more than a normal amount of water is used and/or the battery temperature is 150 F. or more above ambient, it indicates too much charge and the setting should be lowered.

SHOP CHARGING

Under normal operating conditions, no special charging is required as the battery is properly maintained in a fully charged condition. The small discharges (in ampere hours) from engine starting and other loads when the engine is not running are automatically replaced during operation.

However, if the battery should become unusually discharged for some reason or become abnormally sulphated due to standing in a discharged condition, or show irregular cell voltage and/or specific gravities, it should preferably be recharged from a source other than the

unit. When a battery is in any of the above conditions, its charge should be carried to completion at or near the normal (finish-charge) rate and this is not practical from the unit. It can be done from a separate charger (either motor-generator or rectifier). If the cause warrants it, the battery should be shopped and the recharging done there, with a complete inspection at the same time.

This charging may be done entirely at the finish rate or may be started at higher rates to save time. As the battery approaches full charge the rate should be reduced to the finish rate and continued as an equalizing charge until the lowest cell shows no rise in gravity for at least one hour. At the end of charge read and record the individual cell voltages while still on charge, and the specific gravities a few minutes after the charge has stopped. Compare these readings for uniformity, and with the normal full charge specific gravity of the battery.

Any specific gravity values more than 20 points either higher or lower than the average of the battery should be cause for investigation. Any cell voltages more than one-tenth volt (0.1) lower than average should likewise be investigated. Cell voltages somewhat higher are normally not cause for concern unless they should exceed the average by more than at least one-quarter (.25) volt. (Of course, a new cell installed in an older battery will have higher values.)

WATER AND ADDITIVES

WATER

The water used with the battery electrolyte should be of a quality to obtain maximum battery efficiency and service life.

A water suitability table is provided below classifying water impurities and showing the maximum permissible amounts to aid in the determination of its acceptability for use in the battery.

Impurity		Maximum Parts Per Million
Total Solids		350
Fixed Solids		200
Organic & Volatile		150
Calcium		40
Iron		4
Nitrates		40
Chlorine, Bromine	} Combined	40
Fluorine, Iodine 5	} Total	
Copper		2.5
Chromium		1.0
Manganese		0.1
Nickel		0.2

NOTE: The above data is applicable to both acid and alkaline cells.

Add approved water to the cells at sufficiently frequent intervals to keep the electrolyte level above the tops of the splash covers. When adding water, fill to 1/8" below the bottom of cover filling tubes, but no higher, Fig. 7.

Careless addition of water above the normal level point results in subsequent overflow of electrolyte through the vent openings provided in the vent plugs, for normal gas escape.

An overflow of electrolyte lowers the gravity, reduces battery capacity, and

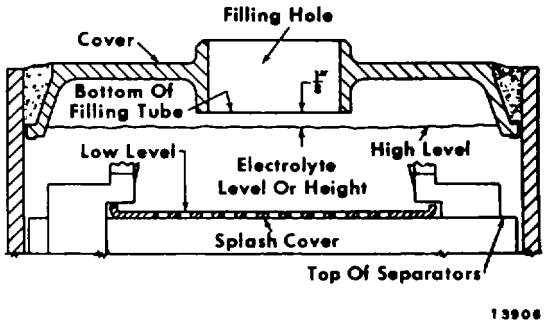


Fig. 7. - High And Low Limits Of Electrolyte Level

damages the battery compartment. It also causes corrosion and troublesome grounds in the electrical circuits. Eventually it will necessitate removal of the battery for gravity adjustment and repairs to damaged parts.

The amount of water used is a good indication whether the battery is receiving the correct amount of charge. As a general rule, a battery in good condition, in diesel engine service should use an amount, per month, within these limits:

> Types MGD, MVG, MVD AND MVE - not more than 1/2" or less than 1/4". All types beginning with KG, KX, LF and LX - not more than 1/4" or less than 1/8".

All cells should require the same amount of water. If one takes more than the others, check it for leakage.

Always take hydrometer readings before adding water as it takes several days for water to mix with the electrolyte.

In cold weather (below freezing) do not add water if unit is not in use. The water may freeze on the surface before it becomes mixed.

ADDITIVES

Various battery "additives" have been offered for use with lead-acid batteries but the Association of American Battery Manufacturers has found no satisfactory substitute for the simple mixture of sulphuric acid and water.

CLEANING

Keep the battery, its connections and surrounding external parts clean and dry.

Electrolyte spilled on the battery cell covers, trays or battery compartment, never dries or evaporates. It causes grounds, and corrodes any metal parts that are subject to attack from sulphuric acid.

With the vent plugs in place and tight, the tops of the batteries and containers should be washed with cold water under moderate pressure as often as found necessary, but not in freezing temperatures. Increase the water pressure for washing out the battery compartment.

NOTE: Do not use steam, hot water or high pressure air for cleaning or drying, as either will remove the protective grease from the grease seal nuts on the posts.

If tops are damp with electrolyte, or if electrolyte is spilled, it should be neutralized by applying bicarbonate of soda solution (one pound of soda to a gallon of water). For best results, apply a warm solution. Wait until foaming action stops, and then rinse off with clear water. A periodical washing with warm soda water is recommended at least twice yearly. Make sure vent plugs are in place to prevent the solution from getting into the cells.

If any corrosion of connectors or lugs is experienced, scrape or brush off. Then wash with warm soda solution to neutralize any electrolyte remaining. After rinsing with water and drying, apply a thin coating of No-Ox-Id grease or vaseline.

Keep vent plugs in place and tight at all times to avoid loss of electrolyte due to gassing or spillage. The gas-escape holes in the vent plugs should be examined to see that they are not clogged with dirt. Wash all vent plugs yearly, or as needed, by immersing in a bucket of water and wiping clean.

If any corrosion exists on metal parts of the compartment, clean as above and repaint with acid-resistant paint.

Do not permit oil or grease to drip or accumulate on the battery. It disintegrates the sealing compound and causes leakage. If any does get on the battery, wipe it off with a cloth dampened with carbon tetrachloride or a similar cleaner. Do not pour this solution on the battery as it must not be allowed to get in the cells.

RECORD

It is vitally necessary that a continuous record be kept of certain items checked at the inspection periods, as well as any unusual conditions found, or repairs made. This provides a "history" from which troubles can be traced to their source, and indicates, when and by whom, the various services are performed.

Records should contain the following information:

1. Specific gravity and temperature of pilot cells.
2. Electrolyte height.
3. Amount of water added.
4. At annual inspections, include record of the voltage and specific gravity of all cells.

REPAIRS

Lead-acid batteries do not require any routine repairs, overhauling or reconditioning throughout their entire life. They do not require any addition of acid unless some has been lost by overfilling, leakage or otherwise.

If repairs or a specific gravity adjustment should be necessary due to damage or for any other reason, the battery should be sent to a qualified shop where proper facilities for doing such work are available.

INDICATIONS OF TROUBLE

With proper operation and normal maintenance, a storage battery is a quite trouble-free piece of equipment. However, related parts of the electrical system may become improperly adjusted, the battery may suffer physical damage or some items of maintenance may be unknowingly neglected. In order that such things may be detected before any real damage is done to the battery, certain indications of possible trouble should be kept in mind during all battery inspections. Any such indications must not be ignored, trace the trouble to its source and remedy it.

HIGH TEMPERATURE

If a battery is running "hot" there is something wrong. Normally the battery temperature should be only a few degrees, certainly not more than 15° F. above the local ambient (air) temperature. If it is much higher than this check the following:

1. Check the battery charger setting to see if it is too high.
2. See if battery is near any source of heat.

3. Read voltage or gravity of the individual cells to see if any are very low due to damage or short circuits, allowing a relatively high voltage across the remaining cells.

WATER USE

If the battery as a whole is using more or less water than expected, it probably indicates a required adjustment of the battery charger. However, if an individual cell is regularly using more or less water than the others, it is an indication of leakage or internal trouble in the cell. Leakage may be due to an actual slow leak in the container itself or cracks in the sealing compound at the cover. In any case, the trouble should be located and remedied.

LOW GRAVITY OR VOLTAGE

As mentioned elsewhere, uniformly low gravity and/or voltage is probably an indication of either actual discharge for some reason or a low battery charger setting.

Low gravity and voltage in one or several cells may be due to actual leakage of electrolyte either through a crack in the container or sealing compound, overfilling the battery when adding water, or possible internal trouble. Look for evidences of leakage under or near the container and check the other possibilities.

Irregularly low gravity throughout the battery - cells more than 20 points below the average - is probably due either to a low battery charger adjustment over a considerable period of time or to overfilling various cells when adding water. Arrange to give the battery an equalizing charge. If this restores the gravity of all cells to within 20 points of normal full charge value, the battery had become "starved" by lack of sufficient charge due to low charger setting. If this charge does not correct the condition, the battery should be shopped for a specific gravity adjustment and any other attention that may be necessary.

If one tray requires repairs due to damage or any other cause, there is no need to send the entire battery to the shop. A few spare trays should be kept available for substitution while such repairs are being made. These "spares" should be painted a distinctive color and kept for that purpose. When the repaired tray is ready for service again, it should be returned to the battery from which it was taken. Do not interchange or mix the trays if different batteries as they are likely to be of different ages and in different condition and best results cannot be expected.

Spare trays should, of course, be kept charged and ready for immediate use.

INDICATIONS OF END OF LIFE

1. Batteries in diesel engine service, properly operated, will give a long and satisfactory life but eventually replacement will be necessary. There are certain indications, coupled with the age of the battery, which make it possible to anticipate end of life and make replacement before actual failure occurs.

   A certain nominal average battery life under the specific operating conditions is usually known. As that age is approached, and some of the following conditions are noted, it is quite likely that the battery is nearing the end of its useful life.

   Its temperature may run appreciably higher than normal. The water requirements will usually increase.

   The cells are likely to become more irregular in gravity and voltage to the extent that normal charging will not correct.

2. It is often desired to "test" the battery in some manner during this period, so that its use may be continued as long as practical but without danger of a service failure. There is no simple test which will give an infallible answer, but an extended starting operation will give some assurance that all is well - or not. This is about the only type which can easily be done in the field.

   The engine starting operation is of course, the most difficult job the battery has to do, and it usually requires only a few seconds. As a test, shutoff the fuel to prevent the engine from

firing. Then start and roll the engine for perhaps 20 to 30 seconds. If it turns over at a reasonable firing speed for such a period, the battery is certainly serviceable at the time.

STORAGE OF BATTERIES

Spare batteries should be kept charged and in such condition that they are ready for immediate service. They should be stored in a cool dry place away from radiators or any source of heat, and be kept clean and dry. Keep vent plugs in place and closed. When the cells require water, add it before charging so that it will become completely mixed.

At monthly intervals read the specific gravity of several cells. Charge the battery before the gravity falls more than 25 points below its full charge value as shown on the nameplate. The frequency of such charge will vary with the temperature, being required perhaps every two months at 80° F. or higher and every four months at 60° F. or lower.

When charging is necessary, charge at the finish charge rate shown on the nameplate. Continue as an equalizing charge, until all cells gas, freely and the gravity (corrected for temperature and level) shows no further rise for at least one hour.

MAINTENANCE DATA

RATINGS

Based on electrolyte temperature of 77^0F. at beginning of discharge, full charge specific gravity as indicated and final voltage of 1.75 volts per cell.

Type of Cell	Plates per Cell	Finish Charge Rate Amperes	Discharge Capacity 8 hr. AH	5 hr. AH	3 hr. AH	Full Charge Gravity
MGD	13	14	280	250	220	
EXIDE	19	21	420	375	3301	240-1.250
IRONCLAD						
Approx. Specific Gravity Drop-Points			145	125	100	
	9	11	155	139	122	
	11	13	194	174	152	
	13	15	233	209	183	
	15	17	272	244	213	
MVG	17	19	310	278	244	
EXIDE	19	21	349	313	274	1.240-1.250
IRONCLAD	21	23	388	348	305	
	23	25	427	383	335	
	25	27	466	418	366	
	27	29	504	452	39_	
	29	31	543	487	427	
	33	35	621	557	488	
Approx. Specific Gravity Drop-Points			130	110	90	
	7	5	68	61	54	
	9	7	90	81	72	
	11	9	112	102	91	
KG	13	10	134	122	109	
EXIDE	15	12	157	142	127	1.265-1.285
IRONCLAD	17	14	179	162	145	
	19	15	202	183	163	
	21	17	224	203	181	
	23	19	246	223	199	
Approx. Specific Gravity Drop-Points			130	120	105	
	7	5	63	58	51	
	9	7	84	77	68	
	11	9	105	96	85	
KGM	13	10	126	115	102	
EXIDE	15	12	147	134	119	1.240-1.250
IRONCLAD	17	14	168	154	136	
	19	15	189	173	153	
	21	17	210	192	170	
	23	19	231	211	187	
Approx. Specific Gravity Drop- Points			125	115	100	

Type of Cell	Plates per Cell	Finish Charge Rate Amperes	Discharge Capacity 8 hr. AH	5 hr. AH	3 hr. AH	Full Charge Gravity
	7	5	53	48	42	
	9	7	71	64	56	
	11	8	89	80	71	
KFM	13	10	107	96	85	
EXIDE	15	11	125	112	99	1.240-1.250
FLATPLATE	17	13	142	128	113	
	19	15	160	144	127	
	21	16	178	160	141	
	23	18	196	176	155	
Approx. Specific Gravity Drop-Points			110	95	80	
	11	7	93	83	72	
	13	8	111	99	86	
	15	9	130	116	100	
LFM	17	10	148	132	114	
EXIDE	19	12	167	149	129	1.240-1.250
FLATPLATE	21	13	185	165	143	
	23	14	204	182	157	
	25	16	222	198	172	
	31	20	278	248	215	
Approx. Specific Gravity Drop-Points			170	150	120	
	13	14	213	190	165	
MVD	15	16	248	222	192	
EXIDE	17	18	284	254	220	
IRONCLAD	19	20	319	285	247	
	21	22	355	317	275	1.240-1.250
MVE	23	24	390	349	302	
EXIDE	25	26	426	380	330	
FLATPLATE	29	30	497	444	385	
	31	32	533	475	412	
Approx. Specific Gravity		MVD	130	110	85	
Drop-Points		MVE	120	100	80	
	9	7	76	69	61	
	11	8	95	86	76	
	13	10	114	104	91	
KX-A	15	11	133	121	106	
EXtDE	17	13	152	138	122	1.265-1.285
IRONCLAD	19	15	171	158	137	
	21	16	190	173	152	
	23	18	209	190	167	
	25	19	228	208	182	
Approx. Specific Gravity Drop-Points			130	110	85	
	11	7	85	76	68	
	13	8	101	92	81	
LX-A	15	9	118	107	95	
LX-G	17	10	135	122	108	
LXM	19	12	152	137	122	1.250-1.270
EXIDE	21	13	169	153	135	
FLATPLATE	23	14	186	168	149	
	25	16	203	183	163	
	31	20	254	229	203	
Approx. Specific Gravity Drop- Points			140	125	115	

LUBE OIL FILTERS

GENERAL DESCRIPTION

The Michiana lubricating oil filter assemblies used can be broadly grouped into four categories. Each can be identified according to its appearance. The two current types are the single tank models containing several elements, Fig. 1, and the multiple tank models, Fig. 2. Filters which were used on early railroad equipment are the rectangular tank filters containing several elements and the circular tank single element filter.

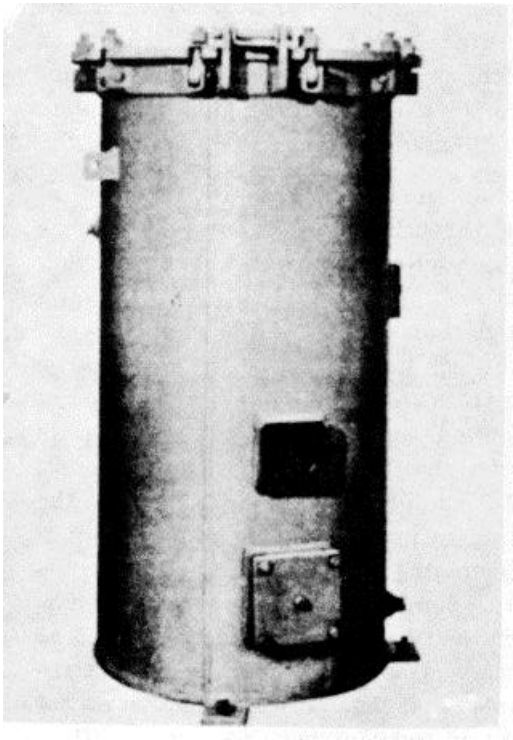


Fig. 1. -- Single Tank Filter

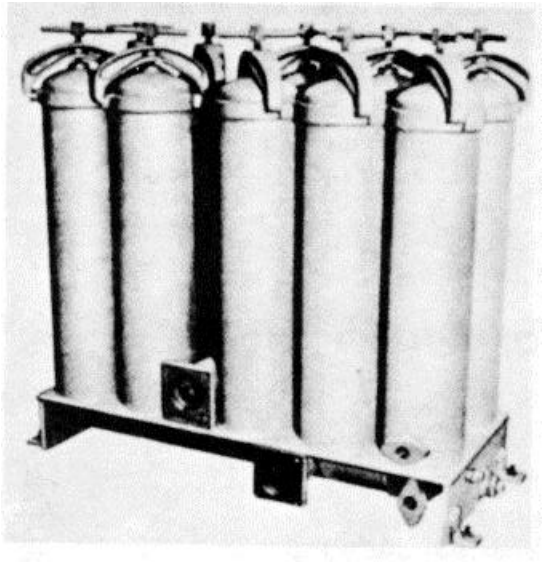


Fig. 2.- Multiple Tank Filter

Regardless of the model of filter used with the engine, it serves the prime function of removing oxidation and contamination products from the oil that may have been taken up by the oil as it circulated through the engine. Oil is taken from the engine sump by the scavenging oil pump and is forced through the oil filter. Clean oil leaving the filter is returned to the engine.

Filter elements, Fig. 5, are used to clean the oil. The element used in the filter may consist of a perforated metal container which encloses a replaceable filter, or an integral element consisting of an outer

perforated shell of hard paper board enclosing a pleated cotton paper filter material and having a perforated center tube. A filter element may also consist of an inner perforated metal tube which is completely covered by a specially packed cotton wastex filled woven cloth sock. The sock is securely fastened to the inner center tube. Cotton waste elements are classed as cageless and non-cageless. They are similar in construction but the cageless type has an extra sock covering. Non-cageless elements must be used inside a perforated filter shell. A cageless element can be used as is, without a shell, in filter assemblies constructed or modified to accomodate the cageless element.

CIRCULAR TANK FILTERS

The circular tank model filters can be divided into two designs; the seven element and the four element types.

SEVEN ELEMENT FILTER

Representative views of the seven element filter are shown in Fig. 3. A hinged cover closes the open end of the tank and is held tightly by the cover hold down bolts. A gasket is used between the cover and the rim of the tank to prevent oil leakage during operation. Flanged openings are provided for the oil inlet and outlet connections and for filter housing drain lines. When the filter is installed, a separate drain line (not shown) extends from the filter to a valve in the engine mounted strainer housing. The valve is opened to provide quick draining of the filter during maintenance by permitting oil to return to the engine oil pan.

Internally, the filter is divided into two compartments by a false bottom or separator plate. The plate is about 10-1/2" above the true bottom on the current filter 8319852 and about 5" above the true bottom on other models. The portion above the false bottom is the element compartment which receives the unfiltered oil. The lower portion is the discharge compartment which receives the oil after it has passed through the filter elements.
The current filter is equipped with short standpipes in the bottom of the filter housing which replace the drilled tubes used in previous model filters.

The filter elements are properly positioned within the housing by cradles, Fig. 3, which are located in such a position as to ensure correct application of the elements. In previous filters 8272268 and 8291381 the elements were completely supported by the center tube.

In current model filters the elements are placed over the standpipes and allowed to rest on the cradle. Hold-down springs, Fig. 3, which are mounted on the filter door are compressed by the elements as the door is closed. The hold-down springs eliminate the need for a hold-down plate as in older models.

In older model filters the filtered oil flows through holes in the center tubes and then into the discharge compartment. In filter 8319852 the filtered oil flows through the center of the elements and out through the standpipes to the discharge compartment. All elements are sealed at the bottom so that dirty oil cannot pass directly into the discharge compartment. Baffles are provided at the oil inlet of the housing to prevent direct impingement of the incoming oil against the filter elements. Some of the early model 8319852 filters had to have the baffle extended so that it was approximately 8" beyond the oil inlet opening. Any filters that do not meet this requirement should be modified. Provision is made in the filters to permit oil circulation in the event of cold oil or dirty filters. The oil begins to bypass the filter at differential pressures greater

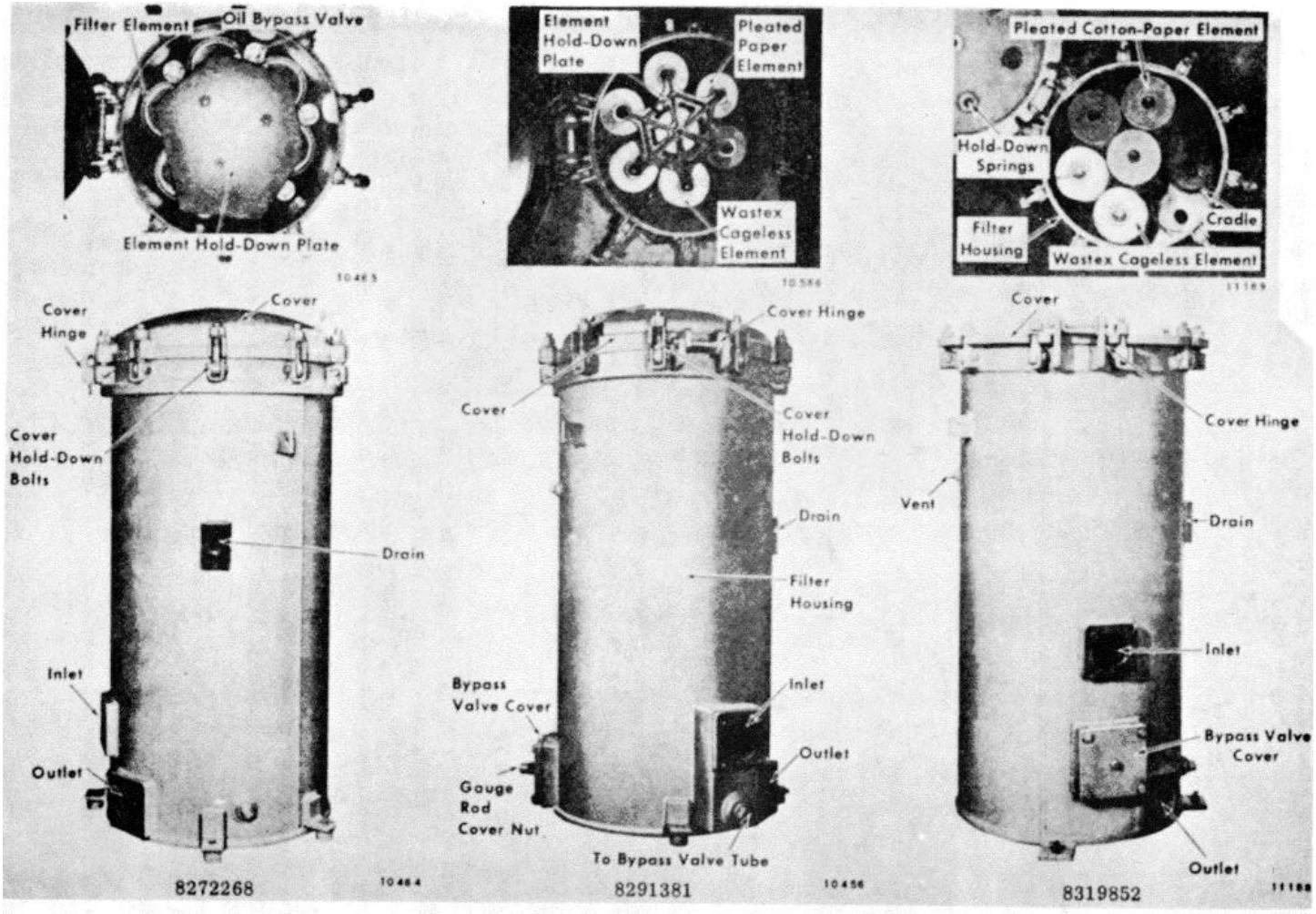


Fig. 3.- Seven Element Filters

than 40 psi. Filter 8272268 is equipped with five separate bypass valves as shown in Fig. 3. All 8291381 and 8272268 filters were equipped with 17 20 psi bypass valves. To get full benefit of the full flow filter, all 17 20 psi bypass valves still in use in seven element filters should be replaced with 40 psi valves. This can be done by substituting compression spring 8317190, valve retainer spring 8316866, and valve port gasket 8296030 for existing parts in seven element filters used on turbocharged engines. To convert seven element filters used on normally aspirated engines to use a 40 psi bypass valve, a 1/8" orifice must be added to the filter vent line so the oil flowing in his line will be held to a minimum. Install venturi 8290236 directly in the 1/2" vent opening in the filter housing. Use elbow 144283 to connect the venturi to the existing 5/8" vent tubing.

Seven element filters still equipped with five internal bypass 20 psi valves can be converted by substituting the 8282144 compression spring for the existing spring and installing the 8290236 venturi and 144283 elbow in the filter vent line as explained previously.

The arrangement of the bypass valve is shown in Fig. 4. The current model filter 8319852 and filter 8291381 are similar in operation in that the bypass valves in both filters have a passage connecting them to the oil inlet. If oil pressure exceeds 40 psi the valve opens and oil is dumped into the filter discharge compartment. Filter 8291381 is equipped with a plunger that is pushed outward when the valve opens and must be manually pushed in again to reset it. To check whether the valve has opened, the plunger cover nut is removed and the position of the plunger observed.

The individual bypass valves in filter 8272268 are located inside the case at cartridge height. Each valve consists of a valve body, piston spring and headless plug. The valves are threaded at the bottom to screw on the extended pipe. Oil passing through the bypass valve continues through the extended pipe into the discharge compartment.

Filter 8330094, which is the standard unit for marine application, is equipped with inlet and outlet pressure gauges and a temperature gauge, but has no internal relief valve. Otherwise, it is similar to filter 8319852.

Filter Elements For Seven Element Filters

The type of filter elements used depends upon the application of the filter.

All locomotives using a seven element filter must use a combination of five 8345482 or 8359745 pleated cotton-paper elements plus two 8275432 cageless cotton waste elements, Fig. 5.

All marine seven element filters use pleated cotton-paper elements 8345482 or 8359745.

FOUR ELEMENT FILTERS Four element filters are basically the same in construction and operation as seven element filters. They can be mounted either horizontally or vertically. The elements are held in place by holddown springs mounted on the door, Fig. 6. The older model filters were equipped with a spider plate and threaded rod to hold the elements in place.

The oil enters the element compartment through the inlet hole and passes through the filter elements flowing down the center of the element and into the discharge compartment. The bypass valve is provided to permit oil circulation in the event of cold oil or dirty filter elements. If the oil pressure exceeds 40 psi the valve opens

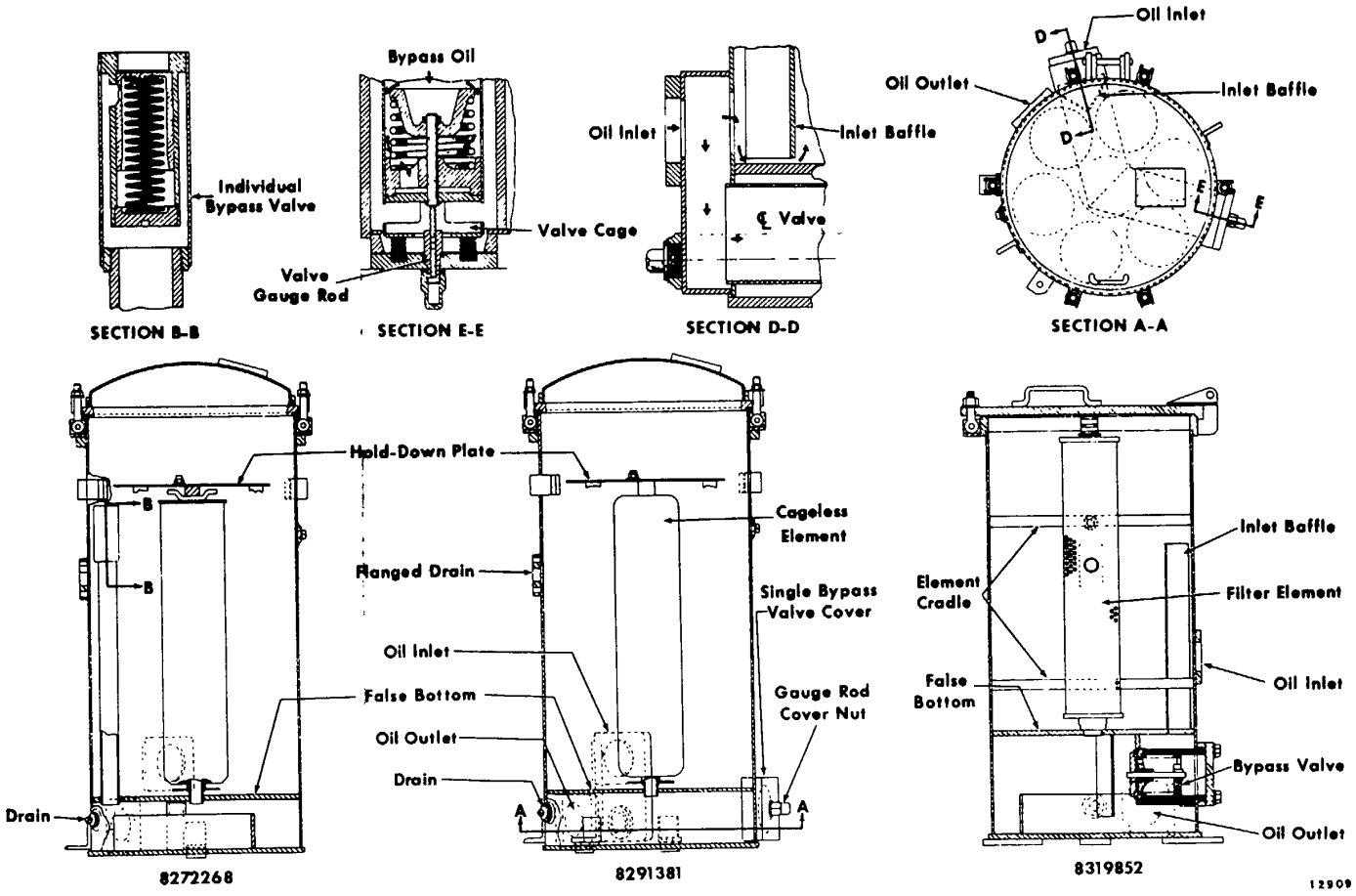


Fig. 4.- Bypass Valve Arrangement

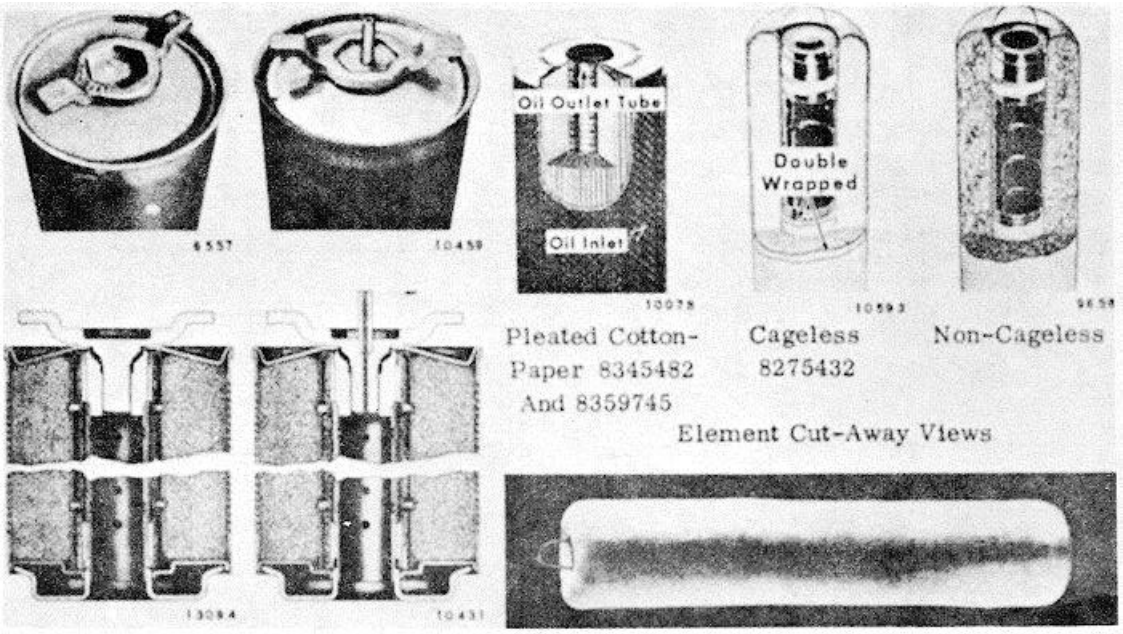


Fig. 5. - Filter Elements

and the oil flows directly from the element compartment into the discharge compartment. Previous model filters were equipped with 17 20 psi bypass valves. These bypass valves can be replaced with 40 psi valves but if this is done it is essential that the external relief valve be changed from a 60 psi to 80 psi valve.

Filter Elements For Four Element Filters

The basic element used in all four element circular model filter assemblies is cageless element 8275432. Earlier model four element filters which do not have a deflecting baffle installed at the oil inlet must use caged element 8168621 to prevent possible erosion of the outer cover. These filters may be modified to use the cageless element by installing the baffle as shown in Fig. 7.

Caged elements 8168621 are basically used in single bypass filter assemblies applied to export locomotives but cageless elements 8275432 can be used in these filters if desired.

MULTIPLE TANK FILTER ASSEMBLY

A ten element, multiple tank filter assembly is shown in Fig. 8. Ten individual filter housings are mounted on a common base. Filters similar to that shown in Fig. 8, having two or six individual housings mounted on a common base, are also used. Each housing accommodates one filter element.

The base is divided into inlet and outlet oil manifolds, as shown in Fig. 8. The

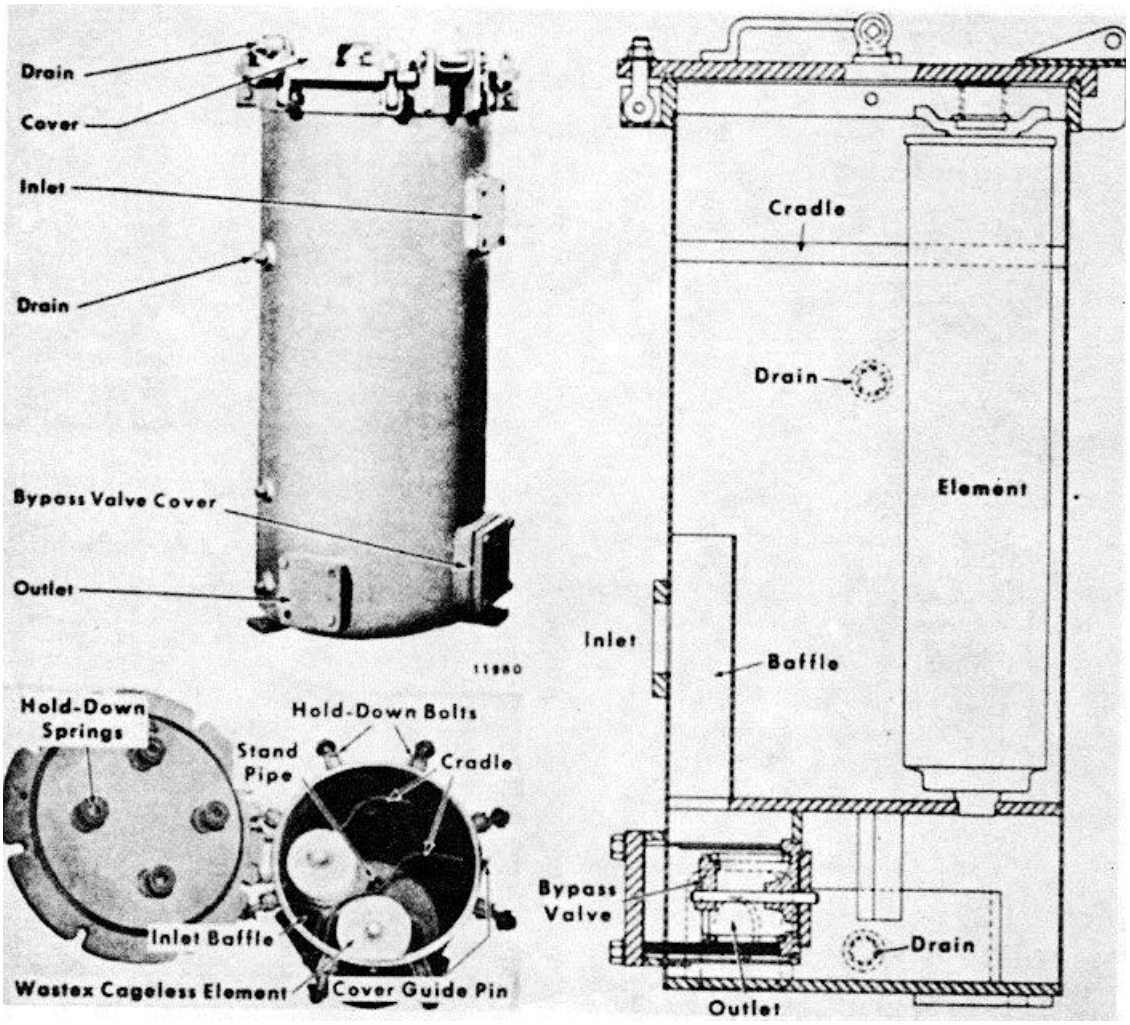
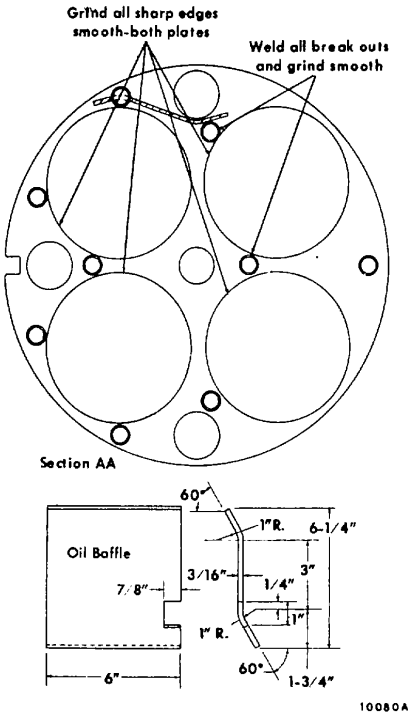


Fig. 6. - Four Element Filters

filter housings are located above openings to these manifolds so that the outside of the filter element is connected to the inlet manifold and the center or discharge portion of the element is connected to the oil outlet manifold. A number of bypass valves are located between the manifolds so oil can bypass the filter elements in the event of high pressure caused by cold oil or dirty elements, or oil volume in excess of the element capacity. Flanged pipes to each manifold are provided for external oil line connections.

Each individual housing is provided with a removable cover to permit application and removal of the filter elements. A spring at the underside of the cover contacts the top of the element and holds it down when the cover is applied. A tee handled screw, at the center of a yoke bridging the shell, is used to hold the cover against a gasket at the top of the housing.

Later filter assemblies have a baffle plate between the element and the oil inlet, to prevent direct impingement of oil on the element. Filter assemblies having the baffle may use the cageless type filter element, unless specified otherwise.



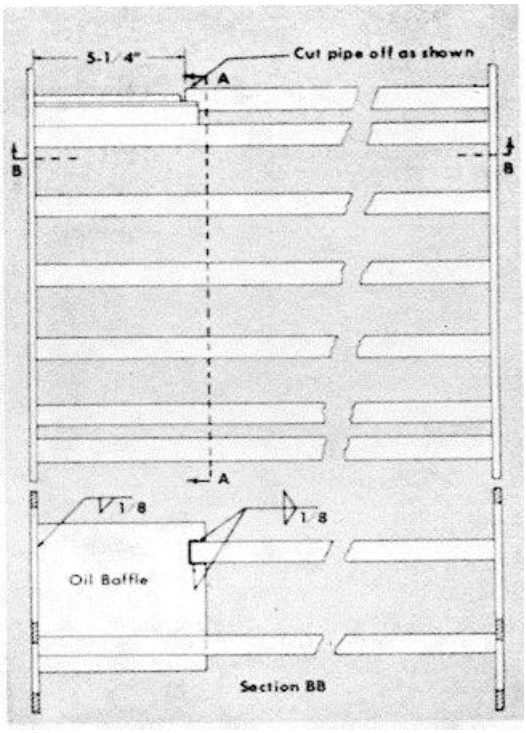
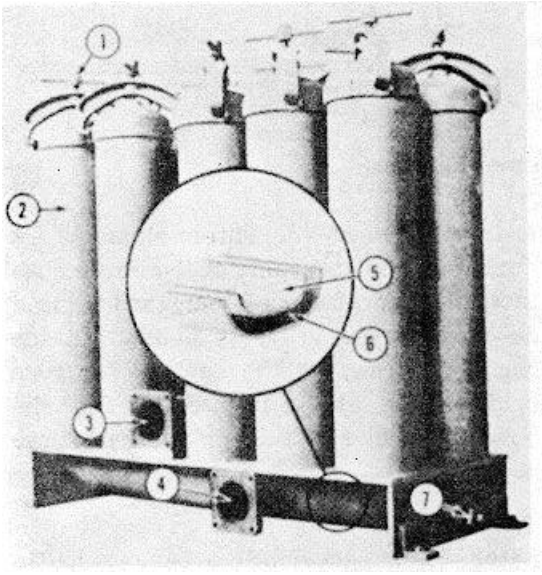


Fig. 7.- Modification Of Four Element Filters



1. "T" Handle And Yoke
2. Element Container
3. Oil Inlet
4. Oil Outlet
5. Oil Inlet Manifold
6. Oil Outlet Manifold
7. Filter Drain

Fig. 8. - Multiple Tank Filter Assembly

The multiple tank filter assembly installed on turbocharged units has one housing, Fig. 9, separated from the others which does not connect to the oil inlet and outlet manifolds common to the other nine housings. It has its own 1" oil inlet and outlet pipe connections and an individual 1/2" drain pipe. This filter is used in a separate oil supply system for the engine turbocharger.

FILTER ELEMENTS FOR
MULTIPLE TANK FILTERS

The filter assemblies can be divided into two designs. These are the current designs having an integral vent arrangement, and the earlier filters which were originally equipped with external vent lines from each housing.

The internal vent design filter assemblies are 8249387, 8253177, and 8248239. These filters replace prior external vent filters

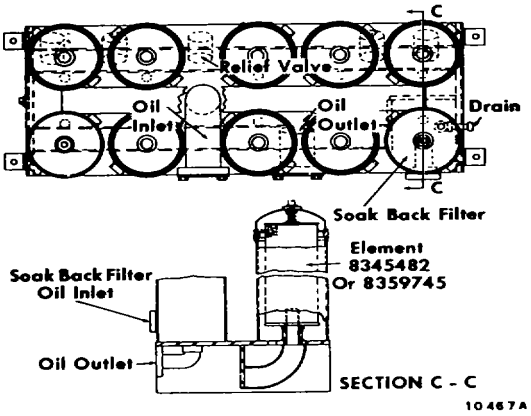


Fig. 9. Turbocharged Engine Filter Details

8207645, 8214050, and 8212458, respectively. External vent filters may be changed to internal vent design as outlined later.

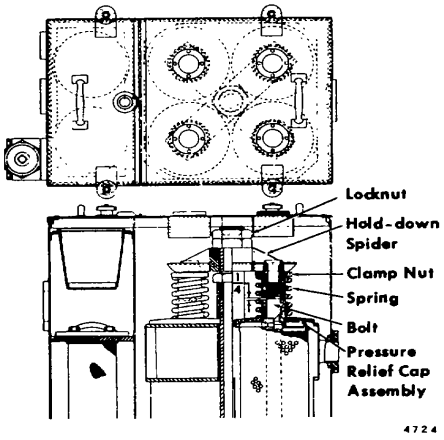
All filters use either cotton-paper element 8345482 or 8359745. The use of a combination of paper and waste type elements is no longer necessary as long as the above recommended elements are used. However, ten element filters which have one can isolated for use as a primary fuel filter will continue to use cageless cotton waste element 8275432 for the fuel filter.

To realize the full benefits of full flow filtration the multiple tank lube oil filter bypass valves should be changed to 40 psi by replacing the existing 17 20 psi springs with spring 8282144. Filters 8249387 and 8253177 require three springs while filter 8248239 requires five springs. All existing springs are directly interchangeable with spring 8282144. All later model filters were equipped with 40 psi bypass valves as original equipment.

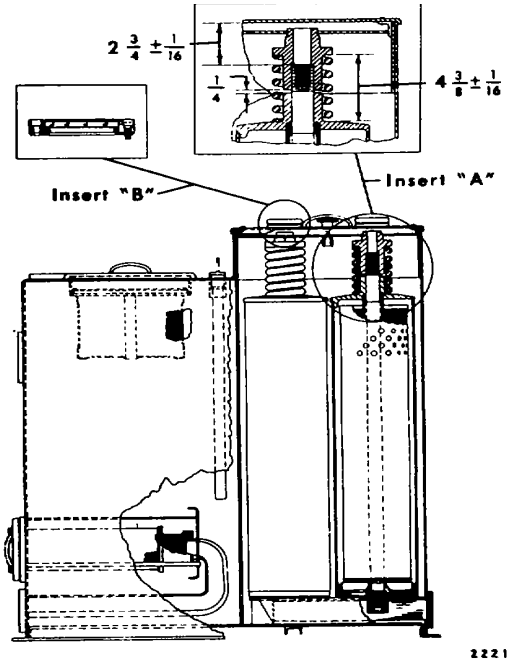
RECTANGULAR TANK FILTER ASSEMBLY

The rectangular design filter assembly is used on early model locomotives.

Representative drawings of these filter assemblies are shown in Fig. 10. Inlet oil to the filters either enters the element



E7 LOCOMOTIVE FILTER



E6 AND EARLY SWITCHER LOCOMOTIVE

Fig. 10. - Rectangular Tank Filter Assemblies

compartments from the bottom or the side and after passing through the filter, discharges out the top. Four sight glasses, in the tank cover, each directly above an element discharge, allows visual observation of the oil flowing from each element. Spring loaded caps on each filter element serve as bypass valves relieving at about 20 psi and as a means of securing the filter elements in their respective compartments. A portion of the oil is relieved through the element compartment bypass valve caps under normal operating conditions.

FILTER ELEMENTS FOR RECTANGULAR TANK FILTERS

Filter element 8054713, open at both ends, is used in these filter assemblies so that the oil can discharge out the top. Cartridge 8262493 is used in assembly 8054713.

SINGLE ELEMENT FILTER

This filter, Fig. 11, is used in the earliest switcher locomotives and uses cartridge 8262493 in element assembly 8168621.

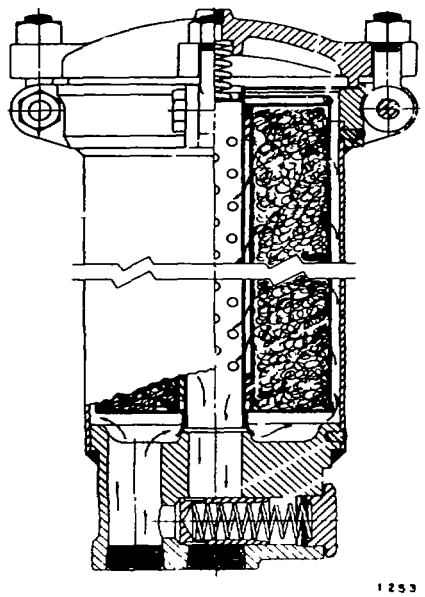


Fig. 11. - Single Element Filter

FILTER ELEMENTS

There are nine different filter elements for use in lube oil filters as listed below. Elements having a small tube diameter are to be used in perforated shells that do not have center screens. Those with a large tube diameter are to be used with shells having center screens. All EMD elements have reinforced center tubes for operation with 40 psi bypass valves.

Part No,	Tube Diameter	Remarks
8275432	Small	Cageless type having colored waste. Used in seven and four element filter tank having inlet baffles.
8345482 and 8359745	Small	Pleated cotton paper element type car tridge. Used in all locomotives with seven element lube oil filters.
8262493	Large	100% white wastex.
8281232	Large	50% white and colored wastex.
8262492	Small	100% white wastex.
8281231	Small	50% white and colored wastex.
8168621		Consists of a perforated shell, w a s t e x element 8262493 or 8281232, screened center tube, element cover and cover wing bolt assembly 8168656.
8261050		Same as element 8168621 except has vented design cover wing bolt assembly 8252176.
8054713		Consists of a perforated shell, wastex element 8262493 or 8281232,screenedcenter tube. Element

cover, cover snap ring and element handle. This element has a center opening at each end.

MAINTENANCE

CHANGING CARTRIDGES

Cartridges should be changed at intervals given in the Scheduled Maintenance Program for the type of equipment used. However, unusual operating conditions will require filter changes other than on a scheduled basis. In the event of lube oil contamination, engine breakdown because of parts failure, or in some cases when changing types of oil, it will be necessary to change filter cartridges. Also refer to the latest revision of the instruction covering flushing of the oil system.

INSTALLING ELEMENTS

Care should be taken to install the filter element which is correct for the type of tank in which it is to be used. Closed center tube elements are used in round tanks and open center tube elements are used in rectangular tanks. Vented type elements should be used in multiple tank single element shells without vent piping and conventional elements in those with external vent piping. It is suggested that sufficient spare perforated shells be kept on hand so that immediate reconditioning is not necessary.

Check the center tube seats when installing the elements to determine that there is no foreign material on the surface which will prevent proper seating of the element or cartridge. Check the element covers to make certain that the screw, snap ring or handle holding it are tight and properly applied.

Be sure that the plugs at the upper end of the elements are properly aligned with the centering bosses on the hold-down plate.

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Approximately 25 ft-lbs. torque should be applied to the hold-down nuts when using cageless cartridges or pleated paper elements.

Handles should be removed from open tube assemblies 8054713 after installation in the rectangular tanks. The handles interfere with the bypass valve assembly bushing used in this application. The elements should be aligned properly so that the bypass valve assemblies and internal tube (where used) are tight and that the spider will hold them during operation.

CLEANING FILTER ASSEMBLY TANKS

At intervals listed in the Scheduled Maintenance Program corresponding to lube oil change periods, lube oil filter tanks should be cleaned thoroughly. Wash and flush tank interior, using petroleum solvent. Drain and wipe out using only bound edge towels. Be sure discharge area between true and false bottoms of the tanks does not contain trapped cleaning solution.

BYPASS VALVES

It is recommended that the filter bypass valves be removed, cleaned, and inspected, at intervals specified in the applicable Scheduled Maintenance Program.

The bypass valves are located toward the bottom, or discharge end of the filter, on other than seven element or rectangular tank filters, and may be identified by their hexagon head plugs. The separate spring type bypass valves are located inside the oil discharge compartment of the four and seven element filter assemblies. No regular maintenance is required on single relief valve assemblies.

After draining the tank, remove the hexagon plug, slotted head screw plug, spring and piston.

Clean and inspect the parts and check the springs for proper tension. Minimum length of springs should not be less than 2-7/8" under a compressive load of 30 lb.

Reassemble the valves by inserting the piston, closed end first, and insert the spring. Apply the spring screw plug all the way to its stop. Apply a new gasket on the hexagon plug and tighten the plug in place in the filter.

On seven element filters the bypass valves are screwed into stand pipes inside the filter. To remove these valve assemblies, use special spanner wrench 8277270, which has four pins to fit the relief valve, and a hexagon stem to accommodate a wrench. The valve spring specification for this valve is the same as that for the preceding valve. There is no adjustment provided on either of the valves,

Bypass valves on rectangular tanks, Fig. 10, are similar in function but different in construction when compared to other bypass valves. The bolt, cap, spring and clamp nut make up an individual assembly on E7 locomotive tanks, one of which covers each element container and is held by a spider as shown. It is not necessary to disassemble this valve when changing elements. On assembly, maintain 1/4" space between clamp nut and cap to allow for spring compression. When applying the spider do not tighten it excessively.
Construction details of a filter nut wrench are shown in Fig. 12.

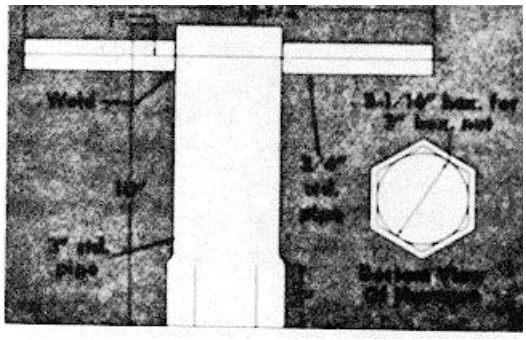


Fig. 12.- Filter Nut Wrench Construction

It is necessary to take apart the bypass valve assembly, Fig. 10, on rectangular tanks used on E6 and early switcher locomotives, to change filter elements. In this assembly a perforated hollow tube extends upward to serve as the bolt for the relief valve assembly. Insert "A", Fig. 10, shows dimensions to be held at assembly of this valve. The tube or bolt top should be 2-3/4" +1/16" and the space between cap and clamp nut should be 1/4".

REPACKING HAND PACKED FILTER ELEMENTS

Replaceable prepacked wastex cartridges are recommended in place of manually hand packed filter elements. However, wastex is available for hand packed elements which are still in use.

On elements using lose hand packed wastex the center screen tube must be in good condition. Also, early element cans such as 8035047 and 8054713 with the large perforated outer shell must have the screen around the inside of the outer shell intact and in good condition. Cartridges must be used if either of these conditions cannot be satisfied.

After the element is removed, carefully take out the used wastex. Drawing 8102979 available upon request, provides the information necessary to construct a filter unpacking rack which also has a provision for used wastex disposal. Thoroughly clean the element container after the used wastex is removed.

A full package of wastex 8032230 (7 lbs.) should be used to repack each element. Drawing 8062925, available upon request, shows construction of an element packing rack that will hold the element and aid hand packing. Apply the wastex to the element and push it down evenly around the center tube using a blunt ended stick. Use the element cover occasionally to check center tube alignment.

When the element is properly packed, replace the element cover and screw or snap ring. Replace cover handle, if used. If the element is not to be installed soon after packing, it should be covered during storage. Drawing 8070917 showing construction of an element storage box is available upon request.

CONVERSION OF EXTERNAL VENT DESIGN FILTERS TO INTERNAL VENT FILTERS

External vent filters 8207645, 8212458, and 8214050 can be converted to the internal vent design as follows:

1. Shut down the engine and drain the filter.
2. Remove all the external vent piping from the filter housings and from the lube oil system piping.
3. Plug the vent holes in the filter housings using 1/4" bronze plugs 112578. Solder the plugs in place to prevent oil leakage.
4. Plug the vent connection at the oil system pipe with 1/2" plug 103868.
5. Replace the nonvent design wing bolt 8168656 in each element with vented type assembly 8252176.
6. Retain the square cross section cover gasket 8213372 in the converted filters. Flat cover gasket 8253898 can only be used in filter assemblies originally built with internal vent, as mentioned in the preceding item covering filter elements and cartridges.

MODIFICATION OF ORIGINAL SEVEN ELEMENT FILTER HOLD-DOWN PLATE

When applying the original filter hold down plate in the seven element lube oil filter, Fig. 13, it is difficult to determine

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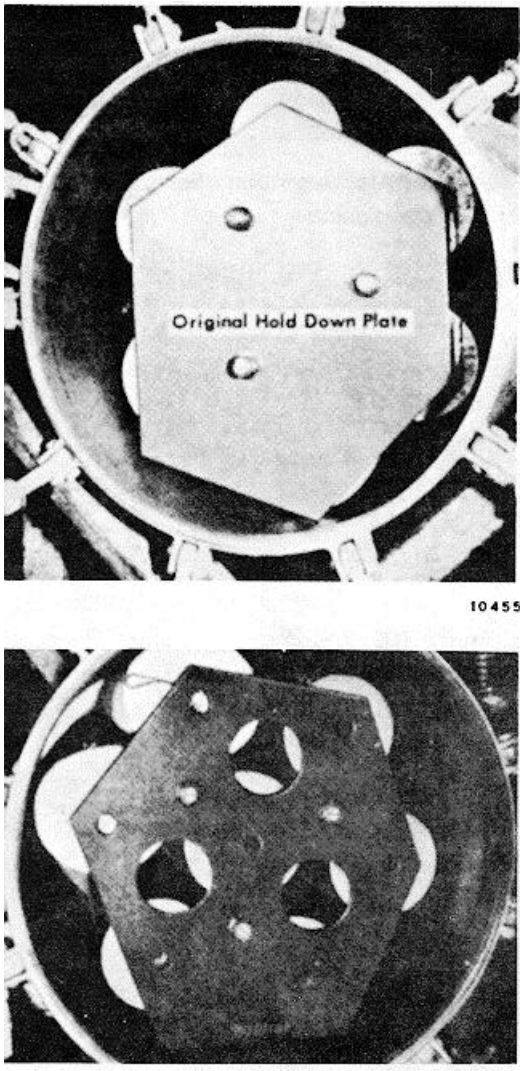


Fig. 13. Modification Of Original Seven Element Filter Hold-Down Plate

whether or not the pipe stubs on the holddown plate are centered on each filter. To make the application of this plate more convenient we suggest the plate be modified as shown in Fig. 13.

This modification can be done in the following manner:

1. Locate the bottom of the plate and label it by stamping the word BOTTOM on the outer face. This will assist in properly positioning the plate during installation.
2. Drill a 1" hole through the plate at the center of each of the seven pipe stubs. These holes will make it possible to observe the center of each element when installing the plate.
3. Drill or machine three holes 3-1/2" in diameter as shown in Fig. 13 to permit observation and any repositioning of the center element that may be necessary.

EQUIPMENT LIST

	Drawing
Michiana filter element packing rack	8062925
Michiana filter element storage box	8070917
Michiana filter unpacking rack (with waste cart)	8102979
Filter nut wrench	8107833
Wrench (spanner - to relief valves inside housing on early seven element filters)	8277270

DEPROCESING, INSPECTION AND TIGHTENING OF NEW AC~OWER GENERATING UNITS

DESCRIPTION

After construction and testing, new AC power generating units are processed for shipment by the application of protective materials to vital components for the purpose of preventing corrosion or other damage that could be encountered during shipment. These materials generally consist of VPI corrosion protective paper, silica gel bags for moisture absorption and plywood or heavy paper coverings.

Before placing a new unit in service, it is important that it be carefully deprocessed to remove all protective materials. Since the type and extent of protective materials applied vary with the unit model, shipping destination, and other considerations, no exact procedure for deprocessing can be given. It is therefore advisable to make a careful systematic inspection of all equipment, removing protective materials as they are found. Particular attention should be given to removing any blocking applied to protect the various electrical devices such as contactors, relays, and switches.

BEFORE SERVICE INSPECTION

After deprocessing and before placing a power unit in operation, it should be carefully inspected to insure complete readiness for service. The mechanical and electrical inspections are given below.

MECHANICAL

1. Check engine lubricating oil level using dipstick in side of engine oil pan. Should be above the "full" mark with engine stopped. Add oil if necessary following specifications given in Maintenance Instruction 1752.
2. Check governor lubricating oil level.
3. Fill engine cooling water system with treated water or antifreeze solution.

   Level should be at the "full" mark on tank sight glass.
4. After inspecting the generator for possible restrictions, bar engine over by hand one full turn to check for freedom of rotation.
5. Check to see that all hand hole inspection covers are securely in place on the engine crankcase and oil pan.
6. Check lubricating oil level in the engine oil bath air intake filters. Refer to Maintenance Instruction 431 for oil type and quantity.
7. Check cooling fan for freedom of rotation and observe that air flow through radiators is unrestricted.
8. Check that fuel supply is adequate for operation. Observe that emergency fuel cutoff valve is in "set" position.
9. Note position of engine overspeed trip lever at front top of engine. Should be in "set" position facing fuel filter side of engine.
10. See that covers are tight on all fuel and lubricating oil filters.

ELECTRICAL

1. Check synchronous generator to engine alignment. Refer to procedure in Maintenance Instruction 1753.
2. Check synchronous generator and exciter for freedom of rotation. See Step 4 under preceding Mechanical Inspection.

3. Check storage battery electrolyte level, specific gravity and voltage.

See that battery cables are tightly connected to terminals.

4. Check fuses to see that all are in place. Close necessary knife switches.

5. Check brushes on exciters, generator slip rings, eddy current coupling, and fuel pump motor to see that they are installed and making proper contact.

6. Check all wiring connections to terminals for tightness. See that all connectors and plugs are properly installed.

7. Check alarm systems for proper function.

8. If provided, position the delta-wye switches and generator connections to agree with voltage requirements.

9. Check and adjust if necessary, settings of overcurrent relays to satisfy requirements of the particular application.

10. Check oil level in oil type circuit breaker (where used). Air type circuit breakers should be removed from compartment and arc chute removed for inspection and application of barrier stacks. Check mechanical operation of breaker with maintenance closing handle.

AFTER SERVICE INSPECTION AND TIGHTENING

After approximately 72 hours of service, the following items should be given attention.

MECHANICAL

1. Remove rocker arm assemblies and tighten all cylinder head to liner stud nuts to proper torque. Replace rocker arm assemblies and set valve lash adjusters, injector racks and injector timing.

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2. Tighten the following engine nuts and bolts to proper torque: cylinder head crab nuts, cylinder head cover frame bolts, crankcase to oil pan bolts, engine and generator base bolts, and all nuts and bolts at both ends of engine.

3. Check tightness of all bolts, nuts, and connections for equipment and piping on engine plumbing stack.

4. Remove and discard fuel filter elements, clean housings, and replace with new elements.

5. Remove, clean and inspect lube oil strainers in housing at front of engine.

6. Inspect all the flexible couplings, and check the vee belts for proper tightness.

7. Check engine and governor oil level.

8. Visually inspect air box and note condition of pistons, piston rings, and cylinder liners.

9. Visually inspect oil pan and observe condition of upper connecting rod bearings. Check tightness of connecting rod basket bolts.

10. Visually inspect top deck. With engine idling, observe for proper lubrication.

11. Check cooling system water level.

12. Check and clean, if necessary, car-body and engine air intake filters.

ELECTRICAL

1. Inspect generator carefully, wipe insulated surfaces with soft cloth if necessary.

2. Check air circuit breaker and high voltage section of cubicle. Wipe dust from insulator bushings.

3. Visually check all contactors, relays, and switches.

4. Check battery electrolyte level, specific gravity and voltage.

SCHEDULED MAINTENANCE PROGRAM MU-15TBL, 30TBL, 45TBL, 60TBL, 75TBL (Baseload)

INTRODUCTION

This instruction bulletin is comprised of recommendations which we believe will insure the most economical maintenance cost consistent with satisfactory operation.

It must be recognized that certain responsibilities for a successful operating program are beyond the control of anyone but the user, such as:

1. Lubricating oil used must meet the specifications in Maintenance Instruction 1752.

2. Lubricating oil filters should be changed in accordance with Item 21 at 500 hours of operation and filters must be of equal quality to original equipment.

3. In accordance with Item 23, lubricating oil should be changed at 2000 hours.

4. Fuel oil used should meet specifications as listed in Maintenance Instruction 1750.

5. All work scheduled will be done in a workmanlike manner, which assumes that the proper tools, facilities and supervision will be available.

EVERY MONTH

REMARKS

1. VISUALLY INSPECT FOR LEAKS
   a. Cooling system
   b. Fuel system
   c. Lube oil system
   d. Exhaust system

2. CHECK BATTERIES
   a. Level of electrolite
   b. Cell voltage
   c. Specific gravity

3. CHECK BATTERY CHARGING EQUIPMENT FOR PROPER OPERATION

4. COMPARE CLARITY OF COOLANT TO PREVIOUS SAMPLES

Small samples of coolant collected monthly and saved in clear glass bottles offer a reliable method of evaluating coolant in the field. The agitated coolant sample can be taken from the right bank water pump drain valve while the engine is running and hot. Any sudden change in sediment or clarity is cause for submitting a coolant sample to the laboratory for immediate analysis.

Frequency dependent on weather conditions.

5. CHECK IMMERSION HEATER FOR PROPER OPERATION

6. DRAIN CONDENSATE FROM FUEL TANKS

7. CHANGE AND/OR CLEAN SOAK BACK LINE FILTERS

   a. Change soak back filter element

   b. Change metal soak back line filter

8. TAKE SAMPLE OF ENGINE LUBE OIL FOR LABORATORY CHECK

Soak back filter is the inboard filter closest to the fan. (Use cartridge 8286567.)

Use cleaning fixture 8315754 for disc type filter or fixture 8320033 for pleated screen filter. Cleaning procedure outlined in Pointers dated March 16, 1962.

EVERY SIX MONTHS	REMARKS
9. EPLACE AIR INTAKE FILTERS	Replace every six months regardless of hours of operation.
10. CHECK OPERATION OF PROTECTIVE DEVICES	
a. Annunciator	
b. Protective relays (Reverse power, over-current, etc.)	
c. Engine protector	
11. IMMEDIATELY AFTER ENGINE OPERATION TAKE SAMPLE OF AGITATED ENGINE COOLANT FOR LABORATORY CHECK	Additional requirements of liquid Nalco borate water treatment 8241520 should be determined by corrosion analysis conducted by a reliable laboratory.
EVERY YEAR	
12. CHECK SETTINGS	
a. Overspeed trip setting	
b. Lash adjusters	Engine Maintenance Manual
c. Injector rack settings	
13. CLEAN AND VISUALLY INSPECT ALTERNATOR	
14. VISUALLY INSPECT	
a. Voltage regulators	
b. Synchronizer	
c. All relays, contactors, and circuit breakers	
15. REMOVE MAIN CIRCUIT BREAKERS FROM COMPARTMENTS	
a. Clean insulators	
b. Lubricate linkage bearings	
c. Check operation	
EVERY TWO YEARS	
16. UNIT EXCHANGE	
a. Immersion heater pump and motor	

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PERFORM THE FOLLOWING ITEMS ON RUNNING TIME BASIS

EVERY 250 HOURS OF OPERATION	**REMARKS**
17. INSPECT COOLING FAN BELTS	Inspect cylinder head mechanism with engine at idle speed and engine at operating temperature.
18. INSPECT CYLINDER HEAD MECHANISM	
19. CHECK LEVEL OF ENGINE LUBE OIL .	Approximately 150 gallons of oil is required to bring oil level up to full mark on dipstick if level is at the "low" mark. Maintain at proper level.
EVERY 500 HOURS OF OPERATION	
20. INSPECT ENGINE a. Pistons and rings b. Cylinder liners	Engine Maintenance Manual
21. CHANGE LUBE OIL FILTERS a. Change engine lube oil filters b. Change turbo oil supply filter .	Requires seven paper cartridges 8286567, and two waste cartridges which are to be installed in the two inboard containers nearest the engine. Use cage type waste elements 8262493 unless filter housings are equipped with bottom pressure plates which allow use of cageless waste elements 8275432.
EVERY 1,000 HOURS OF OPERATION	
22. CHANGE AND/OR CLEAN FUEL FILTERS a. Engine mounted fuel b. Suction - fuel c. Discharge - fuel transfer pump	
EVERY 2,000 HOURS OF OPERATION	
23. CHANGE ENGINE OIL a Inspect lube oil filter differential valves for proper operation a. .	

EVERY 16,000 HOURS OF OPERATION	REMARKS
24. UNIT EXCHANGE	Engine Maintenance Manual
a. Turbocharger	
b. Cylinder assemblies	
c. Injectors	
d. Engine water pumps	
e. Governors	
f. Lube oil coolers	
g. Radiators	
h. After coolers	

EVERY 56,000 HOURS OF OPERATION

25. UNIT EXCHANGE

a. Power units complete

LUBRICATION SCHEDULE

EVERY MONTH	
1. LUBRICATE FAN BEARINGS	Two shots of ball bearing grease.
a. Cooling fan	
b. Ventilating fan motor bearings	Light motor oil.

EVERY THREE MONTHS	
2. CLEAN AND LUBRICATE STARTER DRNE	
3. CHECK OIL LEVEL IN OIL BATH OIL FILTERS	
4. LUBRICATE DOOR HINGES AND LOCKS	
a. Inspect door seals	Replace where required.

EVERY 250 HOURS OF OPERATION	
5. FILL OIL CUPS ON WATER PUMPS	Engine Maintenance Manual

EVERY 2,000 HOURS OF OPERATION

6. CHANGE ENGINE LUBE OIL

a. Clean scavenging pump screens

b. Clean suction pump screens

7. HANGE OIL IN OIL BATH AIR FILTER M.1. 440

a. Clean filter bowl

EVERY 16,000 HOURS OF OPERATION

8. INSPECT ALTERNATOR BEARING
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ENGINE COOLANT

DESCRIPTION

Coolant is circulated throughout the engine to provide the means for heat transfer from the engine components. Water, corrosion inhibitor and, in some applications, antifreeze are used in coolant solutions.

Because the function of the coolant is so necessary to the operating efficiency of the engine, it is important that the selection of a coolant solution be carefully considered.

COOLANT SOLUTIONS

A coolant suitable for use in engine cooling systems must meet four basic requirements:

1. It must adequately transfer heat energy through the cooling system.

2 It must not form scale or sludge deposits in the cooling system.

3. It must not cause corrosion within the cooling system.

4. It must not deteriorate any of the cooling system seal materials.

These requirements are normally satisfied by combining a suitable water with a reliable corrosion inhibitor. Certain operating conditions may dictate the use of antifreeze-coolant. In this case the basic requirements can be satisfied with a combination of suitable water and an ethylene glycol type antifreeze which contains an adequate corrosion inhibitor. However, the use of antifreeze involves special consideration regarding Items 1

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and 3 above. This will be discussed in detail in the section on antifreezes.

It should be recognized that coolants which perform satisfactorily in other applications may not be satisfactory for use in engine cooling systems. Differences in coolant volume to-cooling system surface area ratios, coolant velocities, temperatures, and the types of materials employed make such comparisons meaningless.

The formulation of "home made" inhibitors and antifreezes is not recommended since such processes are difficult to monitor and control. The ready availability of suitable proprietary products makes these practices uneconomical and impractical.

Water quality should be evaluated whenever a new water source is to be used, or when changes in existing water sources occur. Likewise, quality of the coolant solution should be tested when a new engine is put into service, and at regular intervals thereafter. The quality of coolant should always be known and should be maintained as required.

WATER

When determining the suitability of water for use in coolant, four characteristics must be examined. These are the concentrations of chlorides, sulfates, total dissolved solids, and total hardness in the water. These materials are objectionable for a number of reasons: Chlorides and/or sulfates will promote

corrosion, while hardness will cause the deposit of sludge and/or scale. Depending on its components, total dissolved solids can cause scale deposits, sludge deposits, corrosion, or combinations of these.

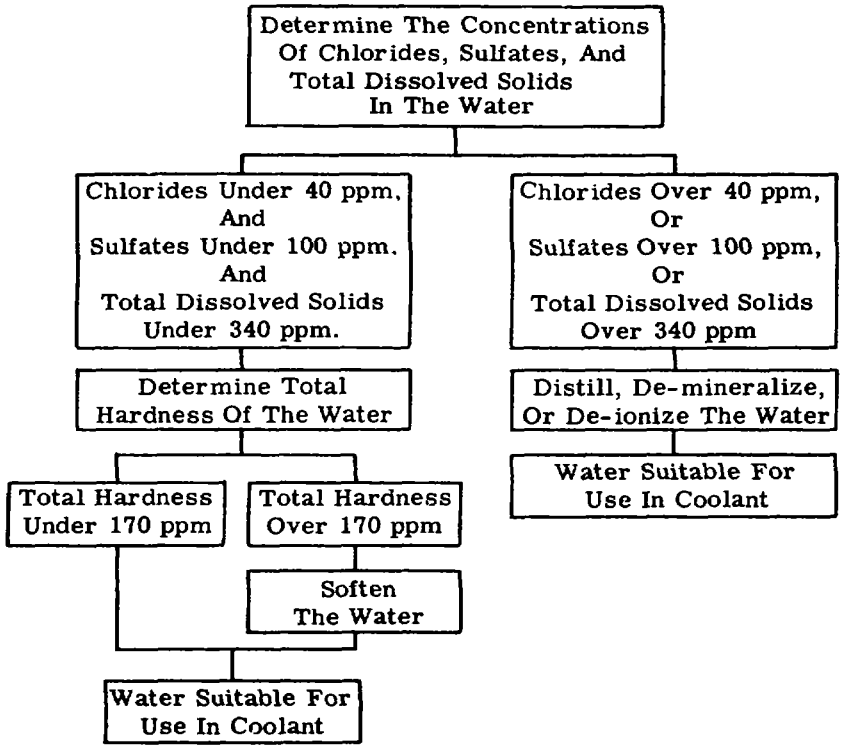
It should be recognized that chlorides, sulfates, and hardness are among, but not necessarily all, the materials which can make up dissolved solids. Each of these three categories could account for none, part, or all of the dissolved solids in a given water. Miscellaneous substances can account for substantial dissolved solids concentrations; even though chlorides, sulfates, and hardness are not present.

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TABLE 1.

	PARTS PER MILLION	GRAINS PER GALLON
Chlorides (Maximum)	40	2.5
Sulfates (Maximum)	100	5.8
Total Dissolved Solids (Maximum)	340	20
Total Hardness (Maximum)	170	10
Refer to Table 2 for evaluation of water intended for use in a coolant solution.		

Table 2.



Water which does not exceed the limits given in Table 1 is considered suitable for the formulation of engine coolant.

For the purpose of coolant formulation, steam condensate can usually be considered equivalent to distilled water.

In some instances, water containing up to twice the recommended maximum amount of sulfates or chlorides can be used in coolant, provided a higher than the normal inhibitor dosage is used. Electro-Motive Service personnel should be consulted if there are questions regarding a specific application.

CAUTION: Uninhibited water should never be used to fill a cooling system because of the possibility of rapid corrosion and rusting. This applies to all uninhibited water but is especially true for distilled, de-ionized, or demineralized waters, including steam condensate. Prior to application, the water should be mixed with the inhibitor or inhibited antifreeze which is to be used in the coolant.

INHIBITOR

Two basic types of inhibitors, chromate and borate, are most commonly used in EMD engine cooling systems where nonantifreeze coolants are employed. Typical products and information regarding their application are as follows:

NOTE: The units of measure throughout this publication are those commonly used in the United States.

Dry Measure:
16 Ounces = 1 Pound

Liquid Measure:
32 Ounces = 1 Quart
4 Quarts = 1 Gallon

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CHROMATE TYPE

NOTE: Chromate type inhibitors should not be used in cooling systems containing ethylene glycol antifreeze solutions.

1. Nalco 38 Nalco Chemical Company (or equal)

2. Dearborn 517 Dearborn Chemical Company (or equal)

   These products are marketed in the dry pellet and/or pulverized form. When the cooling system is first filled, use either one of these products at a concentration of 0.6 ounces per gallon of water. Thereafter, the inhibitor concentration should be maintained at a minimum of 0.4 ounces per gallon. Make-up coolant should contain at least 0.4 ounces per gallon.

To avoid possible skin irritation, the usual safety and hygienic precautions should be exercised when handling chromatetype inhibitors.

BORATE TYPE

1. Nalco 39 Pellet or Pulverized Nalco Chemical Company (or equal)

2. Nalco 40 Pulverized Nalco Chemical Company (or equal)

3. Dearborn 527 Dearborn Chemical Company (or equal)

   When the cooling system is first filled, use any one of the above products at a concentration of 1 ounce per gallon of water. Thereafter, the concentration should be maintained at a minimum of 0.75 ounces per gallon. Makeup coolant should contain the 0.75 ounce per gallon dosage. Pellet and pulverized borate inhibitors are difficult to

dissolve. Therefore, it is suggested that these products be pre-mixed into a water slurry prior to preparation of the coolant solution.

4. Nalco 39 Liquid Nalco Chemical Company (or equal)

When the cooling system is first filled, use at a concentration of 3 fluid ounces per gallon of water. Thereafter, the concentration should be maintained at a minimum of 2 fluid ounces per gallon. Make-up coolant should contain at least 2 fluid ounces per gallon.

ANTIFREEZE

With certain qualifications, ethylene glycol type antifreezes can be employed successfully in engine cooling systems. Alcohol type antifreezes are not recommended .

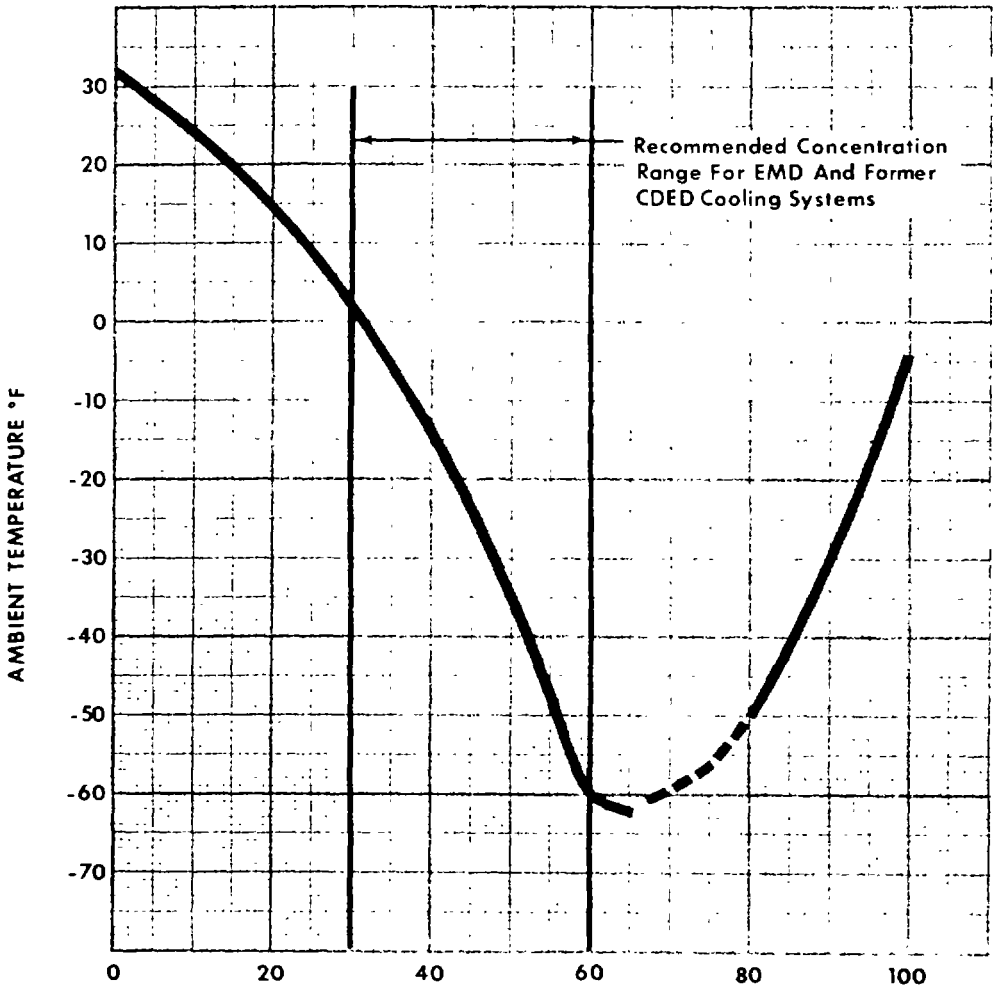
Fig. 1 depicts the freezing points of typical ethylene glycol antifreeze and water solutions. The freezing points of specific brands may vary slightly from prints

shown on the graph. However, the graph is sufficiently accurate for use in estimating antifreeze requirements, regardless of brands.

Proprietary brands of antifreeze should be used at no less than 30% and no more than 60% in the coolant solution. Solutions of less than 30% do not provide sufficient corrosion inhibitor protection for engine cooling systems. On the other hand, there is nothing to be gained by using antifreeze concentrations of over approximately 60%. As can be seen in Fig. 1, the freezing point actually occurs at higher temperatures as antifreeze concentration is increased over the 60% level.

Although the use of antifreeze is acceptable within the 30 to 60% range, it is not desirable to use more than necessary within that range. For example: if a 40% solution will provide the required freezing protection, then nothing more than a 40% solution should be used. Aside from the fact that this is good economics, we recommend against the use of excessive

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Fig. 1. - Freezing Points Of Aqueous Solutions Of Ethylene Glycol Antifreezes

concentrations of antifreeze because of the adverse effects on heat transfer within the cooling system. As he antifreeze concentration in the coolant is increased, the thermal conductivity of the coolant decreases.

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DIESEL FUEL RECOMMENDATIONS

RECOMMENDED LIMITS FOR FUELS

Method of Test	ASTM Designation	Limits
Cetane Number	D-613	40 (Min.)
90% Boiling Point	D-158	650°F. (Max.)
Final Boiling Point	D-158	700°F. (Max.)
Distillation Recovery	D-158	97.5% (Min.)
Total Sulfur	D-129	0.75% (Max.) Note 1
Corrosive Sulfur (3 Hr. @ 2120F.)	Modified D-130	#2 Strip or Better
Conradson Carbon Residue (on 109% Bottoms)	D-189	0.15% (Max.)
Water and Sediment	D-96	0.05% (Max.)
Cloud and Pour Point	D-97	Note 2
Flash Point	D-93	Note 3
Organic Chlorides	D-808 or D-1266	20 PPM Total Chlorine (Max.) Note 4
Filtration Cleanliness Test (Solid matter such as rust, cracking catalyst, clays)	1962 ASTM-D2 Report, App. X, Page 35	5.0 Mg. Per Gallon (Max.) of Ash Residue on 0.80 Micron Filter Note 5.

GENERAL COMMENTS

The use of any fuel additives should be limited until it is established that there are no detrimental effects such as rapid engine wear, corrosion, or excessive deposits.

The fuel should be free from acid, which, when in contact with any metal, forms enough soap to plug the fuel filters.

NOTES ON TEST LIMITS:

1. The maximum total sulfur content has been set at 0.75%. Fuels containing larger amounts of sulfur can be used but will increase engine wear and maintenance.

The user should weigh the economics of less expensive higher sulfur fuels against the increases in maintenance costs.

2. The "Cloud and Pour Points" of a fuel are measures of its fluidity at low temperatures. To assure an adequate flow through the filters and strainers in the fuel system during cold weather, the user must specify the proper "Cloud and Pour Point" requirements based on the lowest temperature expected. Fuels with lower than normal flash points may be required when unusually low pour points are essential.

3. Fuels normally used have minimum flash points of 1500 F. Fuels with lower flash points can be used without affecting engine operation, however fuel handling and storage may require added precautions.

4. Rapid wear of chrome plated and iron surfaces in the combustion chamber results from the use of fuel containing organic chlorides. The presence of organic chlorides in fuel is rare but can occur from the use of halogenated dewaxing agents in cold weather pipeline operations or from improper desalting of crude oils at an unexperienced refinery followed by a reaction between the olefins and salt in the distillation unit. From past experiences, most refineries in the U. S. A. are alert to prevent the presence of chlorides in the fuel. Their precautions are now so automatic that cases of chlorides in the fuel seldom occur, and since routine control testing for chlorides is a time consuming procedure involving relatively large samples of fuel, it is not considered necessary in the United States. When testing for chlorides, we prefer the ASTM D-1266 procedure, where at least 10 grams of fuel are burned followed by Volhard Titration, rather than combining a number of burnings in the ASTM D-808 procedure.

5. Until recently Filtration Cleanliness Tests have not been generally employed or required in connection with diesel fuel. Experience has been that usual foreign contaminants, rust for instance, are removed by the filtration facilities at fueling stations and by the filtration equipment normally supplied with engines. The increasing use of catalytically cracked fuels, however, has produced instances where minute catalyst fines were accidentally introduced into the diesel fuel production. These cannot be removed by the commercial filters used at fueling stations and on the engines. It is to guard against contaminants of this nature that we have added the Filtration Cleanliness Test to our diesel fuel recommendations.

Because an involved laboratory procedure is required to distinguish the objectionable catalyst particles from other impurities, we suggest that all ashable material should not exceed 5.0 mg. per gallon of fuel when filtered through an 0.80 micron Millipore paper. This sample should be taken at the refinery where any significant ash material is most likely to be catalyst fines in the fuel. In checking the cleanliness of diesel fuel samples taken from tank cars or customer fuel storage tanks, the sample should be taken by acceptable sampling methods. Before the laboratory filtration evaluation is made, the sample of fuel should be well agitated and permitted to settle for five minutes. The upper portion of the fuel sample should be decanted so that any sediment which has settled will not be disturbed. The filtration tests are run on the decanted fuel as a measure of the ashable solids present in the fuel which will not settle quickly or which might be difficult to filter.

LUBRICATING OIL SPECIFICATIONS
DIESEL ENGINE AND GOVERNOR

The necessity for correctly lubricating the moving parts of any piece of apparatus is so apparent that further comment should be unnecessary. This instruction is therefore confined to listing specifications for particular lubricants which we have learned from experience are best suited to the application.

DIESEL ENGINE

OIL QUALITY

It should be recognized that the only real measure of quality in a lubricating oil is its actual performance in the diesel engine. This is so because of the impossibility of establishing limits on all physical or chemical properties of oils which can affect their performance in the engine.

The responsibility for recommending and consistently furnishing a suitable heavy-duty oil must rest with the individual oil supplier.

OIL TYPE

An SAE #40 heavy-duty additive type lubricating oil, which conforms to the following specifications, should be used in all engine applications.

Physical Properties	ASTM Designation	Limits
Saybolt Universal	D88 or D446	
1. Seconds at 1000 F.		1300 Maximum
2. Seconds at 210° F.		74 Minimum
Viscosity Index	D567	35 Minimum
		75 Maximum
Flash Point, °F	D92	4200 Minimum
Fire Point, °F.	D92	475b Minimum
Pour Point, °F.	D97	400 Maximum
Zinc		10 ppm Maximum

The oil should be a heavy-duty additive type having a high resistance to oxidation, a low tendency toward the formation of carbon deposits, and shall be noncorrosive to silver metal at 285° F.

We strongly recommend that zinc dithiophosphate or similar additives not be present in the engine-lubricating oil. Oils containing more than 10 ppm zinc are considered excessively contaminated with zinc dithiophosphate additive and should not be used since they may not satisfactorily lubricate the reciprocating bearings used in these engines.

MIXING OF OILS

Our recommendation against mixing different kinds or brands of heavy-duty oils is substantially supported by numerous recorded cases where various mixtures of incompatible oils were detrimental to engine operation. Unfortunately, expensive failures or abnormally high wear rates caused by incompatible oil mixtures cannot be predicted by laboratory procedures.

The mixture of oils usually results in a lubricant that is less stable than any of its constituents. Sludge and lacquer formation caused by this instability results in excessive wear and in shorter oil and filter life.

Ordinary laboratory techniques cannot be used to analyze samples of lube oil mixtures because it is impossible to establish a starting base line condition against which to measure the level of oil deterioration. As a result, problems caused by unsatisfactory lubrication are difficult to diagnose when using an oil mixture.

OIL CHANGES

Many diesel engines that are shipped from Electro-Motive have their systems charged with heavy-duty lubricating oil. This original oil should be left in the engine and used during normal operation. No make up oil should be added in order to keep the system full. This original oil should be drained when the level reaches the low mark on the dipstick. At that time, the filters should be replaced, the strainers cleaned, and the system then recharged with oil that is to be used. Subsequent oil changes should be made at intervals specified in the Scheduled Maintenance Program for the model involved, unless laboratory analysis dictates an earlier change.

Engines intended for export, marine, industrial, or other special installations are usually shipped dry and are often treated with rust preventive material which need not be removed. Oil meeting the specifications given should be used when placing the units in service. This oil should be changed and the lubricating system maintained as specified in the applicable Scheduled Maintenance Program. Here again, laboratory analysis may dictate oil changes at shorter intervals than those specified in the Scheduled Maintenance Program.

The oil change intervals prescribed are based on average operating conditions. When oil change intervals are extended, serious and costly engine problems usually result. This occurs when the heavy-duty lubricating oil loses its detergent-dispersant properties, allowing partially oxidized oil and other contaminants to form deposits in the engine.

Replacing old oil with a fresh charge of heavy-duty oil in a contaminated engine will result in the new oil picking up some of these deposits and rapidly losing its detergency and dispersancy. With the oil losing these properties quickly, and with continued operation, the deposits will become progressively worse and will ultimately lead to serious engine problems.

Laboratory analysis should not be used as the only guide to the condition of a lubricating oil. Of equal importance is the condition of the engine, which could be poor even though the oil appears satisfactory. Both engine and oil condition should be considered when attempting to arrive at oil change intervals beyond those recommended.

FILTER CHANGES

Oil filter element replacements should be made as specified in the applicable Scheduled Maintenance Program, unless a laboratory lube oil analysis dictates earlier replacement.

Where highly dispersant oils are employed, carbonaceous matter may be suspended so finely in the oil that it is essentially unfilterable. In such situations, it might appear that an extension of the filter element replacement interval would be practical. Caution should be exercised when contemplating such action. Filter materials have not yet been developed to tolerate prolonged exposure to lube oil without deterioration and possible disintegration of the filter elements.

OIL DILUTION

Engines found to have lubricating oil diluted with fuel oil should be serviced in the following manner:

1. From 0 to 3% dilution

   Within this range there is generally no need for concern or corrective action.

2. From 3% to 5% dilution

   Engine operation may continue until the next scheduled shutdown, provided total dilution does not exceed 5%. However, repairs should be made as soon as practical.

3. Above 5% dilution

   When dilution exceeds 5%, the engine should be removed from service until the fuel leak is repaired and the oil is changed.

GOVERNOR

Governor oil should be selected on the basis of the application. An SAE 10OW-30 oil is specifically recommended for governors used on synchronous speed, alternating current, generating sets. All other applications, including governor test stands, should employ either the SAE 10W-30 oil or a turbine-type anti-foaming oil containing rust and oxidation inhibitors, which conforms to the following specifications:

Physical Properties	**ASTM Designation**	**Limits**
Viscosity - Saybolt Universal	D88 or D446	
1. Seconds at 100° F.		600 Minimum
		700 Maximum
2. Seconds at 210° F.		68 Minimum 71 Maximum
Pour Point, ° F.	D97	5° Maximum

MAINTENANCE INSTRUCTION

ALIGNMENT OF ROTATING EQUIPMENT

I. INTRODUCTION

A. General Alignment Information

The purpose of aligning connected machines is to eliminate all unnecessary stresses in the shafts and couplings. Accurate alignment of coupled shafts of all types of rotating equipment is very important and must be maintained in order to assure trouble free operation. Misalignment causes vibration, bending of shafts and unequal bearing loadings.

In addition to shaft alignment other factors must be considered when installing equipment, which depend on the specific equipment. For example, in motors and generators, rotors must be correctly located in their stators to provide freedom of operation. Equal in importance is the positioning of the stator to the rotor radial clearance or air gap equalization. Also, bearings must be located so as to provide clearance for longitudinal shaft expansion and end play so as not to restrict normal positioning of the rotor during operation. Limiting dimensions governing these factors are given in the instruction covering the particular piece of equipment.

It is common practice to mount equipment on a subbase at the time of assembly at the factory. At the time of this original installation, the preceding factors of alignment are applied to correctly align the equipment, and the various items are securely fastened and doweled to the subbase to maintain their correct position.

It is important to remember that it is the shafts of connected machines that require alignment, not the couplings. Coupling surfaces may be inaccurate and not at right angles to the respective shafts. Misalignment of the shafts may be radial or angular or a combination of these two.

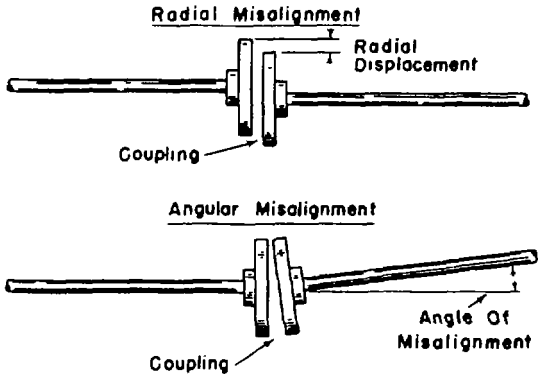


Fig. 1. - Radial And Angular Misalignment

Radial misalignment, Fig. 1, is indicated when the centers of the two shafts do not coincide. In addition to causing excessive vibration, this radial displacement also causes the two halves of the coupling to move radially in respect to each other. This movement results in excessive wear within the coupling. Radial displacement shortens bearing life by causing pulsating loads on the bearings. The magnitude of the pulsating load will depend upon the resistance of the coupling to radial movement.

Angular misalignment, Fig. 1, is indicated by the two shafts coming together at a slight angle. In addition to causing vibration, depending upon the type of coupling, angular misalignment causes bending stresses to be set up in the shafts, plus additional bearing loads. The amount of stress set up depends upon the resistance of the coupling to bending.

The method of alignment will vary with the number of bearings on each shaft and the type of coupling used.

In general, where each shaft to be coupled has more than one bearing, a coupling must be used which will tolerate some angular and radial displacement. This is important since it is almost impossible to secure absolute alignment between two shafts carried in separate housings. The fact that such a coupling is used does not relieve the need for aligning the shafts as close as possible.

When two shafts are to be coupled together and one has two or more bearings and the other one has a single bearing, a coupling must be used which does not have radial flexibility. Such a coupling must, however, be provided with angular flexibility. An example of this type of coupling is the one used between the main diesel engine and the single bearing generator. If two mating surfaces on each half of the coupling are coupled together and are concentric with their respective shafts, the shafts will be in radial alignment, and it will only be necessary to check angular alignment. However, in the case of generators, the rotor, stator, and bearing positions must be adjusted.

B. Alignment Principles

Three possible methods to check shaft alignment are shown in Fig. 2, a, b and c. These methods respectively are: a) straight edge and thickness gauge, b) dial indicator and micrometer, and c) the recommended method using two dial indicators. The plunger of one indicator shown in Fig. 2c, is parallel to the shaft with its button resting on the coupling face at a radius equal to or greater than the coupling disc. The plunger of the other indicator is at right angles to the shaft, with its button resting on the rim of the coupling.

The dial indicators used, similar to one shown in Fig. 3, should have a range of at least .200". This is desirable because when positioning the indicators, their

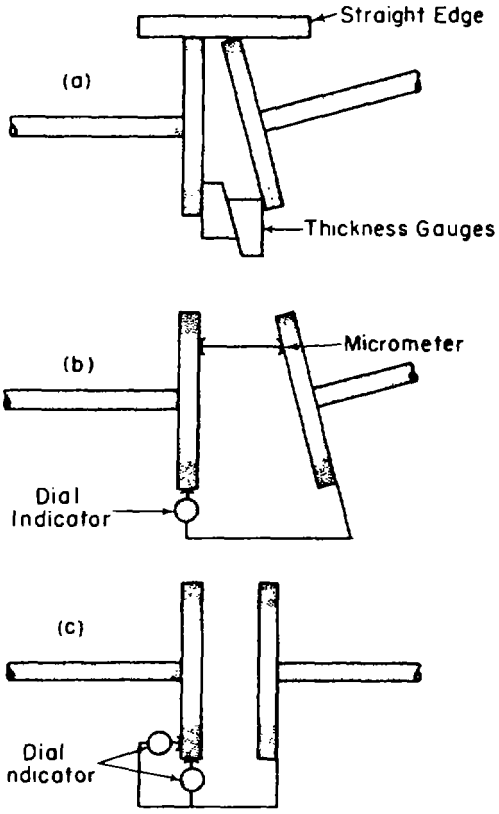


Fig. 2. - Methods Os Shaft Alignment

plungers should be depressed about .100" or about half their total travel. This will permit the indicator pointer to move "in" or "out" when the shafts and couplings are rotated.

After the indicators are applied, the coupling halves should be rotated together

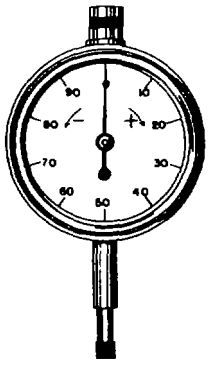


Fig. 3. - Dial Type Indicator

and both indicators brought to the uppermost or top position. In this position the bezels or movable faces of the indicators should be turned so the indicator pointers register zero (0).

Two circles, Fig. 4, should be drawn on a sheet of paper with the figure "zero" written at the top of each circle. ("Zero, " of course, is the reading on the dial indicator at the start of the check.)

One circle should be used to record the angular displacement and the other to record the radial displacement. The shafts, both driving and driven, should now be rotated together through 90° or one-fourth of a turn and a set of readings taken.

The reading on the indicator that is riding the face or back, as the case may be, of the driven flange will show the angular displacement in thousandths of an inch. This reading will be written either as a zero if the indicator does not show movement or as a plus or minus value. If the pointer moves in the direction of increasing numbers, that is, 1020-30 etc., it should be written as a plus value. If the indicator, Fig. 3, reads in the opposite direction such as 90-80-70 etc., it should be written as minus (-) 10, 20, 30 etc., respectively. We will assume it reads a + .003 for this example and therefore will record it as such.

Next, the indicator riding on the rim of the driven coupling is read. The result shows the amount of radial displacement at this point and is recorded. For example we will assume it reads + .005".

This procedure is repeated at 90° intervals and the readings recorded until the indicators are back to the same point they were at the start of the check, that is, the top. At this point both indicators should again read zero. If they do not read zero, the readings just taken should be disregarded and the entire setup checked for tightness and a new set of readings taken. If the indicators return to zero, it may be assumed that the obtained indicator readings are accurate.

A typical set of readings is shown in Fig. 4. These readings show a maximum indicator reading of .004" for coupling angularity, and a maximum indicator reading of .005" for radial run-out.

Generally speaking, the alignment of this coupling would be satisfactory for service; in most cases limits of .010" total indicator reading for angular misalignment, and .010" total indicator reading for radial misalignment are allowable.

In the above example, if it were desired to better the radial alignment, a look at the figures makes it evident that the shaft is satisfactory as far as the vertical plane is concerned; in other words, there is no need to raise or lower the shaft. It is apparent, however, that by moving the shaft a distance of .005" horizontally towards the side having the minus (-) .005" reading, the total indicator reading for radial alignment will be reduced

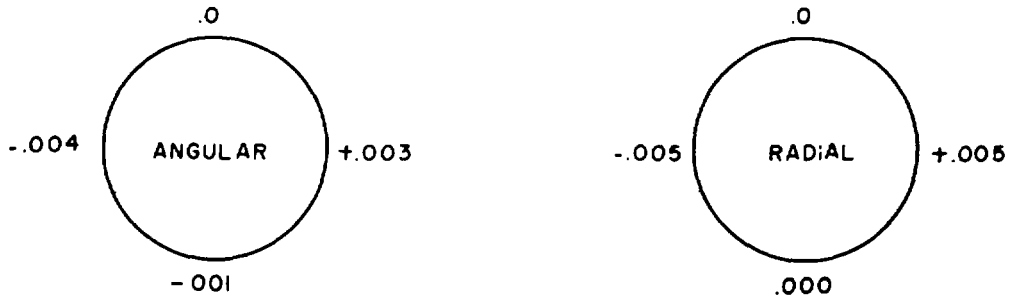


Fig. 4. - Typical Set Of Indicator Readings

to zero; this is a very desirable reading but seldom att2inable in actual practice.

Corrections for angular misalignment are made by moving the driven shaft so that its center line coincides with the center line of the driving shaft. In the case where the radial alignment is good and angular alignment is out of limits, it is apparent that the coupling end of the driven shaft is located properly, but that its remote end must be moved to correct angular misalignment.

Alignment correction is usually a combined operation calculated to correct both angular aid radial misalignment at the same time. It is difficult to give a hard and fast rule governing the thickness in shims to be removed to make a certain correction in alignment because of the varying distances from the coupling to the point at which the shaft is supported. For the correction of radial misalignment when angular alignment is within limits, it is a fairly simple matter to move the shaft at right angles to its axis, the amount shown on the dial indicator where its reading is greatest. It is well worth a few extra minutes study of the readings taken so that when the move to correct alignment is made it will be in the right direction.

There will be cases where no special tools or instructions are available to accomplish alignment of some particular piece of equipment. Some ingenuity on the part of the operator will take care of such situations. However, it should be remembered that the indicators must be securely mounted to read accurately and both shafts should be rotated together. Make a circle and record the indicator readings, and before making a move of the equipment be confident that the readings have been correctly evaluated.

In case a piece of equipment is being changed out, it is good practice to mount the replacement part on the original shims. This, generally speaking, will give the best possible starting point for alignment.

It is recommended that the alignment tools and dial indicator gauges listed in the latest revision of the Service Tools Catalog #91, should be obtained to facilitate alignment procedures used on Electro-Motive Division rotating equipment.

II. ALIGNMENT OF COUPLINGS

A. Couplings

Shown in Fig. 5 are two couplings. These are identified by individual part numbers, 8198238 and 8242730. Coupling 8242730 replaces a prior used coupling 8211729, not shown, which was quite similar.

Coupling 8242730 has a nominal free length of 6-3/4" compared to a nominal free length of 6-5/8" of coupling 8211729. Therefore, to apply coupling 8242730 in place of 8211729, it is necessary to shorten the drive shaft 1/8" or move the driven component so that the nominal free length of the coupling can be maintained within 1/32" of the 6-3/4" dimension. In addition, coupling 8242730 has provision for 12 bolts instead of 6 in coupling 8211729 at the engine flange. It is recommended that the additional six 21/32" diameter holes be drilled in the engine flange when applying the 8242730 coupling.

1. Alignment Tolerances.

   a. Coupling 8198236

      Angular alignment of coupling 8198236 should be determined by attaching a dial indicator to a bracket attached to the engine flange as shown in Fig. 6. The indicator button should contact the indicating plate attached to the opposite flange at a radius equivalent to or greater than that of the coupling outside diameter. Both flanges are to be revolved together. Angular misalignment should not exceed a .020" total indicator

reading. Indicator readings should be taken every 90° of revolution.

Radial alignment should be determined by attaching an additional dial indicator dial indicator to the indicator bracket attached to the engine flange. The indicator button should contact the indicating plate as shown in Fig. 6, or at the outside diameter

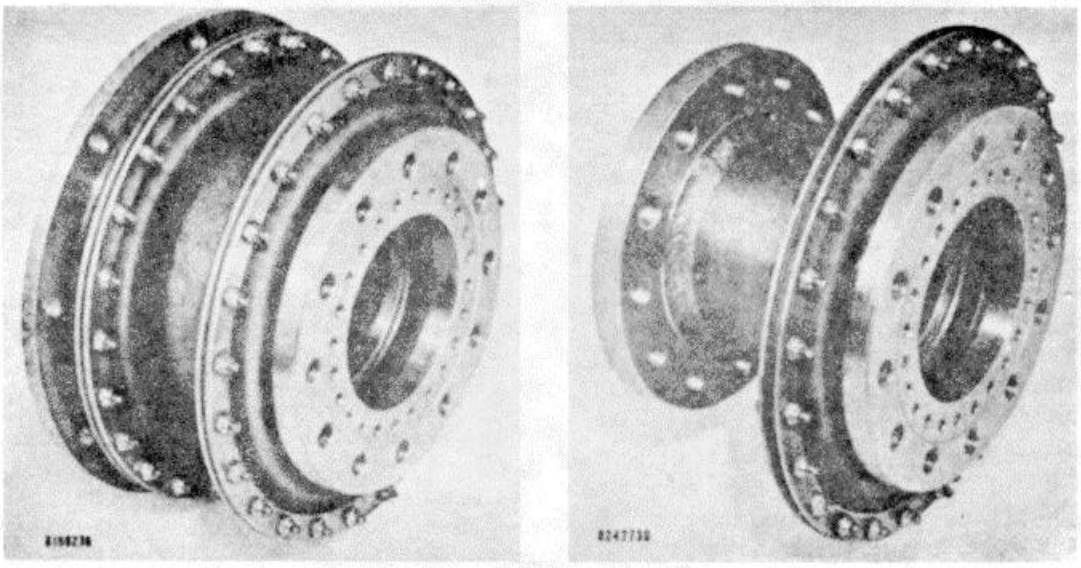


Fig. 5. - Couplings

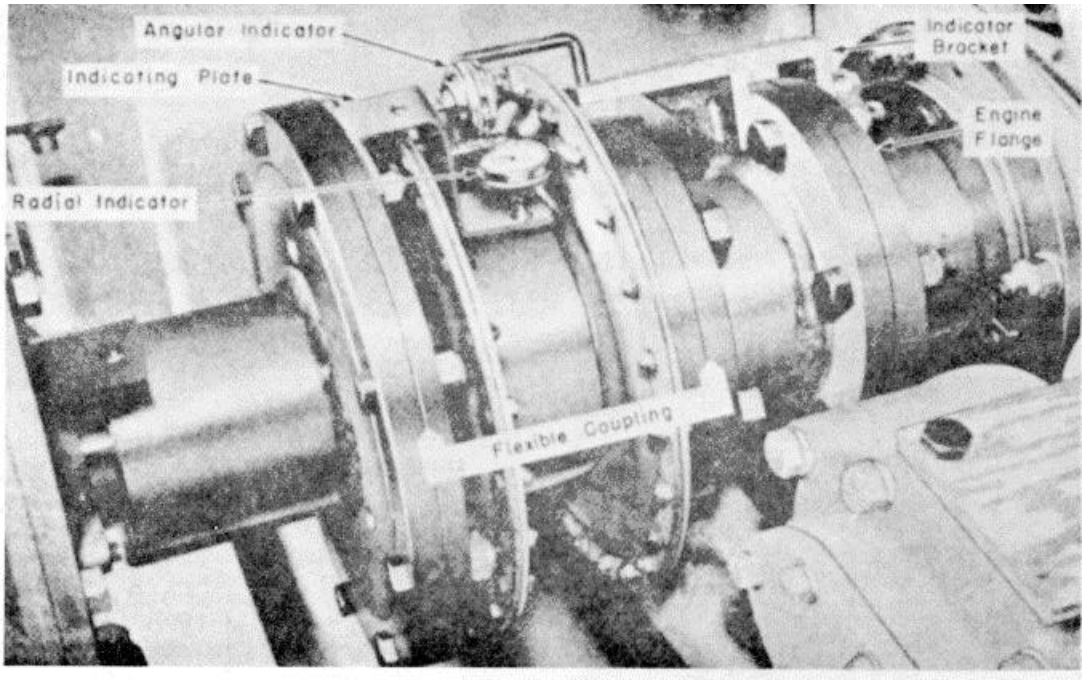


Fig. 6. - Dial Indicator Location For Alignment Of Coupling 8198236

of the end flange. Radial misalignment should not exceed .020" total indicator reading when revolving both shafts together. Indicator readings should be taken every 900 of revolution.

Upon assembly of the coupling, sufficient clearance must be provided so as not to exceed a 6" + .131".081" dimension between the outside faces of the coupling.

To maintain the alignment within the limits given, the driven equipment must be positioned by raising or lowering and/or moving to the left or right, adding whatever shims are required. After securing proper alignment, recheck the readings after bolting the unit down, and if satisfactory apply the locating dowels.

b. Coupling 8242730 Or 8211729

It is only necessary to bring these couplings within angular alignment. The angular alignment should be determined by attaching a dial indicator to a bracket attached to one coupling flange, as shown in Fig. 7. The button of the indicator should contact the back side of the flange on the opposite end of the coupling. When the coupling is assembled and the shaft rotated, indicator readings should be taken every 90° of rotation. Indicator readings must not exceed .020" total indicator readings when indicating point is on not less than an 8" diameter circle.

An assembled coupling overall length between the outside faces of the coupling should not vary more than 1/32" for either the 6-3/4" length of coupling 8242730, or the 6-5/8" length of coupling 8211729.

Positioning of the driven equipment with this coupling as with the coupling

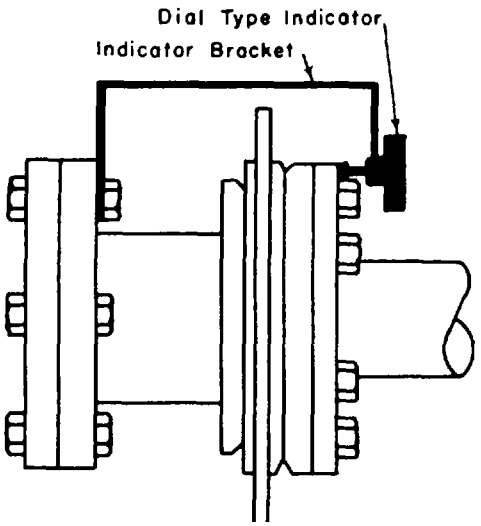


Fig. 7. - Dial Indicator Location For Alignment Of Couplings 8242730 Or 8211729

covered in (a) preceding, is required for correct alignment.

B. Rubber Coupling 8234919, 8236433 and 8236434

A representative application of the rubber drive coupling is shown in Fig. 8.

Two inspections are required when aligning or checking alignment of these couplings. The first inspection is a length measurement, or the distance between the coupling and the shaft. The second inspection is of the angular misalignment which can be checked by either one or two methods. The first method employs a dial indicator, while the second method requires the use of feeler gauges.

1. Length Measurement

The distance between the mating faces as shown in Fig. 8, must be held to .500" + .020" .000", at the 6 o'clock or bottom vertical position, with the engine at room temperature. If the engine crankshaft is hot, that is, if the e n gin e has been running, the measurement will be reduced and may be as low as .470".

2 Angular Alignment

a. Using Dial Indicator

Angular alignment at each flexing member can be measured by attaching a dial indicator, Fig. 8, to coupling flange and indicating against the face of the mating flange. Both indicators should be in the same plane when checking at two couplings.

Mount the indicators on brackets and set the dials at zero (0) with the indicator at the 12 o'clock position. During rotation of the shaft, record the indicator readings every 90° of rotation. Angular misalignment must not exceed .020" total indicator reading when indicating point is on a 10" diameter.

b. Using Feeler Gauges

Angular alignment at each flexible member can be inspected by measuring the distance between the mating flanges at 90° intervals (four points). Rotate the shaft 180° and again remeasure the distance between mating flanges at 90° intervals. The readings taken (8 for each coupling) must be within .020" of each other.

3. Replacement Of Rubber Bonded Bushing

The rubber couplings outlined in the preceding, do not require any routine maintenance or lubrication. However, it may be necessary or desirable to replace the bonded rubber bushings. The need for replacement is evidenced by accumulations of small rubber particles directly under the coupling.

To facilitate the removal and application of the rubber bonded bushing, puller tool 8239562, Fig. 9, may be used. As shown in Fig. 9, the tool parts are used in opposite sides of

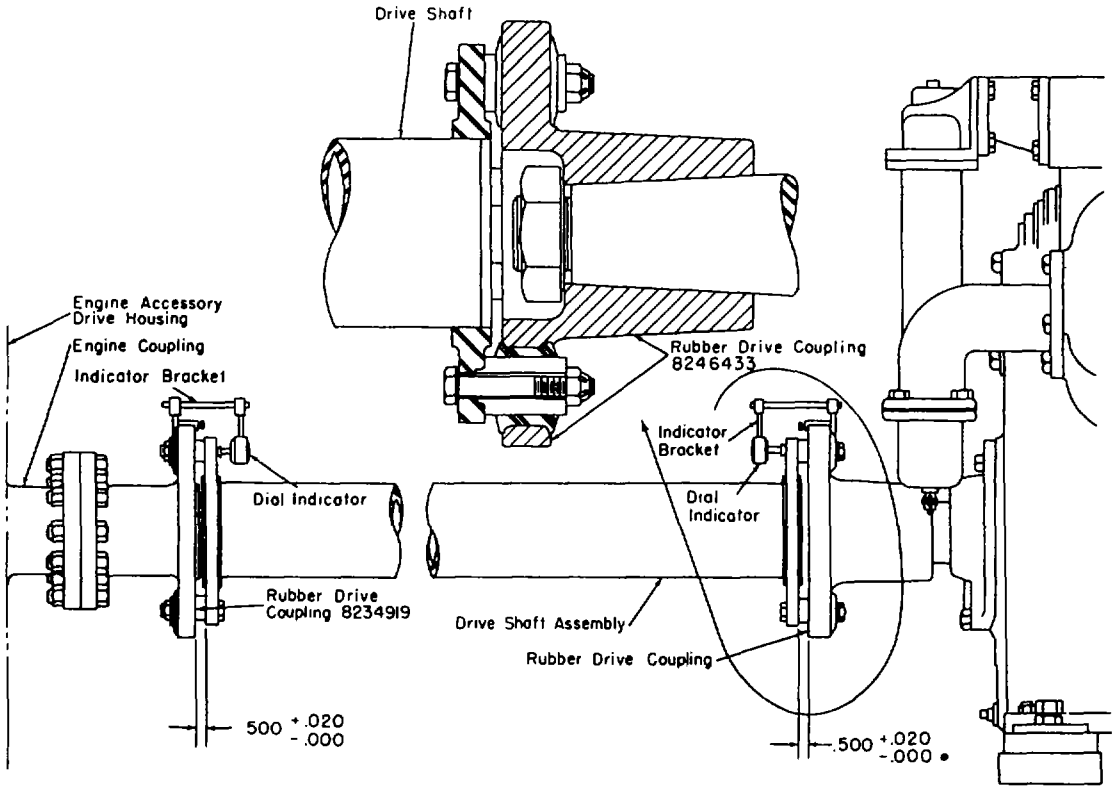


Fig. 8. - Representative Application Of Rubber Drive Coupling

the coupling depending upon removal or application of the bushings.

When installing the rubber bonded joint bushing(s), a small amount of rubber lubricant, 8251651, should be applied on the leading pressed rubber edge of the bushing. (When ordering this lubricant, it is recommended that quantity desired be specified.) Lubricant 8251651 is mixed with three to five parts of water before use, and this mixture should be stirred occasionally while in use.

NOTE: After bushing application, it is recommended that at least 72 hours elapse before installing the coupling. This waiting period is required to allow the rubber lubricant to dry. When the lubricant is still wet, the bushing can easily move from its desired location. Other lubricants may be used which are not detrimental to the bushing.

The bonded joint bushing must be installed past its normal location to

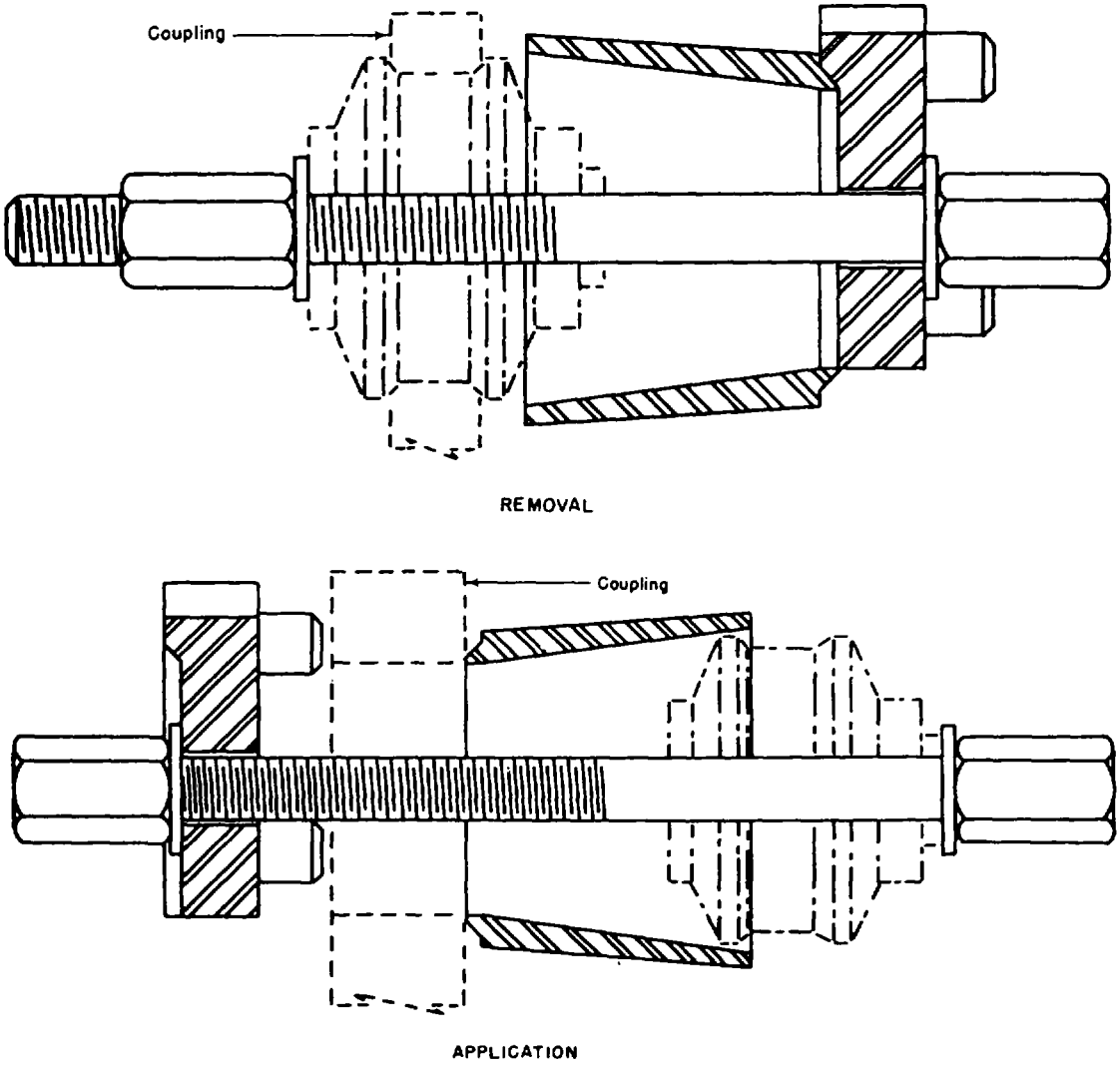


Fig. 9. - Rubber Coupling Bonded Joint Puller

properly seat the lips of the bushing. Bonded joint bushing installing and removing tool 8239562 must be reversed and the bushing centered or until a .470" ± .010" dimension shown in Fig. 9-A is obtained to maintain the bushing faces in the same plane. If tool 8239562 is not available, a press may be used to install the bushing(s).

Special gauge 8254465, Fig. 9-B is available to measure the .470" ± .010" dimension. This tool consists of a tripod-legged base supporting a lever indicating arrangement at its center. To gauge the .470" ± .010"dimension, the gauge is positioned so its large tripod legs rest on the flange of the coupling and its center actuating disc contacting the metal center sleeve of the bushing, inside the locating prongs. If the bonded joint bushing is properly located, the pointer of the gauge will be within the limiting scribe marks on the gauge scale.

A calibration fixture having three calibrating discs, .460", .470" and .480" is a part of this tool to provide a check on the gauge pointer accuracy. A large disc supplements the coupling and the smaller discs are placed on the large disc. Gauge 8254465 is placed on this simulated assembly to check the pointer positioning.

C. Morflex Design Coupling

1. General Coupling Applications

Fig. 10 shows one representative application of the dial indicator on this type of coupling for the auxiliary generator drive coupling alignment. The auxiliary generator, or exciter as the case may be, must be installed so that the mounting distance between the coupling flanges on driving and driven assembly does not vary from the coupling assembly free length more than 1/32". This information is pertinent to all general installations of this design coupling.

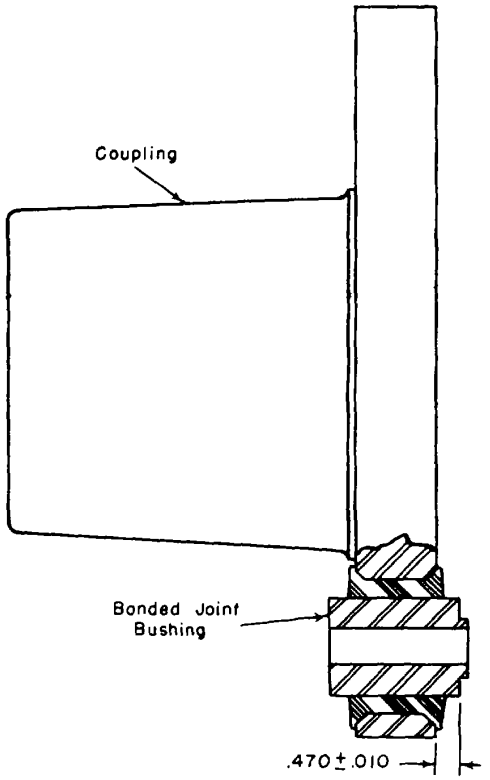


Fig. 9-A, - Application Dimension Bonded Joint Bushing To Coupling

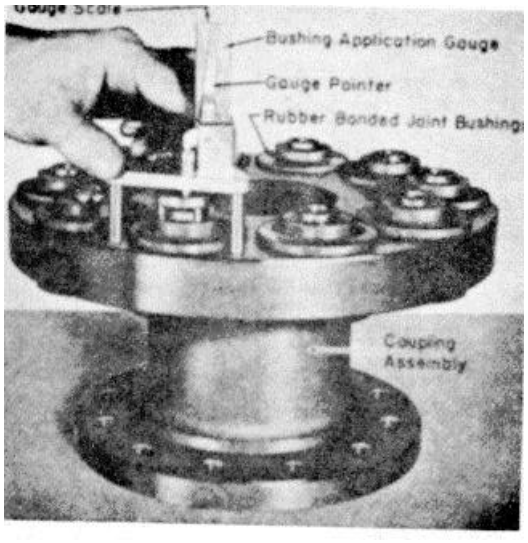


Fig. 9-B.- Bonded Joint Bushing Gauge 8254465 Application

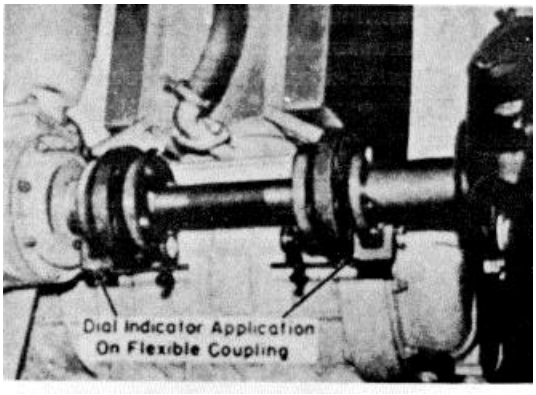


Fig. 10. Auxiliary Generator Drive Exciter Coupling Alignment

Angular alignment is checked by the indicators 8039138 mounted as shown in Fig. 10. The indicators are attached to brackets secured to the respective drive flange with the button of the indicators contacting the inner face of the inside coupling flange. Position the indicators directly across from each other at the 12 o'clock position and set the dial to zero (0). Rotate the coupling by turning the engine crankshaft, taking indicator readings every 90° of rotation. The auxiliary generator or driven equipment must be positioned and/or shims added or removed so an angular deflection shown on either indicator does not exceed .020" total indicator reading.

D. Steel Disc Couplings (All except generator couplings which are outlined in their respective applications)

A representative steel disc coupling is shown in Fig. 11. The aliment of this coupling is generally made in conjunction with another different design coupling at the drive end of the connecting shaft In this event the indicators used should be in the same plane so reading of respective locations will coincide.

Steel disc coupling angular alignment should be determined by attaching a dial type indicator to the shaft coupling as shown in Fig. 11, and the indicator button contacting against the face of the connecting flange at a radius equal to or greater than that of the disc. The equipment aligned must be positioned so that the angular alignment as shown on the indicator does not exceed a .010" total indicator reading when revolving both shafts together.

E. Falk Type Couplings

1. General Coupling Applications

A representative application of these couplings is shown in Fig. 12. This illustration shows two Falk couplings, however, the Falk couplings may be used with other coupling designs outlined in this instruction depending on the application.

Upon assembly of the couplings to the shaft, it is first necessary to provide for a clearance between the hubs of each coupling as shown in Fig. 12.

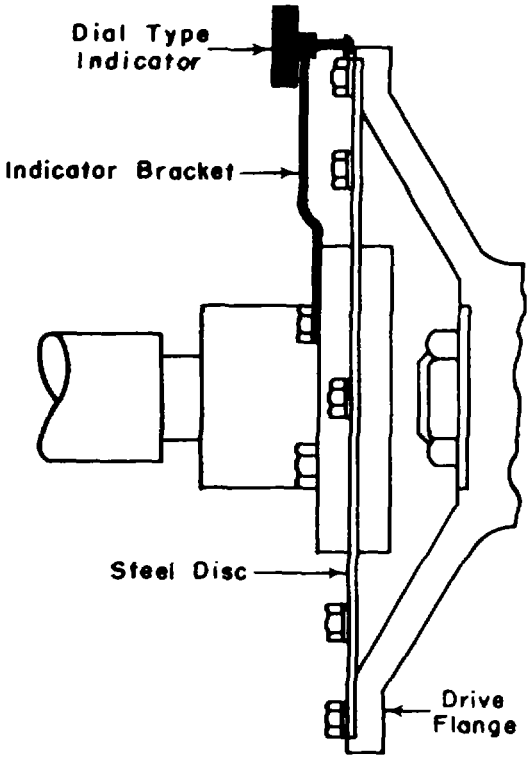


Fig. 11. - Steel Disc Coupling Alignment

The gap between the hubs of the couplings outlined under this Item 1 is minimum 1/8" and maximum of 5/16".

Couplings driving a shaft in supported except by the couplings themselves need not be aligned radially. Couplings connecting shafts both supported in bearings should be aligned radially. In either event, the couplings must be aligned angularly.

Coupling angular alignment should be determined by attaching the dial indicator to a bracket secured to either the hub or shaft as shown in Fig. 12. The indicator button may contact either the coupling cover or the face of the opposite coupling half at a radius equivalent to that of the grid member. Both coupling halves should be rotated together. Indicator readings should be taken at every 90° of rotation. Angular misalignment is not to exceed .010" total indicator reading when revolving both shafts together.

Couplings connecting shafts both supported in bearings should be checked for radial alignment. The dial indicator may be attached to the same bracket used to hold the indicator for angular alignment. The button of the indicator used for radial alignment should contact the outside of the opposite coupling half as shown in Fig. 12. Readings of both angular and radial indicators should be taken together at each 90° of rotation. Radial misalignment is not to exceed .010" total indicator reading when revolving both shafts together.

When couplings a r e assembled to floating shafts, the overall length of the assembly must be maintained within ± 1/32", to insure the centering plungers and spring operate properly. After proper alignment, lubricate the coupling and complete final assembly.

2. Falk Coupling Part Number 8109186

A gap or space must be maintained between the mating faces of the coupling as shown in Fig. 13, which should not be less than 3/16", nor more than 5/16". The driven equipment is moved to provide this gap measurement. After the gap measurement is obtained, check the alignment of the coupling.

Coupling radial alignment is determined by mounting a dial indicator to a bracket attached to the drive half of the coupling. The button of this indicator should contact the outside of the opposite half of the coupling. Radial misalignment should not

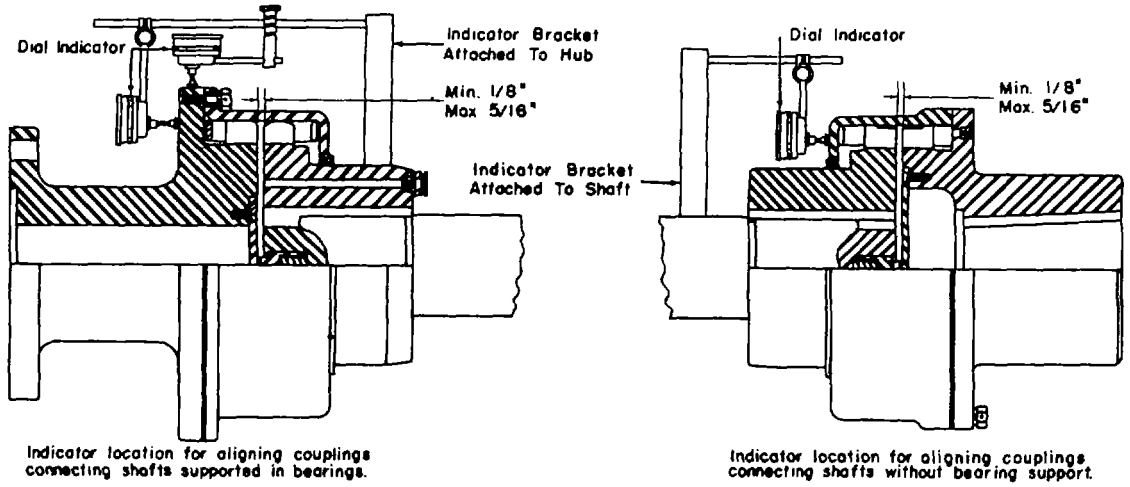


Fig. 12. - Representative Application Of Falk Type Coupling

exceed .010" total indicator reading when revolving both shafts together.

Angular alignment, Fig. 13, should be determined by measuring the gap between coupling halves at 90° intervals about the coupling circumference, using block and feeler gauge. Coupling gap is not to vary more than .010".

After positioning the driven equipment to bring the alignment within limits, secure the mounting bolts, recheck the alignment, and if satisfactory, apply the mounting locating dowels.

3. Lubrication Of Falk Couplings

To insure proper operation and service life, the Falk couplings should be lubricated according to the following procedure.

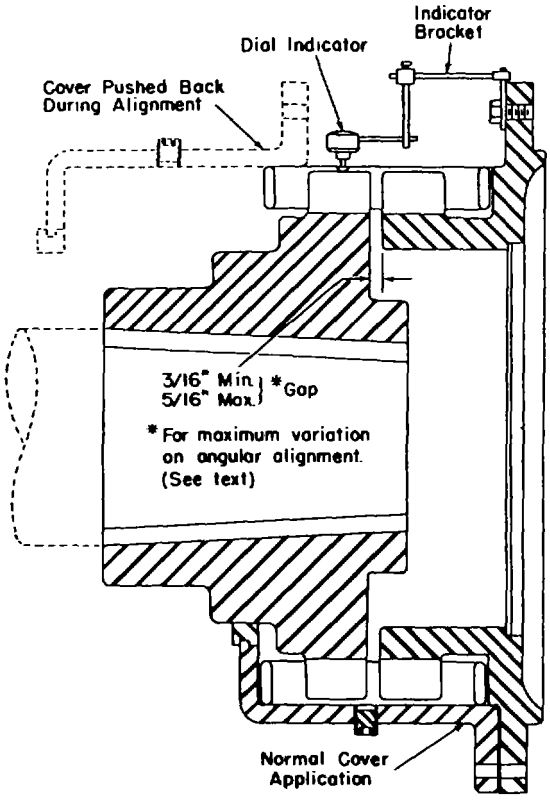


Fig. 13. Coupling 8109186 Alignment Details

When the coupling is in operation, all of the lubricant is thrown outward. Therefore, it is essential that the coupling contain sufficient lubricant to completely surround the grid springs and prevent excessive wear. The lubricant also expands, and if sufficient space is not retained for this expansion, gaskets and seals may be ruptured. The correct lubricant capacity of the coupling is half the volume of the lubrication cavity. Use a lubricant having specification similar to N.L.G.I. #3.

a. Lubrication At Installation

(1) Hand Pack

After the coupling has been aligned, and before inserting the grid spring into the grooves, fill the gap between the coupling faces with lubricant and pack the lubricant into the grid grooves. After installing the grid springs, pack the spaces between and around the springs with lubricant. Add lubricant to the ends of the springs to completely fill the cover when in a closed position.

(2) Pressure Fill

When pressure lubricating equipment with a meter for determining quantity is available, the coupling may be assembled dry and then filled with a specified amount of lubricant as given under following Table I. The lubricant is applied through one of two tapped openings in the coupling. The other tapped opening must be opened during filling to vent the coupling.

b. Routine Lubrication

To replenish the supply of lubricant during regular maintenance operations, the coupling should be

rotated to place the plugged openings on the coupling's horizontal center line. Remove both pipe plugs and apply pressure fitting to one opening only. Add lubricant until level with vent opening. Then remove pressure fitting and reinstall pipe plugs in both openings.

TABLE I

Coupling Size	Gap Between Faces		Lubricant Req'd - Lt
	Min.	Max.	
4	1/8"	3/16"	1/8
7	1/8"	5/16"	1/2
11	1/8"	5/16"	1-1/4
12	1/8"	5/16"	1-1/2
13	3/16"	5/16"	1-7/8
14	1/8"	5/16"	2-1/8
15	1/8"	5/16"	2-1/2

III. ALIGNMENT OF POWER UNIT SYNCHRONOUS GENERATORS

A representative illustration of these synchronous generators is shown in Fig. 14. They are all similar in appearance, but are of different capacity. Nominal ratings of these generators are: All-416 1000 KW, A7-416 750 KW and A5, A5A416 500 KW. Information contained in this instruction will enable a qualified person to align these generators to the engines on Mobile Power Cars, Mobile Highway Units and Model "S" Power Plants.

The prime mover and the synchronous generators installed in any of the aforementioned units have been correctly aligned and tested by before the unit is delivered.

Power units such as the Mobile Railcar and the Mobile Highway units are so constructed that they may be moved from place to place and may be operated at any location. In some cases they may be placed on supports for temporary or permanent installation. These units are designed for this service and consequently once alignment is correctly made, it will remain stable, under normal conditions.

Model "S" power plants are generally installed on a permanent foundation at a permanent location. They may be set directly on the foundation or the subbase may be set on isolation mounts to

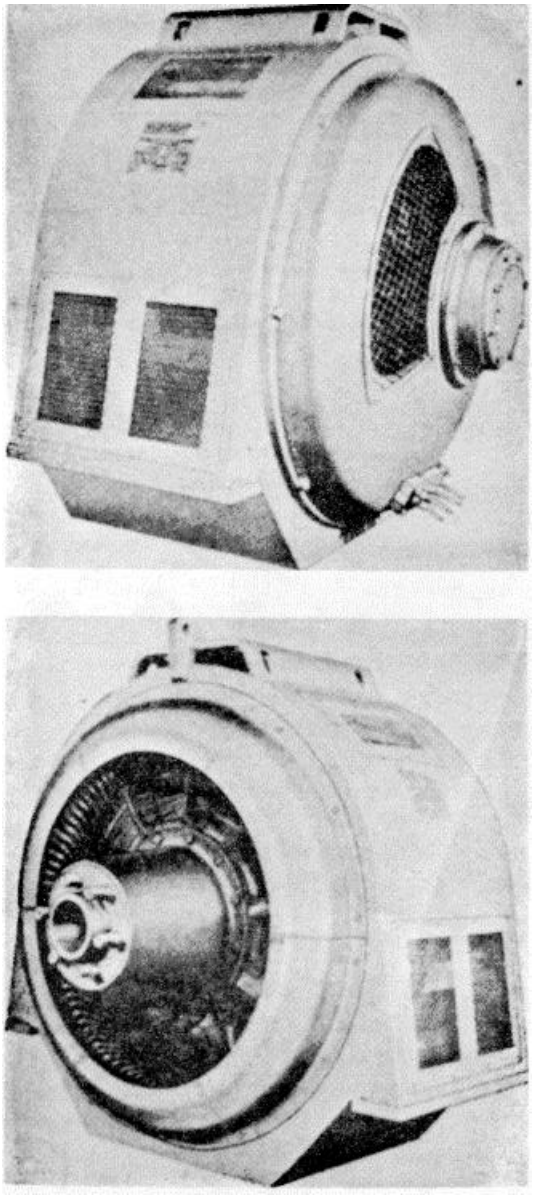


Fig. 14. - AC Synchronous Generator

minimize vibration. In any event the unit subbase should be checked longitudinally and transversely for being level in both directions within 1/16", before checking or aligning the generator.

Equal in importance to shaft alignment when installing a generator is a relation between the rotor and stator to provide a uniform air gap and axial positioning so magnetic alignment will not be impeded during operation. A non-uniform air gap is susceptible to magnetic force which acts on the rotor in the direction of the lessor gap. This force may be great enough to cause interference between the rotor and stator with its accompanying damage. A non-uniform air gap will also cause excessive heating, electrical losses, greater bearing pressures and vibration. Magnetic misalignment will result in a constant thrust to seek its position.

NOTE: Reference to crankshaft deflection measurements are not given in the alignment of the single self-aligning bearing generators outlined in this instruction. Crankshaft deflection is of no consequence when aligning the single self-aligning bearing generators, if they are aligned within the allowable limits. The self-aligning bearing will tolerate slight shaft misalignment since it can act independently within the alignment limits. However, crankshaft deflection measurement is important in aligning two bearing generators.

A. Serrated Coupling Instructions

The serrated coupling, Fig. 15, is basically used for all current engine to generator flexible couplings. Upon installation of the generator, it is matched up to the engine coupling, rim bolts applied, and checked as follows.

1. The gap between the engine and generator coupling halves should not be less than.005". The gap as measured midway between bolts must be uniform within .002" around the entire periphery of the coupling joint. The gap at the bolts must also be uniform, but will be .003" to .005" less than that between bolts.

2. The recessed indicator surface and the serrations on the coupling are held concentric with the center bore. The entire rotating assembly is balanced about this same center. Thus the run-out of the indicator surface is a measure of out of balance. Concentricity is riot held on the outside rim of the coupling disc except at the fan pilot on particular applications.

B. Installing The Generator

Before placing the generator on its base, inspect the mounting pads of both the generator and base to be sure they are clean and smooth, and free from raised nicks and burrs. Also check the shims which will be used, for smoothness.

Place an approximately one-eighth inch thick shim on the base pad. Wipe the top of the shim with a clean oil dampened rag.

Using a suitable hoist, place the generator on the subbase. The front of the generator mounting leg should be about 6" from the engine end of the base mounting pad to avoid possible damage to the engine blower support. (Approximate weights of the generators are: A11-416, 13, 2601bs.; A7-416, 11, 1401bs.; and A5A-416 or A5-416, 9, 170 lbs.)

Using a jack, move the generator toward the engine disc, but not contacting the disc or center shaft pilot. Examine the line up of the two discs and the center pilot that the discs may be brought together without interference. Also check the center holding nuts of the two discs that there will be no interference. See that the rim bolt holes of each disc are also in alignment. If turning is required, rotate the engine disc using the turning bar. If necessary to raise the generator

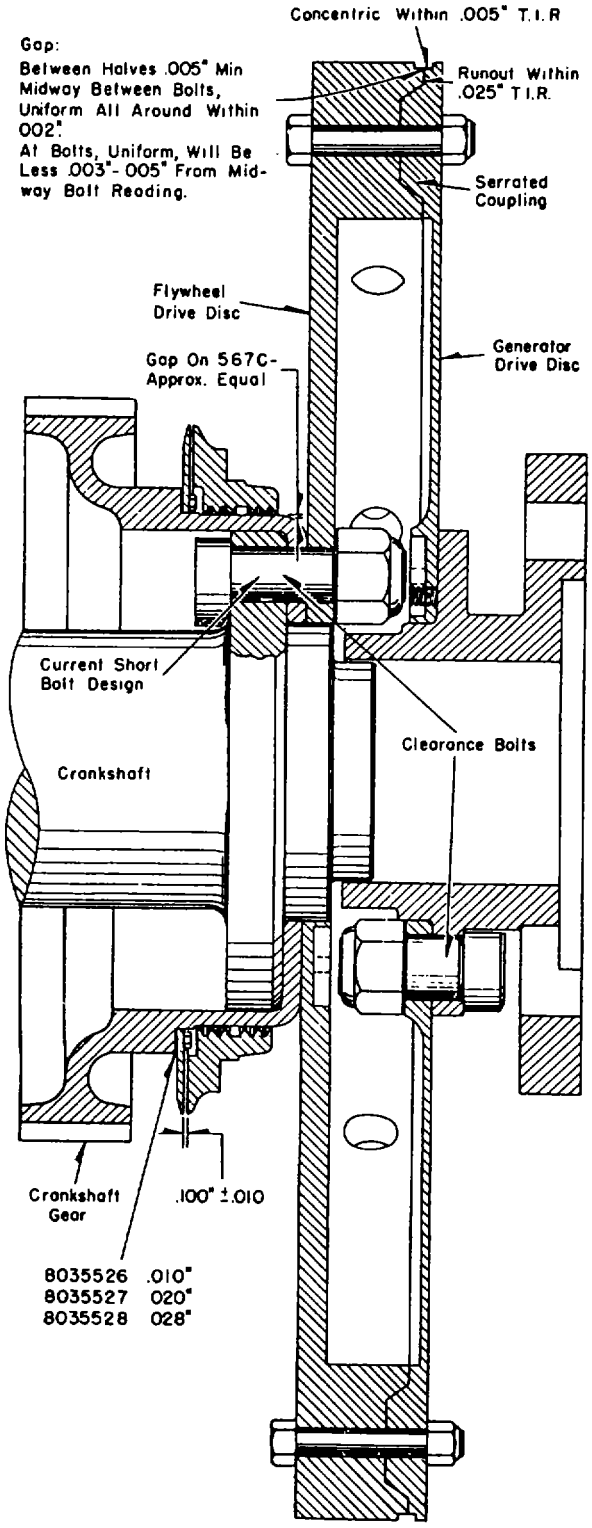


Fig. 15. - Serrated Design Engine To Generator Flexible Coupling

to permit coupling line up, use jacking screws 8164036 in the tapped holes provided in the generator supporting legs. Apply shims as required and lower the generator.

After making sure that the generator and engine disc can be brought together satisfactorily, jack the generator toward the engine to permit disc to disc application. Apply two coupling bolts to hold the discs together. Do not rotate the flywheel until the support shims between the rotor and stator are removed.

After the rotor is free to be turned, rotate the flywheel and apply the remaining coupling bolts. Torque the coupling rim bolt nuts to 295 foot pounds. Review the information regarding the serrated coupling, given under III-A. Open cylinder test valves on the engine several turns, to relieve cylinder compression while rotating the flywheel.

C. General Alignment Information

Instructions covering the alignment of specific generators will be given in the following, to include particulars affecting each generator or a group of generators. In general each instruction will follow a set operational procedure as outlined below.

1. Bearing Positioning, Thrust Clearance Or End Play

   a. This is the longitudinal positioning of the bearing in its housing and armature location in reference to the stator frame.

      During the armature frame assembly, the armature is purposely positioned so that its end movement is all taken up in the direction toward the engine coupling disc, to determine the total longitudinal end play. This permits a bearing dimension to be obtained so that proper thrust clearance is provided at each end of the bearing. Thrust clearance of the bearing is about 1/16" at the engine end and 1/8" at the opposite or outboard end of the bearing. Positioning of the armature to obtain these clearances is made by a reference measuring point on each generator. Proper positioning of the single bearing also automatically positions the armature in relation to the frame on end bell type generators.

2. Generator Shaft Alignment And Air Gap Equalization

   a. Radial Alignment

      Radial alignment of the armature is required to equalize the air gap between the armature and field poles.

   b. Angular Shaft Alignment

      Angular shaft alignment provides for the coaxial positioning of the generator shaft with the engine crankshaft to neutralize any generator shaft inclination.

      Operations "a" and "b" under Item 2 are carried out at the same time, after first completing Item 1.

D. Alignment Of Models A11-416, A7 -416, A5A-416 And A5-416 (Except Model A5-416 And A5A-416 Used On Model MH8 Highway Units)

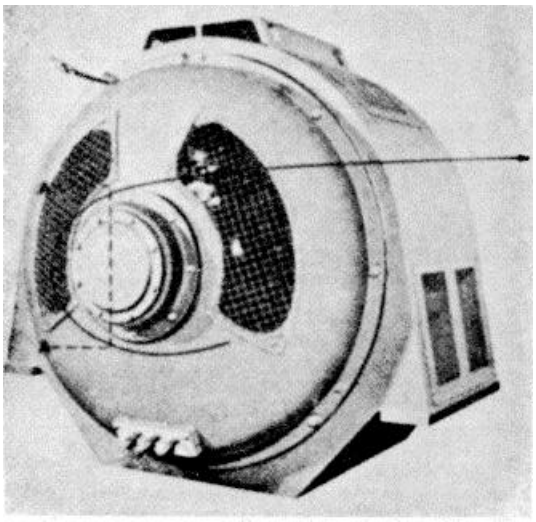
1. Bearing Positioning, Thrust Clearance Or End Play

   a. The total end play of the bearings on these generators is about 3/16". (The 3/16" dimension may change if parts are replaced.) A thrust clearance or end play of 1/16" + .000" 1/64" must be maintained between the inside bearing cap and bearing outer race on these generators.

   b. The 1/16" + .000" - 1/64" clearance is determined by positioning the generator frame in respect to the armature equal to 1/16" less

than reference measurement "x, " Fig. 16. Dimension "x" is determined at original generator assembly by moving the armature as far as possible toward the engine coupling, then measuring the distance from the outside surface of the bearing cover, Fig. 16, to the bearing outer race, measured through a 5/32" diameter hole in the cover.

Reference measurement "'x" will be approximately 1-7/8" on A11 and A7 generators, and about 1-1/2" on A5 and A5A generators. This measurement to the nearest 64th of an inch is stamped (on later generators) either on the bearing cover or end bell in 1/2" high numerals. Consequently, to provide the 1/16" clearance at the inner bearing cap pilot flange and the bearing outer race, the stator must be positioned so dimension "x" equals about 1-7/8" or 1-1/2" (depending on the generator) minus 1/16" or 1-13/16" or 1-7/16" respectively. This procedure should result in about 1/8" clearance for crankshaft expansion at the outer bearing pilot and outer race.



The generator base bolts are tightened after the stator is located, in preparation for alignment.

2. Generator Shaft Alignment And Air Gap Equalization

The aligning procedure is divided into two operations, both of which are carried out at the same time. Any angularity of the generator - engine disc coupling is neutralized and the air gap is balanced between the generator rotor poles and stator laminations.

Two indicators mounted as shown in Fig. 17 are used. The plunger of one indicator contacts the generator disc between the rim bolts and the plunger of the second indicator rides on the machined inside diameter of the stator frame pilot. The indicators are mounted on rods screwed into 1/4" pipe thread tapped holes in the generator coupling adapter. Two rods are required, 8122000 14" long at the coupling end and 8067338 20" long at the generator end. A dial

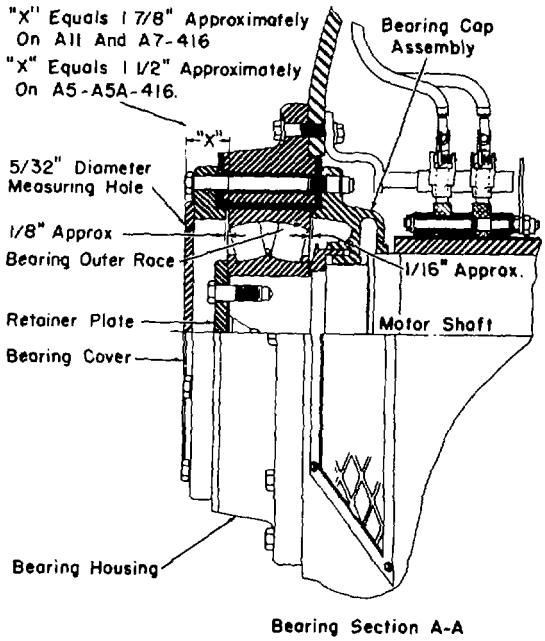


Fig. 16. - Bearing Clearance Dimensions
AC Synchronous Generators

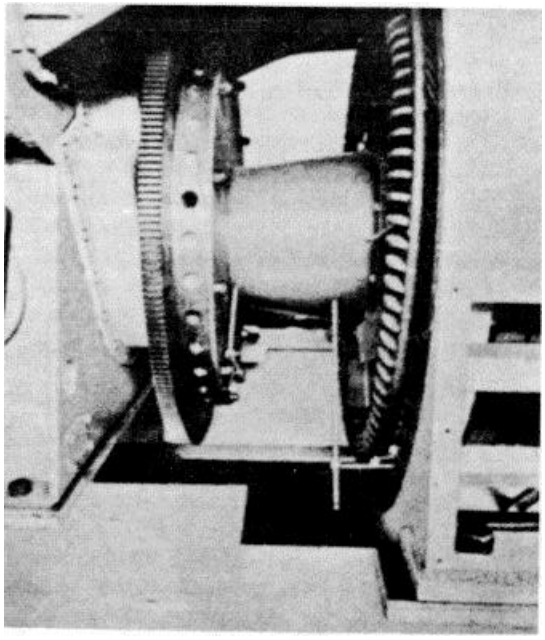


Fig. 17. - Generator Shaft Alignment And Air Gap Equalization

indicator 8039138 can be used, one on each rod. Both indicators will revolve with the rotor.

After clamping the indicators on .the rods and ascertaining that the rotor and crankshaft are free to rotate (coupling bolted securely), turn the rotor to place the indicator rods in the top vertical position. Depress the indicators to complete one turn and then secure it and adjust the knurled bezel to locate the pointer at zero (0). Check indicator installation that it is satisfactory. Depress slightly the indicator button and release to check pointer action. Turn the rotor one revolution using a turning bar in the flywheel to check indicator application. When the indicators are returned to the original position the pointer should again indicate zero.

Starting again from the top vertical position, record the indicator readings which are taken every 90° of rotation. The generator is considered to be aligned when the indicator readings correspond to the limits given in Fig. 18.

The stator may require slight relocation and or shim adjustment may be necessary under the generator supports. Full length shims should be used if possible, however, spot shims may be used to conform to the limits given in Fig. 18, for the coupling and air gap. Since any movement of the generator frame affects both the air gap and the coupling, readings must be repeated following any correction. Also, the bearing thrust dimensions should be carefully rechecked after final coupling alignment to be sure that the measurement at the front bearing cover is correct.

After final tightening of the generator hold down bolts, recheck the alignment tolerances to be sure they have not changed. If tolerances are satisfactory, dowel the generator to its mounting base.

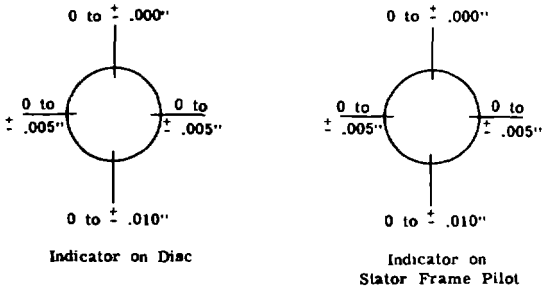


Fig. 18. - Alignment Dial Indicator Tolerances AC Generator (Except MH8 Application)

E. Alignment Of Generator Models A5-416 And A5A-416 In MH8 Mobile Highway Units

NOTE: The MH8 Mobile Highway Unit should be placed at a level location before aligning the generator, so the carbody will be level. Also the unit should be supported by its own tires and support jacks which are adjusted to attain the level condition.

1. Bearing Positioning, Thrust Clearance Or End Play

   a. The total end play of the bearings of these generators is about 3/16". (The 3/16" dimension may change if parts are replaced.) A thrust clearance or end play of 1/16" + .000" 1/64" must be maintained between the inside bearing cap and bearing outer race on these generators.

   b. The 1/16" + .000" 1/64" bearing clearance is determined by positioning the generator frame in respect to the armature equal to 1/16" less than reference measurement "x, " Fig. 18. Dimension "x" is determined at original generator assembly by moving the armature as far as possible toward the engine coupling, then measuring the distance from the outside of the bearing cover, Fig. 16, to the bearing outer race, measured through a 5/32" diameter hole in the cover.

      Reference measurement "x" will be approximately 1-1/2"on A5 and A5A-416 generators. This measurement to the nearest 64th of an inch is stamped (on later generators) either on the bearing cover or end bell in 1/2" numerals. Consequently to provide the 1/16" clearance at the inner bearing cap pilot flange and bearing outer race, the stator must be positioned so dimension "x" equals 1-1/2" minus 1/16" or 1-7/16". This procedure should result in about 1/8" clearance for crankshaft expansion at the outer bearing pilot and outer race. After stator location is made the base bolts are tightened in preparation for alignment.

2. Generator Shaft Alignment And Air Gap Equalization

   The aligning procedure is divided into two operations, both of which are carried out at the same time. Any angularity of the generator -engine disc coupling is neutralized and the air gap is balanced between the generator rotor poles and stator laminations.

   Two indicators mounted as shown in Fig. 17 are used. The plunger of one indicator contacts the generator disc between the rim bolts and the plunger of the second indicator rides on the machined inside diameter of the stator frame pilot. The indicators are mounted on rods screwed into 1/4" pipe thread tapped holes in the generator coupling adapter. Two rods are required, 8122000 14" long at the coupling end and 8067338 20" long at the generator end. A dial indicator 8039138 can be used, one on each rod. Both indicators will revolve with the rotor.

   After clamping the indicators on the rods and ascertaining that the rotor and crankshaft are free to rotate (coupling bolted securely), turn the rotor to place the indicator rods in the top vertical position. Depress each indicator to complete one turn then secure it and adjust the knurled bezel to locate the pointer at zero (0). Check indicator installation that it is satisfactory. Depress slightly the indicator button and release to check pointer action. Turn the rotor one revolution using a turning bar in the flywheel to check indicator application. When the indicators are returned to the original position the pointer should again indicate zero.

   Starting again from the top vertical position, record the indicator readings which are taken every 90° of rotation. The generator is considered to be aligned when the indicator readings correspond to the limits given in Fig. 19.

   The stator may require slight relocation and or shim adjustment may be necessary under the generator supports. Full length shims should be used if possible, however, spot shims may be used to conform to the limits given in Fig. 19, for the coupling and

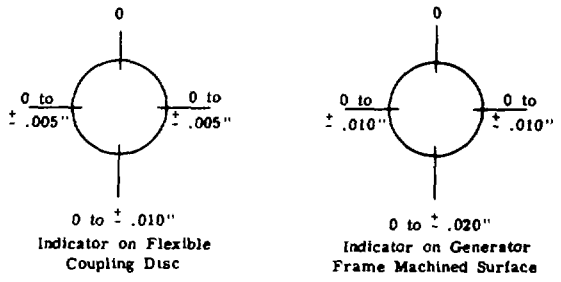


Fig. 19. - Dial Indicator Alignment Tolerances Model A5A-416 EMD AC Generator On Model MH8 Highway Unit

air gap. Since any movement of the generator frame affects both the air gap and the coupling, readings must be repeated following any correction. Also, the bearing thrust dimensions should be carefully rechecked after final coupling alignment to be sure that the measurement at the front bearing cover is correct.

After final tightening of the generator hold down bolts, recheck the alignment tolerances to be sure they have not changed. If tolerances are satisfactory, dowel the generator to its mounting base.

F. Alignment Of Synchronous AC Generators Other Than EMD Model "A, " Having A Single Bearing In The Bell Housing

1. Bearing Positioning, Thrust Clearance Or End Play

a. The total end play of the bearings of these generators is about 1/4". A thrust clearance or end play of 1/16" + .000" - 1/64" must be maintained between the inner bearing cap and the bearing outer race.

b. The 1/16" + .000" 1/64" bearing clearance is determined by positioning the generator frame in respect to the armature equal to 1/16" less than reference measurement "x" similar to that shown in Fig. 16 on EMD Model "A" generators. Dimension "x" is determined at original generator assembly by moving the armature or rotor as far as possible toward the engine coupling, then measuring the distance from the outside surface of the bearing cover, to the bearing outer race, measured through a 5/32" diameter hole in the cover.

Reference measurement "x" will be approximately 1-3/4" when measured through the 5/32" hole in the cover. Consequently to provide the 1/16" + .000" 1/64" clearance at the inner bearing cap and bearing outer race, the stator must be positioned so dimension "x" equals 1-3/4" minus 1/16" or 1-11/16". This procedure should result in about 3/16" clearance at the opposite end of the bearing. After stator is correctly positioned, tighten the base bolts in preparation for alignment.

2. Generator Shaft Alignment And Air Gap Equalization

The aligning procedure is divided into two operations, both of which are carried out simultaneously: 1) neutralizing the angularity of the generator-engine disc coupling; 2) balancing and setting the air gap between the generator rotor poles and the stator laminations. By means of one indicator mounted on a rod which is screwed into a tapped hole in the coupling flange, and when the stator frame has a machined face or pilot available a second indicator can be mounted on the above mentioned rod, a measurement of the coupling angularity and generator air gap variation is determined. (When the stator frame does not have a machined face or pilot the air gap variation must be determined by the use of feeler gauges placed between the rotor pole laminations and the stator laminations.) The indicators will revolve with the rotor. The plunger of one indicator will ride on the generator disc face of the coupling and when

two indicators are used the plunger of the second indicator will ride on the machined face or pilot of the generator stator.

When the generator and engine are free to be rotated manually, that is, fish paper shims removed, coupling bolted up and so forth, the shaft is turned so that the indicator rod will be in a vertical position pointing upward. This will place the indicator or indicators near the top of the stator frame. At this point the indicator or indicators are set at zero (0). From this point, the rotor is revolved a half a revolution (180°) in a clockwise direction (facing the slip ring end of the generator).

Indicator readings are to be taken at 90° and 180° points. The rotor is then revolved three-quarters of a revolution (270°) in a counterclockwise direction and indicator readings taken at this point. The generator is considered to be aligned when using two (2) indicators when a set of readings within those shown in Fig. 20 are obtained.

When a second indicator cannot be used on the stator frame, the indicator on disc readings will be the same but the air gap between the rotor poles and the stator laminations must be taken with feeler gauges and the total air gap variation must not exceed 0.010".

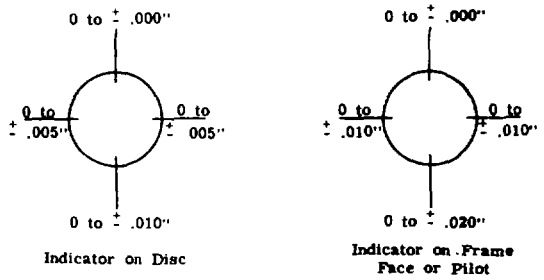


Fig. 20. Dial Indicator Alignment Tolerances Single Bearing In Bell Housing Synchronous Generators Other Than EMD Model "A"

G. Alignment Of Synchronous Generators Having One Pedestal Bearing

1. Bearing Positioning, Thrust Clearance Or End Play

Since the single bearing is located in a pedestal separate from any end housing of the generator, the bearing positioning and stator to rotor relative longitudinal positioning requires two separate operations.

a. Locating The Bearing In Its Pedestal

There is a designed total clearance or end play of 3/16" + 1/64" 0", between the bearing race and its housing. The rotor is properly positioned relative to the bearing assembly when there is a clearance of 1/8" + 1/64" 0", between the bearing outer race and the housing at the outboard end and at the generator end a 1/16" clearance.

After the generator disc has been coupled to the engine disc, rim bolts applied and torqued and rotor free, the rotor is positioned relative to the bearing as follows.

(1) Remove an engine oil pan inspection cover, and using a suitable bar, force the engine crankshaft toward the generator to remove crankshaft thrust in this direction.

(2) Relieve rotor shaft weight from the bearing pedestal and without moving the rotor, position the bearing pedestal as far as possible axially toward the engine.

(3) Scribe or otherwise mark the rotor shaft where the bearing cap meets the shaft.

(4) Then move the bearing pedestal away from the engine until there is a measured distance between the shaft marks and bearing cap of 1/8" + 1/64" - 0". This will provide the bearing clearance dimensions given.

b. Stator To Rotor Positioning

After obtaining the axial position of the rotor with respect to the bearing, the axial positioning of the stator with respect to the rotor must be established. This can be accomplished by moving the stator axially until the rotor poles protrude on both sides an equal distance from the stator laminations and is to be held within ± 1/8".

When the stator is correctly positioned relative to the rotor, tighten the base bolts in preparation for shaft and air gap alignment.

2. Generator Shaft Alignment And Air Gap Equalization

The aligning procedure is divided into two operations, both independent of each other. One operation is neutralizing any angularity of the generator shaft and simultaneously adjusting the bearing cap labyrinth to shaft clearance. The other operation is equalizing the air gap between the rotor poles and the stator.

a. Neutralizing Angularity And Adjusting Bearing Labyrinth Clearance

Generator shaft angularity is checked by a dial type indicator which is placed so that its plunger is contacting the inside face of the coupling disc at the bolt circle. The indicator is mounted on a support attached to a rod which is screwed into a tapped hole in the hub of the rotor shaft. The indicator revolves with the rotor when it and the engine crankshaft are free to be turned, that is, coupling securely bolted, bearing pedestal properly located and any protective supports between the rotor and stator removed.

After clamping the indicator on the rod and it is ascertained that the shaft is free to rotate, turn the rotor to place the indicator at the top vertical position. Depress the indicator to make the pointer complete one turn and secure it, then turn the knurled bezel to bring the pointer to zero (0). Check the indicator installation to make sure it is satisfactory. Depress the indicator slightly and release it to check pointer action. Turn the rotor one revolution, using a turning bar or jack at the flywheel, to check indicator application. When the indicator is returned to the original position, the pointer should again indicate zero. If not, further adjustment to correctly position the indicator is necessary or the indicator is defective.

Starting again with the indicator at the top vertical position, rotate the rotor and record the indicator reading every 90°. Also, at the time of taking the indicator reading, the gap between the bearing cap labyrinth and the rotor shaft should be taken every 90° and recorded.

The angularity of the generator to engine coupling is neutralized and bearing labyrinth clearances are adjusted by shifting the bearing pedestal and/or placing shims under the pedestal. The shaft alignment and bearing labyrinth clearance are considered satisfactory when the readings are to or within the tolerances for these locations shown in Fig. 21.

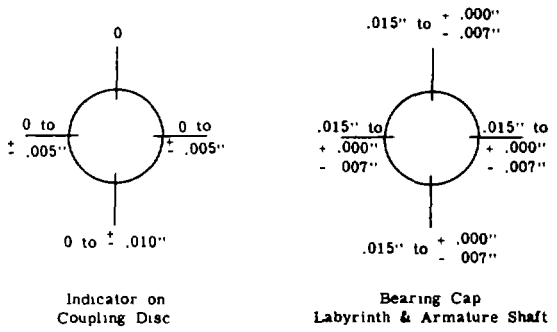


Fig. 21. Dial Indicator Alignment Tolerances Bearing Cap Labyrinth To Armature Shaft Tolerances Single Pedestal Bearing Synchronous Generators

b. Air Gap Equalization

The air gap can only be measured to a close tolerance by removing the paint from the stator and rotor where the measurements are to be taken and it should be done in the following locations:

(1) The paint should be removed from the inside diameter of the stator laminations in a patch four inches wide and six inches deep, the depth running from both ends of the stator lamination assembly inward and located on a radial line, Fig. 22, 36° either side of the stator diameter vertical center line, top and bottom. This will provide eight measurement points on stator.

(2) The paint should be removed from the outside diameter of one pole in a patch three inches wide and six inches deep, the depth starting at both ends of the pole, and the width located symmetrically about radial center line of pole. This will provide two measurement points on rotor.

After the paint is cleaned off as indicated, number the scraped poles (and the stator frame) with chalk, placing the numbers in a visible position on the slip ring side of the generator so that the pole location, with respect to the stator, is known at all times. The air gap between the rotor and stator should be obtained by placing a feeler gauge between the rotor and stator at the points where the paint has been removed. The feeler gauges must extend to a minimum depth of 4 inches from the outer edge of the pole end piece and the measurements should be taken at both ends of the poles.

Clearances for points A, B, C and D of Fig. 22 are to be held to within .010" of each other. The total variation between any of the four (4) readings should not be more than .010". The difference in air gap at either end of the pole piece cannot vary over .005".

The shaft should be rotated so that the pole which is marked #1 will stop at points A, B, C and D where readings are taken. The necessary adjustments should be made by shifting the stator frame and/or placing shims under the mounting feet to raise it.

After final tightening of the generator hold down bolts, recheck the alignment tolerances to be sure they have not changed. If tolerances are satisfactory, dowel the generator to its mounting base.

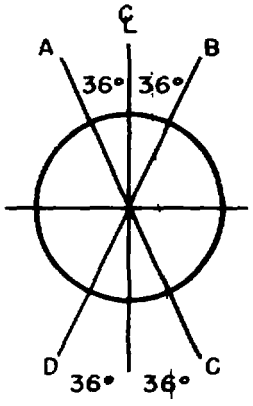


Fig. 22. Rotor And Stator Front And Rear Single Pedestal Type Synchronous Generators

IV. SPECIFICATIONS

COUPLING ALIGNMENT TOLERANCES

COUPLINGS

	Limits	
	Radial	Angular
EMD Design 8198236	.020"	.020"
8242730 or 8211729	Not Req'd	.020"
Rubber Couplings		
8234919, 8236434	Not Req'd	.020"
8246434	See II-B for distance between faces.	
Morflex Coupling	Not Req'd	.020"
	Distance between faces at assembly should not exceed free length more than 1/32".	
Steel Disc (Not Generator Coupling)	Not Req'd	.010"
Falk Couplings	.010"	.010"

	Gap Between Faces	
	Min.	Max.
#7, 11, 12, 14 and 15	1/8"	5/16"
#4	1/8"	3/16"
#13	3/16"	5/16"

ALTERNATORS (GENERATORS)

Model	Bearing Clearance		Ref. Dim. "X"	Alignment Air Gap (Top"0")		Angular-Coupling	
	Outboard	Inboard		Sides	Bottom	Sides	Bottom
A11-416 A7-416	Approx. 1/8"	1/16" +.000" -1/64"	1-7/8"	±.005"	±.010"	±.005"	±.010"
A5-416 A5A-416 Other than MH8 Unit	Approx. 1/8"	1/16 -.000" -1/64"	"1-1/2"	±.005"	±.010"	±.005"	±.010"
A5-416 A5A-416 on MH8 Unit	Approx. 1/8"	1/16" +.000" - 1/64"	1-1/2"	"0" to -.010"	"0" to -.020"	+.005" +.015"	+.010" to +.030"
Other than EMD Bell Housing Bearing	Approx. 3/16"	1/16 +.000" - 1/64"	1-3/4"	±.010"	±.020"	±.005"	±.010"
Single Pedestal Bearing Gen.	Approx. 1/8"	1/16"		For air gap, stator positioning and coupling limits, see Item III-G.			

MAGNAFLUX INSPECTION OF ENGINE COMPONENTS

DESCRIPTION

Engine components are designed and manufactured to provide excellent service over an extended period of time. Upon removal of such components from the engine, they should be carefully inspected to qualify them for continued service. Such inspections generally include dimensional checking for wear and physical checking of the structural condition of the item.

The Engine Maintenance Manual provides detailed information on dimensional checking while this section covers the physical aspects of component inspection. Both types of inspection are very important from the standpoint of safe, efficient and economical operation.

The Magnaflux method of inspecting the physical condition of parts is used on parts that are capable of being magnetized. This is a magnetic particle inspection which is a safe, non-injurious type of inspection that is capable of disclosing indications of apparent damage in the parts that might not otherwise be visible to the naked eye.

The principles of magnetism are used in Magnaflux inspections. A suitable magnetic field is set up within the part by current flow or by placing the part within a magnetic field. The part becomes a path for the magnetic flux or lines of force. Irregularities such as cracks and/or non-magnetic inclusions or bodies cause a distortion or interruption of the lines of force. Magnetic poles are set up by such interruptions or distortion. When specialized particles capable of being magnetized are applied to the piece being inspected, these particles will congregate at those places of opposite polarity, or north and south magnetic poles, and indicate possible defects. When the particles are coated with material having the property of fluorescence under 'black light, " the method of inspection is called "magnaglo." The magnaglo method aids in inspection since it allows the indication to be seen better.

This section outlines the application of the magnaflux method of inspection on selected parts. Information is provided covering the preparation, procedure and inspection standard to be followed. It serves as a guide to determine if the inspection indicates the part may be reused or rejected.

It should be noted that the magnaflux method of inspection is very searching. Our recommendations in the use of magnaflux inspection are based on our knowledge of material standards in effect on our products during past years, in addition to investigation of parts performance in service. Indiscriminate scrapping of parts showing magnaflux indications without regard to their effect on part function may be very costly. If any doubt exists concerning the significance of a specific magnaflux indication, the Engineer of Tests or equivalent authority should be consulted.

EQUIPMENT

The equipment required for magnaflux inspection will vary from the XRR unit shown in Fig. 1, used for crankshaft inspection to portable KC units which may be used for the same purpose as the XRR but not as conveniently. Conditions such as number of parts in use, necessity of portability, and availability of the apparatus for general magnaflux inspection in the shop will determine the types of equipment required. The current capacity required may vary from 500amperes or less to much higher values such as the 2000 amperes required for piston magnaflux inspection.

Magnetic particles used in the magnaflux inspections may be used in the "dry" or "wet" method. As implied, the fine metallic powder may be used dry or in a liquid with or without magnaglo particles. Magnaglo lends itself to rapid inspection and may be preferred for this reason. Also, the metallic powder may be of different colors. The color and powder selection will have to be chosen for the particular inspection to provide maximum contrast for easy visibility to facilitate the inspection. Some recommendations are made for the individual parts in the respective inspection procedure. It is recommended, however, that full details covering the types of equipment and supplies be obtained from the Magnaflux Corporation or their representative.

PREPARATION

Before magnaflux inspection of any part, it must be thoroughly cleaned to remove any oil deposits and loose carbon. Other carbon deposits should be removed by wire brushing or other non-destructive means. It is particularly important to dry the part after cleaning, especially so if the dry method of inspection is used, to permit free flow of the powder to prevent false indications.

INSPECTION PROCEDURE CRANKSHAFTS

Magnaflux inspection of the crank- shaft should conform to the following procedure and inspection standard.

A. Procedure

Indications of detrimental defects will be produced by flowing alternating current through a coil around the crank- shaft. The axis of the coil must be parallel with the normal axis of the crankshaft. When the XRR type unit, Fig. 1, is used, place the coil over the center of a 24" section, magnetize with 600-800 amperes alternating current and proceed to the next 24" section until the remainder of the shaft is magnetized. The current must be shut off before proceeding to each new section. The inspection medium may be applied while the current is flowing or after the current is shut off.

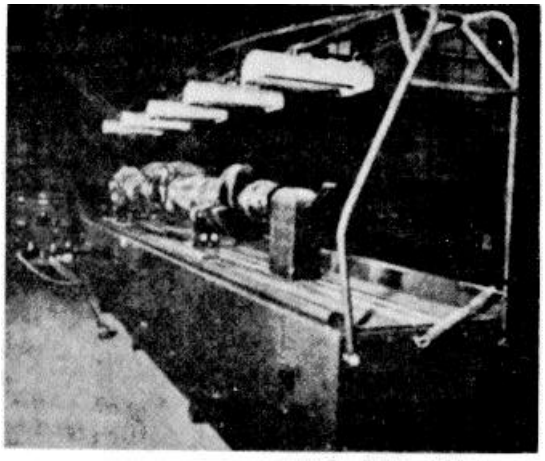


Fig. 1. - Type XRR Magnuflux Unit

Where an XRR type unit is not available, the leads from the power pack may be formed into a coil by making three loops and taping them together for ease of handling. The magnetizing procedure is the same as described above. Another satisfactory method is to take

the leads and make continuous loops around the entire crankshaft. As nearly a complete loop as possible should be made around each journal. Magnetize with 600-800 amperes alternating current.

When dry powder is used, the powder should be applied sparingly so as not to hide possible indications. It is often helpful to tap the shaft with a lead or wood hammer to remove excess powder and to permit more pronounced build- up of indications.

B. Inspection Standard

1. Types of Indications, Interpretations and Dispositions

The four types of indications disclosed by magnafluxing used crankshafts are: nonmetallic inclusions, hardening or "Tocco" checks, seizure cracks, and fatigue cracks. Particulars relative to each indication are as follows:

a. Nonmetallic Inclusions: These are shown in Figs. 2a, b and c. All steels contain varying quantities of nonmetallic materials which may appear as magnaflux indications. Those shown in Fig. 2c are confined to welded shafts. They are oxide deposits which resulted in incomplete fusion during the welding process. The practice in the past was to remove the inclusion in its entirety by "dimpling." Present practice is to fiat the sharp edges to prevent bearing scraping but not necessarily remove all of the inclusion. Inclusions have in the past been highly overrated as causes for failures. In our experience we have never been able to definitely correlate a crankshaft failure with inclusions. Unless very definite evidence of fatigue progression from one of these nonmetallic inclusions is found, it may generally be considered that the crankshaft has been

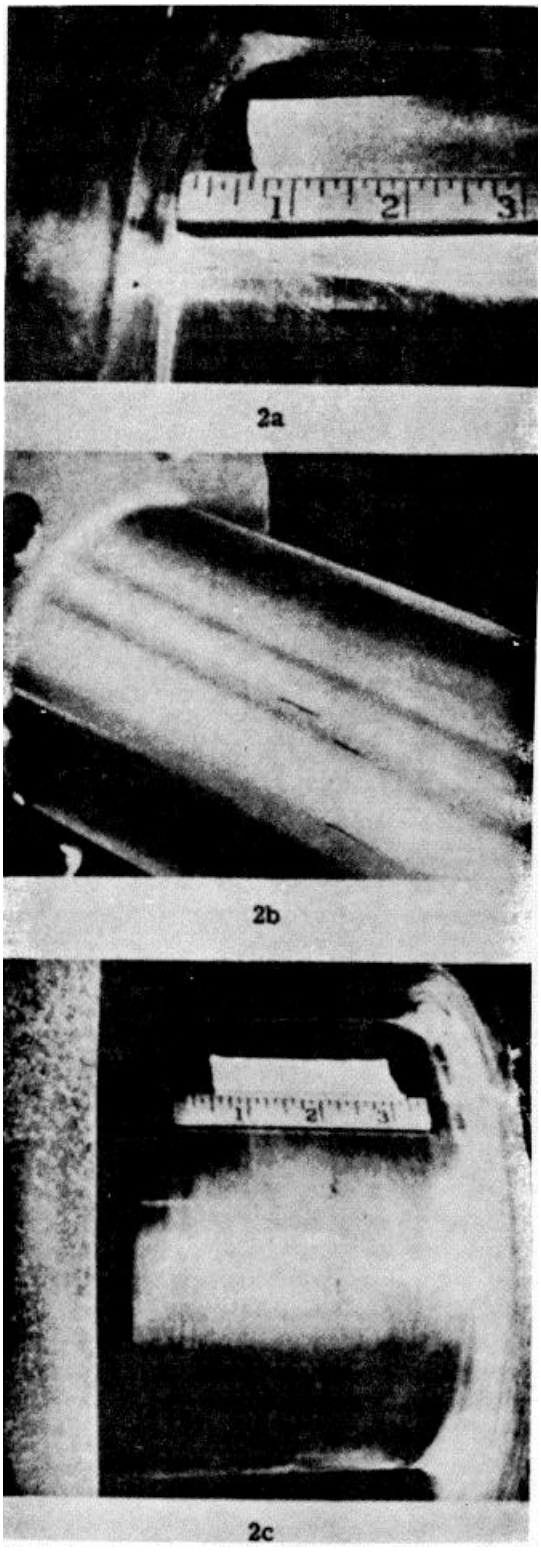
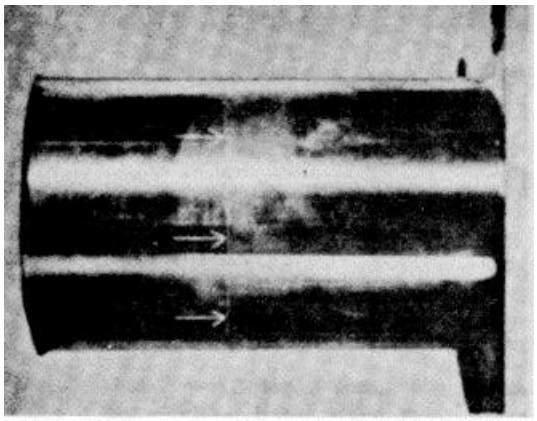


Fig. 2.- Nonmetallic Inclusions

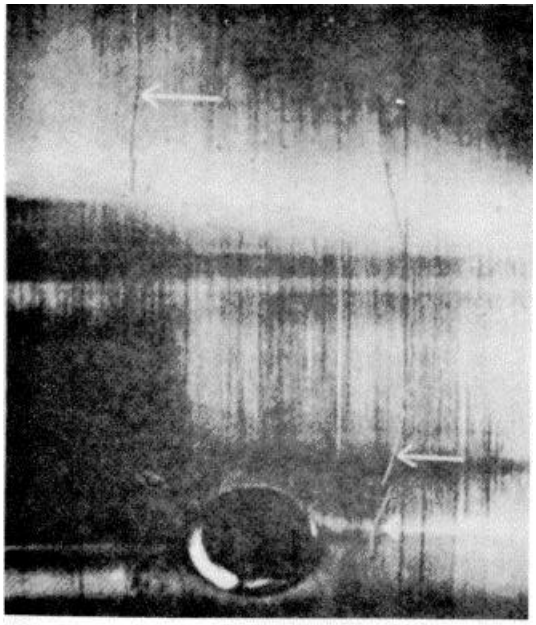
qualified by its service to date of inspection.

b. Hardening or "Tocco" Checks: Figs. 3a, b and c. Hardening or "Tocco" checks sometimes develop in the induction hardening process on the journals. They are very fine hairline cracks found at the edge of the hardened zone circumferentially to the axis of the shaft. Occasionally, they are found on the crank-pin journals but more often on the mains, especially at the edge of the hardened area near the center of the last or double main journal. They are never in the fillets but approximately 5/8" from the thrust wall. On welded shafts this condition exists also at the edges of the welds as shown in Fig. 3b. These "Tocco" checks have definitely been established as harmless insofar as the life of the crankshaft is concerned.

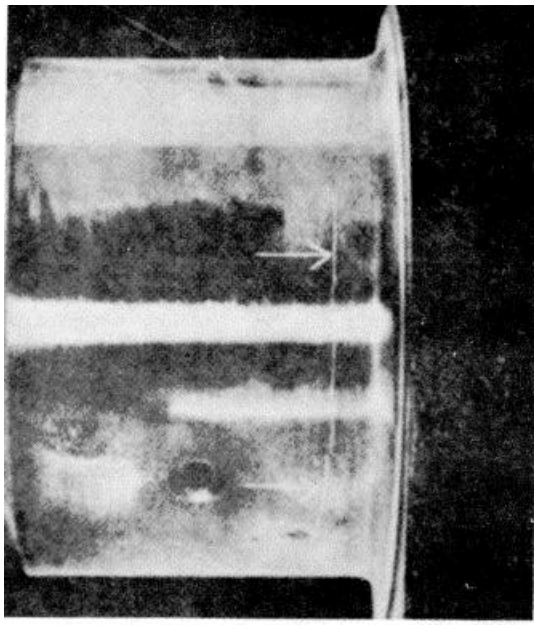
c. Seizure Cracks: Figs. 4a, b and c. When an oil failure results in bearing seizure, quite often there are longitudinal or circumferential cracks sometimes accompanied by a network pattern of cracks. This is usually associated with discoloration and other evidences of bearing seizure. The circumferential heat cracks are often deep, how- ever, when using wet magnaflux medium, one must differentiate between actual heat checks and



3a

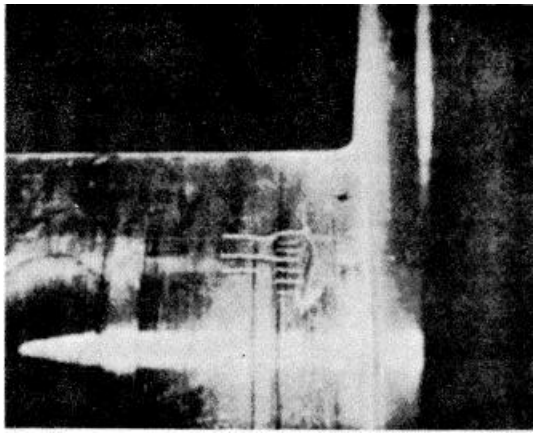


3b

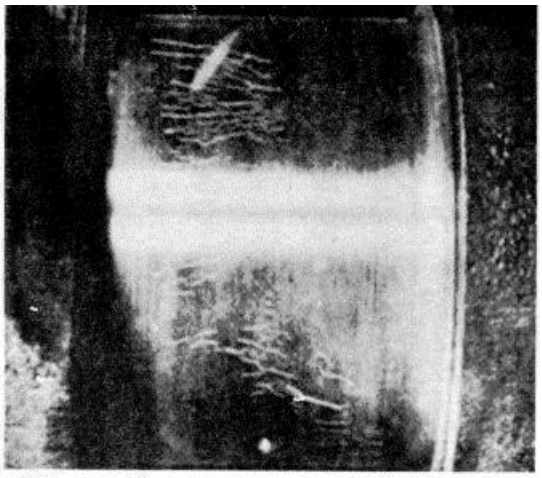


3c

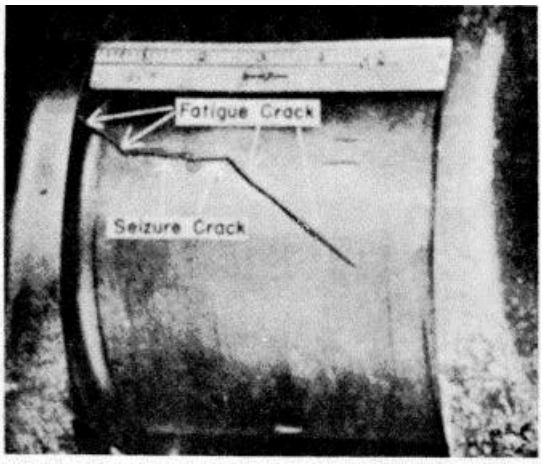
Fig. 3.- Hardening Or “Tocco” Checks



4a



4b

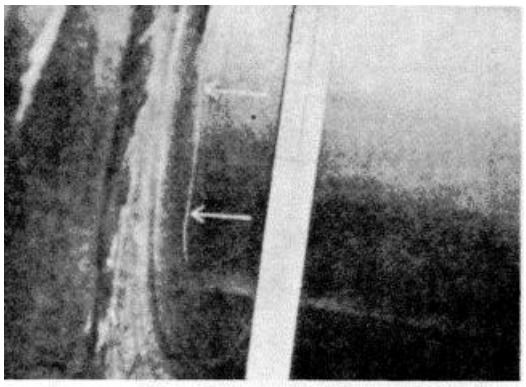


4c

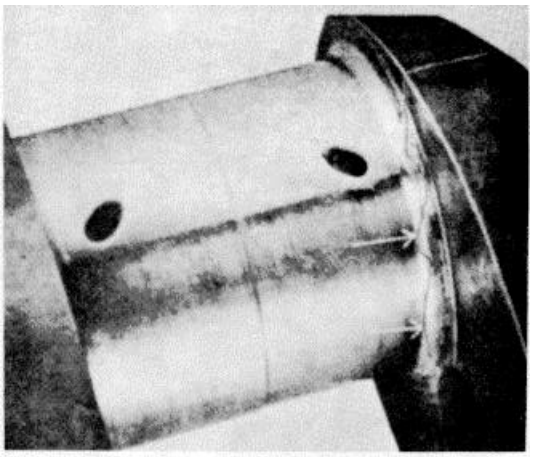
Fig. 4. - Seizure Cracks

indications developed due to scoring. Discoloration is usually the distinguishing evidence in this case. When still in doubt, observation with a magnifying glass is often helpful. Any crankshaft which shows indications of heat checks resulting from bearing seizure should not be placed back in service. Fig. 4c is a photograph of a journal which shows a fatigue crack starting from a heat check.

d. Fatigue Cracks: Figs. 5a and b. Occasionally, due to the lack of proper bearing support, the crankshaft is subjected to



5a



5b

Fig. 5. - Fatigue Cracks

excessive bending stresses. Fatigue failures originating due to this overstressing generally occur in the center of the fillets, run circumferentially for several inches in the fillet and then proceed through the cheek to ultimate failure. Circumferential indications in the center of the fillets should be viewed with extreme suspicion since it is probable that they represent the start of fatigue failure of the shaft.

INSPECTION PROCEDURE - CONNECTING RODS AND BASKETS

There are two designs of connecting rods and baskets in use: the trunnion design, and eye type connecting rods; the current bolted design basket and the prior used hinged type fork rod basket. The trunnion design blade connecting rod is shown in the magnaflux unit, Fig. 6. Although the connecting rods and baskets differ in design, the method of inspection and the inspection standard for the respective parts are the same.

A. Procedure

1. Connecting Rods

When an XRTL type of unit is employed, place the connecting rod inside the coil as indicated in Fig. 6,

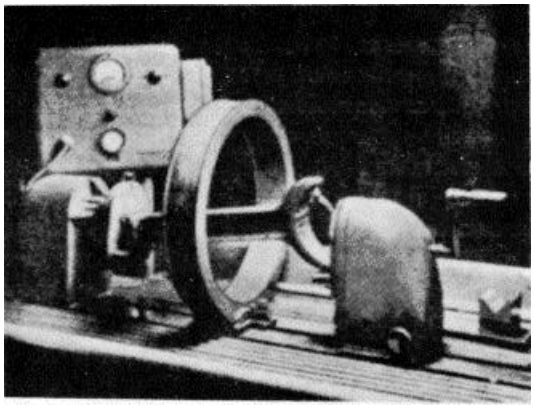


Fig. 6. - Blade Rod In Magnaflux Machine

showing the blade rod in place. Another satisfactory method of magnetizing the rods is to make

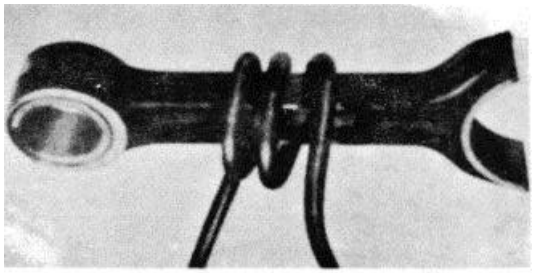


Fig. 7. - Cable Magnetizing Application

three loops of cable as shown in Fig. 7 around the rod.

The fork portion of the fork rod should be magnetized by placing it within the field of the coil or loops to check for possible defects at the bottom of the serration. The coil or loop should also be placed over the slipper end of the blade rod.

Magnetize with 500600 amperes alternating current. Apply the inspection material, magnaflux or magnaglo, either while the current is flowing or after the current is shut off. The parts will 'usually retain enough magnetism to permit residual inspection. Apply the powder sparingly so that minute indications are not hidden.

2. Fork Rod Baskets

Although the fork rod basket is inspected separately from its mating connecting rod, care must be taken
of transverse defects in the rod

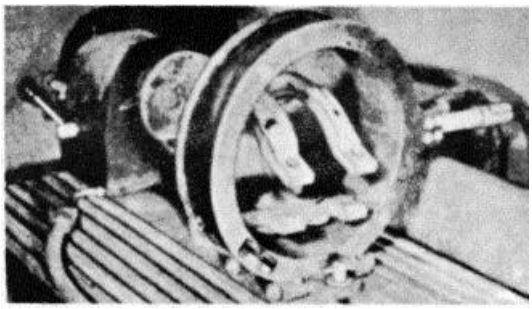


Fig. 8. - Position Of Rod Basket For Magnafluxing

to be sure an acceptable basket is again matched to the mating rod. To aid in this identification, both the rod and its matching basket have the same serial number.

Place the basket within the coil as shown in Fig. 8. When such a coil is not available, a suitable coil may be made with three turns of #0000 flexible cable and connecting the ends to a portable magnetizing unit. Magnetize with 500-600 amperes alternating current and apply the inspection material, magnaflux or magnaglo, either while the current is flowing or after it has been turned off.

B. Inspection Standard

1. Connecting Rods

Fig. 9 shows magnaflux indications of transverse defects in the rod.

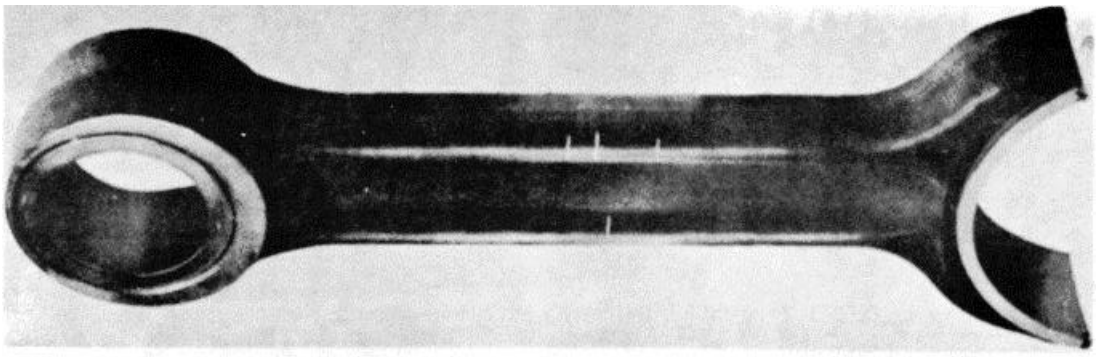


Fig. 9.- Connecting Rod Defect Indications

flanges, using gray magnaflux powder. Any defects in this direction and location reject the blade or fork rod, since they usually result in failure.

Sometimes due to bearing seizure, heat checks develop in the blade rod slipper face. Special attention should be paid to this area, since defects of this nature will probably result in failure. Therefore these indications are cause to reject the blade rod.

Detrimental defects in the fork rod are usually confined to the serration area. The indications will appear at the end of the serrations with their origin at the root or in the cap screw hole. Further progression of such defects will probably result in failure. Accordingly, these defects are cause to reject the rod.

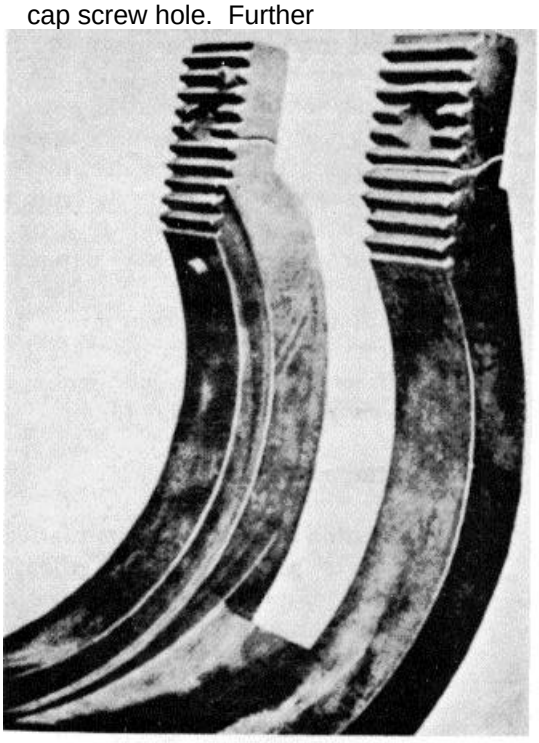


Fig. 10. - Example Of Fatigue Cracks

Indications of longitudinal laps, seams, or inclusions in the "I" beam section or similar indications on other areas of the connecting rod are usually considered harmless.

NOTE: Lap is defined as a surface discontinuity in forgings due to the hammering in of folds in the metal. Seams are defined as a discontinuity caused by a void or crack found in rolled material parallel to the axis of the material. Inclusions are defined as particles of impurities, usually oxides, sulphides or silicates that are generally dispersed at random through all steel products.

2. Fork Rod Baskets

Failures of the fork connecting rod baskets are mostly due to loose cap screws and are confined to the serrated ends. The "Procedure" for the baskets has therefore been aimed at disclosing cracks in these areas which may lead to ultimate engine failure. Fig. 10 shows an example of typical defect indications of fatigue cracks. Any baskets which show indications of cracks emanating from serrations or bolt holes should be rejected.

INSPECTION PROCEDURE - PISTONS

The following magnaflux inspection procedure is intended as a basis to determine if a used piston should be accepted for reuse (provided it is otherwise conditionally and dimensionally satisfactory) or rejected according to the inspection standard.

A. Procedure

Satisfactory magnetization can be accomplished by connecting one conductor from a portable KC unit to a flat head plate, and the other conductor to a bar conductor inserted in the piston. The bar conductor should be a ½" copper or brass tube about 18" long to hold the piston in the unit securely, as shown in Fig. 11. Magnetize with 2000 amperes direct current.

Use a 12" diameter coil similar to that shown in Fig. 11 and energize with 1500 amperes direct current with the coil around the piston at its approximate center, as an alternate method.
Then remove the piston and apply magnaflux gray powder or magnaglo to the inside and outside of the piston. Shake out excess powder or let drain and inspect. If heat checks are suspected in the crown contour, clamp the piston diametrically on the outside diameter, above the upper ring band and repeat the preceding current application.

B. Inspection Standard

Piston nomenclature referred to in the following is given in Fig. 12, for the two designs of pistons currently found in 567 series engines.

1. Crown Rim

Fatigue failures of the crown have their origin in the recess under the crown rim. See Fig. 12 for location. This area is difficult to inspect. Extreme care must be exercised in interpreting accumulations of powder or magnaglo because of the natural tendency for the inspection material to settle in this area. When using magnaglo, the piston should be tilted to permit excess to drain away from the area being inspected If a crack has progressed at any extent, it should be visible on the outside of the piston at the crown rim. Heat checks in the crown or 'bowl" as well as fatigue cracks under the crown rim reject the piston.

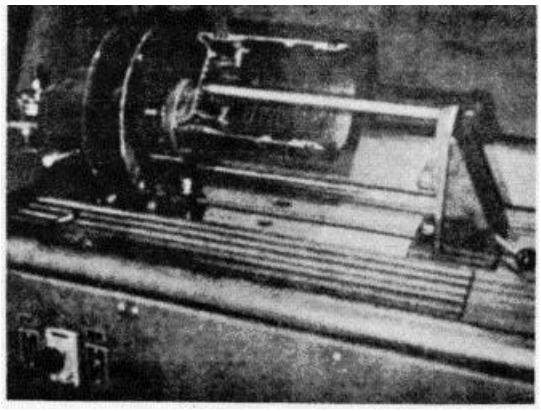


Fig. 11. - Piston (Section) Showing Application

2. Platform Supports

Indication of cracks In the platform supports are cause for rejection of the piston. Frequently the inspection material accumulates at the casting parting line of the sup-port, which should not be confused with an actual crack.

3. Platform Tie Ribs

Cracked platform tie ribs reject the piston. Generally, indications on the tie ribs are due to casting

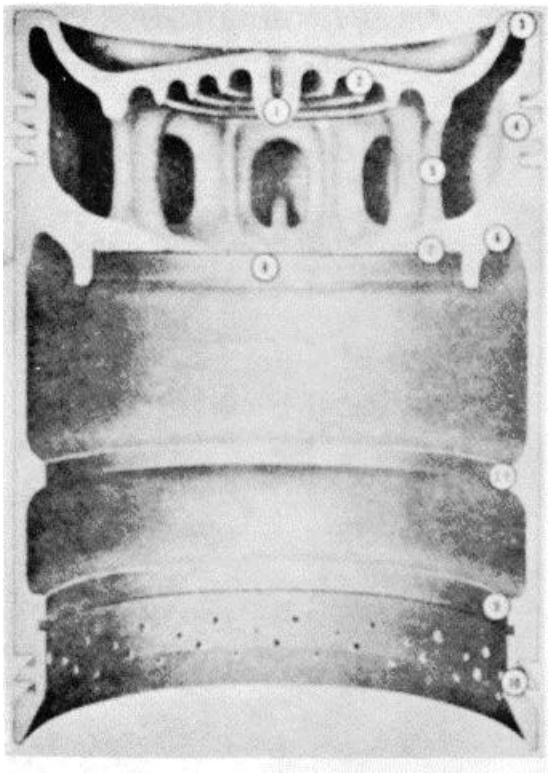
characteristics, and are not true indications of cracks. Fig. 13 shows the tie rib core parting line with normal lighting. The same area taken with "black light" is also shown. Fracturing the casting through this parting line reveals no defect and shows that false indications are prevalent in this area. If doubt remains as to the interpretation of the indications, typical samples should be sectioned through the questionable area.

4. Platform

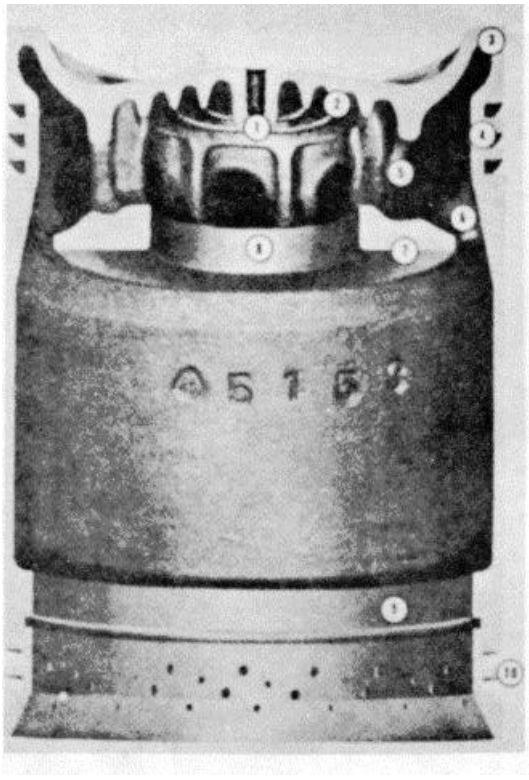
Pistons having platform rims, Fig. 13, should be rejected when the platform rim is cracked. A false indication may appear in the machined recess. Unless the indication emanates from the corner, the piston should be accepted.

5. Cooling Fins

Fig. 14 shows indications on the piston cooling fins. A certain percentage of pistons in the field are known to have cracked cooling fins. They may be found on all the fins, inline or staggered. Pistons showing cooling fin cracks are acceptable for further service, except those pistons which have been damaged due to some related part failure, as for example a valve, since the cracks induced by the



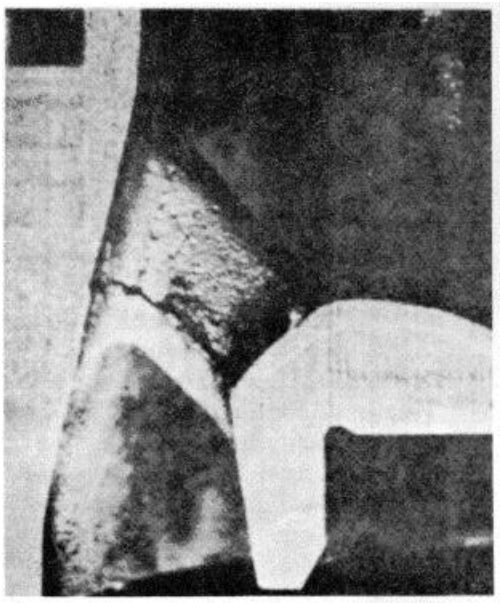
This Piston Uses
Floating Pin Design Carrier



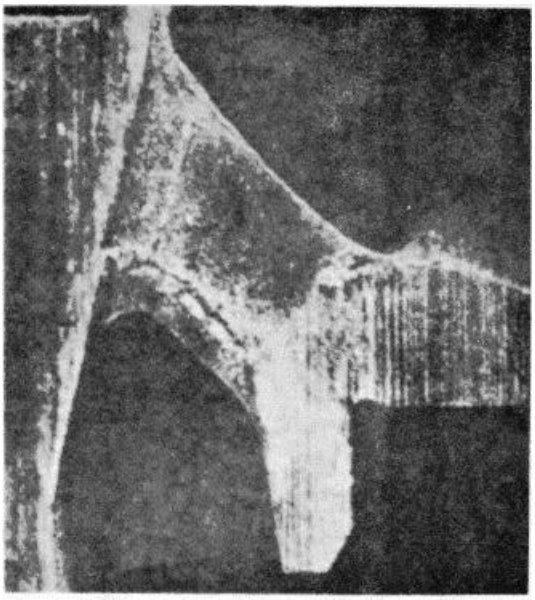
This Piston Uses
Trunnion Design Carrier

1. Puller Hole Boss
2. Cooling Fins
3. Crown Rim
4. Compression Ring Lands
5. Platform Supports
6. Tie Ribs
7. Platform
8. Upper Pilot
9. Lower Pilot
10. Oil Ring Lands
11. Pin Ring

Fig. 12. - Piston Nomenclature



Normal Lighting.



Under Black Light

Fig. 13. - Tie Rib Core Parting Line

failure have not been subjected to the thermal stress relieving operations which our production pistons undergo.

6. Inside Crown Area
   Fig. 15 shows indications in this area. Cracks encircling the puller

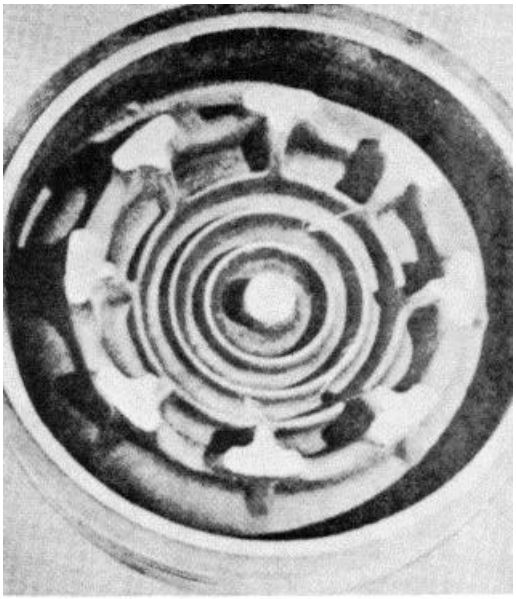


Fig. 14. - Cooling Fin Magnaflux Indication

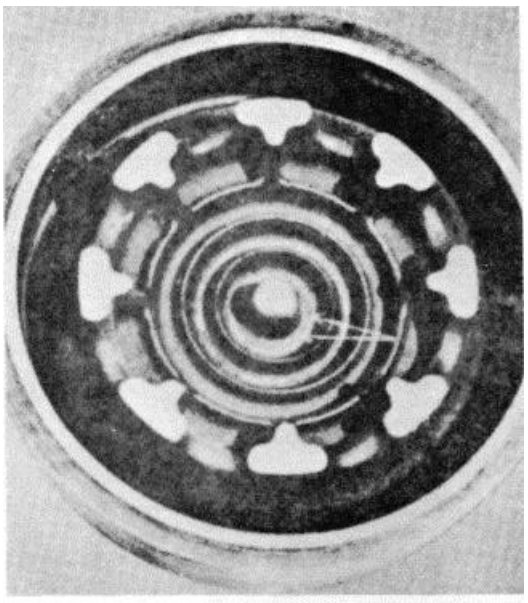


Fig. 15. - Defect Around Puller Hole Boss

hole boss or similarly concentric cracks between the cooling fins, reject the piston.

7. Pin Ring

Fig. 16 shows an indication in the pin ring. Pin ring cracks are acceptable, provided they do not ex-tend into the piston wall. Pin ring cracks extending into the piston wall are cause for rejection of the piston.

8. Ring Grooves

Magnetizing the ring land area with a coilor high current densities may produce false indications in the sharp corners of the ring grooves. Magnaflux indications may also be produced if scale is not completely removed, or because of subsurface porosity. This is especially true when magnaglo is used. Currently produced pistons are free from porosity in the ring grooves. There are, however, numerous pistons in the field that have provided satisfactory service which contain porosity in varying degrees. Any indication in the ring land area should be carefully appraised to determine whether it is a real crack or due to conditions stated above. Any indication proved definitely a crack in the ring land area rejects the piston.

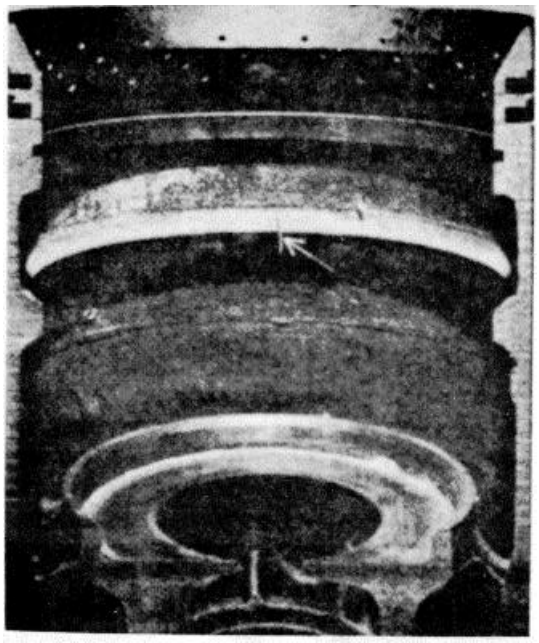


Fig. 16. - Pin Ring Magnaflux Indication

9. Other Areas

Indications of cracks may be found on the inside or outside of the skirt or wall. These are usually due to mishandling and are found more at the bottom taper than in the upper part of the wall, and are cause to reject the piston.

C. Preparing Part For Use

All pistons magnetized with the coil method must be demagnetized after inspection. Demagnetization may be accomplished by withdrawing the piston from the influence of a coil energized with 600-1000 amperes alternating cur-rent.

The piston should then be washed and flushed to remove any magnetic particles used in the inspection.

INSPECTION PROCEDURE - PISTON CARRIER

Two designs of piston carriers are in use in the field. The “trunnion” forged design carrier, Fig. 17a, which is used with the trunnion or “saddle” design connecting rod and piston assembly; and the cast iron carrier, Fig. 17b, having pin bushings and is used with the “eye” type connecting rod and piston assemblies. The magnaflux procedure is the same for both carriers, however, the inspection standard for the carriers is different.

A. Procedure

The following methods may be used to magnetize the piston carriers.

1. Insert an approximately 2” diameter copper or brass bar through the piston pin bore of the carrier. Use care not to damage the pin bearing surface of the trunnion type carrier or the piston pin bushings used in the other design of carrier. Clamp the bar (or tube) between the heads of a magnaflux unit, as shown in Fig. 18.

2. Thread a single cable through the pin bores as shown in Fig. 19, and magnetize with 500-600 amperes AC current.

3. Make three loops of the cable through the carrier as shown in

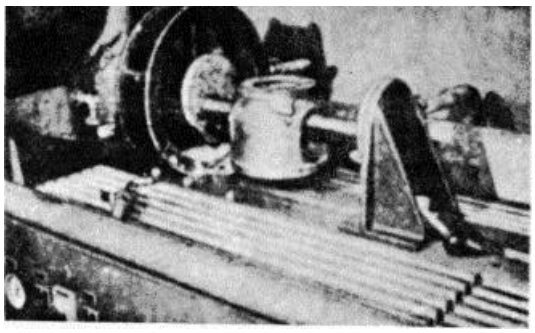
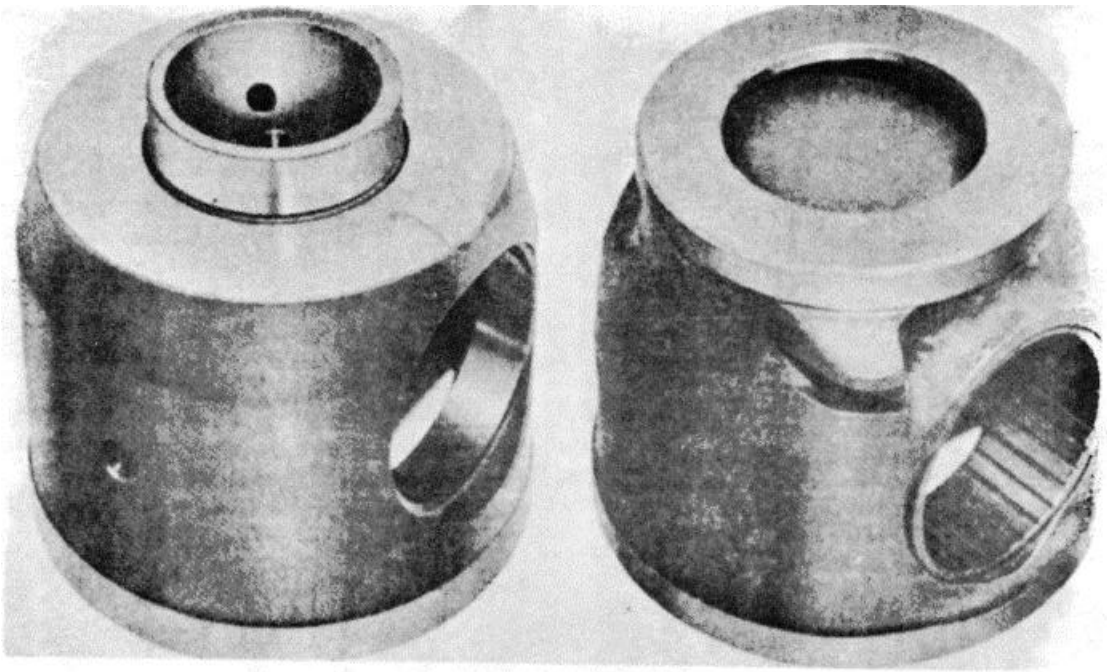


Fig. 18. - Carrier On Magnaflux Unit



17a *17b*

Fig. 17. - Piston Carriers



Fig. 19. - Magnetizing With Single Cable

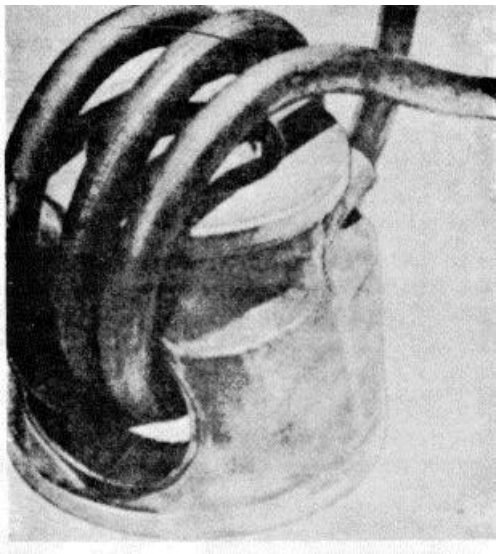


Fig. 20. - Magnetizing With Multiple Cable

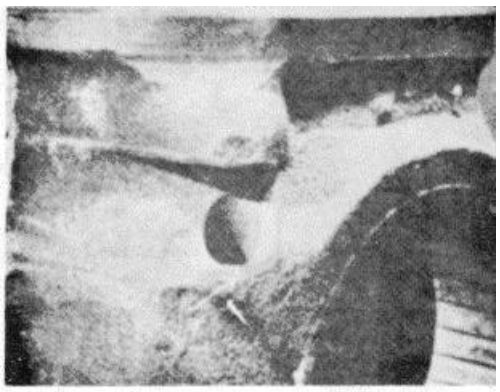


Fig. 21.- Oil Hole Defect Indication

Fig. 20, and magnetize with 300-400 amperes AC current.

The inspection medium may be applied while the current is flowing or after the part is magnetized. If powder is used, it should be applied sparingly so as not to hide possible indications of cracks. The excess powder may be shaken off or blown off using low pressure compressed air.

B. Inspection Standard

1. Trunnion Carrier In the inspection of the trunnion design carrier, cracks found any where on the carrier are cause for rejecting the carrier. Particular attention should be given to the polished pin bore where fine heat checks may develop.

2. Carriers Using Piston Pin Bushings

Magnaflux indications found on these carriers are generally three types: fatigue cracks, foundry defects, and mishandling defects.

a. Fatigue Cracks Usually fatigue cracks have their origin in oil holes of the carrier. Figs. 21 and 22 are



Fig. 22. - Oil Hole Defect Indication (Inside)

photographs of the beginning of failures. Fig. 23 shows an advanced stage of failure where the fatigue crack has progressed to piston pin bore. Carriers which reveal magnaflux indications in these locations should be rejected.

b. Foundry Defects

Certain defects may be revealed at overhaul inspections which are due to abnormal conditions in the foundry at the time the parts are cast. The most common of these are shrink cracks surrounding the piston bore boss as shown in Fig. 24. Similar indications may also appear in the crown recess. Unless definite progression of these can be found, they should be accepted. In general, indications found on the lower half of the carrier are harmless.

c. Mishandling Defects

Occasionally, due to dropping the carrier or other mishandling, cracks will be found in the bottom wall. These are usually through the wall, and the part should be rejected. 'The indication shown on Fig. 25 is one type which may be attributed to mishandling and is cause for rejection of the part. Often, cracks will be vertical in direction.



Fig. 23. - Defect Progression From Oil Hole

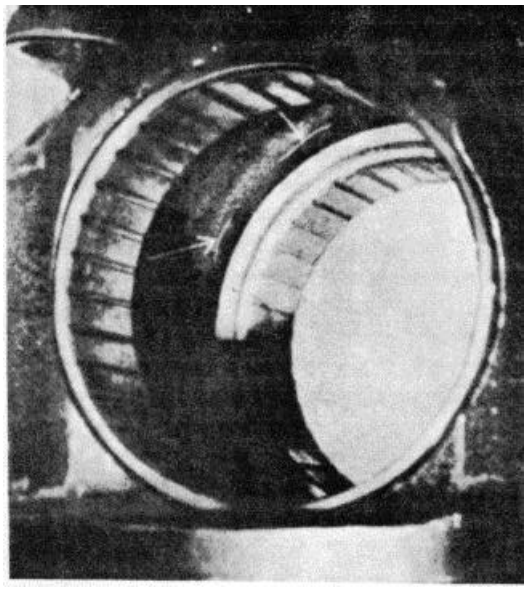


Fig. 24. - Magnalnux Indication Inside Of Pin Boss

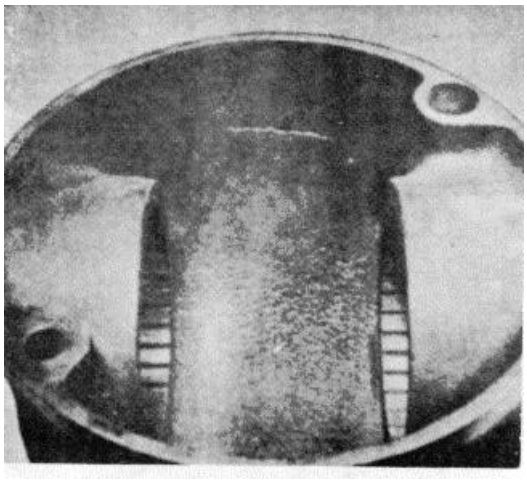


Fig. 25. - Defect Indication Bottom Wall

INSPECTION PROCEDURES - PISTON PINS

There are two designs of piston pins in use; the trunnion type, Fig. 26a, which bolts to the saddle of its respective connecting rod, and the floating type, Fig. 26b, used with eye type connecting rods. The magnaflux procedure is similar for both types of piston pins, however, the inspection standard is different.

A. Procedure

Before magnetizing the piston pin and after they are initially cleaned, ex-amine the pins for obvious pitting, etching and surface cracks. Also examine the pins for discoloration caused by localized heat. Any discoloration caused by localized heat will disqualify the pin. Dimensionally the piston pin must qualify for use according to the recommendations in the Engine Maintenance Manual.

Insert a central conductor, either a copper or brass bar about 1-1/2" in diameter through the bore of the piston pin. Then mount the pin (or pins) in the magnaflux unit as shown in Fig. 27. Magnetize with 500-600 amperes AC current.

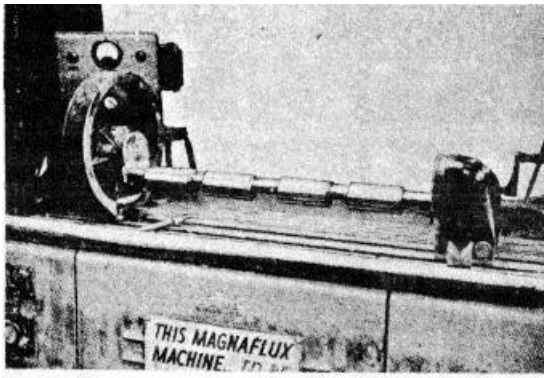


Fig. 27. - Piston Pins In Magnaflux Machine

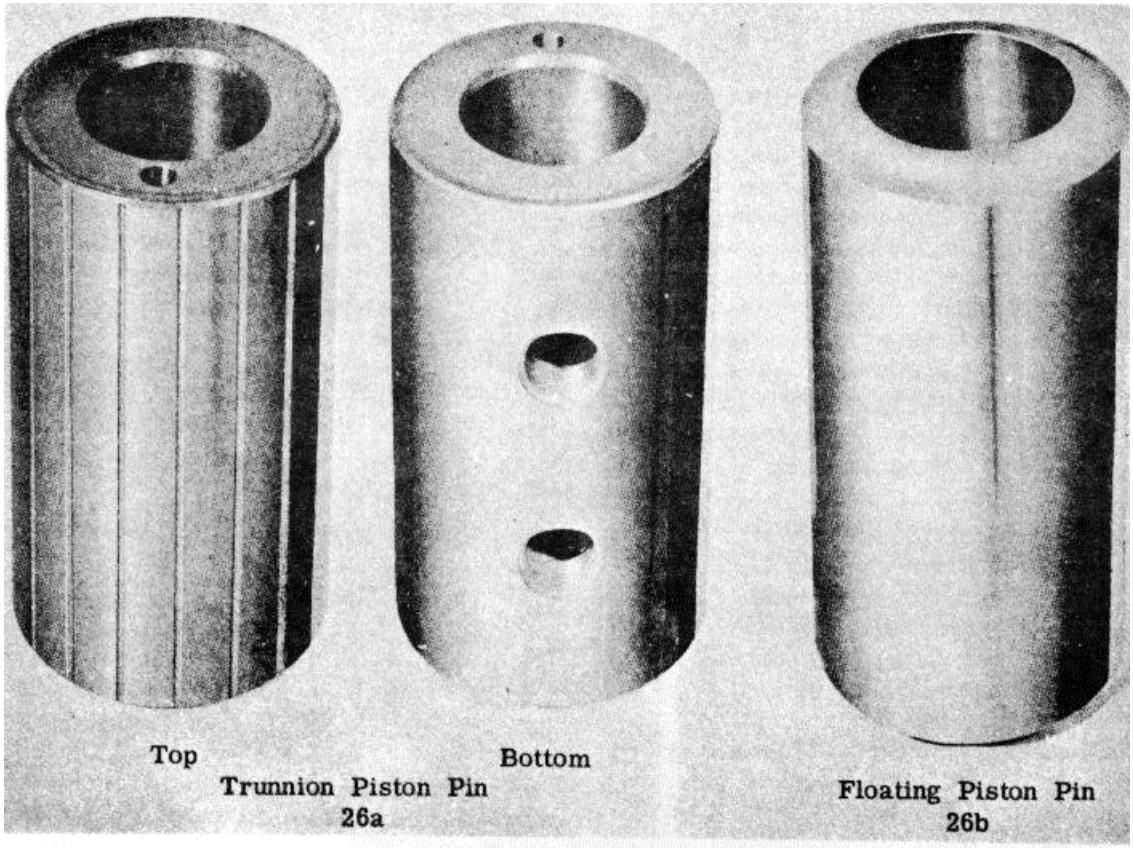


Fig. 26. - Piston Pin Designs

Apply the inspecting medium, magnaglo or magnaflux powder while the current is flowing or if desired after the current is discontinued.

B. Inspection Standard

1. Trunnion Piston Pins

Inspection of the trunnion pin should be confined to the bore and the two 7/8" diameter bolt holes. Fatigue cracks in the bore and/or bolt holes are cause for rejection of the pin.

2. Floating Piston Pins

Failure of this type of piston pin is nearly always a result of overheating. Fatigue cracks originate from heat checks on the surface. These checks are longitudinal in direction in the center section of the pin, Fig. 28. As the fatigue cracks progress, they tend to become circumferential at the witness band (the area between the rod bushing and the carrier bush ing), Fig. 29. The surface of overheated pins is sometimes straw to blue black in color. At other times, however, no dis coloration is present due to subsequent polishing action in the engine.

Nonmetallic inclusions, the impurities contained in various amounts in all steels, are also in a general longitudinal direction. It is therefore often difficult to differentiate between nonmetallic inclusions and fatigue cracks when high cur rent densities are employed. This is especially true in the absence of discoloration. The indications of inclusions shown in Fig. 30 were produced with high amperages on new pins.



Fig. 28. - Piston Pin Magnaflux Defect Indication



Fig. 29. - Progression Of Magnaflux Defect Indications

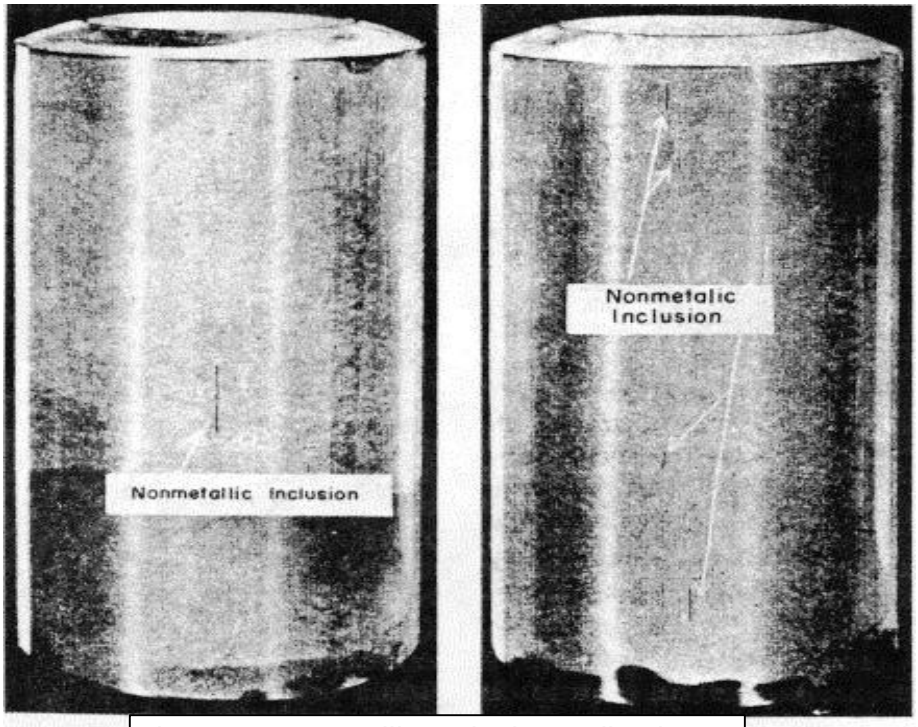


Fig. 30. Nonmetallic Inclusion Indications

Although fatigue cracks are nearly always confined to the portion of the pin under the rod bushing, inclusions may be anywhere on the part.

Where question arises as to the type of indication in the center portion of the pin, hardness tests may be made to determine if the pin has been overheated. A Shore scleroscope is the preferred instrument for making these tests since it does not damage the surface finish of the pin appreciably. It is recommended that a hardness check be made in the witness band compared to the suspected over heated areas. A hardness of scleroscope 71 or less in the center of the pin as compared to a scleroscope 78 or higher in the witness band will indicate overheating and such a pin should be scrapped.

Evidence of frictional distress on the silver connecting rod bushing will often serve as a tip-off to a piston pin which has overheated. Magnafluxing of the pin, observation of the mating silver bushing, and scleroscope test should be used if a question exists on a particular piston pin.

Magnaflux indications of fatigue cracks or heat checks are cause for rejection of the pins. Indications of nonmetallic inclusions are acceptable.

INSPECTION PROCEDURES - CYLINDER HEADS

A. Procedure

Place a copper tube or a bar of proper diameter through the valve seat and valve guide. Clamp leads from the magnaflux unit to this central conductor. Magnetize with 600-800 amperes alternating current. Repeat these operations for the three remaining valve openings. The inspection medium (powder or solution) may be supplied while the current is flowing or residually (while current is off).

B. Inspection Standard

Magnaflux indications in the areas which are cause for acceptance or rejection of the cylinder head are illustrated as an aid in making a definite decision as to a usable cylinder head and one which should be removed from further service.

1. Indications of cracks on the bottom of the cylinder head around the injector well or valve seat as shown in Figs. 31 and 32 are cause for rejection of the cylinder head.

2. Indications of cracks on inside of the head, such as in the exhaust ports are cause for rejection of the cylinder head.

3. Heads disclosing stud hole cracks in the outer wall as shown in Fig. 33 are usable, unless the crack exceeds 4” in length:

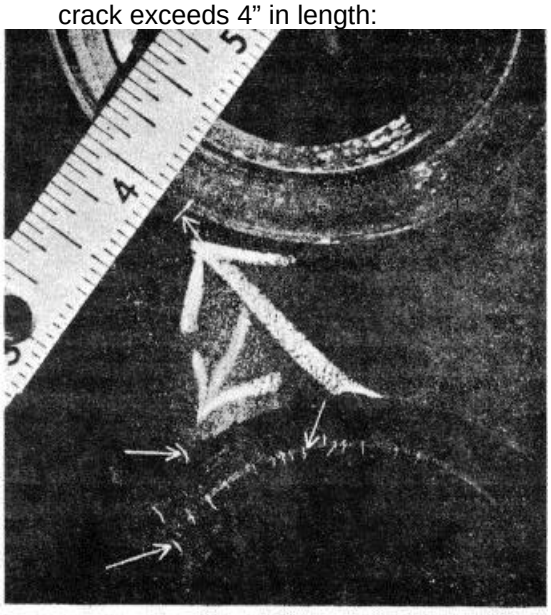


Fig. 31. - Magnaflux Indication Of Cracks On Valve Face

Although the cylinder head may pass this inspection, other consideration should be given in determining its reuse**,** such as valve seat wear and so forth. For information on these factors refer to the Engine Maintenance Manual.

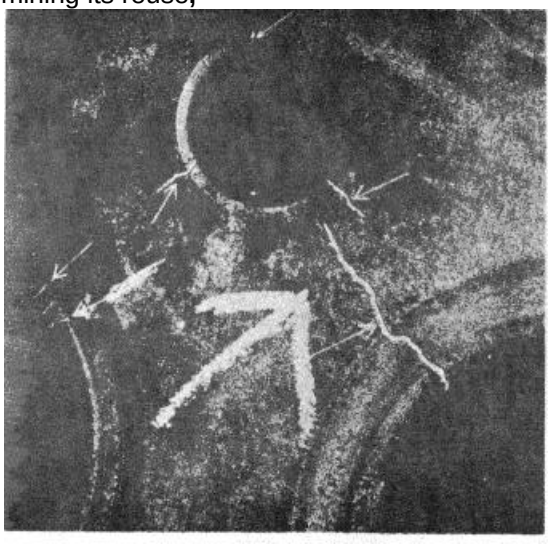


Fig. 32. - Magnaflux Indications At Injector Well And Valve Faces

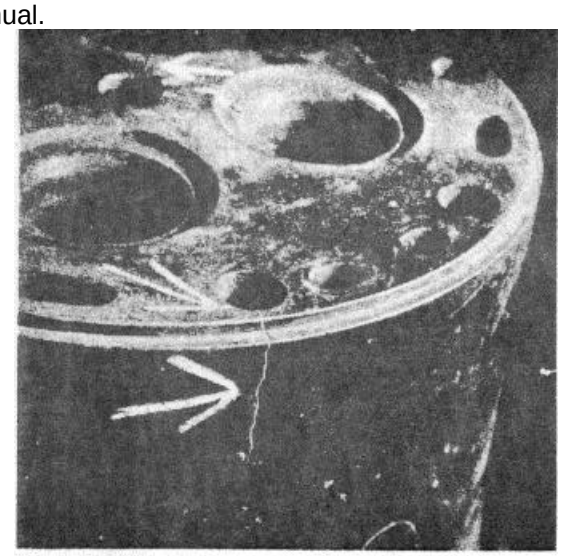


Fig. 33. - Magnaflux Indication At Stud Hole Of Cylinder Head

INSPECTION PROCEDURE - CAMSHAFT

Only camshaft segments ad stub shafts that show heat discoloration or signs of distress on the journals require magnaflux inspection and hardness tests. Discoloration on the Unfinished portion of the camshaft should be disregarded as it is the result of the manufacturing process as may be seen on a new cam-shaft.

A. Procedure

The same type of unit used to magnaflux the crankshaft may be used to inspect the camshaft as shown in Fig. 34. However, a 9” diameter coil should be used on the camshaft. Place the coil over the center of a 24” length of cam-shaft and magnetize with 600-800 amperes of AC current. Proceed along the length of the camshaft in 24” sections until the entire segment or camshaft is magnet-ized. The current must be shut off before proceeding to each new section. (Moving the coil with the AC current flowing is equivalent to withdrawing the part from the AC magnetizing influence which causes demagnetization.) The inspection material, magnaflux powder or magnaglo, may be applied while the current is on or off.

If the crankshaft magnafluxing unit is not available, the camshaft can be magnetized by making three loops of

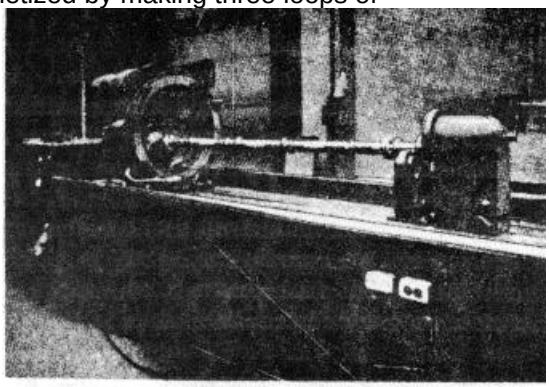


Fig. 34. - Camshaft Magnaflux Inspection

#0000 cable, taped together, using 600-800 amperes of AC current. The magnetizing procedure is the same as is used with the unit, working along the camshaft in 24" sections.

B. Inspection Standard

Thermal cracks or heat checks on any journal are cause for rejection of the camshaft.

Hardness values on the journals and cams should be checked using a Shore scleroscope. Hardness values below 73 Shore scleroscope (Rockwell "C" 55) on any journal or cam are cause for rejection of the camshaft.

NOTE: The outer edges of the journal may drop off slightly due to the tempering effect of hardening the adjacent cam.

INSPECTION PROCEDURE - ENGINE PARTS

A. Procedure

Clamp the gear between the contacts of the magnaflux unit as shown in Fig. 35, so the current will pass through at right angles to the bore. Magnetize with two "shots" of 800-1000 amperes AC current. Revolve gear 90° and repeat magnetization applying the magnaflux material during the time current is flowing. If a magnaflux unit is not available, the inspection may be made by placing a three turn coil of #0000 flexible cable around the gear and magnetize with 200-300 amperes. The powder should be applied while the current is flowing.

B. Inspection Standard

The purpose of the magnaflux inspection of the gears is to detect fatigue cracks which may develop in service. Fatigue cracks reject the gear, and they usually occur in the root area of the teeth.

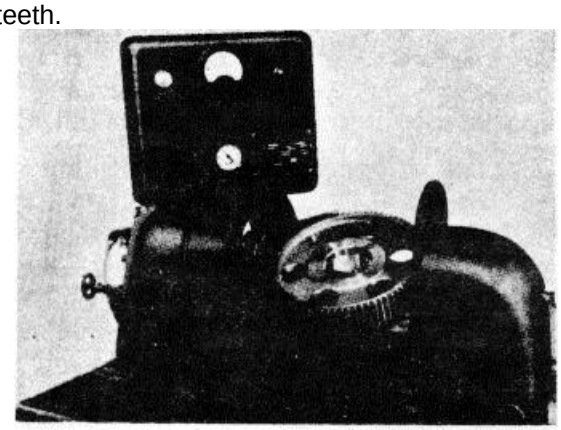


Fig. 35. - Gear Magnaflux Inspection

MAINTENANCE INSTRUCTION

FLUSHING DIESEL ENGINE LUBRICATING OIL SYSTEM

DESCRIPTION

Under normal operating conditions, it is NOT considered necessary or advisable to flush the engine lubricating oil system as a routine maintenance practice. The only attention necessary is that pre-scribed in the Scheduled Maintenance Pro-gram, Maintenance Instruction 1704 which covers such routine items as oil and filter change intervals. There may, however, be instances when flushing the system would be desirable and to assist in making such decisions, the following information is presented to serve as a general guide.

FLUSHING IS NOT NECESSARY WHEN:

1. Draining oil and replacing with fresh oil of the same brand and type.
2. Replacing an oil that has been diluted with diesel fuel oil.

FLUSHING MAY NOT BE NECESSARY -
Check with oil supplier on the question of compatibility when:

1. Replacing oil with another type or brand of oil.

FLUSHING IS NECESSARY WHEN:

1. A part failure has occurred and met-al particles have been distributed throughout the oil system.
2. Excessive contamination by water has occurred.
3. The engine is very dirty or badly lacquered.

FLUSHING OIL

When flushing is deemed necessary, the oil to be used may be the same as recommended in Maintenance Instruction 1752 for regular diesel engine lubrication. This is an SAE #40 oil and should be at a temperature of 150-200r F. for effective flushing. A lighter grade of SAE #10 oil may be used as an alternate provided that it is comparable to the regular engine oil. When using this lighter oil, the engine should not be loaded or run faster than about 425 RPM.

The use of flushing compounds or strong solvent flushing oils is not recommended because they would remove sludge and varnish deposits from metal surfaces too rapidly without properly dis-solving them. Such materials might then clog restricted oil passages before they could be flushed from the system.

GENERAL FLUSHING PROCEDURE

When flushing is necessary the procedure is basically one in which the engine and its lubricating oil system is drained and cleaned to the best extent possible. After careful inspection, the engine is then run for at least 30 minutes on flushing oil. In some cases a longer flushing period up to 2 hours may be required. After flushing and further inspection the flushing oil is drained and replaced by the regular lubricating oil.

In some instances, external pumping of flushing oil is recommended, particularly in cases where a part failure has

distributed metal throughout the engine. Such external pumping requires connections to the accessory oil manifold and the blower oil lines. The flushing oil is then pumped simultaneously to both areas at a pressure not to exceed 60 psi. By applying pressure at the blower end, a reverse flow of oil from this point prevents the forcing of metal particles from the main bearing manifold into the gear train. After simultaneous flushing in this manner, oil should be pumped into the blower end only which will remove dirt in the rear oil lines.

The specific details for the various instances when flushing is recommended is covered in the following:

FLUSHING AFTER A PART FAILURE

1. Completely drain oil from engine and lubrication system.
2. Remove upper main bearings.
3. Using kerosene spray and external flushing remove all traces of metal particles.
4. Install bearings.
5. Fill with flushing oil and run engine for at least 30 minutes.
6. Stop engine and remove main and connecting rod bearings to inspect for chip scoring.
7. Remove and clean oil cooler core.

FLUSHING AFTER WATER CONTAMINATION

1. Completely drain engine and lubricating oil system.
2. Using kerosene spray and external flushing, remove as much of the water-oil emulsion as possible.
3. In cases of severe water contamination it is advisable to inspect the main bearings. The main bearing condition will indicate if an additional inspection of connecting rod bearings is necessary.
4. Reapply bearings and add flushing oil to engine.
5. Run engine on flushing oil at least 30 minutes.
6. Remove and clean oil cooler core. Particular attention should be given to those applications having heat exchangers wherein the oil flows through core tubes. This type is more susceptible to clogging than those using elements designed for water flow in the tubes.

FLUSHING A VERY DIRTY OR BADLY LACQUERED ENGINE

Charging a very dirty or badly lacquered engine with new oil warrants special consideration in addition to the thorough flushing of the oil system. Of primary concern is the possibility of de-posits remaining in the engine, even after flushing, that may be detrimental to the functioning of the new oil to be used. This condition would be most critical after extended use of an oil which has allowed considerable deposits to build up within the engine.

Special attention should be given to the following points during and after the flushing operation.

1. Lube Oil Coolers

   The oil cooler is a likely area for deposits to accumulate due to the restricted passages in the core. Upon removal, if inspection shows partial clogging from operating on the first

oil, the cooler should be cleaned. If the cooler is found to be clean or has been cleaned, the new oil may pick up deposits from the engine and re-deposit them very quickly in the oil cooler. It is therefore recommended that. the cooler be removed and inspected a second time and cleaned if necessary.

2. Lube Oil Filters

Lube oil filter elements should be inspected and changed at very frequent intervals. When improvement in filter appearance becomes notice-able, the time interval may be gradually extended until satisfactory operation permits a return to intervals prescribed in the Scheduled Maintenance Program, Maintenance Instruction 1704.

3. Lubricating Oil Changes

As in the case with lube oil filters, it is very important that the new oil is drained and charged at frequent intervals. The condition of the oil is the best guide to the frequency of such changes. When improvement is noted, the intervals can be gradually extended until operation has returned to normal which will permit a return to recommendation in the Scheduled Maintenance Program,

4 High Lube Oil Suction

A high lube oil suction alarm occur-ring while the engine is operating should be given immediate attention. This **is** an indication that the suction strainers are clogged which will pre-vent the engine from receiving sufficient lubricating oil. The engine should not be operated after such an alarm until the strainers have been cleaned. To prevent such a condition from occurring, the strainers should be checked and cleaned frequently. As an added precaution, it is advisable to inspect the high lube oil suction protective equipment.

REUSE OF FLUSHING OIL

After completion of a flushing opera-tion, the flushing oil should be drained and saved if desired for future use in flushing additional engines.

Before reusing, the foreign materials picked up during flushing should be allowed to settle where they can be drained away. After carefully inspecting oil condition it may then be reused by adding make up oil to compensate for that drained out.

When not in use, flushing oil should be kept in marked containers (to prevent its inadvertent use) that are covered to prevent dirt and other contaminants from entering.

MAINTENANCE INSTRUCTION

PISTON PHOSPHATE TREATMENT

DESCRIPTION

The phosphate treatment of pistons outlined in the following instruction provides such an acceptable surface aid for lubrication on the 567 series engine cast iron pistons, that all pistons used in new engines, those supplied by our Parts Department, and pistons returned for Factory Rebuild Service are given this treatment. This treatment produces a non-metallic, oil absorbent, anti-friction coating on the piston surface that aids rapid break-in and reduces subsequent wear.

To assure continued service life of used pistons, the skirt surface should be inspected whenever pistons are removed from an engine and, if required, given a new phosphate treatment. A used piston should be given re-treatment whenever any area of the skirt shows shiny bare metal, of approximately three (3) square inches.

A piston properly phosphatized will have a uniform dark grey appearance with a fine smooth grain structure and a flat dull finish where the metal being processed is uniform in composition.

A. EQUIPMENT REQUIRED

The piston treatment layout shown in Fig. 1 should be applicable to most shops. The size of the tanks will provide adequate facilities for a large shop where piston turnover is heavy. However, only a small saving would result if the tanks were reduced in size for a smaller volume of pistons. The schematic piping diagram, Fig. 2, is a suggested method for piping the tanks in Fig. 1. A list **of** the material required is included in Fig. 1.

A small cabinet should be provided, as shown in Fig. 1, for storing and protecting the laboratory equipment. The cabinet may be shop built, as may a bench with a protective shield for air blowing the pistons following the final graphite treatment, as explained under “Procedure.”

Several piston holding fixtures should also be made, as indicated in Fig. 3, for properly immersing pistons in the various baths, at an angle of about 45°. The cross-member of the hook is held in the notched brackets welded to the front of the tank to provide a pivot bearing for the piston when lowering into solution and for automatically up-ending and draining the piston when lifting it out of the solution.

If it is planned to keep the equipment in constant use, it will be necessary to provide a spare steam coil for tank #2. The coil in this tank becomes coated rather quickly with the phosphate deposit, and it should be changed often in order that solution temperature can be maintained. The design should be such that the pipe unions are well above the level of the solution, facilitating the removal of the coil for cleaning. One inch drain valves should be installed at the bottom of each tank,

except tank #2. A valve used on this tank would have to be of stainless steel construction and is not considered necessary. In normal practice, the phosphate solution is not thrown away, but is siphoned out periodically in order to dispose of the sludge which accumulates at the bottom of the tank. During this time a rinse tank may be used to receive the solution while the stainless steel tank is cleaned.

The phosphate solution tank #2 and the graphite tank #4 should be equipped with temperature regulating steam admission valves and accurate thermometers in order to maintain proper temperatures during processing. Air agitation, or surface c 1 e a n i n g air should be provided for tank #4 to pre-vent excessive graphite deposit on the pistons at time of removal.

B. SOLUTIONS REQUIRED

1. Tank #1

Tank #1 should be filled with plain water and kept at the boiling point and allowed to overflow slightly to prevent soil build-up.

2. Tank #2

The phosphate solution in tank #2 consists of ten (10) gallons of Thermoil-Granodine #112 (or equal),

or Parco Lubrite #1 or #2 (or equal),

to every ninety (90) gallons of water. Tank #2 phosphate solution temperature should be kept between 190' - 205' F. A temperature much below 190' F. will result in a poor coating.

The coating produced on articles in a freshly prepared bath is not as desirable as a coating produced in an "aged" bath. For this reason a freshly prepared bath should be "aged" by adding about one (1) pound of steel wool for every 100 gallons of solution. The steel wool should be suspended in the solution in a wire basket. Avoid throwing steel wool into the phosphate tank in lumps or wads that may cause sludge deposit on the pistons. The wire basket with steel wool should be agitated occasionally to assure proper iron build-up, then withdrawn when iron content is correct, in the proper range.

The "aging" period will last about one hour and, at the end of this time, free and total acidity of the solution should be checked by the method given under "Testing And Maintenance Of Solutions."

NOTE: Pistons should not be processed while bath is being aged with steel wool.

3. Tank .3

This tank contains plain water kept at a temperature of 150° - 180° F., and allowed to overflow slightly to prevent soil build-up.

4. Tank #4

This tank contains the graphite solution consisting of 3-1/2 gallons of soluble oil (Texas CX or equal) and one (1) pound of Acheson Colloid Company "Aquadag" (or equal) added to every 100 gallons of water and mixed thoroughly. Temperature of this solution can be from room temperature to 140' F. maximum. Air agitation should be provided to prevent the colloidal graphite from accumulating on the surface.

NOTE: In the event that this solution is allowed to become too hot, the graphite will separate and float to the surface. When this occurs, it should be skimmed off and new colloidal graphite added. A certain amount of this separation takes place normally, - hence the need for air agitation.

C. PHOSPHATE TREATMENT PROCEDURE

1. Cleaning

In order to insure complete adhesion of the phosphate coating, the outer surface of the piston must be clean prior to treatment. Ring grooves must be free of deposits and all oil and varnish removed from surfaces to be coated. Mild alkali cleaning in a hot soak tank with agitation or with high pressure spray can be used to remove most of the soil. Any hard carbon or rust deposits remaining can then be removed by careful wire brushing or by machines employing soft abrasives, such as ground corn cobs or ground peach pits for cleaning. Washing tank, drawing 8041054, maybe used for the cleaning process. Copies of this drawing to show construction may be obtained on request.

2. Piston Preparation For Tank #1 Immersion

Wipe piston clean with a cloth saturated in a high flash point petroleum solvent (such as Stoddard Solvent 1050 F. flash point or equal), mount on piston rack and submerge in tank #1 for 10 - 15 minutes. Lift out and allow excess water to drain out, and immediately place in phosphate solution, tank #2.

NOTE: Wiping with petroleum solvent is important, since it helps control the grain size of the phosphate coating. Change wiping cloths and solvent frequently to avoid soil build-up on the piston.

3. Phosphate Application - Tank #2

Immerse piston in phosphate solution for a total time of 15 minutes. After completion of the operation, the piston should be drained and transferred quickly to rinse tank #3.

4. Piston Rinse, Tank #3

Rinse thoroughly by dipping in the hot rinse water for at least 30 seconds.

5. Graphite Treatment, Tank #4

After removal from tank #3, sub-merge hot piston quickly in tank #4 to coat with soluble oil and colloidal graphite and remove. After removal of piston from graphite treatment, it should be blown dry with clean compressed air before storing or returning to service.

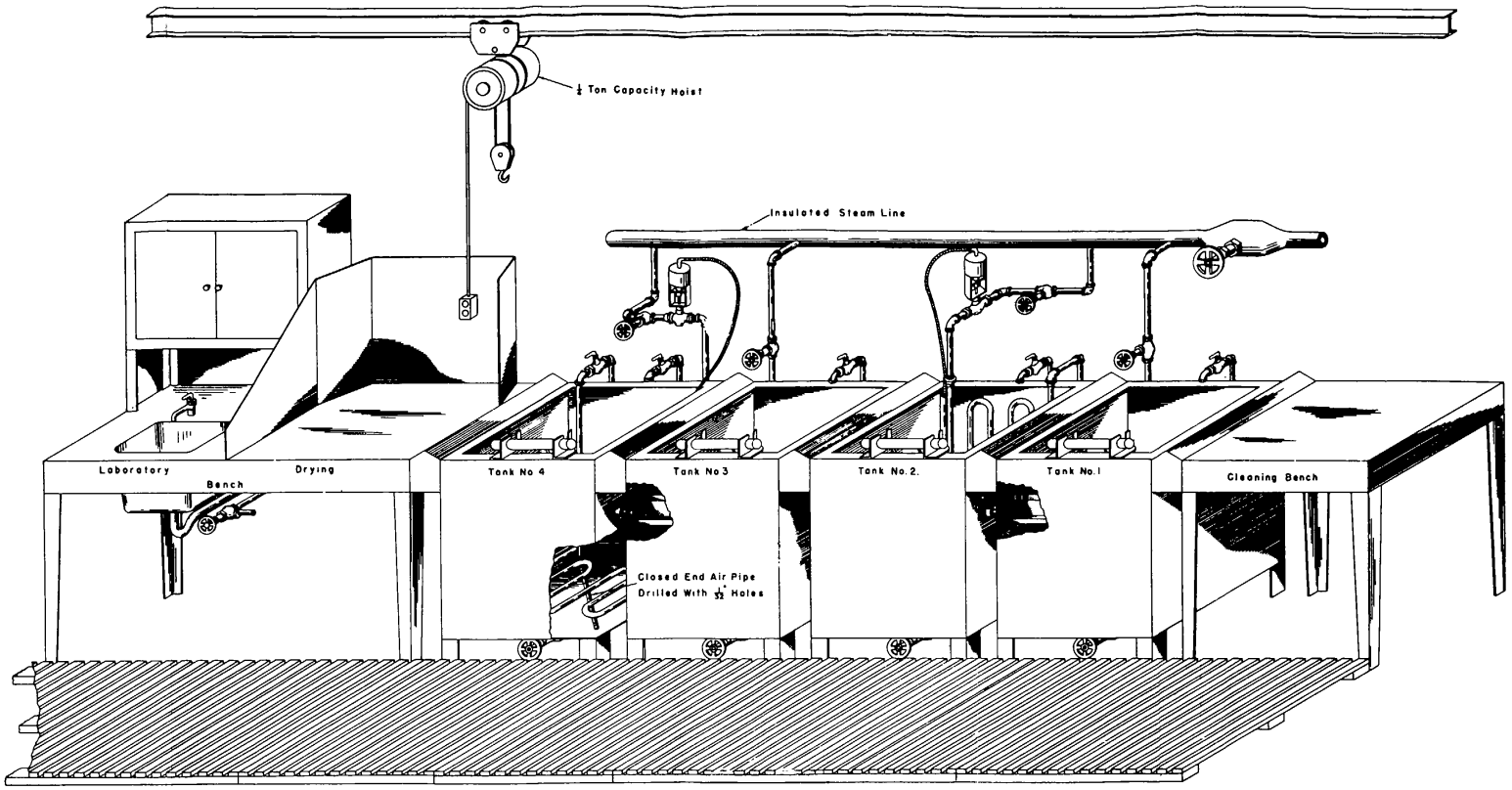
† **NOTE**: The phosphatized coating has only limited rust resistant qualities and is not a permanent type rust preventative. If pistons are to be stored for any length of time, place piston with V.P.I. paper in fairly airtight container. V.P.I. paper should not be used to wrap piston as activated side of paper will rust metal in contact.

D. TESTING AND MAINTENANCE OF SOLUTIONS

For best results, maintain and control phosphate and graphite solutions as follows:

1. Phosphate Tank #2

a. Total Acidity Pipette 2 cc. of the tank #2 solution into a clean glass beaker and add 35 drops of phenolphtha , in indicator. Measure in 0.1N sodium hydroxide (NaOH) (this is 4 grams NaOH in 1000 cc's distilled water or .1 the strength of normal solution consisting of 40 grams NaOH powder in 1000 cc's of distilled water) until a light pink color develops. The number of cubic



EQUIPMENT LIST

Quantity	Description
3	Dipping tanks, 36" x 30" x 28" - 1/4" steel plate
1	Phosphate tank, 36" x 30" x 28" - 11 gauge, stainless steel
275 feet	1/2" wrought steel pipe
100 feet	1" wrought steel pipe
12	1/2" Globe valves 150#
3	1" Globe valves 150#
1	1" Glove valve 150# stainless steel (optional)
	Miscellaneous pipe fittings

EQUIPMENT LIST (Cont'd)

Quantity	Description
1	1/4 Ton Monorail hoist with 35 ft. rail
2	Temperature regulating valves - indicating type with stainless steel bulb - 3/4" pipe size 170-230 psi
1	Tank construction details, File Print #581
1	Tank cover arrangement, File Print #484

This equipment list is in accordance with the general arrangement shown in Fig. 1 and will necessarily vary according to location installation requirements.

centimeters (cc's) of sodium hydroxide solution added will indicate the strength in points of.

total acid in the phosphate solution which should be maintained at 12 plus or minus 1 point.

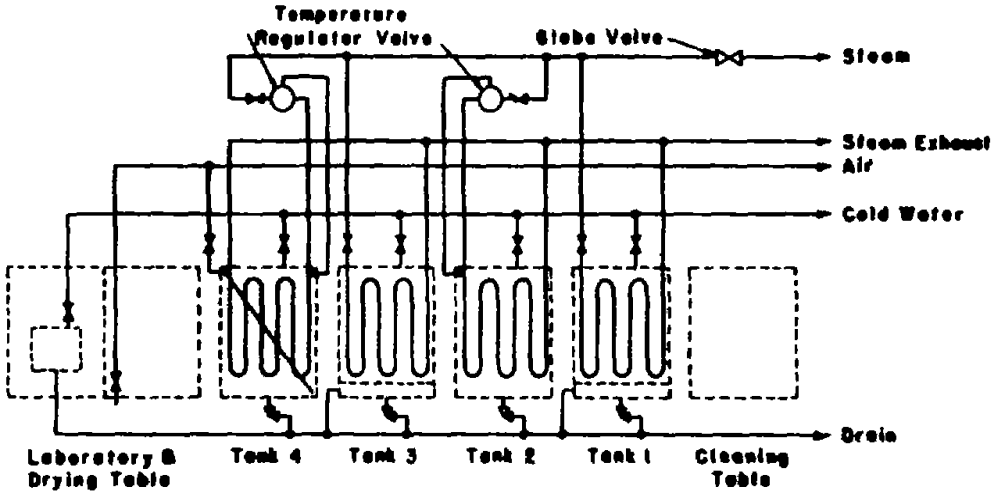
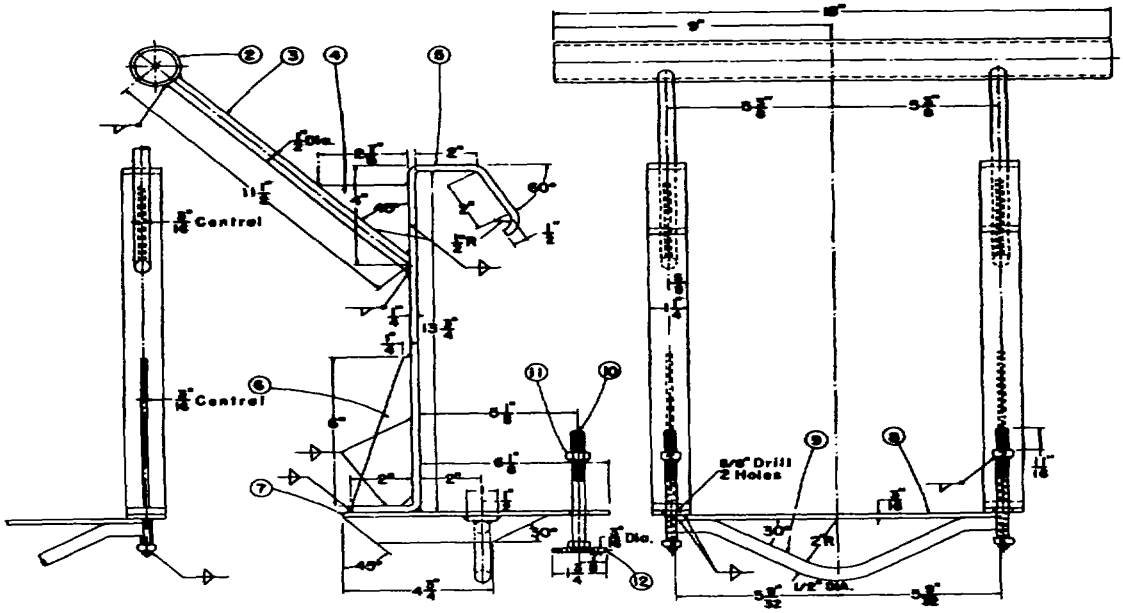


Fig. 2. - Piston Treatment Layout - Schematic Piping Diagram



Item	Name	Material	No. Req.	Item	Name	Material	No. Req.
1	Assembly			7	std.	Tee 1-1/4 x 1-1/4 x 3/16	2
2	Cross Member	1-1/4 NPS	1	8	Cross Bar	SA 1020 Steel	1
3	Arm	SAE 1020 Steel		9	Eye	SAE 1020 Steel	1
4	Gusset	SAE 100 Steel	2	10	He Hd. Bolt	3/8-16x4-1/2l	2
5	Piston Book	SAK 1020 Steel	2	11	Hex. Nut	3/8-18	2
6	Gusset	SAE 1020 Steel	2	12	Thumb Bar	SAE 1020 Steel	2

Fig. 3. - Piston Holding Fixture

Small quantities of Parco Lubrite #2 or Thermoil Granodine #112 should be added at intervals in order to restore the total acid strength of the solution. The amount being governed by the results of the total acid test.

b. Free Acid

Take 2 cc's of tank #2 solution, add a few drops of methyl or ange xylene cyanole indicator, then add 0.1N sodium hydroxide from a burette until a faint green color appears. The number of cc's used indicates in points the strength of free acid in the phosphate solution. The strength of the solution should be maintained at 2 plus or minus 0.2 points.

For every part of free acid present, there should be 5.5 to 6 parts of total acid. This is obtained by dividing the total acid points by the free acid points. When the total acid is at 12 points or higher, and the free acid is low, the free acid should be brought up by boiling the solution. This will cause the total acid to break up into free acid. If the total acid is low and free acid is low, the total acid may be brought up by add ing Thermoil Granodine #112 or Parco Lubrite #2 and then boil ing the solution to bring up the free acid. Too high free acid content of the solution can be remedied by neutralization. The addition of 4 ounces of neutralizer No. 200 per 100 gallons of processing solution will reduce the free acid 0.1 point (0.1 milli liters), or 40 ounces approximately to reduce the free acid 1 point. Add water to the neutralizer No. 200 in a container to form a slurry (thick soupy mixture) and distribute over the surface of the phosphate solution. The solution should then be stirred thoroughly. Allow to settle before using again.

c. Iron Content

A processing solution high in iron is apt to result in an in complete coating in the normal processing time, a non-adherent coating, uneven etch of the metal surface, a thinner than normal coating, and light grey color instead of dark grey.

To test for iron, pipette a 10 cubic centimeter sample of the tank #2 solution into a glass beaker, add 10 to 20 drops of a 50% sulphuric acid and, using a 10 cubic centimeter Mohr pipette, titrate (process of determining amount of substance, by smallest amount to have a given effect in reaction with another known sub stance) the prepared sample with titrating solution #18 (potassium permanganate) until a pink color persists. Each cubic centimeter of titrating solution #18 used indicates the presence of .1 of one per cent of iron in the solution. Thus 3 cubic centimeters of titrating solution #18 indicates .3 of one per cent iron in the tank #2 solution. In general, the iron content of the Lubrite solution is maintained between .2 to .3 of one per cent (0.2 to 0.3%) equivalent to use of 2 to 3 cubic centimeters of titrating solution #18.

When the upper limit of iron (0.3%) in the tank #2 phosphate solution is reached, hydrogen peroxide is added to precipitate and remove part of the iron. One pound (1 pint) of 100 volume (30%) hydrogen peroxide will remove .1 of one per cent iron

from each 100 gallons of solution. The phosphate solution should be stirred after each addition of hydrogen peroxide to insure a uniform mix in the bath. To avoid a dusty coating on pistons after precipitating iron from the solution, sufficient time should be allowed for the sludge to settle out before introducing work into the bath.

CAUTION: Hydrogen peroxide is a strong oxidizing agent and customary precautions should be taken in handling it and other solutions or materials used in this procedure.

2. Graphite Solution, Tank #4

The strength of this solution should be tested at least once a week to determine the proportion of oil. To do this, place 100 cc's of the solution in a graduated cylinder and add 20 cc's of 50% sulphuric acid or reagent 44. This will cause separation of the oil and it will float to top of cylinder. The separated oil should be about 2% of the total volume. Surface scum should be re-moved periodically from tank #4.

E. REAGENTS USED FOR TESTING

Alkaline Testing Solution or (Test Solution #11)	Dissolve 4.0 grams NaOH in I liter distilled water, standardize against a known acid, and adjust to 0.1N.
Methyl Orange-Xylene Cyanole or (indicator Solution t#)	Dilute methyl orange-xylene cyanole solution 200% with distilled water.
Potassium Permanganate or (Titrating Solution #18)	Dissolve 6.0 grams potassium permanganate in a liter of distilled water, standardize against a known (ferrous) iron solution and adjust so that the 1 cc, is equivalent to 0.01 grams of iron.
50% Sulphuric Acid or (Reagent *44)	Add slowly to 540 cc. of distilled water, 410 cc. concentrated C.P. sulphuric acid.

F. PISTON PHOSPHATE TREATMENT MATERIAL

Quantity	Description
1 drum	Parker Rust Proof Company Parco Lubrite No. 1 or No. 2 - approximately 400 lbs. (55 gal.) or American Chemical Paint Co. Thermoil-Granodine #112
1 drum	Soluble Oil (Texas CX or equal)
100 lbs.	Neutralizer No. 200
24 lbs.	Graphite (Acheson Colloid Co. "Aquadag" or equal)
1 gal.	30% hydrogen peroxide solution
	Testing Apparatus And Reagents
9 lbs.	Concentrated C.P. sulphuric acid
1 gal.	Sodium hydroxide
1 pint	Methyl orange xylene cyanole indicator
1 pint	Phenolphthalein indicator
1	Erlenmeyer flask - 250 cc.
1	Pipette - 2 cc.
1	Burette - 25 cc.
1	Burette stand
2	Beakers - 250 cc.
1	Pipette - 10 cc.
1	Mohr Pipette - 10 cc.

MAINTENANCE INSTRUCTION

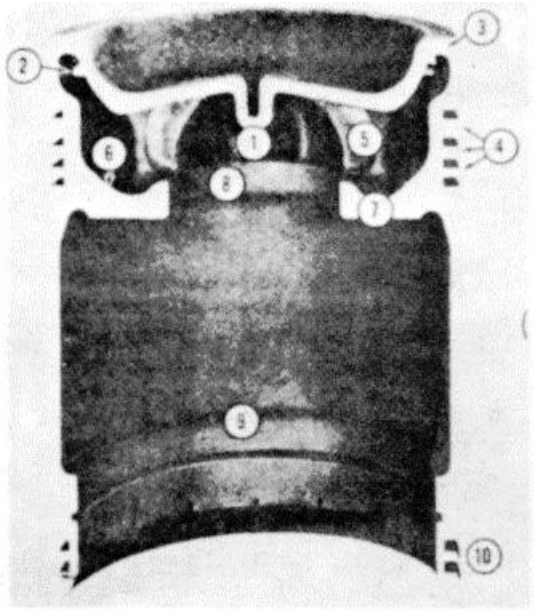
REMOVAL OF UNDERCROWN DEPOSITS FROM 567 ENGINE PISTONS

DESCRIPTION

The full floating pistons used in the 567 series diesel engines are efficiently cooled during operation by means of lubricating oil. This oil comes from the piston cooling oil pipe which directs the oil through a hole in the piston carrier to the u n d e r s i d e of the piston crown. After providing the necessary piston cool-ing, as well as thrust washer and piston pin lubrication, this oil then drains to the engine oil pan. The flow or circulation of oil through the piston is continuous.

During normal operation, there is often a tendency for carbon deposits to form in-side the piston, Fig. 1, in the cooling fin and crown rim areas. If allowed to accumulate, such deposits reduce piston cool-ing efficiency by preventing the necessary heat transfer to the cooling oil. The resulting temperatures at the crown rim and number one compression ring areas might then be such as to cause cracking in top ring groove or crown area. It is therefore recommended that any time pistons are removed from an engine, they be thoroughly cleaned to remove any undercrown deposits that may have formed.

Two steps are recommended for the complete cleaning of pistons. The first step is to follow the conventional method using solutions. However, this treatment will not remove all deposits from the under-side of the crown in the center and crown rim areas. A second step is therefore recommended which involves the use of a sand or grit blasting method to remove the hardened undercrown deposits. A suitable fixture for such cleaning is shown in Figs. 2 and 3.



1. Puller Hole Boss
2. Spine
3. Crown Rim
4. Compression Ring Lands
5. Platform Supports
6. Tie Ribs
7. Platform
8. Upper Pilot
9. Lower Pilot
10. Oil Ring Land

Fig. 1. - Piston Cross-Section

Correct use of this fixture will insure satisfactory removal of the undercrown deposits without damage to the pistons.

The amount of sand or grit blasting material required depends to a great extent on

the grade and type used as well as the thickness of deposit to be removed. When first starting the cleaning program, it is recommended that a few scrap pistons be cleaned, then cut in half in order that the effectiveness of the cleaning operation may be observed. The blasting interval can then be adjusted to the minimum time required to completely remove the deposits.

CLEANING PROCEDURE

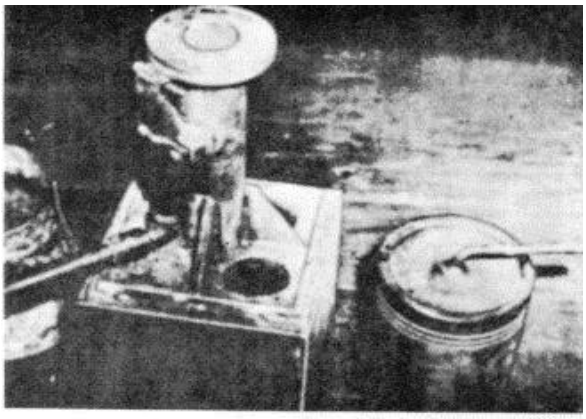
For best results, it is recommended that the cleaning procedure outlined below is followed:

1. Clean pistons in a suitable solution.

2. Remove from cleaning solution and allow to dry for 2 to 4 hours.

3. Apply rubber gasket on top of fixture to protect the piston platform from damage.

4. Place piston on fixture and apply turning handle to threaded piston pulling hole.



C763

Fig. 2. - Sand Blasting Fixture

5. Securely clamp air supply hoses to fixture since any leakage at this point may damage the finish on the piston skirt.
6. Using fine sharp sand or light grit, commence the blasting operation. Rotate piston at a rate of one turn every 10 seconds.
7. After about 30 seconds of blasting (or to the extent indicated by experience) stop blasting and remove the piston from fixture.
8. Place piston in liquid cleaning solution as outlined in Step 1. Remove piston from solution and spray rinse with clear hot water.
9. Blow piston dry with compressed air and carefully inspect to make sure all traces of the cleaning material have been removed.
10. Following procedure outlined in Maintenance Instruction 1758, apply phosphate treatment to piston if required. Make sure piston is protected from rusting if it is to be stored for any length of time.

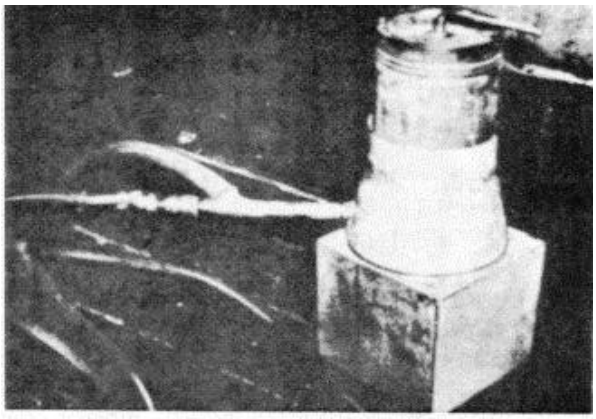


Fig. 3. - Piston Being Cleaned

MAINTENANCE INSTRUCTION

SELF-SEALING WINDOW WEATHER STRIP

DESCRIPTION

The self-sealing weather strip used widely on locomotive windows, has an added application on certain panel sections in power generating units. This weather strip is comprised of two parts as shown in Fig. 1, namely a sealing strip and a filler strip. Application of this strip can generally be made only to openings originally built to accommodate this method of sealing.

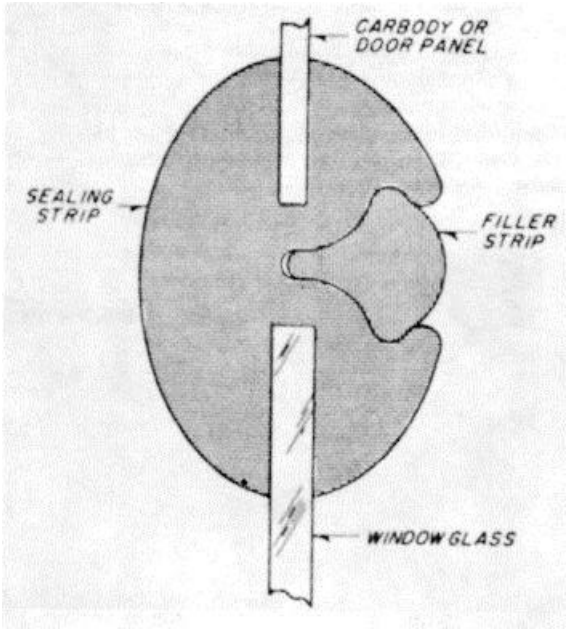


Fig. 1. - Cross-Section Of Window Sealing Arrangement

MAINTENANCE

Prior to replacement of a window or panel, the sealing and filler strips should both be carefully examined for cuts and general deterioration. Any condition found on the old strips that could contribute to leaks or difficulty in installation is cause for replacement. Application of the weather stripping is facilitated by special tools designed for this purpose. Fig. 2 illustrates on the left the hook type sealing strip in-stalling tool 756475 and on the right, the eye type filler strip tool 756460.

The use of these tools together with the procedure to be used is illustrated in the following 12 step sequence.

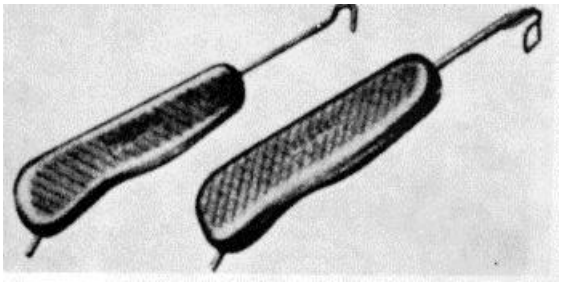
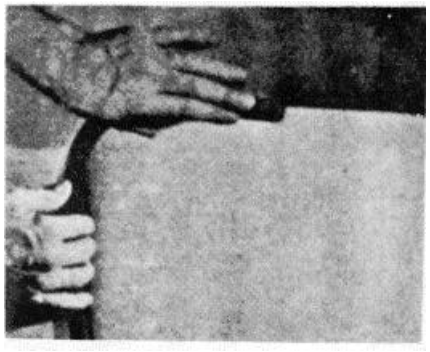
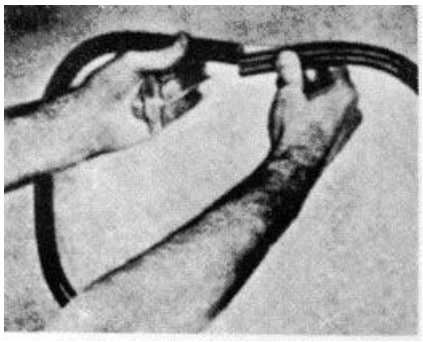


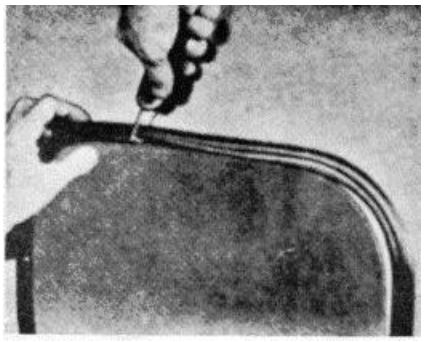
Fig. 2. - Seal And Filler Strip Installation Tools



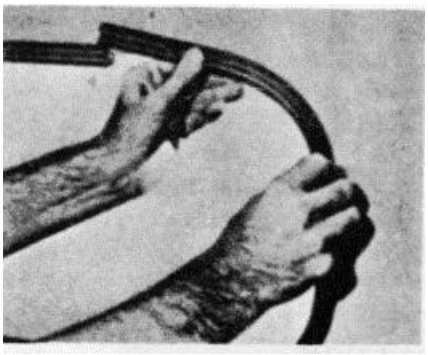
1 For easy seal installation, window opening in car body or door is rubbed with paraffin or the seal is lubricated with soap and water solution. Starting along the top of the open-ing the body panel channel of the seal is then fitted over the openings edge.



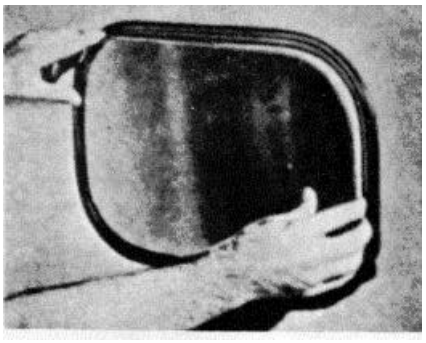
3 Seal is withdrawn slightly at the starting point in such a way that it matches the overlap. Ends of the seal are brought together and are then forced over the body panel. The result is a tight, smooth joint.



5 Working in both directions from starting point, specially designed seal installation tool, Fig. 2, lifts the glass channel lip while glass is easily slipped into position.



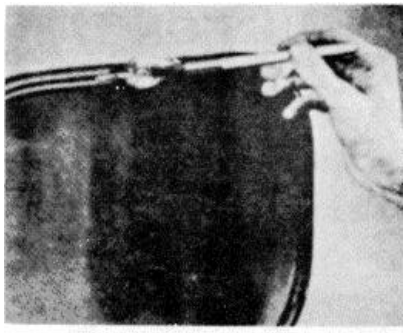
2 Seal is continued around perimeter of window opening with the panel channel of the seal enveloping panel in a snug fit. The seal will overlap the starting point by approximately 1/8" per foot of window opening perimeter. This will permit a tight fit.



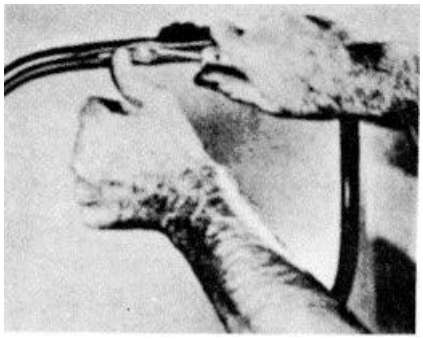
4 Seal is designed with glass channel lip opened at 45' for easy installation of glass panel. Starting from lower corner glass panel is fitted into channel as far as it will go without forcing.



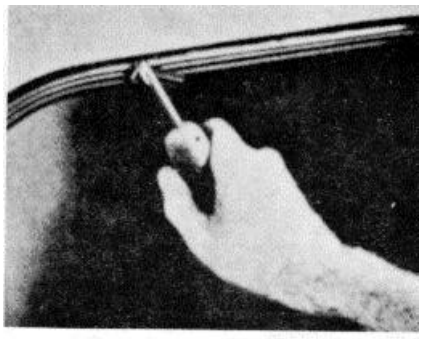
6 At final corner this same handy tool opens glass channel to permit entry of remaining glass edge. Entire operation requires but a few minutes.



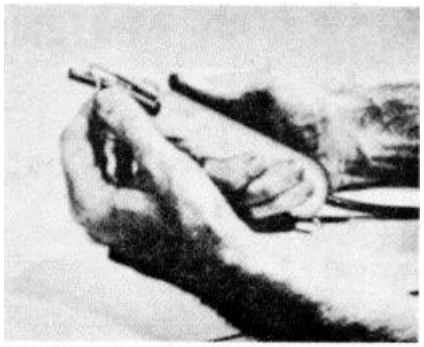
7 With a small brush, soap and water solution is applied to seal's filler channel. This preparation greatly facilitates final operation of installing filler strip.



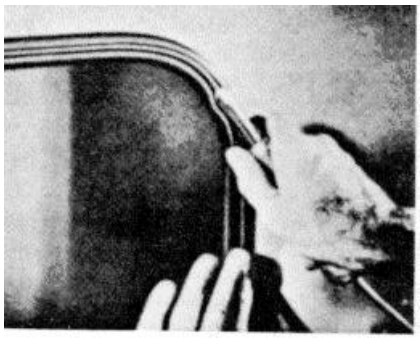
9 At top, away from seal joint, filler strip and eye of tool are inserted into seal's filler strip channel. End of filler strip is held in position with thumb during first motion of tool.



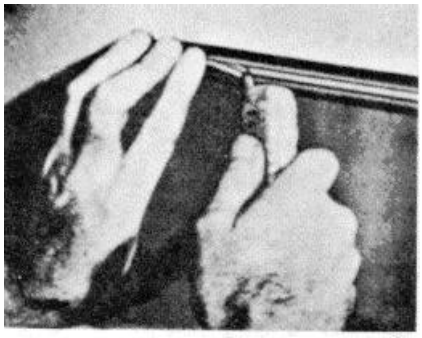
11 When starting point is reached, remove tool. Filler strip should be cut to overlap starting point so that when both ends are forced into place, joint will be under pressure.



8 Filler strip is inserted into handle and eye of filler strip installation tool, Fig. 2. Both handle and eye are so constructed that they prevent filler strip from twisting.



10 Tool is moved along channel with zipper-like motion. Filler strip feeds through handle and eye, threads into channel. Rounding corners is easiest when tool is "wiggled" slightly.



12 Spur on handle is used to compress filler strip overlap into channel for a tight joint. Spur is also useful in repositioning any part of filler strip not properly seated.

FRACTIONAL HORSEPOWER MOTORS MODELS A-731, A-9385 AND A-732

DESCRIPTION

The Model A-731 fuel pump motor, Fig. 1, is a 1/4 HP, 4.3 amperes, 64 volt DC, 1100 RPM motor with a double end shaft. The Model A-9385 fuel pump motor is identical to the A-731 with the exception of having a single end shaft.

The Model A-732 cab heater motor, Fig. 2, is a 1/6 HP, 2.5 amperes, 72 volt DC, 1350 RPM motor with a single end shaft.

All three models are assembled with shielded, sealed grease packed ball bearings, requiring no additional lubrication. Their rotation is counterclockwise when viewed from the commutator end.

Two brushes are mounted at angles with the surface of the commutator and are held under pressure by coil springs.

Due to their similarity, the maintenance instructions which follow will apply to all three models of motors. Any exceptions will be specifically identified.

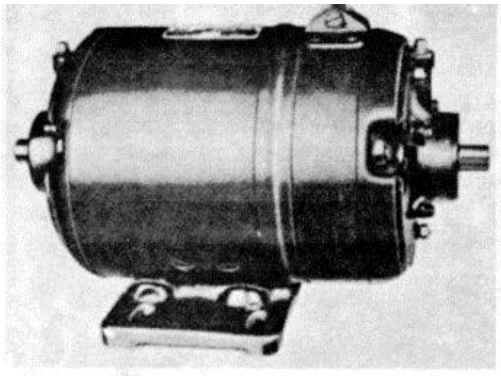


Fig. 1. Model A-731 Fuel Pump Motor

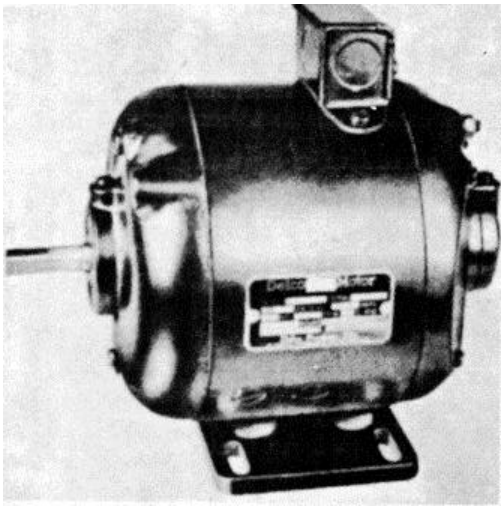


Fig. 2. Model A-732 Cab Heater Motor

MAINTENANCE

Motors of this type perform important functions and should be kept in good working condition. Besides the specific inspection intervals these motors should be given additional attention as necessary to insure the continuous trouble free operation expected of them.

INSPECTION

The motor and device it drives should be inspected for tightness of the coupling or connection for freedom of rotation. Circuit connections to the motor should be tight with voltage drop at terminals not to exceed 10% of rated voltage. Using a megohmmeter, check for

grounded armature and frame. A reading of less than one megohm will necessitate removing the motor from service for further inspection and overhaul if necessary to determine and correct the difficulty.

CLEANING

The motor exterior should be wiped to keep it free of oil and dirt accumulations. Remove the inspection covers and occasionally blow out the motor interior with clean, dry, low pressure air to re- move carbon dust and dirt.

In severe cases of dirt and oil accumulations, the use of a cloth, dampened with solvent maybe necessary to properly clean the motor. When using solvents take care to prevent it from coming in contact with the commutator. Also allow the motor to dry thoroughly before re- turning it to service.

BRUSHES

The brushes should be free to move in the brush holder slots. If they bind or stick, remove the brushes and correct the cause. If the brushes are chipped or worn shorter than 3/4" they should be replaced. Replacement brushes should be the same grade as those removed.

When new brushes are installed, they should be sanded-in by placing a strip of #00 grade sandpaper, sand .side up, on the commutator under the brushes and rotate the armature by hand in the direction of normal rotation. Rotate until brush is seated to the contour of the commutator. Remove the sandpaper and blow out carbon dust. If the brushes squeal during operation they should be sanded-in to remove the squeal. Never lubricate the commutator.

Brush spring pressure should be checked and meet the requirement listed in the Maintenance Data section. Replace the springs when pressure is low.

COMMUTATOR

The commutator should be inspected to see that the slots between the bars are free of dirt. Surface of the commutator should present a polished appearance free from pitting, burning or raised bars. Check the section where the armature windings connect to the commutator for evidence of loose connection or thrown solder. If any of these conditions exist, the motor should be removed from service and repaired.

If there is only slight pitting from arcing of the brushes, the surface should be cleaned with fine sandpaper. Never use emery or carborundum paper.

BEARINGS

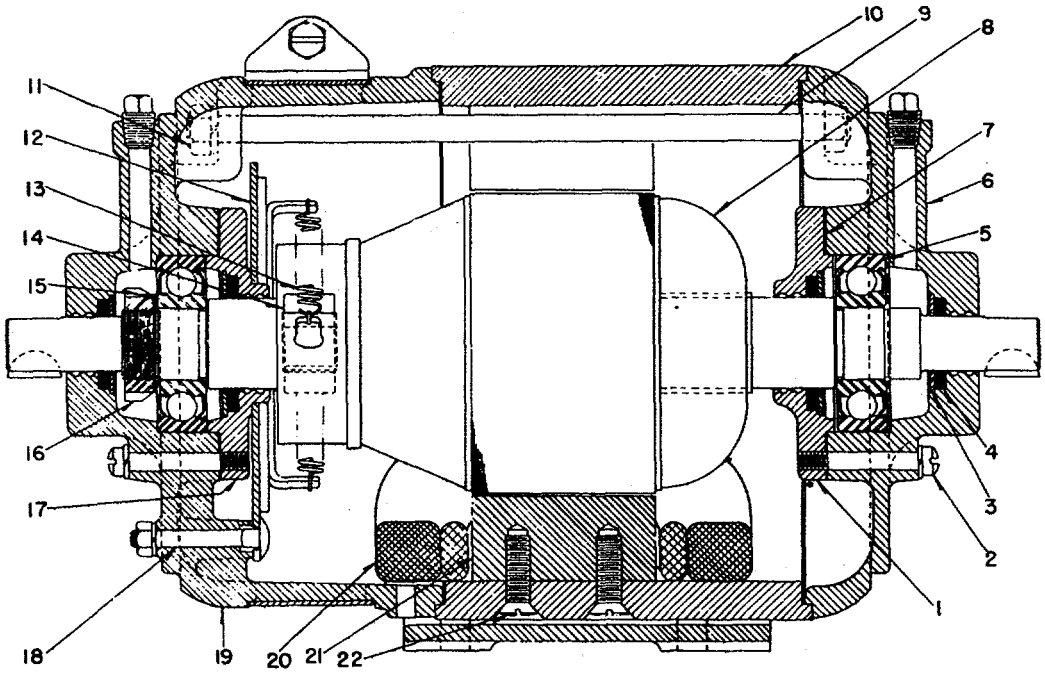
The ball bearings are of the sealed grease type and require no further lubricating during operation. When the motors are overhauled, the used bearings should be scrapped. Always reassemble the motors using new sealed bearings.

NOTE: Some of the early motors of these models were constructed to be lubricated during operation. These motors, when overhauled, should be reassembled using sealed bearings. The lube holes should be plugged to prevent the addition of unnecessary grease.

Bearings should be checked during operation by listening or feeling for roughness. Any suspicious noise or vibrations should warrant the motor's removal to prevent complete bearing failure and severe damage to the motor components.

OVERHAUL

When it becomes necessary to overhaul the motors either for defects found during inspection or because of the overhaul period as outlined in Scheduled Maintenance refer to Fig. 3 or Fig. 4 and follow the suggested procedure below.



1. Bearing Cover
2. Bearing Cover Cap Screw
3. Expansion Plug
4. Felt Seal
5. Ball Bearing
6. End Frame
7. Gasket
8. Armature
9. Through Bolt
10. Motor Frame
11. Through Bolt Nut
12. Brush Bracket
13. Brush Spring
14. Brush With Hook
15. Bearing Lock Washer
16. Bearing Lock Nut
17. Bearing Cover
18. Brush Bracket Bolt
19. End Frame
20. Field Coil
21. Pole Piece
22. Pole Piece Screw

Fig. 3. Cross-Section Fuel Pump Motor

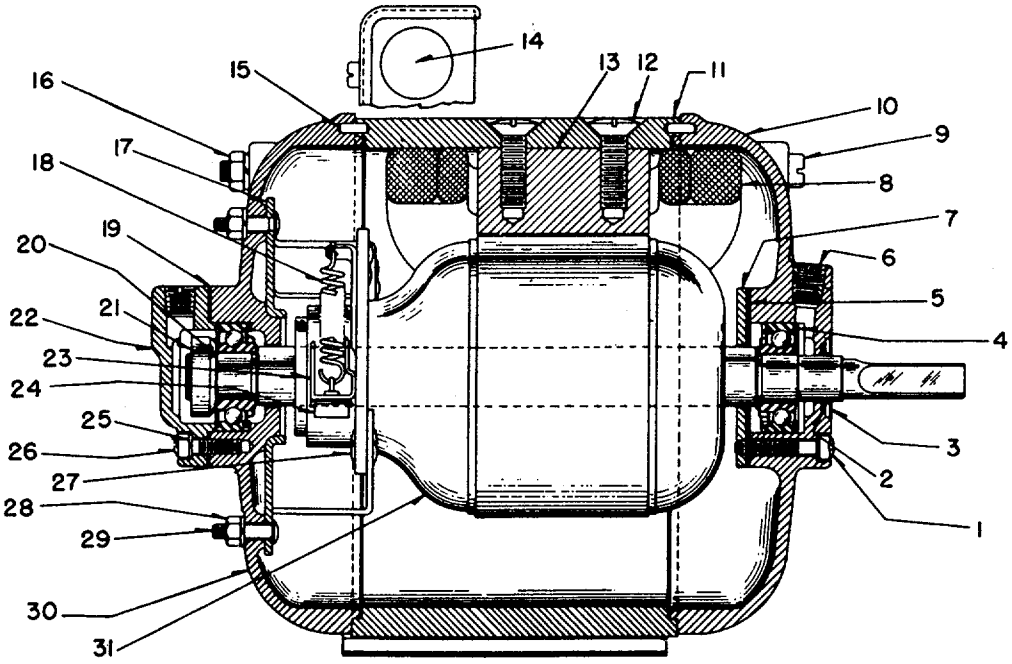
NOTE: Because of the similarity of the motors, information given below applies to all models except where otherwise noted.

DISASSEMBLY OF MOTOR

1. Remove cover band or cover plates.
2. Disconnect the brush leads and field leads. Remove the brushes.
3. Remove the screws from both ends of the motor holding the bearing caps to the end frames.
4. Remove the key from the shafts.
5. Remove the two through bolts.
6. Tap gently on the shaft extension opposite the commutator end to free the armature and commutator end housing assembly from the frame.
7. Remove this assembly and place on a suitable stand to remove the bearings.
8. Remove the commutator end housing.

NOTE: On the fuel pump motor it will be necessary to remove the brush bracket screws to allow the commutator end housing to move off the bearing.

9. Remove the drive end housing from the frame.
10. Remove the bearing lock washer and nut from one end or both ends depending on type being dismantled.
11. Remove bearings and bearing caps from armature using puller or one



Commutator End

1. Bearing Cover Cap Screw
2. Felt Seal
3. Expansion Plug
4. Ball Bearing
5. Gasket
6. Pipe Plug
7. Bearing Cover
8. Field Coil
9. End Frame Bolt
10. End Frame
11. Motor Frame
12. Pole Piece Screw
13. Pole Piece
14. Conduit Box
15. Locating Dowel Pin
16. End Frame Nut

Drive End

17. Brush Bracket Plate
18. Brush Spring
19. Gasket
20. Bearing Lock Washer
21. Bearing Lock Nut
22. Bearing Cover
23. Brush Holder
24. Brush With Hook
25. Lock Washer
26. Bearing Cover Cap Screw
27. Brush Holder Bracket Rivet
28. Brush Holder Nut
29. Brush Bracket Bolt
30. End Frame
31. Armature

Fig. 4. Cross-Section Cab Heater Motor

similar to that illustrated in Service Tools Catalog 91B, Section G.

12. Discard old bearings and gaskets.
13. Clean out grease cavities in bearing cap and end frames.
14. Remove old felt seals and expansion rings.
15. Clean and check all parts. Replace any parts showing wear or damage.

ARMATURE

The armature should be cleaned be- fore any electrical inspections are made. Stoddard solvent may be used, blowing off excess solvent with low pressure high volume air. No electrical inspection should be made while armature is still wet from the solvent.

When the armature is clean and dry perform the following checks:

1. Using a megohmmeter check the armature insulation to ground. If less than one megohm, armature may be wet. Place in a convection oven set at 160° C. and dry armature for 3 hours, then remove and cool to room temperature. If reading is still low, armature should be repaired or replaced. If the reading has come up proceed with the inspection.

2. Visually check shaft diameters to see that they are in good condition.
3. Check the commutator for all defects listed under "Commutator."

   If there is evidence of raised or loose bars, armature should be replaced. Should there be signs of solder thrown out of the connection area between the armature windings and the commutator, they should be resoldered. When the commutator is badly worn or burned, the armature should be placed in a lathe and the commutator turned just enough to give a uniform surface. See Maintenance Data section for limits on commutator while turning. The peripheral speed of the commutator surface should be about 300 ft./min. Round off the ends of the commutator bars to break the sharp edges.

   The area between the commutator bars should then be undercut 1/32" deep and .030" wide.

   After undercutting, polish the commutator surfaces with #00 sandpaper. Remove all mica fins and see that no copper chips remain in the slots.

   With a dial indicator, check the out-of-round of the commutator. It should bewithin.001" total indicator reading.
4. Armature should be given a test for shorts and open circuits.
5. Hy-pot at 500 volts for 10 seconds. If the armature passes the above check it should be given a varnish treatment as follows:

   a. Place armature in a convection oven set at 120-130°C. for 2 hours.
   b. Remove from the oven and while hot, dip the armature into clear baking varnish 8136692 for 3 minutes. Be careful not to get varnish on the commutator.

   NOTE: Varnish viscosity should be maintained between 40 and 55 seconds at 21.1° C. using a #4 Ford cup. Average varnish temperature should be maintained between 20° and 50° C.

   c. Remove the armature from the varnish. Clean varnish off the shaft using Xylol 8089758 (or equal)
   d. Place the armature in the oven now set for 160° C. and bake for 4 hours.
   e. Remove and cool.

FIELD COILS

The field coils should be clean and free from all dirt and oil. The field coils may be cleaned using Stoddard solvent. Blow off the excess solvent and let coils dry before any electrical checks are made. Proceed with inspection as follows:

1. Using a megohmmeter check the insulation to ground as outlined under "Armature."
2. Coil leads and connections must be secure and all taping intact.
3. Check resistance of field coils using data outlined in the Maintenance Data section.

   Whenever resistance is out of tolerance, connection between coils should be examined for possible cause before replacing coils.

4. If insulation on the coils is charred or brittle and the coil checks within limits, the insulation should be replaced.
5. To remove the field coils disconnect the leads that join them together. Remove the bolts which hold the pole and coil through the end of the frame. The field coil can readily be slipped off the pole.

6. Reconnect replaced coils as indicated in connection diagram, Fig. 5.
7. When the field coil and frame assembly has been repaired, recheck resistances and megger check. If satisfactory, varnish treat assembly as outlined under "Armature." Protect leads and connections from varnish.

ASSEMBLY OF MOTOR

1. Place new felt seals and expansion rings in caps and end frames.
2. Place armature in motor frame.
3. On A-731 and A-9385 motors, apply 1/2 oz. Of grease 8190451 on each side of the double shielded bearings and in the cavity surrounding the bearing.
4. On the A-732 motor, apply 1/2 oz. of grease on the shielded side of the bearing toward the end of the shaft, and in the cavity surrounding the shielded side of the bearing.
5. Place bearing cover and a new gasket on drive end of shaft. Place a new factory-packed bearing on shaft and tap in place up to the shoulder of the shaft with the aid of a brass tube. Tapping should be done around the inner race only. Do not strike the outer race of ball bearings when driving bearing on shaft.

NOTE: Install new double shielded bearings in Model A-731 and A-9385 motors. In Model A-732 motors, install new sealed-shielded bearings with the sealed side toward center of motor.

On A-731 type, place bearing cover on commutator end of shaft and a new gasket on this cover. Place a new factory-packed bearing on shaft and tap bearing in place. Place lock washer and lock nut on shaft. Tighten lock nut and secure nut with lock washer.

On the A-732 type, insert the bearing into the commutator end frame and

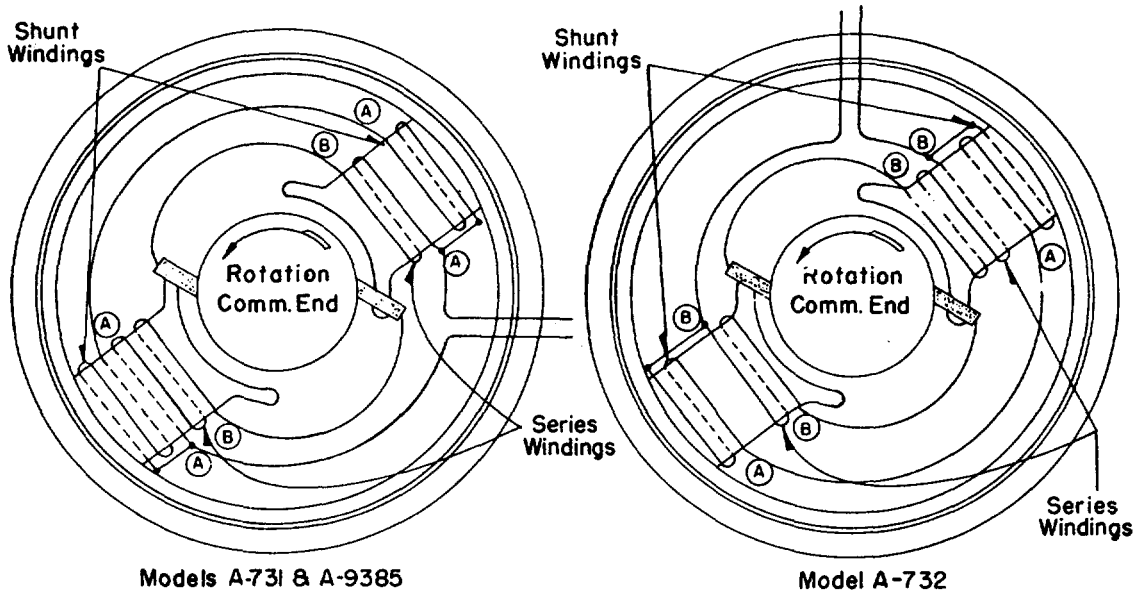


Fig. 5. Connection Diagrams

place this assembly on the shaft. The armature should be out far enough to prevent the endframe from striking the motor frame. Place lock washer and lock nut on shaft and tighten nut against inner race of bearing. Secure nut with lock washer.

CAUTION: Do not force the outer race of bearing into its housing by blows on the inner race.

Apply end frames over ball bearings and line up bearing covers to end frames and secure with cap screws.

Permanently seal bearing housing by installing a pipe plug in threaded opening.

Hy-pot assembly using 440 volts AC for 1 second.

BRUSH SETTING (KICK NEUTRAL)

Having reassembled the motor and before it is put into service, it is of the utmost importance that the brushes are placed in the proper location with respect to electrical neutral. When it is necessary to check this position the following instructions should be used:

1. Lift all brushes off the commutator.
2. Count the number of commutator bars and main field poles. Divide the number of commutator bars by the number of main field poles.
3. Locate the center of one bar and count off bars to equal the number found in Item 2. This will be the span. Mark the center of the last bar in the span.
4. Position the center of a brush and its holder on the center of the first bar. The center of the last bar in the span should now be near the other brush.
5. Apply current from a 6 volt storage battery to the main field. Include a switch in the field circuit.
6. Use a 50 millivolt center reading voltmeter. With the leads and prods from the meter, place the prods on the first and last bar of the span. Kick the field by opening and closing the field circuit switch. Note the deflection on the meter. Rotate the armature about one commutator bar and kick the field by opening and closing the field circuit switch. Note the deflection on the meter. If the second reading is greater than the first and of the same polarity, the armature was rotated in the wrong direction. If the meter shows a deflection of the opposite polarity, the neutral point has been passed. Follow the above pattern of rotating the armature until the deflection of the meter is zero or as near zero as possible.
7. Hold the armature in this position and rotate the brush bracket so that the center line of the first brush lines up with the first bar center and the second bar center lines up with the other brush center. Work to $\pm$ 1/64" of location setting.
8. A recheck should be made of kick neutral after moving the brush bracket to make certain the armature did not move.

Motorize to check for proper rotation of armature; should be counterclock-wise when viewed from the commutator end.

MAINTENANCE DATA

	Model A-731 & A-9386 Motor	Model A-732 Motor
Brush Pressure		
New brush	14.5 ozs.	9.5 ozs.
Worn brush	7.5 ozs.	4.0 ozs.
Brush wear	5/8" off new brush (3/4” minimum length	5/8" off new brush (3/4" minimum length)
Resistance		
Shunt field	69-76 ohms each	392-436 ohms total
Series field	.071-.079 ohms each	.31-.344 ohms each
Armature	1.19-1.31 ohms between opposite bars	2.5-2.75 ohms between opposite bars
Air gap	.032"-.036"	.027"-.031"

NOTE: All resistance values are given at 25° Centigrade or 77° Fahrenheit.

Commutator Limits		
Commutator diameter condemning limit	2-21/32"	1-23/32",
Neck width condemning limit	7/64”	7/64”
Maximum runout	.001" total indicator reading	.001" total indicator reading

FUEL PUMPS

DESCRIPTION

Tuthill and Viking pumps are highly efficient, positive displacement, rotary internal gear types having mechanical seals. The Tuthill pump has an output of 2.5 GPM at 1100 RPM while the Viking pump discharges 4.0 GPM at 1200 RPM. The type of pump employed depends upon the quantity of fuel needed by the particular application.

These pumps provide the very important function of supplying the diesel engine with adequate fuel for operation. In most applications the pump is driven by a small electric motor, however, in other cases it is driven directly by the diesel engine. In the latter instance, a separate priming pump is required to provide the engine with sufficient fuel for starting purposes.

Since the Tuthill and Viking pumps differ somewhat in construction, specific instructions pertaining to each of them is provided in this bulletin. In instances where no particular pump is identified, the information will pertain to both pumps.

OPERATION

The operation of both the Viking and Tuthill pumps is based on the "internal gear" pumping principle. This principle is based upon the use of a rotor, idler gear, and a crescent-shaped partition that is cast integral with the cover, Fig. 1. Thus only two moving parts are responsible for the actual pumping. Power is applied to the rotor and transmitted to the idler gear with which it meshes. The space between the outside diameter of the idler gear and the inside diameter of the rotor is sealed by the crescent. When the pump is started, there is an increase in volume as the teeth of the idler and rotor come out of mesh. This creates a partial vacuum, drawing fuel into the pump through the suction port. The fuel then fills all the spaces between the gear teeth. As the pump shaft rotates, the liquid is entrapped between the teeth of the rotor and idler and is carried past the crescent partition to the pressure or discharge side of the pump. When the teeth once again mesh on the pressure side, the fuel is forced from the spaces and out through the discharge port.

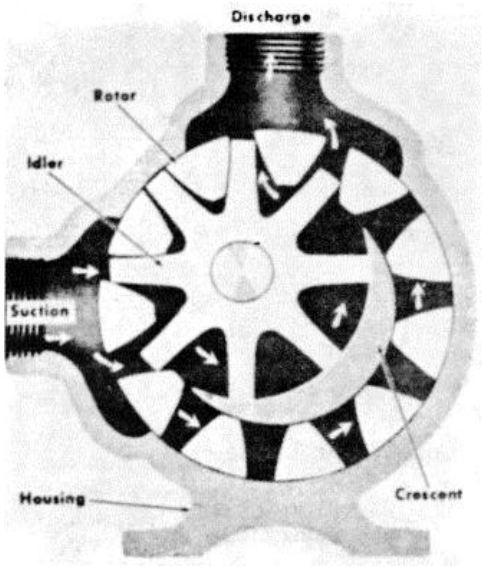


Fig. 1. "Internal-Gear" Pumping Principle

NOTE: It is very important that fuel pumps be driven in the direction of the arrow stamped on the pump body.

There is a passage from the suction part of the pump to the seal assembly so a partial vacuum is created in the seal which tends to hold the seal faces together. Should the pump rotation be reversed, there will be a pressure on the seal which will force the seal out of its seat as the pump pressure increases.

SEAL

The seal is a device which prevents leakage between the pump body and rotating shaft. This is accomplished by providing a perfectly smooth surface on both the shaft and pump body. The clearance is so small that resistance to fuel flow is great enough to prevent fuel from leaking out or air from entering the pump body.

The Tuthill pump, Fig. 2, employs a rotary seal which turns with the shaft. This assembly is attached to the shaft by a copper washer which when compressed by the hex seal nut prevents fuel and air from leaking down the shaft past the seal. A flexible diaphragm incorporated in the seal is spring loaded to control the tension on the seal face.

Fuel leakage is prevented in the Viking pump, Fig. 3, by a seal which rotates with the shaft and rides against the gland assembly. The seal is secured to the shaft by means of two notches on the seal which mate with two corresponding tangs on the bronze sealing assembly. The shaft is sealed by and secured to the seal assembly by a neoprene seal which is internal to the assembly and is press fitted on the shaft. Tension is provided by a load spring and washer which push the seal against the gland assembly. The entire sealing assembly is contained within the pump by the packing nut.

Both the carbon seal and the neoprene seal within the sealing assembly prevent fuel from leaking around the shaft while the gasket on the gland assembly is compressed by the packing nut and prevents fuel from leaking between the gland and pump body.

MAINTENANCE

Fuel pumps should be removed from service and reconditioned at intervals prescribed in the Scheduled Maintenance Program, Maintenance Instruction 1704. Procedures for the disassembly, inspection, replacement of worn parts, assembly and testing, are covered below.

DISASSEMBLY OF TUTHILL PUMP (Fig. 2)

1. Place pump in a vise so that one jaw grips across the two ports. Do not tighten excessively as pump housing may be distorted.
2. Remove housing cap with special spanner wrench 8017824.
3. Slip felt washer off the shaft.
4. Place one wrench on hex seal nut, and another wrench across flat of pump shaft to keep shaft from turning while loosening hex seal nut.
5. Back off hex seal nut five or six turns.
6. Remove pump from vise.
7. Carefully grip hex seal nut in vise and pull oil seal off shaft as one assembly.
8. Remove pin key from shaft using a small pair of tweezers.
9. Inspect shaft where pin key enters. Any small burr will interfere with removal of housing plug. Use a small file to remove burr if necessary.
10. Place pump in vise and remove housing plug with special spanner 8017825.
11. Place matching marks on cover and body of pump for proper reassembly.
12. Remove the eight cover cap screws, then remove pump cover.
13. Remove rotor and idler.

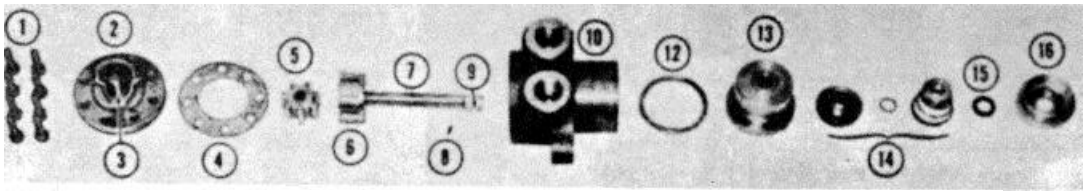
14. Inspect pump components for wear and scored surfaces.

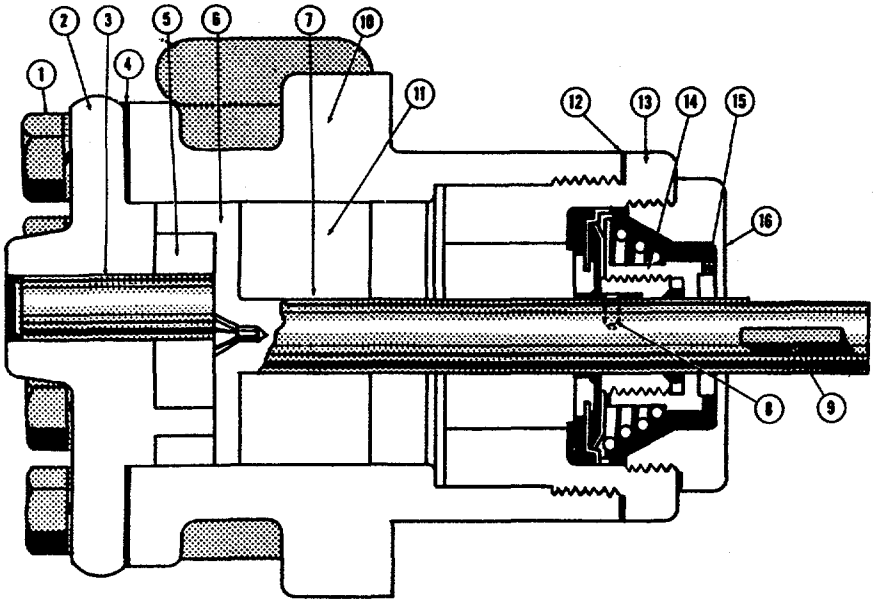
DISASSEMBLY OF VIKING PUMP (Fig. 3)

1. Place pump in a vise so that one jaw grips across the two ports. Do not tighten excessively as pump housing may/be distorted.
2. Remove packing nut using a hook spanner wrench.
3. Carefully remove gland assembly with carbon seal.
4. Place matching marks on cover and pump body for proper reassembly.
5. Remove the six cover cap screws, then remove pump cover.
6. Remove idler.
7. Carefully push in on shaft of the pump until rotor extends beyond the pump body. Then carefully grasp rotor and pull shaft completely out of body. As the shaft is removed, the sealing assembly, load spring, and thrust washer will be pulled off the shaft and remain in the pump body.
8. Remove sealing assembly, load spring, and thrust washer from body.
9. Inspect pump components for wear and scored surfaces.

INSPECTION

The individual parts of both types of pumps should be inspected for damage. The keyway in the end of the rotor shaft must be in good condition. There must





1. Cover Screws
2. Pump Cover
3. Idler Shaft
4. Cover Gasket
5. Idler
6. Rotor
7. Rotor Shaft
8. Shaft Pin Key
9. Woodruff Key
10. Pump Body
11. Rotor Bushing
12. Lead Washer
13. Housing Plug
14. Seal Assembly
15. Felt Washer
16. Housing Cap

Fig. 2. Tuthill Fuel Pump - Exploded And Cross-Section Views

not be any grooves or deep scratches on the following surfaces.

1. The I.D. surface in the housing (the seating surface for the rotor).
2. The O.D. of the rotor.
3. The end face of the rotor.
4. The O.D. of the idler.
5. Both faces on the idler.
6. The tooth surfaces on the idler and rotor.
7. The inside surface of the pump cover including the surfaces of the crescent.

The rotor assembly should be positioned in the housing and checked for clearance in the bearing. The shaft must turn freely without any detectable side play. Any side play will require replacement of the housing, the shaft, or both. The condemning limit for the clearance between the rotor and the housing is .002". The bushing in the Tuthill pump must be positioned with the 3/32 R oil groove on the suction side of the pump.

The idler and bushing assembly must turn freely on the idler pin in the pump cover without any detectable side play.

Obtain the correct end clearance of the rotor on the Viking pump (.001") by adjusting the thickness of the cover gaskets that will result in the rotor shaft turning freely without any detectable end play. This is done without installing the seal assembly. Gaskets are added or re- moved until when the rotor is pushed back and forth no end play is detected. The remainder of the pump may then be assembled and must meet the 3 in.-lbs. of torque requirement listed under "Testing."

Obtain the correct end clearance of the rotor on the Tuthill pump (.001") by adding a .001" spacer between the rotor and bushing, installing the pump cover and gasket, and tapping the bushing until the rotor is tight. Disassemble the pump to remove the .001" spacer and reassemble. As an alternate, the spacer could be omitted and the cover gasket replaced with a.001" thicker gasket using the same procedure outlined above.

ASSEMBLY OF TUTHILL PUMP (Fig. 2)

1. Install idler and rotor in pump body.

2. Install cover gasket.

NOTE: If pump has had a loss of capacity a thinner body gasket maybe used to reduce excessive clearance (should be .001").

3. Install cover and idler on pump, being sure to align the matching marks made before disassembly.
4. Install housing plug in pump body. Be sure lead gasket is in place.
5. Assemble parts of rotating seal before placing on pump shaft. If any one part of the seal needs replacement, an entire new seal assembly should be used. (Do not compress copper washer.)
6. Test seal on shaft. It should be free from binding and be able to slide freely so seal faces make contact.
7. Install pin key.
8. Clean seal faces thoroughly using great care to eliminate all dirt.
9. Install seal assembly so seal faces are in contact.
10. Compress spring in seal assembly. This is done by pressing on hex seal nut.

    The amount of movement should be .040". This will produce approximately 7 lbs. of spring pressure. (If no means is available to measure the

.040" compression, press in on the hex seal nut until it bottoms; then re- lease a few thousandths for clearance.

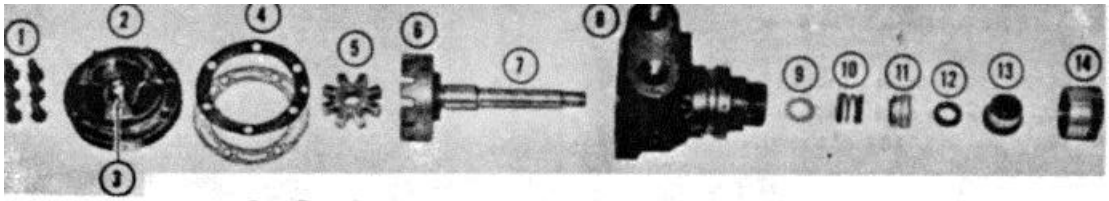
11. Hold spring compressed and tighten hex seal nut which locks the seal assembly to the shaft. Use a wrench on the shaft so that the hex seal nut is tightened securely.
12. Install felt washer, gasket and housing cap. Be sure the gasket is under the cap.
13. Place a small quantity of light lube oil in the pump body for initial lubrication.
14. Refer to test instructions.

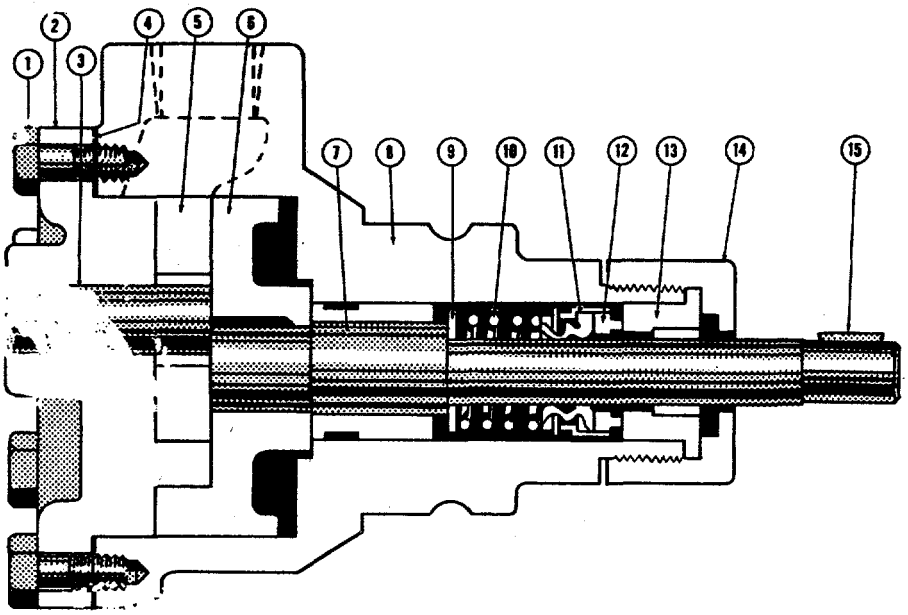
ASSEMBLY OF VIKING PUMP (Fig. 3)

1. Insert spring thrust washer, load spring, and sealing assembly into pump shaft housing.

IMPORTANT: Care must be taken not to forget installing the bronze thrust washer in combination with the load spring. The washer, because it rotates with the spring, rubs against the bronze bushing insert in the pump body and serves as a wear plate. If the washer is left out, the sharp end of the spring will rub against the bronze bushing, scoring it severely.

2. Place pump in vise as for disassembly. Grasp rotor and push shaft through the rotor housing and into the shaft housing. Using the other hand, hold the washer, spring, and seal assembly in the shaft housing while continuing to push the shaft through. Pushing the shaft will require some pressure as





1. Cover Screws
2. Pump Cover
3. Idler Shaft
4. Cover Gaskets
5. Idler
6. Rotor
7. Rotor Shaft
8. Pump Body
9. Thrust Washer
10. Load Spring
11. Sealing Assembly
12. Carbon Seal
13. Gland Assembly
14. Packing Nut
15. Woodruff Key

Fig. 3. Viking Fuel Pump - Exploded And Cross-Section Views

the neoprene seal in the seal assembly must be pressed on the shaft.

3. Place idler over idler shaft in the cover.
4. Place cover with proper gasket thickness and idler over housing, being sure to align the matching marks on the cover and housing which were made before disassembly.

IMPORTANT: Before replacing cover it is necessary to have determined the thickness of cover gaskets needed to allow the shaft to rotate freely with- out any detectable end play. (This was outlined under “Inspection.")

5. Carefully slip the carbon seal over the shaft making sure the two notches fit the tangs on the sealing assembly.
6. Place a small amount of light oil on the carbon seal face and corresponding sealing face of the gland assembly.
7. Slip gland assembly over shaft and seat sealing faces.
8. Place packing nut over shaft and tighten to compress gland gasket using a hook spanner wrench.
9. Refer to test instructions.

TESTING

The shaft should be checked for ease of operation, and the torque required to turn the shaft must not exceed 3 in.-lbs. in either direction.

The pump should then be run at 1100 RPM for 15 minutes with full fuel flow and no restriction on suction or discharge. (This may be done by installing on the pump motor or using some type of test stand.) This 15 minutes of running serves to seat the new seal against the mating seat.

The seal may leak slightly when the pump is first started after a new seal is installed. The seal, if properly installed, will adjust itself in a minute or two and the leaking will stop.

When the 15 minute run is completed the pump should be tested for output. This may be performed using a graduated container and a clock or watch. The pump must meet the following specifications:

Tuthill	Viking
2.0 GPM (minimum)	3.5 GPM (minimum)
@ 1100 RPM	@ 1100 RPM

The seal may be tested by performing pressure and suction tests.

Suction

A hose should be connected from the suction port to some type of suction gauge or manometer tube capable of indicating up to 30" of mercury, and the discharge port should be vented to atmosphere. The pump should build up to at least 25" of mercury at 1100 RPM with partial fuel flow. The duration of this test should not exceed 15 seconds.

IMPORTANT: The suction line should be restricted until the 25" of mercury are attained. This continuance of restriction will allow the partial fuel flow desired to lubricate pump. At no time, however, should the restriction be complete and cut off the fuel supply. This would cut off lubrication and could damage the pump.

If the hose is progressively restricted until up to the point of complete restriction and the 25" of mercury are not reached, the seals should be investigated for leakage.

Pressure

With full fuel flow and the suction vented to atmosphere, the discharge line

is then restricted. The discharge pressure should build up to at least 60 psig.

Excessive end clearance will appear as reduced capacity of the pump while a leaking seal will show up as poor vacuum and/or pressure.

STORAGE

Upon completion of the testing, if the pump will not be used immediately, the pump ports should be filled with SAE #10 or #20 oil and pipe plugs applied to the ports.

INSTALLATION OF PUMP TO MOTOR

Install pump to motor and check coupling end clearance.

It is very important that proper clearance is provided in the coupling between the two coupling halves and the center piece to prevent end thrust on the pump shaft, which in turn, can damage the pump cover.

Both single and double pump units are equipped with a coupling, which should have a distance of 1/2" between the two coupling halves with the end play of the motor armature taken into consideration.

There should be approximately 1/16" clearance between the composition center piece and the two die cast coupling halves with the pump bolted in place and the motor armature pulled toward the pump shaft to its farthest position.

It is a very common error in assembling not to take into consideration the end play of a motor armature, which may cause end thrust on the pump shaft. These pumps are <u>not</u> designed to take end thrust toward the pump cover, and extreme care must be taken to prevent thrust in this direction.

VOLTAGE REGULATOR - MAGNETIC AMPLIFIER TYPE PART NO. 8296851

DESCRIPTION

The magnetic amplifier type voltage regulator consists of one panel mounted on each unit panel. No moving parts are used other than those involved in the relays used for switching of auxiliary functions, such as initial field flashing and voltage matching.

This voltage regulator will perform the following functions common to the conventional types.

1. Maintain the generator voltage constant, at the value predetermined by the position of an adjustable resistor, with a minimum of variation. This is the basic voltage regulator function.
2. Permits voltage adjustment over a given range by means of the voltage adjusting rheostat.
3. Automatic compensation for cross currents caused by two or more generators operating in parallel with different pre-set voltages.

   A current limit feature also limits generator current when the system voltage falls far below the regulator setting.

In addition to the above, several modes of operation are obtainable through control circuitry.

1. VOLTAGE MATCHING

   In preparation for the alternator to be paralleled with another 3-phase source of power, the voltage on the alternator side of the paralleling breaker is regulated (matched) to the voltage on the other side of the breaker to within ± 2%.

2. PARALLEL OPERATION

   After voltage matching and frequency synchronizing has been accomplished, the paralleling breaker is closed and the alternator is paralleled with an infinite bus. When the alternator is paralleled with one or more other alternators, reactive droop is provided for reactive load division. The chief advantage of this mode is that the alternator can operate in parallel with the infinite bus and not exceed the alternator current rating as the KVAR varies with changes in the bus voltage level. This is due in part to the reactive droop, and secondly, to a current-limit feature.

3. DEAD LINE OPERATION

   Voltage level to the load is maintained to within ± 1% of a pre-set level when the alternator is operating singly, or in parallel with one or more similar alternators having similar voltage regulators. This unit or units provide the sole or major power required by the load, and are, therefore, effective in maintaining the load voltage at a constant value. If one or more alternators are in parallel with the first unit, cross current regulation is automatically accomplished by the several

voltage regulators. This minimizes reactive currents circulating between the various alternators. The current limit feature is also operative in this mode and serves to reduce the alternator output voltage if the load current 'exceeds a pre-determined value. Relays detecting generator current are sometimes used to block current limit operation for 60 seconds to permit dead load pick up. Current must be above the regulation point for 60 seconds before the current regulator will operate.

A separate device called a KW limiter receives an engine speed signal and reduces generator voltage settings on all regulators under overload conditions, (more than 2 cycle frequency drop).

OPERATION

1. VOLTAGE MATCHING

A simplified block diagram showing this mode of operation is shown in Fig. 1. In this mode, the voltage detector is not used. The signals and operating power for the voltage regulator unit are supplied from two sets of 3-phase PT's (Potential Transformers); one set steps the alternator voltage down to a rated value of 208 AC volts, and the other set steps down the voltage to a similar value from .the line side of the paralleling breaker. The voltage from the line PT's enters the voltage regulator panel at terminals 11, 12, and 13 after which it is rectified by 3-phase bridge rectifier CR-1. The alternator PT's connect to terminals 1, and 2 and 3; this voltage is stepped up slightly by the isolation transformers T2 and T3 which form an open delta arrangement. This secondary voltage is rectified by a 3-phase bridge rectifier CR2. The DC output voltages of these two rectifiers are electrically compared, and an error signal results when the line and alternator voltages are not equal. Any error signal is applied to control winding 5- 6 on the Signal Amplifier L3 which in turn controls the Static Exciter and alternator field in a manner such that the error signal is reduced to zero,

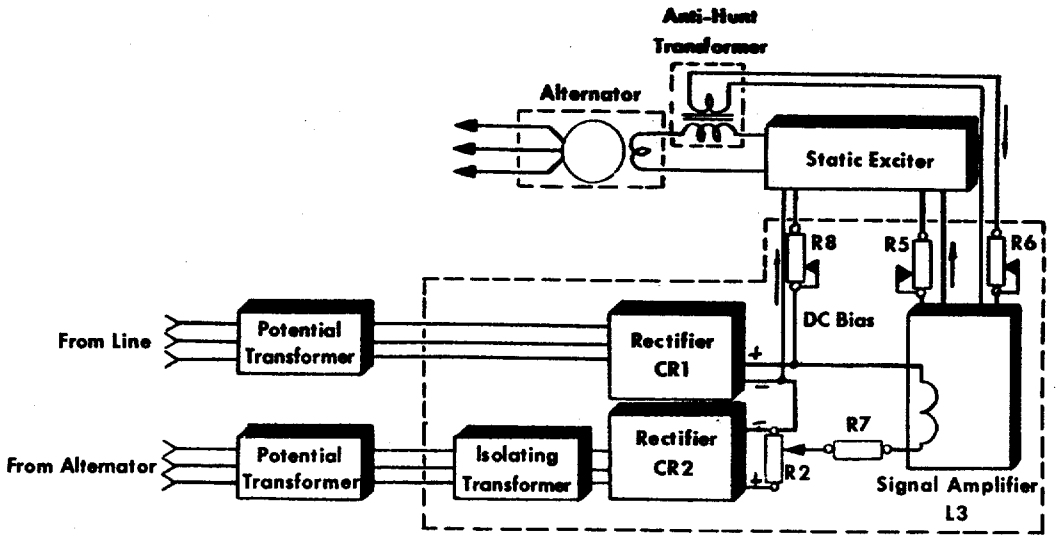


Fig. 1. Voltage Regulator Before Synchronizing Voltage Matching Mode

corresponding to the required condition of the alternator voltage being matched with the line voltage.

The static exciter is supplied with a second control current (positive bias) in a second control winding. This bias current is obtained from rectifier CR-1 in the voltage regulator, and the level of current is determined by the setting of resistor R8. This current causes an increase in the alternator field current, and is adjusted such that the required maximum field excitation can be obtained under those conditions when L3 amplifier is at minimum output (cut-off).

2. PARALLEL OPERATION

On an automatic unit, after voltage matching has been accomplished and the paralleling breaker has closed to connect the alternator to an infinite bus, the voltage regulator is automatically switched to allow the voltage detector to function. The voltage detector circuit consists of reactor L2 and rectifier CR3. Reactor L2 is operated at saturation so that a change in magnitude of the applied voltage (alternator voltage) causes a change in the impedance of L2 and consequently a change in voltage across rectifier CR3. The DC. output current from rectifier CR3 is applied to control winding 7-8 on signal amplifier L3 in such a manner that an increase in signal current (indicating an increase in alternator voltage) causes an increase in the output current from amplifier L3. This increase in output from the voltage regulator panel causes a decrease in the static exciter output to the alternator field. This decrease in field current reduces the alternator output voltage to restore it to the regulated value.

When one or more alternators are operating in parallel with an infinite bus the power each alternator delivers is a function of the driving torque supplied by its associated prime mover and is essentially independent of alternator field excitation. Increasing the field excitation, while maintaining a constant driving torque, will cause only the reactive (lagging) component of the output current to increase. Since the infinite bus can be considered as having considerably greater power generating capabilities than the one or more alternators being considered as operating in parallel with the infinite bus, then the bus voltage level is essentially independent of the power (real or reactive) that is being supplied by the one or more alternators being considered. The alternator output voltage is thus determined by the bus voltage and is allowed to increase or decrease (except for small differences due to voltage drops on the interconnecting lines) in accordance with changes in voltage level on the infinite bus.

Whereas a slight decrease in alternator voltage normally results in an in- crease in alternator field excitation, operation in parallel with an infinite bus would restrict the change in alternator operation to a condition of greatly increasing the reactive (lagging) power. Similarly, a slight increase in alternator output voltage (and infinite bus voltage) would result in a decrease in field excitation with a large increase in reactive (leading) power.

To prevent excessive alternator out- put current due to supplying large values of reactive power, an additional signal is applied to the voltage detector circuit. A simplified block diagram of the voltage regulator under

this mode of operation is shown in Fig. 2. The output of the current transformer is added, across resistor R9, to the voltage signal supplied to the voltage detector circuit. This additional signal is of such a magnitude and phase relationship that if the in- finite bus voltage rises, the resultant voltage change as seen by the voltage detector is less than normal, and the resultant change in alternator excitation is such that the reactive power output from the alternator does not cause excessive alternator currents.

Likewise, a reduction of infinite bus voltage causes a reduction of voltage to the voltage detector, but to a lesser extent than normal. This affects the overall voltage regulator operation such that more regulation (droop) occurs for lagging reactive power output from the alternator. Regulation for leading reactive power results in negative droop (compounding). The reactive droop is normally adjusted to about 4 to 6% and is determined by the setting of R9. In this instruction, % droop is used in terms of the following:

$$\% \text{ Droop} = \frac{(\text{ACV no load}) - (\text{ACV at rated KVAR})}{\text{ACV at rated KVAR}} \times 100$$

Although the % droop is essentially independent of KW output, it is assumed that the determining of per- cent droop as just outlined is accomplished at or near zero KW output from the alternator. The rated KVAR is that value that would exist if the alternator were supplying full rated KW at 0.8 power factor at rated voltage, namely, 60% of rated KVAR for the alternator.

Normally, the alternator excitation is adjusted by the voltage adjust rheostat to a level to provide about 105% of rated AC volts at no load, paralleling breaker open. After breaker closure, rated KVAR output will exist for 5% adjustment with the infinite bus at rated voltage (this neglects line drop effects). If the prime mover is now set

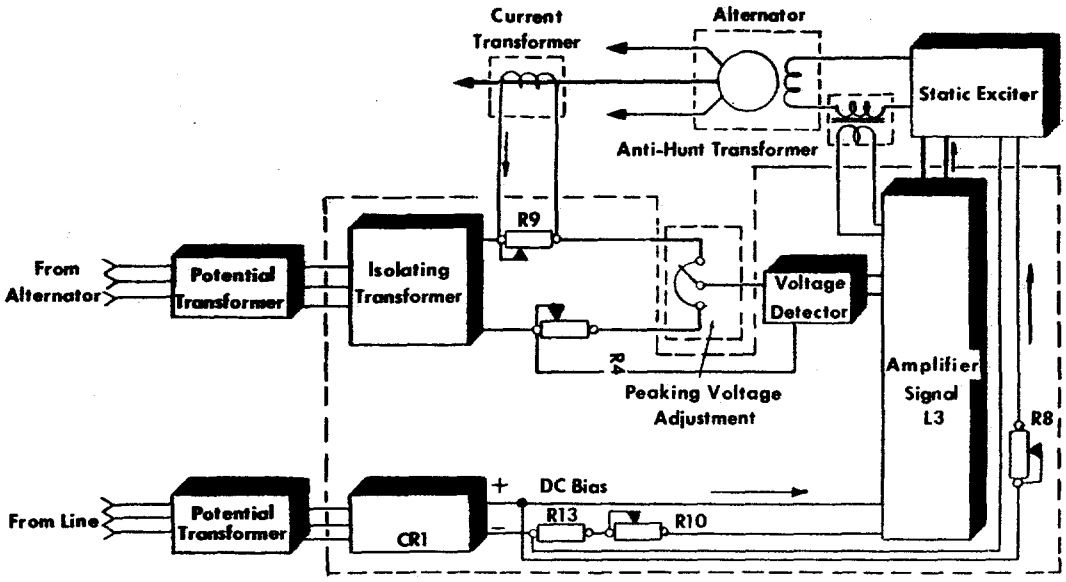


Fig. 2. Voltage Regulator In Parallel Operating Showing Regulating Action For Reactive Loads

to provide an alternator output in KW equal to the rated KW of the machine at 0.8 power factor, the alternator will be supplying rated output current. Any further reduction of bus voltage would result in a further increase in alternator field excitation, and the resulting increase in reactive power would result in tripping of over-cur- rent relays, or would damage the alternator. To prevent this difficulty, current-limit is introduced at this point to prevent any increase in alternator output current and alternator excitation is regulated as a function of output current.

A simplified block diagram of the regulator when operating with current- limit regulation is shown in Fig. 3. A signal from the current transformer is applied to a current detector consisting of reactor L1 and rectifier CR4. The DC output current from CR4 is filtered by L4 and then applied to a "high gain" control winding 9-10 on the signal amplifier L3. This "high gain" control winding allows the current detector to "over-ride" the signals from the voltage detector in controlling L3. Note that the current transformer signal flows through resistor R9 and transformer T-1 in series (see schematic diagram Fig. 5) to provide droop and current limit protection without the necessity of switching.

3. DEAD LINE OPERATION

This mode of operation is similar to the parallel operation mode with one major exception. This exception .is that one or more alternators are supplying a load that is isolated from the bus. This condition can exist due to the opening of the tie-line breaker, or the closing of a main breaker to apply a dead load to one alternator or several alternators operating in parallel.

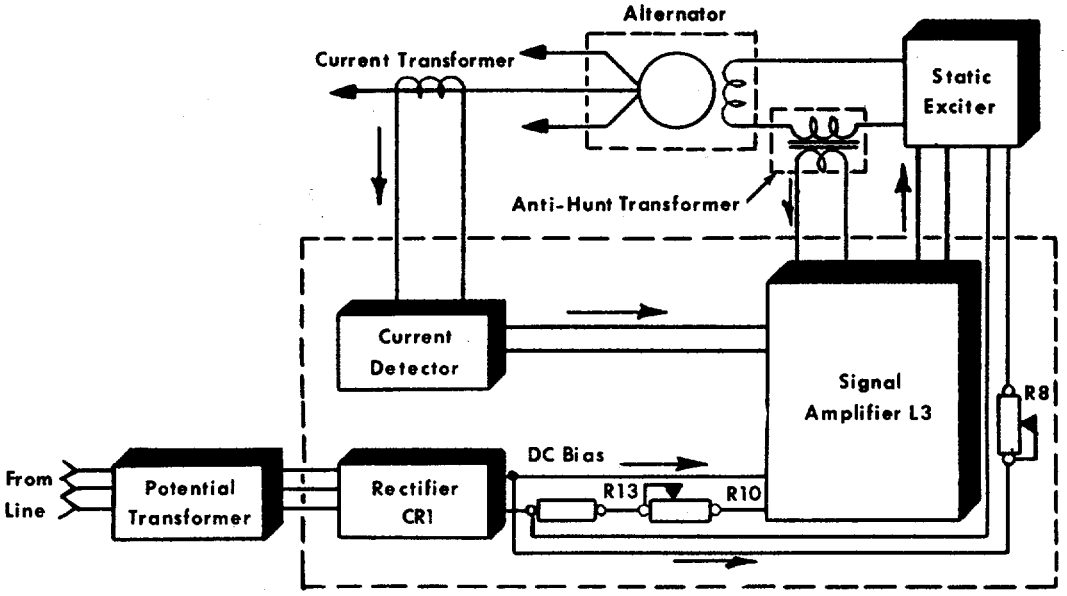


Fig. 3. Voltage Regulator Showing Current Regulation For Current-Limit Action

Since one alternator, or several similar paralleled alternators, will sup- ply all the power required by the load, the load voltage will depend on the excitation level on any one or group of paralleled alternators. If only one alternator supplies the load, no problem exists as any increase or decrease in the alternator field excitation will cause a corresponding increase or decrease in the load voltage. However, if two or more alternators are operating in parallel and each is supplying a proportionate share of the real and reactive power required by the load, an increase in the excitation level of any one alternator will result in a limited rise in the load voltage and a large increase in the reactive power developed by this alternator. Since the reactive power taken by the load remains essentially unchanged, the in- creased reactive power from this over-excited alternator causes circulating current in the remaining alternators. This condition is overcome by "cross-current" regulation.

Cross-current regulation is the means by which each regulator controls its respective alternator in such a manner as to maintain constant load voltage regardless of the relative phase angle between the load current and the load voltage. Each regulator receives a signal from its associated current transformer, which causes reactive droop whenever any reactive circulating currents appear between alternators. The signal from each current transformer is applied to its respective regulator in such a manner as to change the alternator field excitation so that the circulating currents are minimized and a condition of balanced alternator reactive power output is restored.

The reactive droop action in this mode is accomplished in the same manner as was discussed in the Parallel Operation Mode. The major difference between the two circuits is the fact that in this operating mode the current transformers are connected in additive series. That is, the finish of #1 transformer is connected to the start of#2, the finish of #2 to start of #3, etc., with the finish terminal on the last current transformer connected to the start of the first. Because these series-connected control transformers have a common circulating current, a signal is applied to R9.in the voltage detector circuit only when there is an unbalance in the current transformer secondary currents. And, since the voltage detector is essentially insensitive to the in-phase component of load current, only an unbalanced condition of re-active load currents in the control transformer primary is effective in influencing the voltage detector and cause reactive droop in the voltage regulator characteristic. Automatic switching eliminates the droop signal when only one alternator is supplying the load.

Fig. 4 is a simplified block diagram of cross-current regulation. Resistors R15 and R9 are so adjusted that circulating currents will be less than 10% of the alternator rating. A deadline voltage adjusting rheostat is switched into the detector circuit in place of the regular adjusting rheostat when the tie line break occurs to preserve the proper deadline voltage level.

As in Parallel Operation, the current- limit function is always present in the Dead Line Operation Mode. If the loading reaches the level where the alternator current is at its rated level, further increase in load current results in a decrease in field excitation, as well as a decrease in load voltage.

Units that are designed for maximum reactive capability employ power cur rent transformers to provide excite power when the bus voltages are low and generator currents are high. These power CT's augment the control transformer to provide maximum generator excitation to energize a dead power system.

SYSTEM STABILIZATION

It is obvious that should changes ii speed occur very rapidly, a voltage regulator which made instantaneous corrections would not be desirable, as a hunting effect would be present due to the regulator attempting to supply continuous rapidly changing corrective currents.

In order to eliminate this hunting effect, an anti-hunt transformer is use to supply a negative feed back and produce a damping effect in the coils of the first amplifier. Thus the damped signal provides a smooth output voltage during rapidly changing conditions. This effect does not interfere with normal changes.

MAINTENANCE

A properly functioning voltage regulator should make it possible to adjust the alternator output voltage 10% below to 10% above the rated output. The voltage regulator should match the alternator output with the line voltage to within ± 3% of the line voltage.

Should the regulator fail to function properly, the most likely cause is a loose connection or faulty adjustment of one of the adjustable resistors.

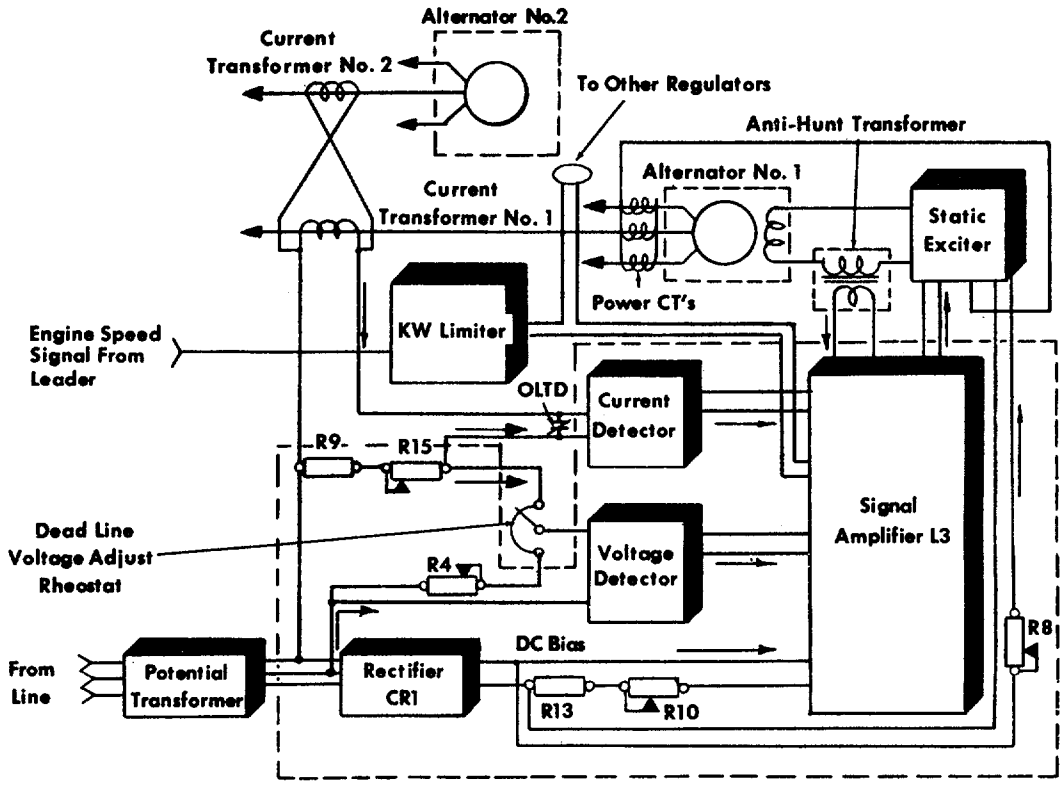


Fig. 4 - Voltage Regulator - Isolated Load Operation

PRE-SERVICE CHECKS AND ADJUSTMENTS

CAUTION: Do not energize the static exciter unless the voltage regulator is also energized and operating properly. This pre- caution must be observed unless a protective series resistance is added to the alternator field, or unless the diesel is not rotating. The static exciter output with no control, or insufficient control, from the voltage regulator out- put will be approximately the field excitation required for full rated alternator load.

Before the voltage regulator is placed in service for the first time, or following any major repairs involving interconnections to the units, the following tests and checks are suggested:

1. Remove external leads from terminals 1-2-3 on the voltage regulator, and place jumpers between terminals 1-11, 2-12, 3-13.
2. Restore power to line PT's. Energize or manually close relay VR. This applies 208 AC 3-phase voltage to the voltage regulator to check the voltage matching function.
3. Measure approximately 260 DCV across R8. Resistor R8 should be warm or hot.' This indicates that bias current is being supplied to the static exciter.
4. Measure approximately 30-45 DCV across resistor R5. This signifies output from L3 signal amplifier to the static exciter control windings.
5. Turn FINE and COARSE voltage adjust rheostats to maximum RAISE position. Energize or manually close relay 52W. This removes the voltage matching signal to L3 amplifier, and applies a bias and a voltage detector signal to L3.
6. Measure less than 10 volts on R5. Voltage should increase to over 35 DC volts on R5 as the voltage adjust rheostats are turned toward LOWER position. Do not set rheostats for more than 40 DC volts on R5 or excessive power will be applied to the voltage detector.
7. Open the line PT disconnect. Remove the jumpers to terminals 1-2-3 and restore the external leads. Restore relays VR and 52W to the normally de-energized position.
8. Turn the FINE and COARSE voltage adjust rheostats to maximum LOWER position.
9. Close the line PT disconnect. Set automatic switching functions to allow operation of this diesel alternator in the Isolated Unit Mode.
10. Start the diesel engine and bring the alternator up to synchronous speed. A speed switch on the diesel should operate to cause power to be applied to the static exciter and voltage regulator as the speed is brought up to rated RPM.
11. Set alternator output voltage to 18% above rated (4900 AC volts) by turning the FINE rheostat to maximum raise and then adjusting the COARSE rheostat.

NOTE: If alternator voltage is unstable, reverse leads from anti-hunt transformer to regulator terminals 19-20.

12. Turn FINE rheostat such that the alternator voltage is matched with the line voltage while the alternator is maintained at synchronous speed.
13. If the alternator connections to the paralleling breaker have been phased out properly, synchronize the alternator with the line and close the paralleling breaker. Adjust diesel governor for an alternator output of 5 to 10% of rated KW.
14. Temporarily jumper terminals 4-5 on the voltage regulator (input from CT). Increase alternator excitation by adjusting the voltage adjust rheostat to obtain approximately 50% rated alternator output current. Temporarily remove Jumper from terminals 4-5. The alternator output current should decrease. If not, shut down and reverse the leads from the CT to terminals 4-5.

NOTE: Proper operation with reactive droop requires a positive phase sequence on terminals 1-2-3 on the voltage regulator, and also that the CT is located electrically in that alternator lead which supplies voltage to terminal 2 on the voltage regulator.

15. Increase the alternator excitation toward a level to supply rated machine current to the line. Current-limit operation will be in evidence when further increase toward RAISE on the voltage adjust rheostat fails to cause an increase in alternator output current. This current-limit level is adjustable by means of resistor R11. Increasing R11 will reduce the current-limit level. This level is normally set at the rated current of the alternator.
16. Adjust the reactive droop for PARALLEL operation by adjusting resistor R9 for the required percent droop (normally 5%). Resistors R14 and R15 are inoperative due to. being shorted by external relay contacts. Raise the alternator excitation until the alternator output current is 60% of alternator rating, with KW output at 5 to 10% of rated. Note the alternator voltage, and trip the breaker. Note the no-load voltage; this should be about 5 to 6% above the voltage that existed prior to tripping the breaker.
17. Adjust the reactive droop for cross- current regulation in the Dead Line Operation mode by adjusting R15. This requires that R15 is in the circuit (relay contacts between terminals 21 and 5 are open). Resistor R14 is to be shorted out by relay terminals or a jumper between terminals 22 and 23 on the voltage regulator panel. Raise the alternator excitation until the alternator output current is 60% of alternator rating with KW output at 5 to 10% of rated. Note the alternator voltage and trip the breaker. Note the no-load alternator voltage; this should be about 10% more than the voltage that existed prior to tripping the breaker.
18. Set the deadline voltage adjusting rheostat on all regulators to secure the proper voltage level and balanced KVAR output.
19. Shut down the diesel, and restore switching functions to automatic. Disable the paralleling breaker.
20. Start the diesel engine and allow the alternator to be brought up to rated speed. The alternator will be in the Voltage Matching Mode. Adjust the slider on resistor R2 as required for proper voltage match.
21. Correct connection of the power current transformers and the exciter potential transformer can be verified by checking exciter line to line input

voltages. Voltages should be balanced and should increase with lagging KVARS and decrease with leading KVARS.

NOTE: If system voltage conditions do not permit unit operation at high lagging KVARS it will be necessary to use 50% of the values mentioned in the above adjustments.

The voltage regulator is now adjusted for automatic operation. When two or more alternators are to be operated jointly in the Parallel mode, it is necessary that all voltage regulators be adjusted for identical operation. This means all alternators to be used must be adjusted to the same settings of alternator excitation (deadline voltage adjust rheostat), the same settings of R9 for similar droop characteristics, and the same settings of R15 for matched operating characteristics in Dead Line Operation.

MAINTENANCE INSTRUCTION

AUTOMATIC ALTERNATOR SYNCHRONIZER - PART NO. 8263907

DESCRIPTION

This synchronizer is designed to operate with no moving parts, using static devices to the fullest extent possible, thus eliminating the necessity for vacuum tubes, vibrating elements and other de- vices requiring maintenance and adjustments.

In this design of synchronizing equipment, magnetic amplifiers, reactors and transformers constitute the major portion of the control equipment. Slide band resistors and rheostats are used for adjustments.

The basic function of any synchronizer is that of causing two or more independent events or actions to assume a definite time relationship. To accomplish this purpose the synchronizing equipment must provide a method of detecting and controlling the time relationship between the events or actions to be synchronized.

The magnetic amplifier controlled synchronizer described in this instruction functions to bring the diesel engine driven generator into synchronism with one or more parallel connected power generating plants or with an infinite bus power distribution system, and apply the generator output to the line at the moment of synchronism automatically.

In order for the equipment to accomplish this, the synchronizer requires two basic and essentially separate circuits: a detector circuit and a frequency matching circuit.

OPERATION

The speed-matching signal is a DC signal with a magnitude proportional to slip frequency, and a polarity dependent upon whether the alternator frequency is above or below synchronous frequency. This signal is supplied to the governor amplifier, which functions only as a speed matching amplifier prior to closure of the main circuit breaker. The amplified signal is applied to the control phase of a two phase motor which in turn controls the governor speed setting on the diesel. The servo motor rotates in a forward or reverse direction, depending upon the polarity of the, speed-matching signal. The connections to the servo motor are phased such that the resulting rotation causes a change in the governor setting which in turn alters the diesel speed, and hence the alternator frequency, such that the slip frequency is reduced toward zero.

As the slip frequency approaches zero, a value of slip frequency is ultimately reached below which the synchronizing circuitry operates in a manner to initiate the sequence of events required for the main paralleling breaker to close. For closure to occur at exact phase coincidence of the AC line voltage with the AC generator voltage, the initiation of there lay sequence must occur in advance of phase coincidence by an amount of time required for the circuit breaker to close (0.4 seconds for MA breakers). This automatic synchronizer provides this required anticipation, and initiates the relay

closure sequence only after the slip frequency has been reduced to 1/5 cps or less. This means that with a synchronous frequency of 60.0 cps, paralleling will occur only after the speed-matching circuitry has caused the governor to raise the alternator frequency above 59.8 cps (lower lock-out point) or has caused the governor to reduce the alternator frequency below 60.2 cps (upper lock-out point).

The remaining requirement for paralleling the alternator with the line (proper phase sequence having been previously established) is that the alternator voltage be equal to the line voltage. This voltage matching is accomplished by the associated voltage regulator which receives the AC voltage signals for matching from the two 3-phase power transformers (PT's), one on the line and the other on the alternator output. These also supply power for metering purposes and for operating the automatic synchronizer.

MAINTENANCE

The automatic synchronizer requires very little maintenance or inspection. Efficient and satisfactory operation will be assured by attention to proper installation and correct adjustments.

This section is divided into two parts: installation check and adjustments.

INSTALLATION CHECK

The following installation check should be performed prior to operating the equipment for the first time or after any repairs which involve the interconnections to the units. It is of the utmost importance that the proper phase relationship be established to the synchronizer as well as to the governor amplifier.

1. Move the paralleling circuit breaker into TEST position so the breaker mechanism may be operated without main contact closure.
2. Disconnect system leads to governor amplifier terminals 11-12 and connect a 2000 ohm (1 watt) resistor to these terminals. On those units using Relay C, disconnect lead #112 from terminal 6. Disable relay 52Z by disconnecting the system lead to terminal 10 on the synchronizer.
3. If more than one diesel-alternator is to be controlled by this synchronizer and governor amplifier, alter the automatic switching circuitry to be sure that only one diesel-alternator will be in operation.
4. Start the diesel engine and bring the alternator up to rated speed and voltage.

NOTE: If the synchronizer is being checked out with a governor amplifier which has not been previously checked out, some difficulty may be experienced in the action of the governor amplifier as it attempts to change the governor setting. Normal operation is such that the diesel speed will respond to the manual governor control switch as it is turned to RAISE or LOWER position, and no change in diesel speed with this switch in neutral position. However, if the diesel speed does change with this switch in neutral position, unlock the shaft-lock on resistor R2 in the governor amplifier and adjust R2 for balance. Balance exists when the control phase voltage on the governor servo motor is at minimum AC volts. Measure this voltage between terminals 6 and 9 on the governor amplifier.

5. Check the voltage at the synchronizer terminals 1-2-3. This three phase voltage must be 208 ± 10%; phase sequence on terminals 1-2-3 must be positive rotation. Check for 120 ± 10% AC volts on terminals 4-5.

6. Check the voltage at the synchronizer terminals 11-13. This single phase voltage is to be the same value as the three-phase voltage measured in Step 5. If not the same, adjust the alternator output voltage by adjusting R2 in the voltage regulator to obtain a proper voltage match. The voltage to synchronizer terminals 1 and 11 must correspond to the same phase (phase A on the line to terminal 1, and phase A on the alternator to terminal 11). Likewise, the voltage to synchronizer terminals 3 and 13 must correspond to the same phase (phase C).
7. Shut down the diesel engine. Remove the 2000 ohm resistor from terminals 11-12 on the governor amplifier and reconnect the system leads to these terminals.
8. Start the diesel engine. If the speedmatching signal from the synchronizer causes an increase in the slip frequency rather than a decrease, reverse the system leads to terminals 7-8 on the synchronizer. If the governor amplifier has not been previously checked out, check the phasing of the governor servo motor by temporarily jumpering terminal 8 to 9 on the governor amplifier. Diesel speed should increase; if not, reverse the system leads to the fixed phase of the servo motor at terminals 4 and 5 on the governor amplifier. If this change is made, the leads to terminals 7-8 on the synchronizer must be restored to their initial connections.
9. Check the speed-matching operation by turning the manual governor control switch to RAISE so as to increase the alternator frequency a few cycles per second above synchronous frequency, releasing the switch, and allowing the alternator frequency to be matched with the line frequency as the speedmatching signal operates through the governor amplifier to control the governor in the required manner. Repeat several times.
10. Continue to check the speed matching operation but with the diesel speed offset by turning the manual governor control switch to LOWER so as to reduce the alternator frequency a few cycles per second below line frequency. With a synchroscope properly connected, the operation should be such that the speed is matched rapidly and phase matching is accomplished with the synchroscope pointer coming to rest in the region of 12:00 o'clock. If satisfactory operation is not obtained, refer to paragraphs 1 through 5 under "Adjustments for Speed Matching Circuitry."
11. After proper speed matching and phase matching operation is obtained, reconnect lead 112 to terminal 6 on Relay C (if used). The synchroscope pointer should now swing to left and to right of 12:00 o'clock and attempt to reach the null which is alternately shifted by Relay C from 11:00 o'clock to 1:00 o'clock, back to 11:00 o'clock again, etc. If this action is not obtained, refer to paragraphs 6 and 7 under "Adjustments for Speed Matching and Phase Matching Circuitry."
12. Restore Relay 52Z to operating condition by reconnecting the system lead to terminal 10 on the synchronizer. Start the diesel engine and allow the synchronizer to function automatically to speed-match and phase-match, and to initiate closure of the paralleling breaker.

NOTE: This may require that a selector relay interlock be temporarily jumpered to prevent de-energizing Relay SR (and the synchronizer) when the paralleling breaker closes.

13. Turn the manual governor control switch to RAISE and allow the synchronizer to speed and phase match the alternator from 2 cps above synchronism. Repeat several times. In each case, the paralleling breaker should close when the line-to-generator phase difference is no greater than five degrees.
14. Repeat step 13 but offset the alternator frequency to 2 cps below synchronism. If proper operation is obtained, proceed to step 15. If the operation is not satisfactory, refer to paragraphs 1 through 4 under "Synchronizing Circuitry Adjustments."
15. After the above installation checks have been completed and satisfactory operation has been obtained, the synchronizer is ready to operate.

ADJUSTMENTS

Some of the resistor adjustments made at the factory prior to shipment should not be changed unless necessitated by replacement of parts in the circuits directly associated with these resistors. These resistors are R8, R9, R10, and R11. The other variable resistors can be adjusted as required in accordance with the steps outlined below.

PRELIMINARY

Move the main circuit breaker to the test position.

ADJUSTMENTS FOR SPEED MATCHING AND PHASE MATCHING CIRCUITRY

1. Before making any adjustments in the synchronizer which affect the speedmatching and phase-matching function, verify that the governor amplifier is balanced. Disconnect system leads to governor amplifier terminals 11-12 and connect a 2000 ohm (1 watt) resistor to these terminals. Adjust rheostat R2 in the governor amplifier for minimum AC volts from terminal 6 to 9 on the governor amplifier. Lock R2, remove the 2000 ohm resistor, and restore the system leads to terminals 11-12.
2. If the speed matching circuit causes the governor to return the diesel engine to synchronous speed too rapidly or too slowly after initially offsetting the alternator frequency to 4 cps above or below synchronism, adjust rheostat R6. Decrease the resistance for faster response by turning the rheostat clockwise(CW). Increase the resistance for slower response by turning the rheostat counterclockwise (CCW).
3. The phase matching signal should become the predominate control to the governor at low values of slip frequency (less than 0.3 cps). The synchroscope pointer should indicate that the alternator frequency is being controlled to an in-phase condition as evidenced by the synchroscope pointer seeking a null at the 12:00 o'clock position with lead 112 to terminal 6 on Relay C disconnected.

   If the pointer seeks a position at 1200 before or after 12:00 o'clock, the incoming leads to synchronizer terminals 1-2-3 and 11-13 are not in accordance with Fig. 1. Check for an advancement of 120° or 240° in the phase rotation on the three-phase input to terminals 1-2-3.

   If the pointer seeks a position at 180°, check for negative phase sequence on terminals 1-2-3, or a reversal in the leads to terminals 11-13.

4. If the synchroscope pointer comes to rest near, but not exactly at 12:00 o'clock, check the line and alternator voltage to determine if the two voltages are matched satisfactorily. If these are matched, make adjustments

in the phase-matching circuitry as follows:

a. Obtain a test condition where the voltage to terminals 1-3 and 11-13 are equal in voltage and phase, such as removing the system leads to terminals 11-13, placing a jumper from terminal 11 to 1, and placing a jumper from terminal 13 to 3.

b. Place a low range DC voltmeter (high impedance type) across capacitor C10 and adjust rheostat R7 for minimum voltmeter reading.

5. The phase-matching function may show some slight difference in the rate at which the synchroscope pointer approaches 12: 00 o'clock from a 9: 00 o'clock position as compared to the rate of approach to 12: 00 from a 3: 00 o'clock position, the slip frequency having been adjusted previously(manually) to zero cps at the 9: 00 and 3: 00 o'clock positions. This slight difference is normal. The rate of approach from both positions can be increased by turning rheostat R35 clockwise or decreased by turning counterclockwise.

NOTE: The setting of R35 is somewhat influenced by the setting of R6.Minimum resistance on R6 normally requires maximum clockwise rotation of R35. If further improvement in the phase-matching operation is required, turn R6 counterclockwise to a higher resistance setting. The combined speed and phase-matching operation is also affected by the gain in the governor amplifier. Refer to the applicable instructions for changing the gain.

Disregard Steps 6 and 7 if relay "C" is disabled or removed

.

6. Proper phase-matching to 12: 00 o'clock with lead 112 disconnected from terminal 6 on Relay C should show a shift in the null to 1: 00 o'clock with R40 jumpered out. If R40 is not jumpered, and instead a jumper is placed across R41, the synchroscope pointer should seek a null at 11: 00 o'clock. If the null does not occur at 11: 00 and 1: 00 o'clock, repeat step 4 above. In addition, check for equal DC voltages on R39, R40, R41, R42.

7. Relay C should recycle at a rate such that terminals 4-6 on Relay C are closed for about 4 seconds (3 to4 seconds), this time being controlled by the adjustment of the upper relay control head on this time delay relay. Also, contacts 2-6 should be closed for about 5 seconds), this time being adjustable by means of the lower control head. If Relay C switches more rapidly than just indicated, the synchroscope pointer will not swing from 11: 00 to 1: 00 and back to 11: 00 o'clock etc. Instead, the pointer will fail to pass through the 12: 00 o'clock position and will alternate through a limited arc on either the 11: 00 or 1: 00 o'clock side of 12: 00.

8. The following adjustment of rheostat R5 should not be made unless necessitated by a change of components in the associated circuits. Obtain a test condition as outlined above in Step 4a. Adjust R5 such that the AC voltage across servo motor control phase is minimum.

SYNCHRONIZING CIRCUITRY ADJUSTMENTS

1. Anticipation signal adjustment, or lock-out (hold-off) signal adjustment is best accomplished by setting up the following test condition:

With the paralleling breaker in TEST position, set conditions to

obtain a controlled value of slip frequency. Install a jumper across silicon diode CR13 in the synchronizer to disable the phase matching signal. In the governor amplifier, unlock rheostat R2 (hereafter referred to as GA-R2), and turn slightly in one direction to offset alternator frequency below line frequency, or turn GA-R2 in the other direction for alternator frequency to stabilize at a value above line frequency. The value of slip frequency that is being regulated will depend on the amount of change in GA-R2 from its initial setting. The new value of alternator frequency is regulated to the set value due to the speed-matching signal being developed to nullify the signal introduced by offsetting GA-R2 from its initial balanced condition. Slight variations in slip frequency will occur due to random effects on diesel speed which result with no change in governor servo-motor shaft position.

2. Anticipation signal adjustment is made by adjusting rheostat R2 in the synohronizer (hereafter referred to as SY-R2). With test condition per step 1 above, set slip frequency to slightly less than the lock-out frequency (approximately 0.18 to 0.2 cps). Paralleling breaker closure should occur at phase coincidence (12:00 o'clock on the synchroscope). Turn SY-R2 clockwise to reduce, or counterclockwise to increase the anticipation.

NOTE: Early synchronizer units had a transformer T1 with more than eight terminals. Any replacement of such transformers with latest type will require circuit connections per Fig. 1, and in addition will require a slight adjustment of SY-R2 per this step.

.

3. Lock-out (hold-off) signal adjustment is accomplished by adjusting rheostat R3 with a test condition per Step 1 above. Any adjustment required per Step 2 should be made first since such adjustment will affect the lock-out points slightly. Adjust R3 in small steps. Adjust R3 clockwise to increase the point where a certain value of slip frequency (about 0.18 to 0.22 cps) results in paralleling breaker closure; however, any further increase in slip frequency results in a lock-out condition (no breaker closure). Adjust R3 counterclockwise to reduce the bandwidth between the upper and lower lock-out points. The upper lock-out point (alternator frequency greater than line frequency) and the lower lockout point (alternator frequency lower than line frequency) should occur at about the same value of slip frequency.

4. The following adjustments should not be made unless circuit components have been replaced that would affect synchronizing, or unless indicated by adverse operation that cannot be corrected by adjustments per Steps 2 or 3 above.

The following adjustments serve to balance the L1 amplifier in the synchronizer for proper operation. This can be done by setting up a test condition per Step 4a under "Adjustments For Speed Matching and Phase Matching Circuitry", and proceeding as follows with the paralleling breaker in DISCONNECT position or otherwise disabled.

a. Clip a jumper across capacitor C4 to short out L1 signal. Connect a 0-10 DC voltmeter across capacitor C8 to measure L1 output. This voltmeter should have a sensitivity equal to or greater than 1000 ohms per volt. Close relay SR

(manually or otherwise). The voltmeter should read about 4 volts (3.8 4.2) with rated voltage applied to the input to synchronizer terminals 1-2-3. If not, loosen shaft lock on L1 rheostat, adjust for maximum voltmeter reading, tighten shaft lock, and proceed to adjust bias rheostat R4 for a voltmeter reading of 4 DC volts.

b. Remove from capacitor C4. If DC voltmeter reading decreases, adjust rheostat R1 in the synchronizer to balance the signal circuit. Adjust R1 to obtain maximum voltmeter reading.

NOTE: This maximum will be the same value as read with capacitor C4 shorted, however, the meter reading may decrease from maximum
.

at irregular intervals due to minor AC line variations.

5. One final check that should be made after any major adjustments or repairs is as follows: With the paralleling circuit breaker in DISCONNECT position, the synchronizer connected for normal operation, and resistor R2 in the governor amplifier rebalanced above, start the engine and allow synchronizer to function in its normal manner. Prior to closure of the main circuit breaker, offset the diesel speed by means of the manual governor control switch (either RAISE or LOWER) for 3 cps slip frequency. Connect a 0-2.5 or 0-5 DC voltmeter across R31 to verify that a DC voltage of one volt minimum exists across this resistor with a slip frequency of 3 cps.

NOTES:
1. Connections #18 AWG W1-128-1.
2. 120 AC volts to terminals 4-5 must be phased as from phase A to neutral as shown.
3. T1 transformer, spare windings coded 9-10, and 11-12-13 discontinued on serial nos. 00800-A4 and above.
4. C3 & C4 were 4.0 mfd. on earlier units.
5. Before energizing the 35C543-3 assy., install jumpers on terminals:
   17-18 for long delay breaker
   16-17 } for short delay
   19-20 } breaker
6. Relay "C" is disabled or removed on latest panels.
7. Six diodes are connected between A5 and C4 on latest panels.

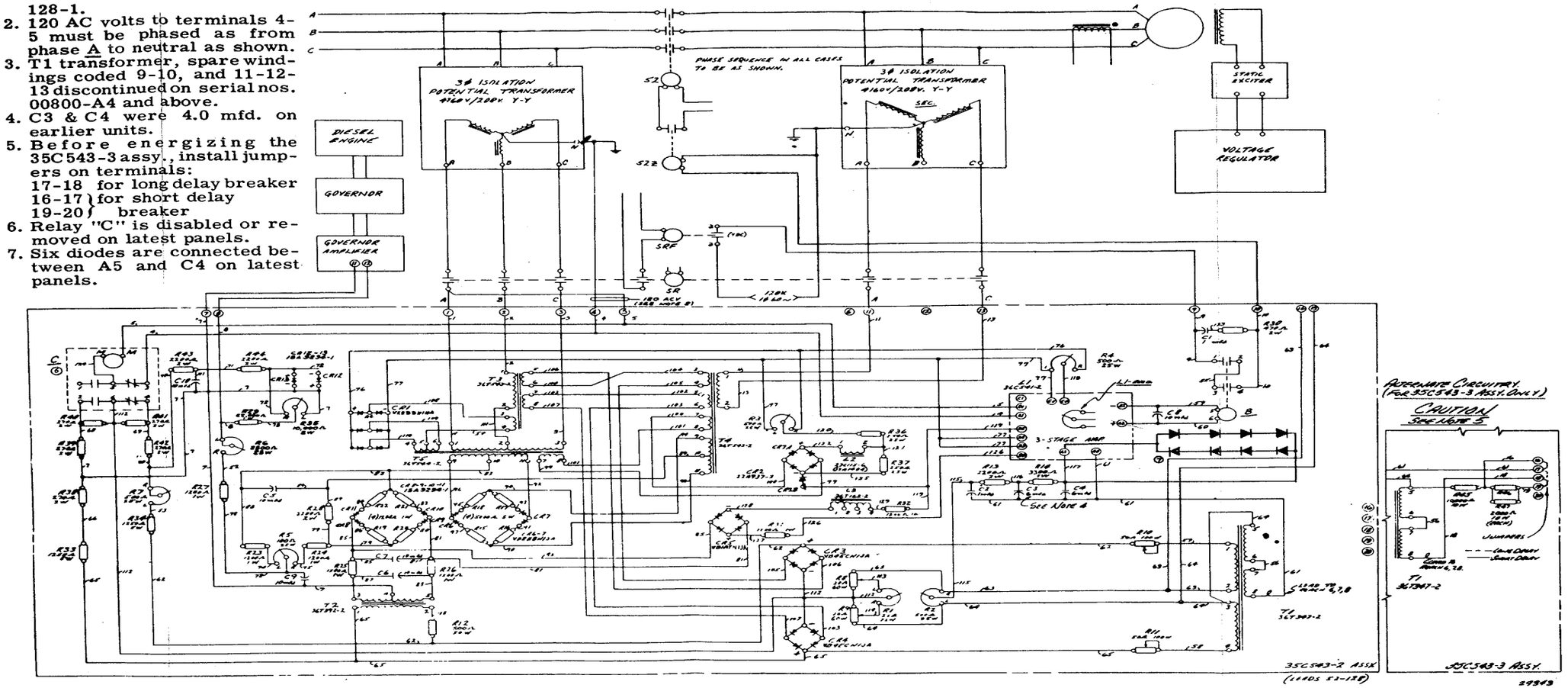


Fig 1. Schematic Wiring Diagram

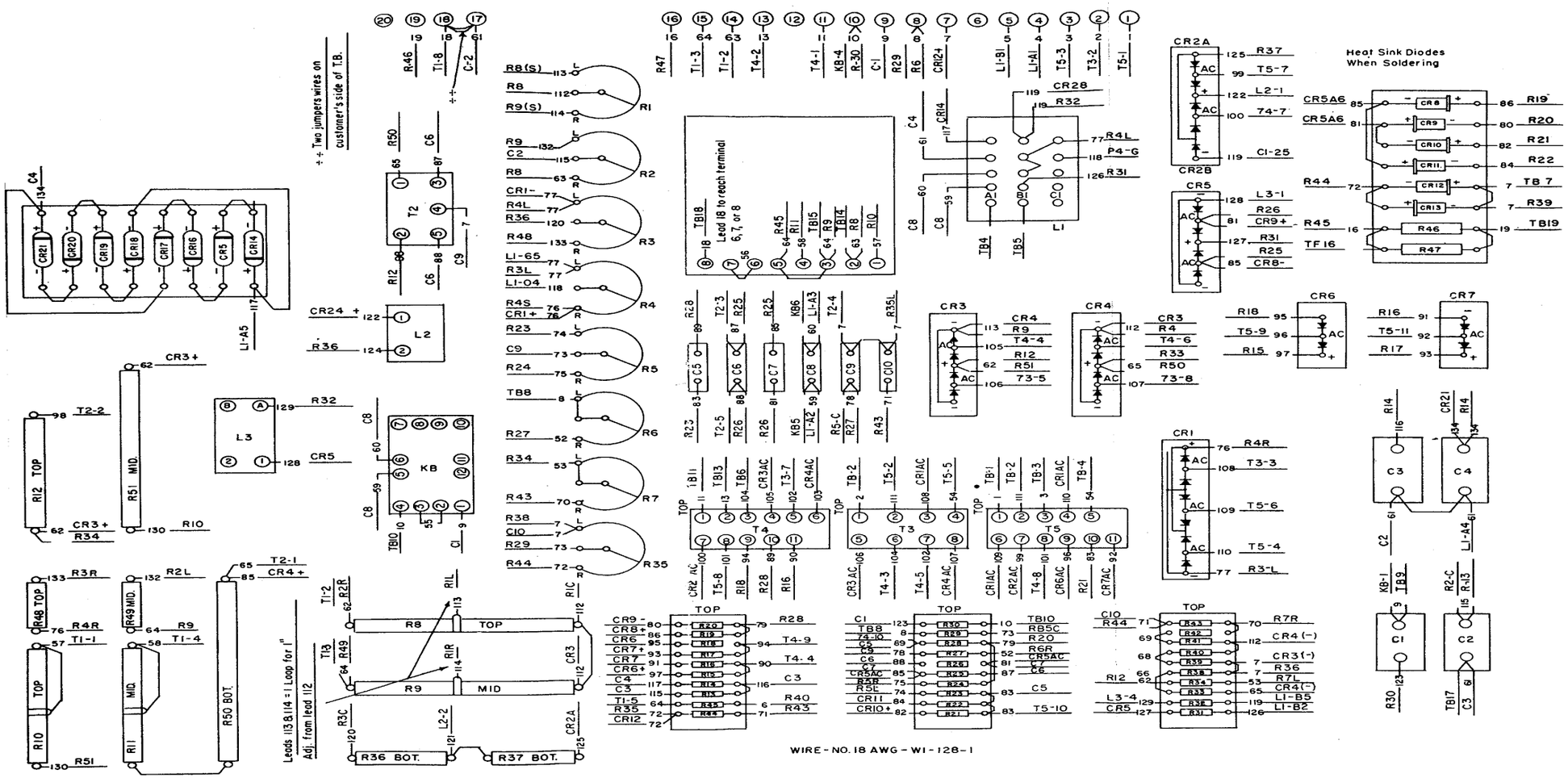


Fig. 2.- Physical Wiring Diagram

AUXILIARY RELAYS

GENERAL DESCRIPTION

The relays covered by this bulletin and tabulated in Table I are all of the same basic construction and are used in a wide v a r i e t y of applications. They differ only in size, number, rating and arrangement. of contacts, and operating values. Figs. 1 and 2 illustrate the two size groups into which all of these relays fall. The smallest size relays, Fig. 1, have a 10-ampere capacity rating while the larger group have a 20ampere rating in most cases. Part number 8210254 has a 35-ampere w ..J ,, 8138583 has a 50-ampere capacity even though these two contactors are of the same size as the relay illustrated in Fig. 2.

The relays all consist of a base, a coil assembly and a contact assembly. The coil of the relay is top mounted and is held in place inside the magnet yoke, Fig. 3, by a hollow center stud and nut. The contact assembly consist of an upper and lower stationary contact assembly, a movable contact assembly, a back cover and a front cover. The upper stationary contact assembly consists of a phenolic block with stationary contacts and external connectors moulded into the block. In some cases tapped inserts are moulded into the phenolic block and the contacts screw into them. The block is attached to the magnet yoke with machine screws

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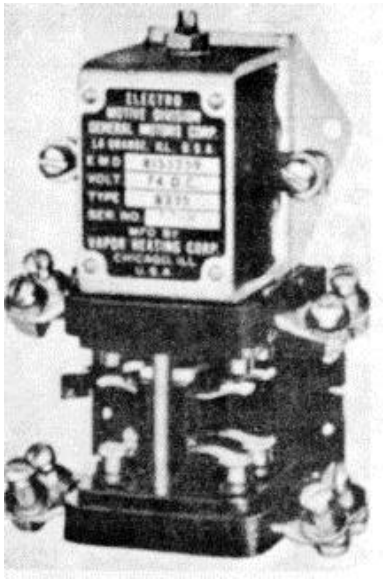


Fig. 1 - Typical Ten Ampere Capacity Relay

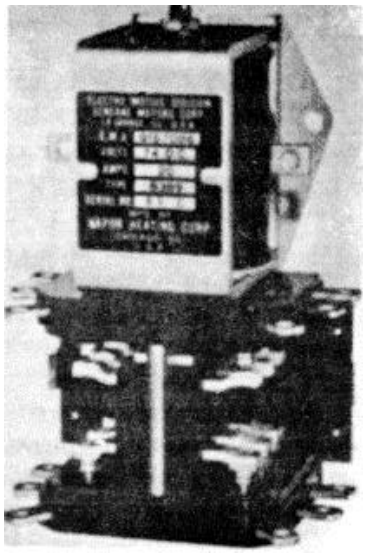


Fig. 2 - Typical Twenty Ampere Capacity Relay

The lower stationary contact assembly also consists of external connectors and stationary contacts or tapped inserts moulded into a phenolic block. The lower block is connected to the upper stationary contact assembly by two guide bars.

The movable contact assembly consists of an armature plunger, a return spring, movable contact bars and phenolic spacers. The armature plunger moves inside the hollow center stud which holds the magnet coil in the yoke. The phenolic spacers are fastened to the armature plunger by a machine screw. The movable interlock bars are connected to the phenolic spacers by small springs held in place by metal studs and retainer rings. The springs provide the necessary over travel and contact pressure. The return spring which is around the armature plunger acts to return the contacts

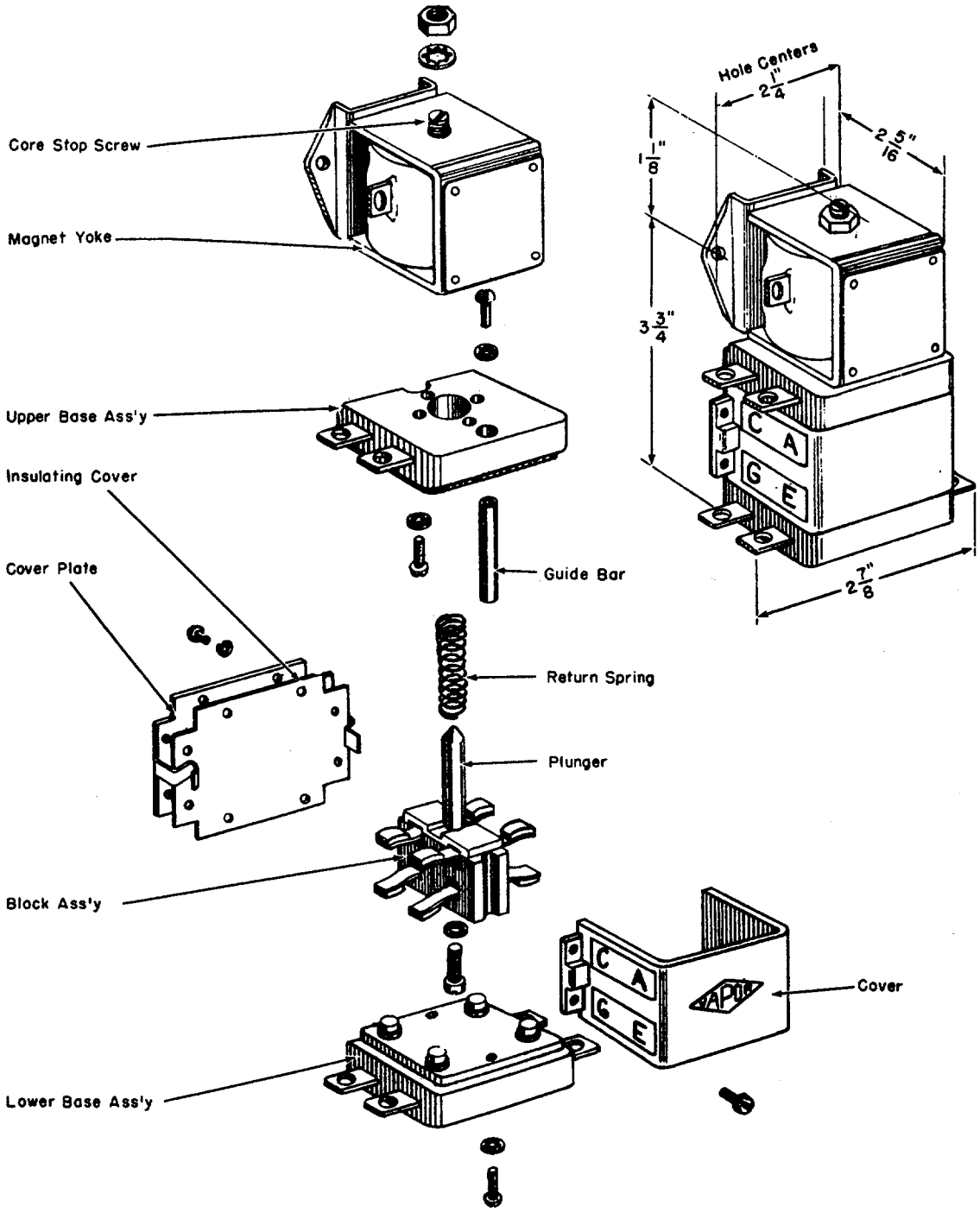


Fig. 3 - Exploded View - All Relays

to their normal position when the relay coil is de-energized. The two guide bars position the spacer blocks to align the movable contacts with stationary contacts.

The coils of these auxiliary relays operate off 74 volt control circuits in most cases. The contact arrangements are designed to set up a variety of control circuits for product operation. The individual wiring diagrams will indicate relay function.

OPERATION

When the top mounted coil of these relays is energized, the armature plunger is attracted upward, overcoming the tension of the return spring. All of the contacts change position when this occurs. The movable contact bars and phenolic spacers of the different relays are arranged to produce the desired sequence of operation such as normally open contacts close before normally closed contacts open or vise-versa.

When the relay coil is de-energized, the movable contact assembly is forced downward by the return spring, returning the contacts to their normal position. The arc created at de-energization is not sufficient to require any form of arc suppression.

MAINTENANCE

Due to simplicity of construction employing a minimum of moving parts together with silver alloy contacts and dust free enclosure, these auxiliary relays will provide satisfactory service over a long period of time. Maintenance requirements center primarily around occasional inspections to qualify the relays for continued service.

INSPECTION

1. Check the cover for cracks, discoloration or poor fit. Clean any accumulation of dirt or dust from the relay with a soft brush and air.

2. Inspect the electrical connection for tightness and electrical contact.

3. Inspect the operating coil for burns or discoloration. Check resistance of the coil according to values given in the Maintenance Data Section, Table I.

4. Inspect the alloy contacts for contact gap, wipe action and surface condition. The contact gap and over travel for each relay is listed in the Maintenance Data Section, Table 1, of this section. Alloy contacts will operate satisfactorily even though blackened, pitted or eroded. Do not clean, dress or file contact surface. Replace contacts when any part of the alloy is worn away to the base metal. For best results, both the stationary and movable contacts should be replaced if either alloy tip is worn to the base metal. In all cases, NO FILING should be done.

5. Check the movable mechanical parts of the relay for proper function.

6. Do not use any oil as these relays need no lubrication.

7. Electrically inspect the relay for pickup and dropout using the values tabulated in the Maintenance Data Section, Table 1, in this section. Adjustment is obtained by positioning the plunger core stop screw and locknut, see Fig. 3.

ADJUSTMENT OF PICKUP AND DROPOUT

There is only a single adjustment for pickup and dropout on these relays. The settings can be made while the relay is mounted in its position on the product or on a work bench. The relay must be in a vertical position in either case. Connect a variable source of DC power (such as a motor-generator set) to the relay coil. A voltmeter must be connected across the line in order to read the voltage. Adjustment is made by loosening the locknut on the top of the magnet yoke assembly and turning

.

the core stop with a screwdriver. Set the pickup of the relay according to the values listed in the Maintenance Data Section, Table 1, of this section. Tighten the locknut and proceed to check the dropout of the relay. It should also agree with the values given under Maintenance Data for the particular relay in question. If dropout value is not satisfactory, check for binding of the armature plunger or a broken or fatigued return spring.

ADJUSTMENT OF CONTACT AIR GAP AND OVERTRAVEL

The contact air gap and contact wipe of the relay being worked on should be correct after the pickup and dropout has been adjusted as outlined above. If the values do not agree with those given under Maintenance Data, Table 1, the contact brush assemblies have become slightly bent. If this is the case, movable contact arms should be straightened.

REPLACEMENT OF OPERATING COIL

To replace the operating coil of the relay first remove the locknut and lockwasher from the tube and stop core assembly, see Fig. 3. Next unscrew the tube and stop core assembly from the magnet yoke assembly. Push the magnet coil, together with the anchor washer underneath the coil, from the magnet yoke, pushing to the right. The anchor washer replaces fish paper spacer washers used on earlier models of these relays. Some older models may have two set screws and locknuts holding the operating coil in place.

Apply the new operating coil by reversing the procedure outlined above. Set the pickup and dropout of the new coil by adjusting the stop core assembly as outlined previously.

REPLACEMENT OF CONTACTS

Except for a few early models, stationary contacts are moulded into the upper and lower contact base assemblies. The stationary contacts on those early models may be replaced by merely unscrewing the contacts from their tapped insert and applying the new contact. When the stationary contacts need replacing on new models, the entire upper or lower contact bases must be replaced. Proceed as follows:

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1. Remove the interlock cover by releasing the cover clips, Fig. 3, and pulling off the cover (older models may have had the cover applied by means of four screws and nuts).

2. Remove the back cover plate and cover plate insulator by removing the four screws holding them in place, Fig. 3.

3. Remove the lower contact base assembly by removing the two screws holding it to the upper contact base assembly.

   When the lower base is removed, the plunger and contact block assembly will come out. Use caution so that the spring does not push it out so that it drops and is broken.

4. To remove the upper contact base assembly, remove the screws holding it to the magnet yoke assembly.

The movable interlock bars may be removed from the movable contact assembly merely removing the screw holding the plunger and contact block assembly together, see Fig. 3. The interlock bars will then slide out of the contact assembly.

Replace the necessary contacts and reassemble following the reverse of the procedure outlined above. Any cylindrical springs which are found supporting the movable contact arm inside the movable contact brush carrier should be replaced by a conical spring, Part #8219585. The conical spring must be applied with the large diameter portion pressing against the bridge contact. Use of this new spring will eliminate cocking of the contact bridge.

MAINTENANCE DATA

TABLE I

	EMD Part Number	Contact Arrangement	Contact Rating	Coil Resistance	Pickup	Dropout	Contact (Minimum) Gap	Contact (Minimum) Lift
*	8089739	2 N.O. 1 N.C.	20 Amps.	345 Ohms ± 10% @ 68° F.	48 Volts Max.	5-28 Volts DC	3/32"	1/32"
**	8090424	2 N.O. 2 N.C.	20 Amps.	345 Ohms ± 10% @ 68° F.	48 Volts Max.	5-28 Volts DC	3/32"	1/32"
#	8120145	1 N.O.	10 Amps.	495 Ohms ± 10% @ 68° F.	48 Volts Max.	5-28 Volts DC		1/16"
##	8130069	2 N.O. 2 N.C.	20 Amps.	495 Ohms ± 5% @ 68° F.	48 Volts Max.	5-28 Volts DC	3/32"	1/32"
##	8130070	3 N.O.	20 Amps.	495 Ohms ± 5% @ 68° F.	48 Volts Max.	5-28 Volts DC	3/32"	1/32"
##	8137370	3 N.O. 2 N.C.	17 Amps.	495 Ohms ± 5% @ 68° F.	48 Volts Max.	5-28 Volts DC	3/32"	1/32"
	8138583	2 N.O. 1 N.C.	50 Amps.	495 Ohms ± 5% @ 68° F.	48 Volts Max.	5-28 Volts DC	3/32"	1/32"
##	8138989	2 N.O. 2 N.C.	20 Amps.	495 Ohms ± 5% @ 68° F.	48 Volts Max.	5-28 Volts DC	.046"	1/32"
	8155259	2 N.O. 2 N.C.	10 Amps.	1160 Ohms ± 5% @ 68° F.	48 Volts Max.	5-28 Volts DC	1/16"	1/32"
	8155897	1 N.O.	20 Amps.	495 Ohms ± 10% @ 68° F.	48 Volts Max.	5-28 Volts DC		1/16"
	8157086	3 N.O. 3 N.C.	20 Amps.	495 Ohms ± 5% @ 68° F.	48 Volts Max.	5-28 Volts DC	3/32"	1/32"
	8157398	2 N.O.	20 Amps.	526 Ohms ± 4% @ 68° F.	52 Volts Max.	5-28 Volts DC	3/32"	1/32"
	8160329	2 N.O. 2 N.C.	20 Amps.	87 Ohms ± 5% @ 68° F.	24 Volts Max.	2-10 Volts DC	3/32"	1/32"
	8174804	3 N.O. 1 N.C.	10 Amps.	1160 Ohms ± 5% @ 68° F.	48 Volts Max.	5-28 Volts DC	1/16"	1/32"
	8174805	2 N.O. 2 N.C.	10 Amps.	50 Ohms ± 5% @ 68° F.	11 Volts Max.	6 Volts DC Max.	1/16"	1/32"
	8182398	2 N.O. 2 N.C.	10 Amps.	50 Ohms ± 10% @ 68° F.	10-13.6 Volts	2.6-3.3 Volts	1/16"	1/32"
	8187245	4 N.O. 2 N.C.	10 Amps.	598 Ohms ± 10% @ 68° F.	48 Volts Max.	5-28 Volts DC	1/16"	1/32"
	8188947	4 N.O. 2 N.C.	20 Amps.	495 Ohms ± 5% @ 68° F.	48 Volts Max.	5-28 Volts DC	3/32"	1/32"
	8190872	3 N.O. 3 N.C.	10 Amps.	598 Ohms ± 10% @ 68° F.	48 Volts Max.	5-28 Volts DC	1/16"	1/32"
	8210254	2 N.O.	35 Amps.	495 Ohms ± 5% @ 68° F.	48 Volts Max.	5-28 Volts DC	3/32"	5/64"
	8227936	3 N.O. 3 N.C.	20 Amps.	1125 Ohms ± 10% @ 68° F.	90 Volts Max.	9-52 Volts DC	3/32"	1/32"

* Replaced by 8157086
**TR Relay Discontinued
Replaced by 81552529
Replaced by 8157086

NOTE: All relays have a 74 volt DC working voltage except,

8174805 - 64 volt circuit with 100 ohms in series
8227936 - 120 Volts DC

MAINTENANCE DATA (Cont'd)

Hi-Pot Test (All Relays Except 8157398) - 1 Minute Duration

Coil to Frame	600 Volts AC RMS - 60 Cycles
Coil to Contact	600 Volts AC RMS - 60 Cycles
Contact to Frame	600 Volts AC RMS - 60 Cycles

Hi-Pot Test (8157398 Only) - 1 Minute Duration

Coil to Frame	1200 Volts AC RMS - 60 Cycles
Coil to Contact	1200 Volts AC RMS - 60 Cycles
Contact to Contact	1200 Volts AC RMS - 60 Cycles
Contact to Frame	1200 Volts AC RMS - 60 Cycles

CONTACTORS BRAKING, SHUNTING, OR STARTING 6918658, 8210242 8214934, 8239796 AND 8288625

DESCRIPTION

Contactors 8214934 and 8239796 are single pole type, rated at 200 amperes DC.

Contactor 8214934 is used on some power units and has a working voltage of 120 volts DC. This contactor has one normally open main contact. Contactor assembly 8239796 differs in that it is designed for 74 volt DC operation, has one normally closed main contact, and two auxiliary contacts, one normally open and the other normally closed. This contactor is shown in Fig. 1.

Contactors 6918658, 8210242, and 8288625 are two pole construction, with two normally open main contacts and are designed for operation on 74 volts DC. Contactor 6918658 is used in the braking systems of some locomotives and differs from the other two previously mentioned contactors in that it has two auxiliary contacts, one normally open and one normally closed.

Contactor assembly 8210242, used in the locomotive starting circuit, also has two auxiliary contacts, one normally open and one normally closed. Contactor assembly 8288625 is used in the dynamic brake circuit of some locomotives and has four auxiliary contacts to be wired for one normally open and one normally closed operation. This contactor is shown in Fig. 2.

OPERATION

When the contactor coil is energized the contact arm moves inward closing the normally open main contacts, with the exception of contactor 8239796 whose main contacts are normally closed. This action compresses the return spring.

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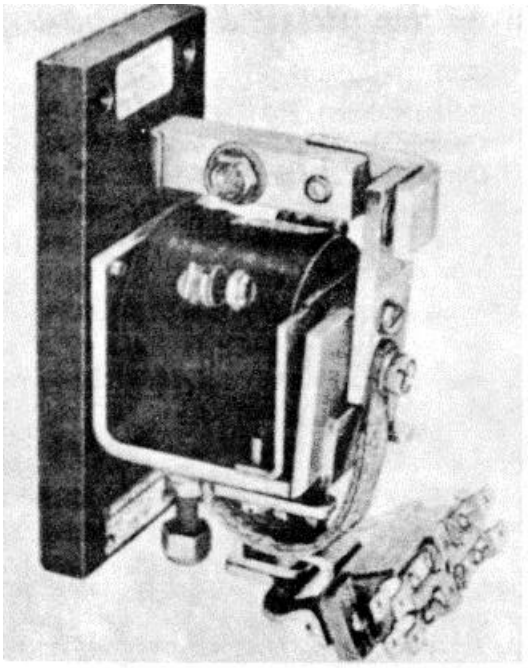


Fig. 1 - Single Pole Contractor

The auxiliary interlocks operate at the same time, thus opening the normally closed contacts and closing the normally open contacts.

When the operating coil is de-energized, the compression springs will act to return the main and auxiliary contacts to their normal position.

MAINTENANCE

The contactors should be inspected at intervals prescribed in the applicable Scheduled Maintenance Program Maintenance Instruction for the following:

1. Correct assembly, gap dimensions, and missing parts.

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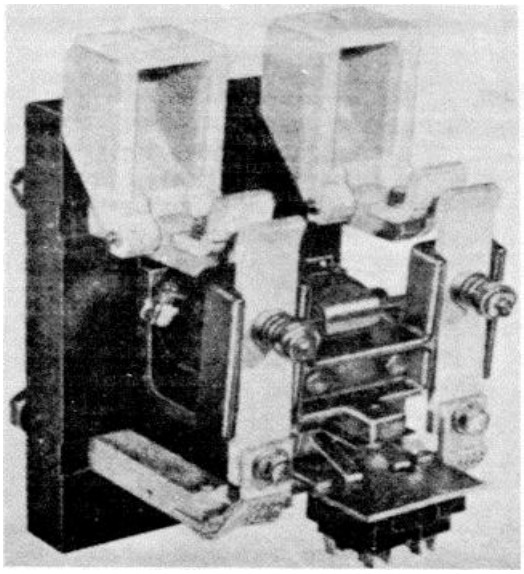


Fig. 2 - Two Pole Contactor

2. Damaged magnet coil insulation, terminals, internal breakage and continuity.

3. Free movement of all moving parts.

4. Security of mounting of all parts.

5. Continuity of bolted and soldered electrical connections.

6. Correct alignment of the contacts.

7. Burned or damaged areas in are chutes.

8. Fraying or burns on braided shunt.

9. Excessive wear of contact carriers, contact supports and contact carrier bearings.

Contact Replacement

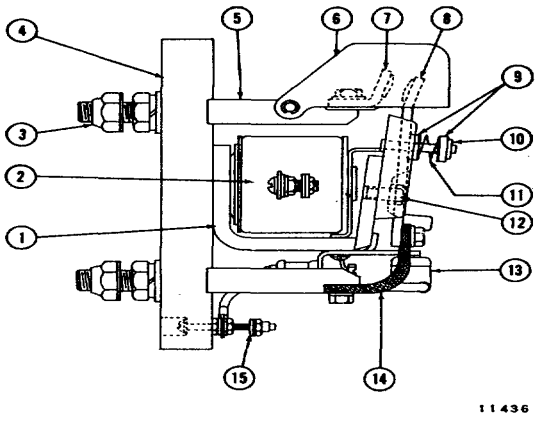
When any of the contacts are pitted, arc burned, or worn to the extent that replacement is necessary, it is recommended that all contacts, both stationary and movable, be replaced. This can be done by referring to Fig. 3, 4, and 5 and following the procedure below.

1. To remove the movable contacts, pry off the "U" washer and remove the contact spring and cup washers (on normally open contactor 8239796 the movable contacts are bolted to the armature). Remove the hexbolts which connect the flexible shunts. The movable contacts can now be removed.

2. The stationary contacts can be removed by removing the hex head bolts holding them in place.

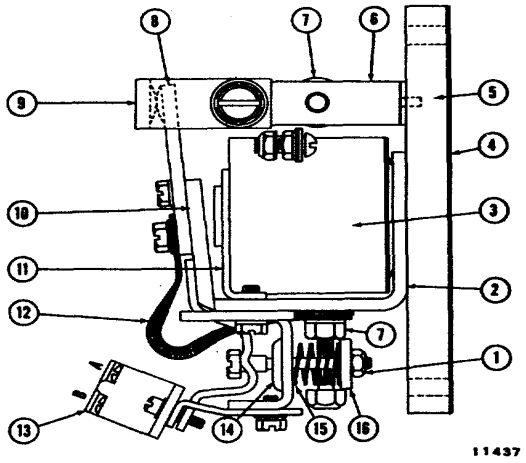
3. To remove the auxiliary interlock remove the fillister head bolts and wiring connections.

4. To remove the remainder of the parts, merely remove the nuts and bolts holding them to the panel.



1. Magnet Yoke
2. Magnet Coil
3. Power Connector
4. Panel
5. Contact Post
6. Arc Chute (No Blowout)
7. Stationary Contact Assembly
8. Movable Contact Assembly
9. Cup Washers
10. "U" Washers
11. Spring
12. Movable Contact Carrier
13. Interlock Assembly
14. Armature Support Bracket
15. Interlock Contact Connector

Fig. 3 - Contactor Assembly, 6918658 8210242, And 8288625 3-184



1. Contact Pressure Adjustment Nut
2. Magnet Yoke
3. Magnet Coil
4. Insulator
5. Panel
6. Contact Post
7. Power Connector
8. Movable Contact
9. Stationary Contact
10. Armature Assembly
11. Coil Retaining Bracket
12. Flexible Shunt
13. Interlock Assembly
14. Interlock And Compression Spring Mounting Bracket
15. Spring
16. Insulating Washer

Fig. 4 - Contactor Assembly, 8239796

5. Using new contacts, reassemble in reverse order to disassembly.

6. When reassembling the contacts, be sure to provide the correct gap, as measured between the closest points of the contact faces. Gap dimensions are provided in the Maintenance Data table in this instruction. Maximum sidewise misalignment between movable and stationary contacts should not exceed 1/16". Correct gap is obtained by bending the armature support fingers as required.

7. After making the adjustment in Step 6, set the tension on the armature spring to obtain contact pressure shown in the Maintenance Data Table.

The pressure reading should be taken with the contacts almost closed, and with the scale attached at the high point of the armature, see "D", Fig. 5.

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Coil Replacement

If it becomes necessary to replace the coil, refer to Figs. 3, 4, and 5 and use the following procedure:

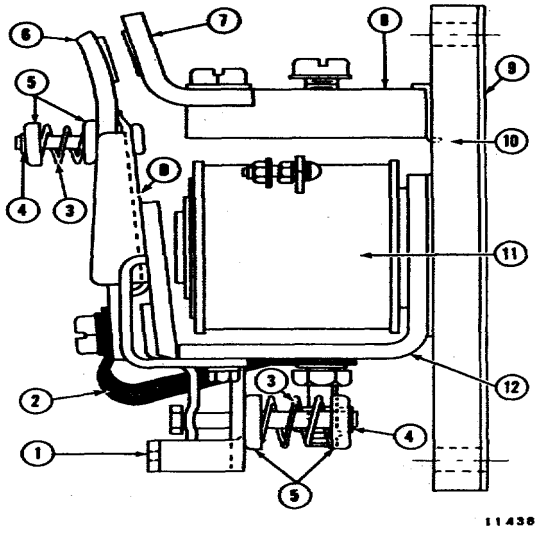
1. Remove the hex head bolts. The armature assembly and coil retaining bracket will come free and the armature may be positioned to provide clearance for coil removal.

2. Slide the magnet coil from the core.

If the spring washer under the coil is removed, be sure to replace it properly, with the large diameter of the washer against the coil.

3. Reassemble the contactor in the reverse order of disassembly.

4. Check contactor manually and electrically for proper operation.



1. Armature Support
2. Flexible Shunt
3. Spring
4. "U" Washer
5. Cup Washer
6. Movable Contact Armature Assembly
7. Stationary Contact
8. Contact Post
9. Insulation
10. Panel
11. Magnet Coil
12. Yoke Assembly

Fig. 5 - Contactor Assembly, 8214934

INTERLOCK ADJUSTMENT

Interlocks are to operate in unison with the main contacts, opening or closing as main contacts open or close. Operation can be checked with the use of test lamps.

Adjust interlock pickup on contactor 8239796 by loosening the hex head bolt holding the interlock mounting bracket through a slotted hole. To insure proper normally closed contact pressure and wipe make sure that the interlock actuating lever barely touches the interlock plunger when the contactor is de energized.

Adjust interlock pickup on contactors 6918658 and 8210242 by raising or lowering the interlock actuating screw or by bending the actuating fingers on 8288625. Insure proper normally closed contact pressure and wipe by allowing the actuator to barely touch the interlock plunger when the contactor is de-energized.

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MAINTENANCE DATA

Contactor	Coil Resistance	Pick-Up Volts DC	Drop-Out Volts DC	Contact Gap	Contact Pressure
6918658	200 Ohms ± 10% @ 20° C.	48 Max.	5-28	7/16" Min.	5 Lb. Min.
8210242	31 Ohms ± 10% @ 20° C.	48 Max.	5-28	3/8" Min.	6 Lb. Min.
8214934	466 Ohms ± 10% @ 20° C.	98 Max.	12 Min.	5/32" to 3/16"	2-1/2 to 3 Lbs.
8239796	170 Ohms ± 10% @ 20° C.	45 Max.	5-28	3/16" to 7/32"	2-1/2 to 3 Lbs.
8288625	200 Ohms ± 10% @ 20° C.	48 Max.	5-28	7/16" Min.	5 Lb. Min.

CONTACT AND INTERLOCK ARRANGEMENT

Contactor	Main Contacts	Interlocks
6918658	2 N.O. 400 Amps.	A-B N.C. C-D N.O.
8210242	2 N.O. Starting Duty	A-B N.C. C-D N.O.
8214934	1 N.O. 200 Amps.	
8239796	1 N.C. 200 Amps.	A N.C. B N.O.
8288625	2 N.O. 400 Amps.	A-B N.C. C-D N.O.

HI-POT — VOLTAGES — RMS — 60 CYCLES — 1 MINUTE

Coil	6918658	8210242	8214934	8239796	8288625
Coil to Ground	600 V	600 V	600 V	600 V	600 V
Coil to Main Contact	2400 V	2400 V	600 V	600 V	2400 V
Main Contact to Ground	2400 V	2400 V	600 V	600 V	2400 V
Auxiliary Contact to Ground	600 V	2400 V	—	600 V	2400 V
Auxiliary Contact to Auxiliary Contact	600 V	2400 V	—	600 V	2400 V

MAINTENANCE INSTRUCTION

AUXILIARY RELAYS8246278, 8249610, 8263337, 8267873. 8269705. 8292627 AND 8297116

DESCRIPTION

The relays covered in this publication are all of similar construction. An example is shown in Fig. 1. They consist of a magnet frame and solid core riveted to two end plates which serve as a support for the contact assembly and as a mounting bracket for the relay. A' cylindrical armature is guided between two graphite-bakelite collars to reduce friction to a minimum and to insure that the relay will not stick open or closed.

An armature lever is riveted to the solid armature which projects through slots in the end plates, where two return springs insure o p e r a t i o n of the relay when the magnet coil is de-energized. Pins in the ends of the a r m a t u r e lever are guided through holes in an angle bracket on each end plate.

Each pole of the relay consists of a precision snap switch, Fig. 2, having one normally closed and one normally open circuit. Contacts are double break, silver to silver. Stationary contacts have a radius face, while the movable contacts have a flat face.

From two to six single-pole double-throw switch assemblies are mounted on top of the relay. Early models of the relay switch assemblies have screw type terminals suitable for wire as large as No. 14 solid. Later models are equipped with No. 250 series fast on tabs. The two, four, and six pole relays are similar except for the number of s w i t c h assemblies employed and electrical characteristics of the magnet coil. The two pole relay uses two switch assemblies, the four pole relay uses four, and the six pole relay uses six. Relay coils are rated for working voltages of 74 V DC, 115 V DC, and 115 V AC.

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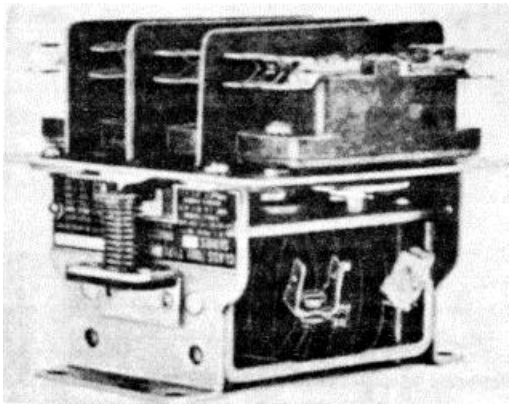


Fig. 1 - Auxiliary Relay, Four Pole Type

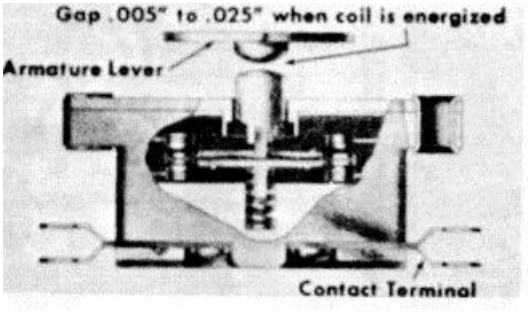


Fig. 2 - Switch Assembly Cutaway View

Refer to the maintenance data table to relate the electrical characteristics of the coil to the relay part number and to relate switch assemblies to relay part numbers.

MAINTENANCE

The relays should be inspected at intervals specified in the applicable Scheduled Maintenance Program Maintenance Instruction for the following:

1. Missing parts.
2. Security of mounting of all parts.
3. Free movement of parts.

4. A d e q u a t e clearance of all electrical parts.
5. Damaged coil insulation and terminals.
6. Damaged switch assemblies.
7. Electrical continuity of coil and switch assemblies.

AIR GAP

The dimension of the armature air gap shown in Fig. 2 is inherent in the relay design and cannot be adjusted. If the gap is incorrect, the component parts that affect the gap must be replaced with new parts.

SWITCH ASSEMBLY CONTACTS

The contacts do not corrode and never require cleaning. If it is determined that a set of contacts is bad, the defective contact assembly should be replaced with a new assembly.

MAGNET COILS

Refer to the maintenance data table in this instruction when checking the coil. If coil is defective, replacement with a new coil is a simple matter of removing four screws holding the contacts assembly and four screws holding the coil retaining plate.

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MAINTENANCE DATA

Relay Part No.	Coil Resistance at 20° C.	Pickup at 20° C.	Dropout at 20° C.	Working Voltages	Contacts
8246278	550 Ohms + 10	48 V DC Max.	5-28 V DC	74 V DC	4 N.O. - 4 N.C.
8249610	550 Ohms + 10	48 V DC Max.	5-28 V DC	74 V DC	6 N.O. - 6 N.C.
8263337	1370 Ohms + 10	98 V DC Max.	12 V DC Min.	115 V DC	4 N.O. - 4 N.C.
8267873	40 Ohms + 10 (DC Equivalent) Resistance)	90 V AC Max.	12 V AC Min.	115 V AC (60 Cycle)	4 N.O. - 4 N.C.
8269705	1370 Ohms + 10	90 V DC Max.	12 V DC Min.	115 V DC	6 N.O. - 6 N.C.
8292627	550 Ohms + 10	48 V DC Max.	5-28 V DC	74 V DC	2 N.O. - 2 N.C.
8297116	62 Ohms + 10 (DC Equivalent Resistance)	90 V AC Max.	12 V AC Min	115 V AC (50 Cycle)	4 N.O. - 4 N.C.

HIGH POTENTIAL TEST

Relays 8246278, 8249610, 8292627

Coil to Ground	600 V RMS - 60 Cycle - 1 Minute
Coil to Contacts	2400 V RMS - 60 Cycle - 1 Minute
Contacts to Ground	2400 V RMS - 60 Cycle - 1 Minute
Contacts to Contacts	2400 V RMS - 60 Cycle - 1 Minute

Relays 8263337, 8267873, 8269705, 8297116

Coil to Ground	1500 V RMS - 60 Cycle - 1 Minute
Coil to Contacts	1500 V RMS - 60 Cycle - 1 Minute
Contacts to Ground	1500 V RMS - 60 Cycle - 1 Minute
Contacts to Contacts	1500 V RMS - 60 Cycle - 1 Minute

MAINTENANCE INSTRUCTION

WIRE IDENTIFICATION OF POWER GENERATING UNIT WIRING SYSTEMS

GENERAL

A wide variety of wiring identification systems is used in industry today to diagram the electrical operation of equipment. The physical and schematic wiring diagrams prepared and issued by ElectroMotive may be somewhat unique to new user's of our products. In that regard, this Maintenance Instruction has been issued to set forth the fundamental wire identification systems used.

Circuit tracing and trouble shooting can be accomplished in a minimum of time when the basic system of wire identification used is understood. The system must make each portion of the circuit easily identifiable and set it apart from other portions of the same circuit.. The components of each circuit portion must also be set up to convey their position in the circuit. In this connection, some orderly system of wire identification must be followed.

It has been determined that the use of the alphabet is best for primary identification purposes. Numerical digits serve best in identifying the branch feeds off the primary feed line. A combination of the two results in an easily readable clue as to the electrical location of any particular wire.

The system as outlined herein is set up so that for the most part only two letters and one numeral are needed to identify any one wire. However, where additional identification is required, three letters and one numeral may be used. This will be determined by the circuitry involved and probably will be encountered
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from time to time. Basically however, the system utilizes a three character identification scheme which is suitable for practically all types of industrial equipment wiring diagrams.

Representative Symbols

A - AC voltage for control, battery charging, light circuit.
B - Battery charging circuit (DC side).
C - Current for metering, relaying, voltage regulator circuits.
D - DC voltage for control circuits.
E - Exciter circuit.
G - -Generator power leads to the power circuit breaker.
L - Line power leads from the power take-off point to power circuit breaker.
LN - Neutral or negative power lead.
V - Voltage for metering, relaying, voltage regulator circuits.
YS.- Synchronizer circuits.

Control Circuit Wire Identification

A DC voltage supply is a typical example, see Figs. 1 and 2. An AC voltage supply would follow the same pattern except the first letter would be "A" instead of "D."

D - Symbol used to indicate a battery source of power.

DP - Symbol used to designate the lead off the battery switch positive terminal.

DN - Symbol used to designate lead off battery switch negative terminal.

The DP lead is directly off the battery switch positive terminal and is generally unfused. The fused branch leads

off DP will follow as DA, DB, DC, etc., according to the following schedule.

DA, DJ, DB - Alarm signal and silencing circuits.

DB -. Circuit breaker control (other than trip).

DC, DD - Annuciator circuits.

DE - Engine temperature indicating circuits.

DF - Fan control circuits.

DG, DH - Governor control circuits.

DK, DL - Spares

DM - DC lighting circuits.

DQ - Control sequence circuits.

DR - Reclosure circuits.

DS - Starting circuits.

DT - Breaker trip circuits.

DU - Stopping circuit

DV - Spares

DW, DX - Cabinet temperature relay circuits

DY - Spares

DZ

When a fused branch lead off DP feeds more than one of the above circuits, the major circuit will determine the designation. Branch leads of DA will be labeled DA1, DA2, etc. The DA line, after passing through an interlock, fuse, switch, etc., will assume a new label such as DAA, DAB, etc., as in Fig. 1. Branch leads off these will be labeled DAA1, DAA2, etc., as shown in Fig. 2. All negative feed lines will be labeled DN, distinguished from each other by a number (DN1, DN2, etc.). DN wires never pass through an interlock or coil, and therefore are all common.

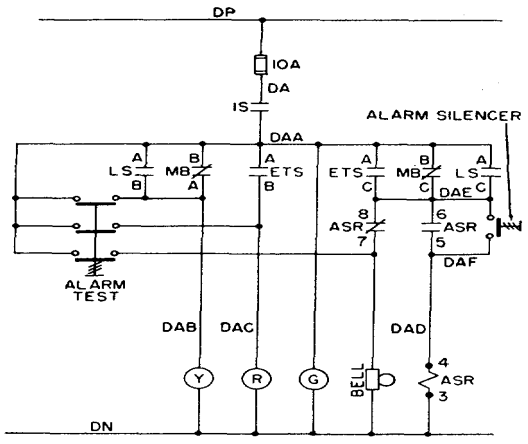


Fig. 1 - Schematic Voltage Supply

Battery Charging Circuit Wire Identification

The direct current side of the battery charging circuit may be connected directly to the battery terminals and therefore will be designated with the symbol B.

BP - Symbol used to designate the lead to the positive terminal of the battery.

BN - Symbol used to designate the lead to the negative terminal of the battery.

The BP lead corresponds in position to the DP lead in the control circuit, Fig. 1, and connects the battery charger positive output terminal to the battery positive terminal. The branch feeds off BP will be BP1, BP2, BP3, etc. The BP lead, after passing through an interlock, switch or coil, will assume an additional letter, BPA, BPB, BPC, etc. The BN lead corresponds to the DN lead in the DC control circuit and is a common feed, never passing through an interlock or coil. All BN leads will therefore be distinguished by a number only, BN,/BN1, BN2, BN3, etc.

Voltage Circuit (Metering, Protective Relaying and Voltage Regulator) Wire Identification

In some applications, voltage is used to actuate meters, relays and regulators. A three phase AC' voltage supply is a prime example of this. A DC

voltage supply would follow the same pattern except that VP and VN would be used instead of VA, VB and VC which are used with 3 phase AC power systems.

V - Symbol used to indicate voltage leads as opposed to current leads.

VA - Symbol used to designate the AC voltage lead off the A phase power bus, either directly or through a potential transformer for metering and protective relaying.

VB - Symbol used to designate the AC voltage lead off the B phase power bus.

VC - Symbol used to designate AC voltage lead off the C phase power bus.

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The VA, VB and VC leads shown in Figs. 3 and 4 correspond in position to the DP lead in the control circuit. Each is a primary feed, off which branch feeds are taken. These branch feeds will be labeled VA1, VA2, VB1, VB2, VC1, VC2, etc. Upon passing through a coil or interlock the voltage lead assumes an additional letter such as VAA, VBA, VCA, etc., with the first two letters always remaining the same to preserve the identity of the voltage source.

The voltage supply for the voltage regulator, wherever possible will carry the symbol VR; however, where more than one phase of the voltage source is

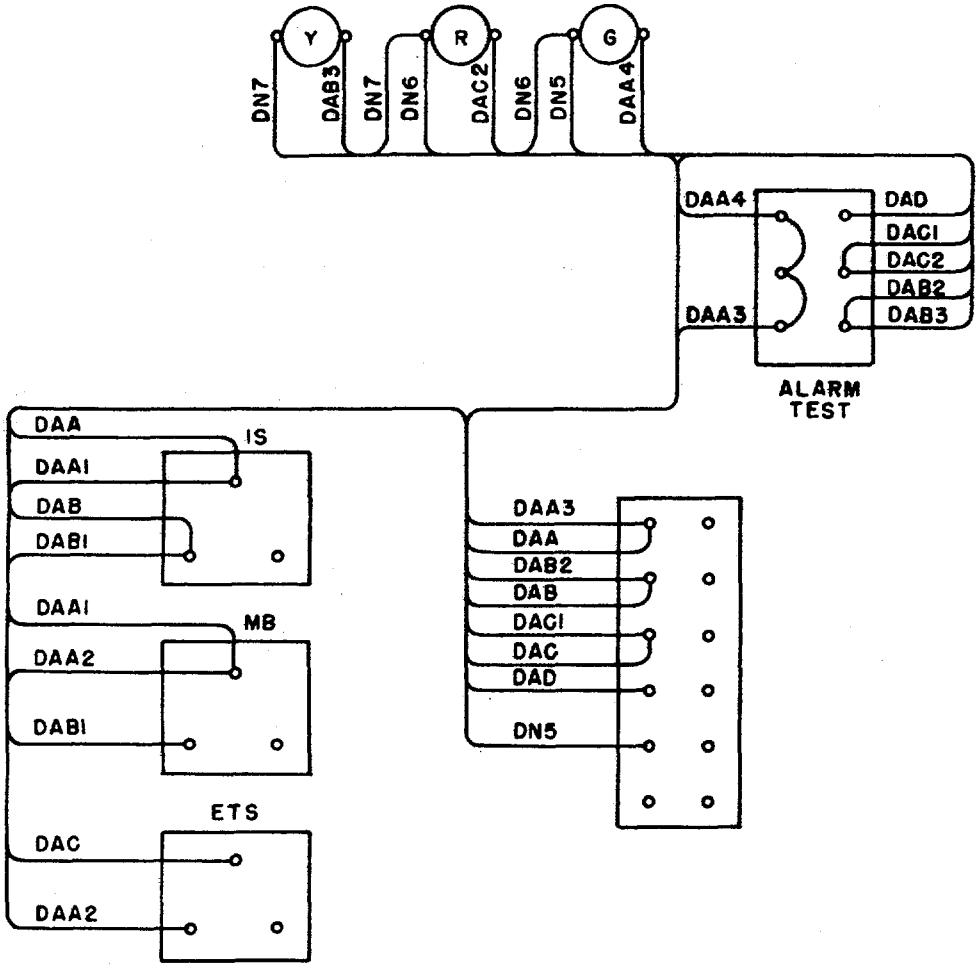


Fig. 2 - Physical Voltage Supply

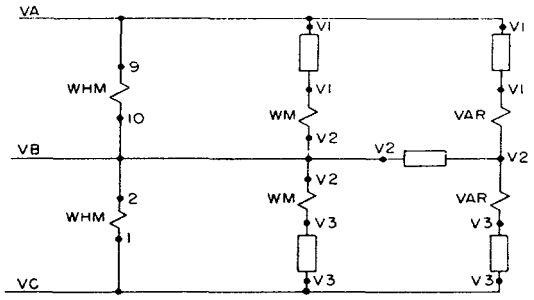


Fig. 3 - Schematic AC Voltage Circuit

used, then the basic VA, VB or VC symbol will have to be used in order to differentiate between phases.

Current Circuit (Metering, Protective Relaying and Voltage Regulator) Wire Identification

In many installations current is used to actuate meters, relays and regulators. A three phase alternating current supply is used as an example, Figs. 5 and 6. A direct current supply (DC power out from the main generator) would follow the same pattern except that CP and CN would be used instead of CA, CB and CC, which are used with 3 phase AC power systems

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C - Symbol used to indicate current leads as opposed to voltage leads.

CA - Symbol used to designate the alternator current lead off the A phase power bus, either directly or through a current transformer, for metering and protective relaying.

CB - Symbol used to designate the alternator current lead off the B phase power bus.

CC - Symbol used to designate the alternator current lead off the C phase power bus.

The CA, CB and CC leads correspond in position to the DP lead in the control circuit. Each is a primary feed, off which branch feeds (normally there are none) are taken. These branch feeds would be labeled CA1, CA2, CB1, CB2, CC1, CC2, etc. Upon passing through a coil, the current lead assumes an additional letter such as CAA, CBA, CCA, etc., with the first two letters always remaining the same to preserve the identity of the current source.

The current supply for the voltage regulator will be designated with the base symbol CR, with additional letters being added as required.

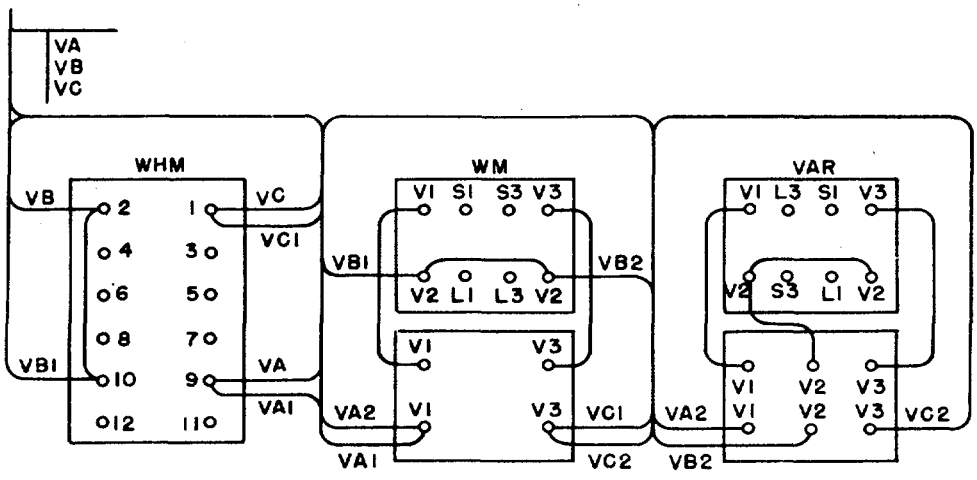


Fig. 4 - Physical AC Voltage Circuit

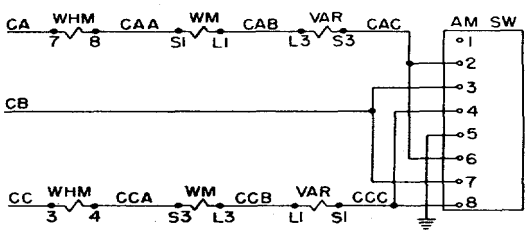


Fig. 5 - Schematic AC Current Circuit

Excitation Circuit Wire Identification

The entire exciter circuit will be designated by the letter E. The different parts of the circuit will be identified by the second letter following the E.

E - Symbol used to indicate the exciter circuit used in conjunction with the main generator.

EP - Symbol used to designate the positive feed to the main generator field.

EN - Symbol used to designate the negative feed to the generator field.

EF - Symbol used to designate the field control portion of the exciter.

The EP lead is directly off the positive side of the exciter armature. The EN lead is connected to the negative side of the exciter armature. The EF portion of the circuit includes the shunt field, field limiting resistor, exciter field rheostat and the feed from the voltage regulator switch. Branch feed lines from EP, EN or EF will carry the two base letters plus one identifying number, EPI, EN1, EF1, etc. After passing through a switch or coil, an additional letter will be added to the two base letters, EPA, ENA, EFA, etc.

Power Circuit Wire Identification

The power circuit can be divided into two parts, the generator side of the power circuit breaker and the line or bus side of the circuit breaker. The generator side of the circuit breaker will be designated by the symbol G. The line side of the circuit breaker will use the symbol L. If the power generated is DC, then the identifying symbols become GP, GN and LP, LN. If the power generated is three phase AC, then the symbols become G1, G2, G3, and L1, L2, L3. The neutral power lead, when used, does not pass through the power circuit breaker and assumes the symbol LN all the way from the generator out to the power take-off point. Branch feeds to the potential transformers or other items will carry a number such as Gl1, G21, G31, GP1, GN1, etc. The same holds true for the line (L) side of the circuit breaker. The only break in the

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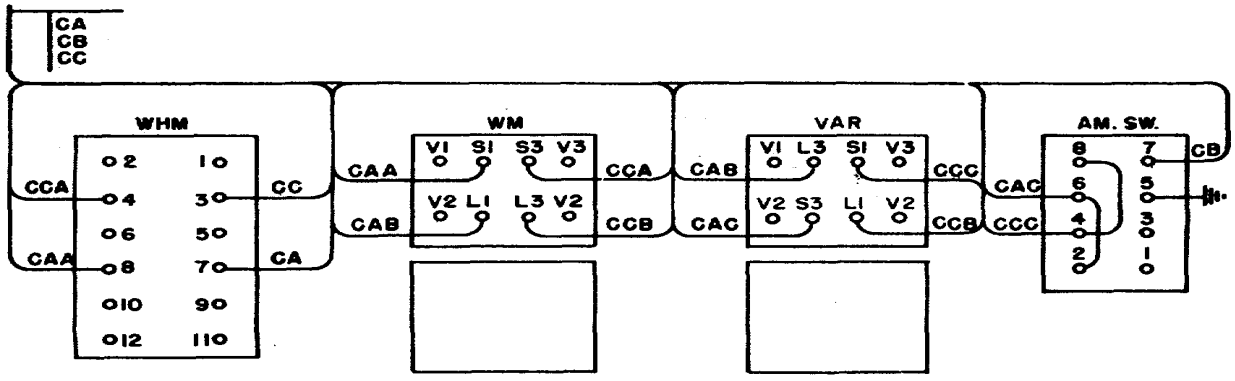


Fig. 6 - Physical AC Current Circuit

power lines will occur at the power circuit breaker and the lead designation will change at this point as outlined above.

If the occasion arises where both AC power leads and DC power leads appear on the same drawings, then the designations of the AC Neutral lead and the DC Negative lead will have to differ in order to avoid confusion. There is also a possibility that the DC system may be a three wire system. Should the above conditions arise, the following designations will be used:

Neu. - AC Neutral lead
LN - DC Negative lead
COM - DC Plus - Minus (+) lead for a three wire DC system.

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APPLICATION OF SOLDERLESS TERMINAL LUGS AND CONNECTORS TO WIRE AND CABLE

DESCRIPTION

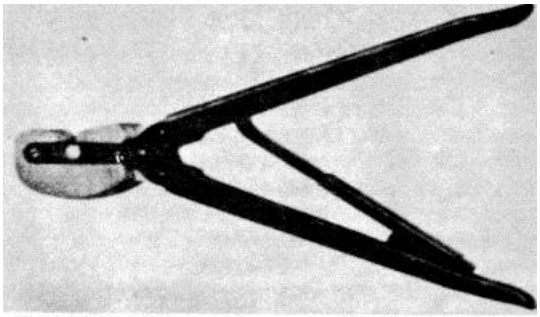
This maintenance instruction provides information on the proper methods and tools required for application of pressure type terminal lugs and connectors. Good, tight electrical bonding between a conductor and lug or connector must be obtained to assure trouble-free service from electrical wiring. The pressure type solderless method provides an effective electrical connection by tightly compressing the components of the connection together. Using this method eliminates the difficulties involved in making good solder type connections.

Shown in Fig. 1 are representative crimping tools, either hand operated or power operated, which maybe used in conjunction with the application of the crimp type connectors. Additional tools available for use with these connectors are listed in the Service Tools Catalog 91B.

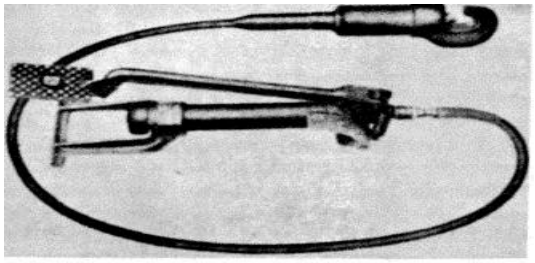
A handy connector kit 8204704, Fig. 2, is also available which includes a general assortment of small lugs and connectors used on equipment, including crimping tools necessary for their application. A lug and connector kit 8211824 may also be obtained which is similar to that shown in Fig. 2, which does not include the crimping tools.

MAINTENANCE

Several tables are provi4elifollowing the procedure for the application of the connectors. Table I is divided into three sections consisting of Section 1, Terminal
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Hand Operated Crimper



Power Operated Crimper

Fig. 1 Representative Type Crimping Tools

Lugs and Receptacles; Section 2, Crimp Type Connectors; and Section 3, Special Hexagonal and Miscellaneous Crimp Type Terminals. Table I lists the tool to be used on the application depending upon the cable size. Table III lists particulars on the different cables used. Reference is made in the tables to AMP (Aircraft Marine Products) and Burndy (Burndy Engineering Co.) both of which are manufacturers of solderless type connectors.

A. **Application Procedure**

The following procedure should be used in the application of lugs and connectors.

1. Select the proper size lug to fit the stud hole size and cable, or connector and cable from Table I and Table MI.

2. Bare the amount of cable for-application as shown in Table II. Insert the conductor into the lug or connector.

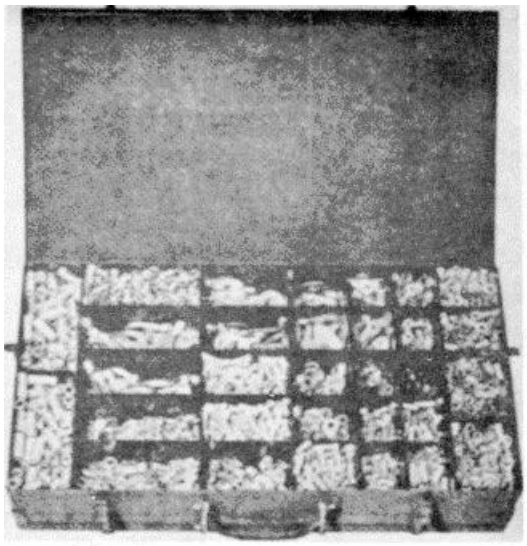
3. Apply the cable and lug, or cable and connector to the hand or power tool, making sure it is bottomed against the shoulder or terminal stop.

   The hand tools shown in Table I have adjustable jaws for the insulation crimp. Adjustment is made by moving a pair of pins to 3 different pairs of locating holes numbered 1 to 3. Pin locations to be used for various outside diameter insulated wire are as follows:

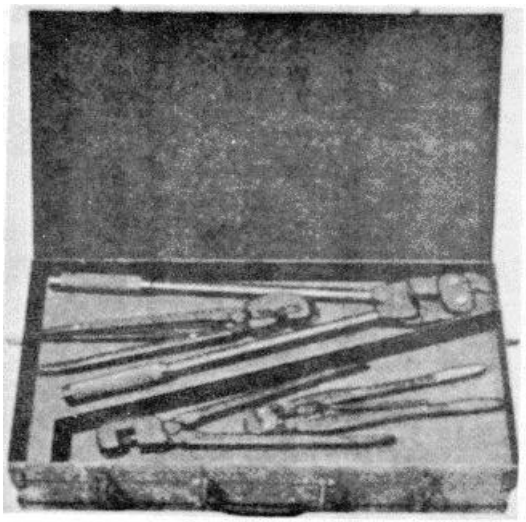
	Pin Location		
Tool No	1	2	3
8200888 . Insulation, Dia. . (Inches)	115"to 130"	.130"to .150"	.150"to .170"
8159849	.135" to .175"	.175"to .210"	.210"to .250"

4. Operate the crimping tool to completely close the die sections. On ratchet type hand tools it is impossible to open the jaws to release until the complete limit of compression has been reached.

5. Inspect the finished crimp for proper indentations corresponding to "Dimension A" and reference number given in the tables and illustrated in Fig. 3, by corresponding reference numbers identifying the different types of crimps. On all cables requiring the special hexagonal type crimp connectors, Items 6 and 9 of Fig. 3, it is permissible to remove and/or nick a total of not more than 1% of total number of strands.



Lug And Connector Kit Portion



Tool Kit Portion

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Fig. 2 - Lug, Connector And Crimper Set

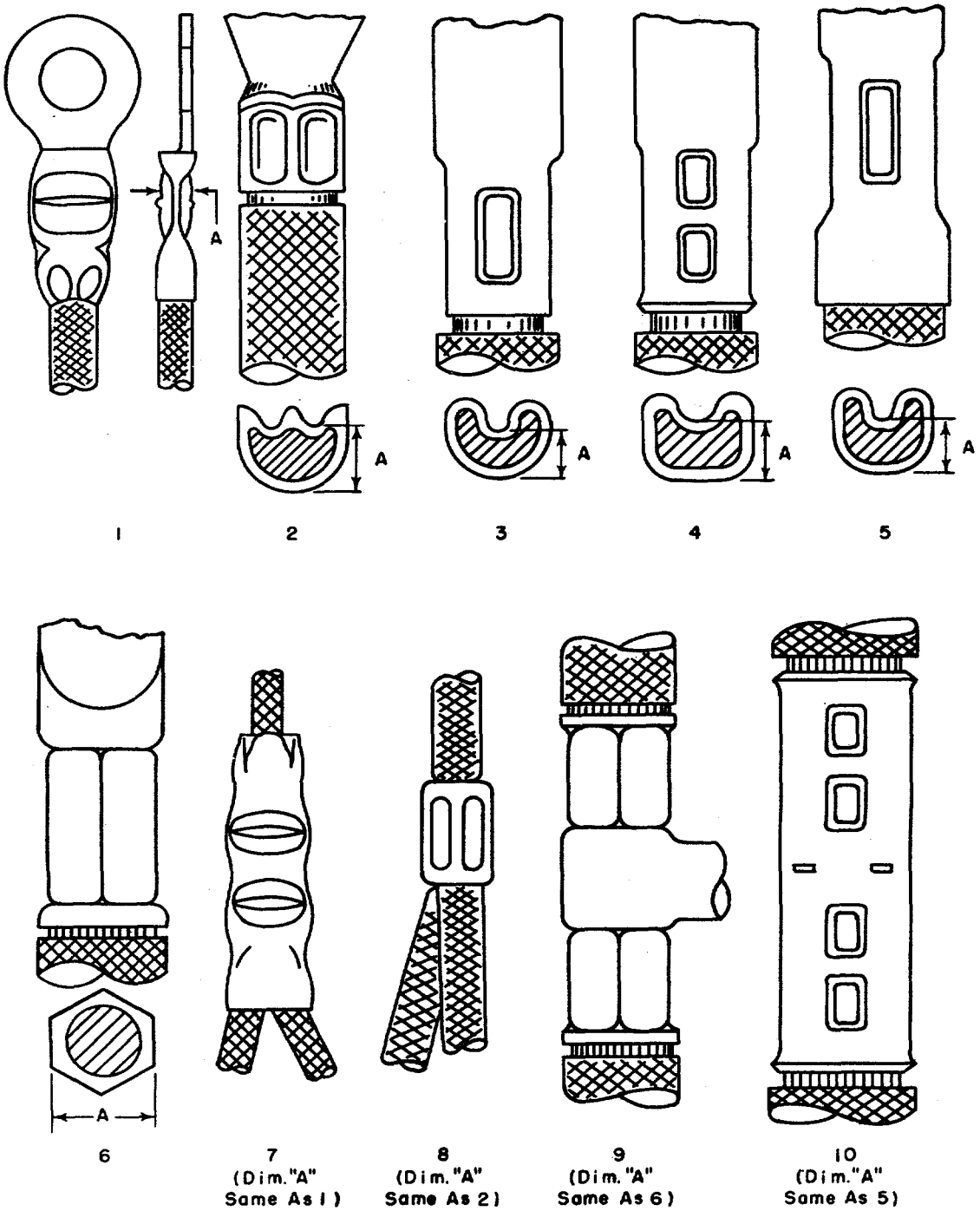


Fig. 3 - Crimp Types And Dimension "A" Referred To In Reference Tables

TABLE I
SECTION 1

TERMINAL LUGS AND RECEPTACLES

PRE-INSULATED CRIMP TYPE TERMINAL LUGS (A.M.P.)

* Cable Size and Insulation Type	Cir. Mils Min.	Cir. Mils Max.	Apply with EMD Tool No.	Stud Hole Size #5 or 6	#10	1/4	5/16	3/8	1/2	3/4	Receptacle
#14-16 Plastic, #14 Glass #14 RH & N (Thin)	2050	4500	8200888	8189218	8210498	8198189	8210499	8210500	Double Back #16 Wire - Use Tool 8159849 8137872	8167600	8250906
19/25 Plastic, 19/25-19/27 Asb. or RH & N, 19/25 AVB or AVA	3800	6150	8159849	8252768	8123281	8123282	8123283	8123284	8137872	8167600	
NON-INSULATED CRIMP TYPE TERMINAL LUGS (A.M.P.)											
#10 Glass 19/23 AVB or AVA, 7/.0486, 37/24 - #8 SW	9680	16840	8159240		8130627	8126872	8126873	8126874	8140346	8137873	
91/24 113/.0144, 6, 4, 4 SW, 125/24	26200	50000	8166676		8130628	8130629	8130630	8130631	8155747	8137874	
NON-INSULATED CRIMP TYPE TERMINAL LUGS (BURNDY)											
91/24 133/.0144, #6	26200	36400	8159244			8131362	8131363	8131364	8131365		
125/24, #4	36400	50000	8159244			8131366	8131367	8131368	8131369		
#1	83000	86000	8159244			8168149		8168150			

* Also for Individual Cables in Multiple Conductor Cables

TABLE I - SECTION 1 (Cont'd)

NON-INSULATED CRIMP TYPE TERMINAL LUGS (BURNDY) (Cont'd)

Cable Size and Insulation Type	Cir. Mils Min.	Cir. Mils Max.	Apply with EMD Tool No.	Stud Hole Size: Blank	#10	1/4	5/16	3/8	1/2	5/8	3/4
225/24 (1/0)	86400	90900	See Table II Burndy Crimping Tools			8228542	8228543	8228541	8228544	8228545	
19/.0745 (1/0)	100300	105500		8229260							
2695/34 (1/0)	100000	105000				8228542	8228543	8228541	8228544	8228545	
325/24	130000	134000				8131370	8131371	8131372	8131373	8131374	8147251
19/.0837 (2/0)	126600	133100						8131372			
4258/34 (3/0)	160000	168000		8211044	(Special Lead Plated 1-3/8" Hole, 1-3/8" × 3/4" Slot)						
19/.094 (3/0)	160000	168000		8229034							
550/24	210000	220000		8118060							
2107/30 (4/0)	210000	220000		8197509	(Special Lead Plated 1-3/8" Hole, 1-3/8" × 3/4" Slot)						
775/24	310000	320000		8118061							
1100/24	430000	450000		8118062							
1325/24	530000	535000		8160274							
1600/24	640000	650000		8137333							
1925/24	740000	778000		8215528							

TABLE 1
SECTION 2

CRIMP TYPE CONNECTORS

Part No.	Type	Fig. 3 Crimp Type	Crimping Tool	Used With	Remarks
8200891	Pre-Insul. Butt	#7	8200888	2 of #14, 2 of #16	Glass or plastic insulation only
8210612	Pre-Insul. 3-Way Parallel	#7	8159849	3 of #16, 4 of #16, Plastic	Crimp both ends
8126723	Pre-Insul. Butt	#7	8159849	19/27, 19/25 RH&N or 19/25 Plastic #16. Dbld. Back	
8152241	Pre-Insul. 3-Way Butt	#7	8159849	19/27 or 19/25 - RH&N and 2 of #14 or #16 Plastic, 3 of #14 Plastic	
*8158242	Non-Insul. Parallel	#8	8159240	4 or 5 19/27, 3-19/25 RH&N or Plastic, 37/24 & 19/27	*Additional Usages: 2-19/23, 19/23 & 19/25, 19/23 & 19/27
8200890	Non-Insul. Butt	#8	8159240	37/24, 133/29, 8SW to 8SW	19/23 & 2-19/27, #8SW & 19/27, 3-19/27
8200889	Non-Insul. Butt	#8	8166676	91/24, 133/.0141, 4SW, 125/24	& 19/25, 2-19/27 & 19/25, #8SW & 19/27
8196734	Same	#10	Use Table II Burndy Tools for Lugs	325/24	
8196733	Same	#10		550/24	
8196732	Same	#10		775/24	
8188707	Same	#10		1100/24	
8188705	Same	#10		1325/24	
8188706	Same	#10		1600/24	
8208194	Non-Insul. Parallel	Spec.	8208195	133/.0141, #4 or #6	Generator Shunt Field Conn. Only

TABLE I
SECTION 3

SPECIAL NON-INSULATED HEXAGONAL CRIMP TYPE TERMINAL LUGS FOR TRACTION MOTORS, OIL RIG MOTOR AND GENERATORS

Size	Part No	Fig. 3 Crimp Type	Crimping Tool	Fig. 3 Dim. "A"	Usage
1100/24	8133497	#6	Special Hex	.990/1.005	D27, D37, D39, D47, D49 Motor Conn.
1100/24	8141061	#6	Special Hex	.990/1.005	D27, D37, D39, D47, D49 Motor Conn.- 15° Angle
775/24	8133494	#6	Special Hex	.750/.765	D27, D37, D39, D47, D49 Br. Holder Conn.- 1/2" Bolt Head
775/24	8133495	#6	Special Hex	.750/.765	D27, D37, D39, D47, D49 Br. Holder Conn.- 1/2" Bolt Head
1100/24 to 775/24	8133492	#9	Special Hex	.990/1.005 to .750/.765	D27, D37, D39, D47, D49 Br. Holder Conn. - 1/2" Bolt Head
775/24 to 259/.0286	8178703	#9	Special Hex	.719/.734 to .577/.592	D19 Br. Holder Conn.- 1/2" Bolt Head
259/.0286	8178689	#6	Special Hex	.577/.592	D19 Br. Holder Conn.- 1/2" Bolt Head
259/.0286	8178701	#6	Special Hex	.577/.592	D19 Br. Holder Conn.- 1/2" Bolt Head
259/.0286	8178702	#9	Special Hex	.577/.592	D19 Br. Holder Conn.- 1/2" Bolt Head
259/.0286	8178691	#6	Special Hex	.577/.592	D19 Motor Conn. & D29 Motor Conn.
775/24	8178690	#6	Special Hex	.719/.734	D19 Motor Conn.
775/24	8178690	#6	Special Hex	.741 ± .007	D29 Motor Conn.
775/24 to 259/.0286	8246538	#9	Special Hex	.758 ± .007 to .647 ± .007	D29 Br. Holder 3 Way Connector
259/.0286	8246537	#6	Special Hex	.647 ± .007	D29 Br. Holder Conn.- 1/2" Bolt Head
259/.0286	8246539	#6	Special Hex	.647 ± .007	D29 Br. Holder Conn. - 1/2" Bolt Head
259/.0286	8246540	#6	Special Hex	.647 ± .007	D29 Br. Holder Conn. - 1/2" Bolt Head

TABLE I
SECTION 3 (Cont'd)

SPECIAL MISCELLANEOUS CRIMP TYPE TERMINALS

Size	Part No	Fig. 3 Crimp Type	Crimping Tool	Usage
19/27, 19/25	8082278	Similar to #1	8196862 or Amp Head #302510	Special terminal used in Train Line And Power Plant Receptacles
133/.0177	8081935	#3	Special - Allison Div. #XMD-161	Solder lug applied with Allison crimper used on alternator stator leads
19/27, 19/25	8195542	Similar #1	8196862	Special terminal used in EMD Train Line And Power Plant Jumpers
259/.0227 with .015 Copper Mesh	8216718 8216719	#3	See Table II	Lugs and cable used for connecting jumper to D15 generator brush holder and collector ring
259/.0286 with .015 Copper Mesh	8201418 8215623 8217438	#3	Special Applications	Lugs and cable used for connecting jumper to D12 generator brush holder and collector ring
1666/44 Bare	8233365			Lugs and cable used for fabricating equalizing shunt for generator brush holders

TABLE II

EMD TOOL CHART - A.M.P. TOOLS FOR LUGS

Cable Size	Insulation Stripped +1/32 -0	Fig. 3 Crimp Type	Lbs. Pull Min.	Fig. 3 Dim. "A"	Hand Crimpers		Remarks
					Insulated	Non-Insulated	
#16	3/16	#1	55	.108-.114	8200888		Plug gauge dimension of closed dies on tool or height of crimp impressed on solder only.
#14 Plastic, Glass, RH & N (Thin)	3/16	#1	70	.108-.114	8200888		
19/27 RH & N	5/16	#1	70	.139-.145	8159845		
19/25	5/16	#1	135	.139-.145	8159849		
19/23, #10 37/24, 7/.048 #8 SW	5/16	#2		.100-.115		8159240	
91/24, #6 133/.0141 #4 SW, 125/24	1/2	#2		.155-.170		8166676	

SPECIAL TOOLS AND SPECIAL APPLICATIONS

Cable Size	Insulation Bared	Fig. 3 Crimp Type	Fig. 3 Dim. "A"	Crimping Tools		
				Hand Tool	Type	
325/24 to 1325/24	According to Cable Size	---	---	8197443	F. M. Anthony Co. Handtool - For use in tight quarters.	
19/27, 19/25	5/16 +1/32 -0	Similar to #1	---	8196862	A.M.P. Handtool - For use on power plant jumper and receptacle - renewable contact.	
133/.0177	9/16	#3	.207	---	Allison Div. of GMC - Tool No. XMD-161 - For use on alternator stator leads.	
133/.0141 #4 or #6	7/8	Spec.	---	8208195	Burndy Handtool, MD2-1. For use on Generator Shunt Field Conn. Only Crimp with Opening 6-C.	
				Hydraulic Tool		
				Hypress	Nest	Indentor
259/.0227 with .015 Copper Mesh	None	#3	.334-.392	8159245	8228347	8159252
259/.0286 with .015 Copper Mesh	None	#3	.408-.473	8159245	8159251	8159252
1666/24 - Bar #10	None			Automatic Machine		

TABLE II

EMD TOOL CHART - BURNDY TOOLS FOR LUGS LISTED IN TABLE I

Cable Size	Insulation Bared	Fig. 3 Crimp Type	Fig. 3 Dim. "A"	Hydraulic Tools			
				Hand Tool	Hypress	Nest	Indentor
91/24 133/.0144, #6	1/2	#3	.140-.197	8159244			
125/24, #4	1/2	#3	.140-.197	8159244			
#1	7/8	#3	.140-.197	8159244			
225/24 (1/0)	11/16	#3	.204-.257	8159244	8159245	8227321	8159252
19/.0745 (1/0)	1-3/8	#3	.274-.320	8159244	8159245	8228346	8159250
2695/34 (1/0)	11/16	#3	.205-.252	8159244	8159245	8227321	8159252
325/24	7/8	#3	.251-.304	8159244	8159245	8159249	8159252
19/.0837 (2/0)	7/8	#3	.308-.361		8159245	8159249	8159250
4256/34 (3/0)	1	#3	.300-.370		8159245 Die Set 8227077		*See Note
19/.094 (3/0)	1-1/2	#3	.340-.393		8159245	8229101	8159250
550/24	2	#4	.408-.473		8159245	8159251	8159252
2107/30 (4/0)	1-5/16	#3	.350-.420		8159245 Die Set 8227078		*See Note
775/24	2-1/8	#4	.510-.548		8159245	8159253	8159252
1100/24	2-1/4	#4	.568-.625		8159245	None	8159252
1325/24	2-1/4	#4	.608-.657		8159254	8167953	8167952
1600/24	2-3/8	#4	.629-.714		8159254	8159255	8167952
1925/24	3	#4	.762-.821		8159254	8227079	8167952

*Substitute head 8227076 for the regular head on tool 8159245 to hold the die sets.

TABLE III

CABLE CHART

EMD Part No.	Total Strands	Strand Dia. AWG	Nearest Equivalent Size AWG	CM Area	Bare O.D. Nom.	Max. Insul. O.D.	Type of Insulation	Voltage	Wt.-Lbs. 1000 Ft.
8210517	19 × 29	.0112	#16	2583	.060	.125	Plastic	600	12.5
8210518	19 × .0147	.0147	#14	4107	.073	.140	Plastic	600	18
8236533	19 × .0147	.0147	#14	4110	.073	.150	RH & N (thin)	600	
8114400	19 × 27	.0142	#14	3820	.071	.173	Asbestos	600	22.3
8079257	19 × 27	.0142	#14	3820	.070	.220	RH	600	33
8077347	19	.0147	#14	4110	.074	.136	Glass	600	
8121798	19	.0147	#14	4110	.073	.192	RH & N	600	30.5
8087122	41 × 30	.010	#14	4110	.078	.240	SCRC	600	32
8005169*	19 × 25	.0179	#12	6088	.090	.225	AVA	750	39
8005170*									
8005171*									
8005172*	* These coded cables have the same physical properties as 8005169.								
8005173*									
8005174*									
8005175*									
8023241	19 × 25	.0179	#12	6088	.090	.245	AVA	750	39
8126525	19 × 25	.0179	#12	6088	.092	.200	Asbestos	600	31.3
8126650	19 × 25	.0179	#12	6088	.090	.240	RH & N	600	48
8238757	19 × 25	.0179	#12	6150	.090	.175	RH & N (thin)	600	
8210516	19 × 25	.0179	#12	6150	.090	.160	Plastic	600	26
8176924	19 × 25	.0179	#12	6088	.090	.247	RH & N	600	40
8005004	19 × 23	.0226	#10	9680	.113	.275	AVB	1000	
8077348	37	.0167	#10	10380	.117	.181	Glass	600	
8005168	37 × 24	.0201	#8	14900	.141	.285	AVA	750	74
8023242	37 × 24	.0201	#8	14900	.141	.300	AVA	750	74
8126651	37 × 24	.0201	#8	14900	.141	.305	RH & N	600	83
8216869	37 × 24	.0201	#8	14800	.141	.232	Plastic	600	62
8004595	Solid		#8	16500	.128	.281	AVB (#8SW)	600	84
8218266	7	.0486	#8	16500	.146	.62 (nom.)	OPR & N	5000	269
8135632	133 × 29	.0112	#8	16800	.168	.370	AVA	600	104
8075685	133	.0141	#6	26200	.212	.415	AVA	600	104
8023243	91 × 24	.0201	#5	36700	.221	.415	AVA	750	155
8126652	91 × 24	.0201	#5	36700	.221	.430	RH & N	600	176
8004596	Solid		#4	41740	.204	.412	AVB (#4SW)	600	210
8082673	133 × 25	.0177	#4	41700	.266	.485	AVA	600	210

TABLE III (Cont'd)

CABLE CHART (Cont'd)

EMD Part No.	Total Strands	Strand Dia. AWG	Nearest Equivalent Size AWG	CM Area	Bare O. D. Nom.	Max. Insul. O.D.	Type of Insulation	Voltage	Wt.-Lbs. 1000 Ft.
8023244	125 × 24	.0201	#3	50500	.286	.490	AVA	750	223
8126653	125 × 24	.0201	#3	50500	.286	.498	RH & N	600	240
8166785	2156	.0063	#1	83690	.375	---	Bare	---	260
8023245	225 × 24	.0201	#0	90900	.390	.690	AVA	750	375
8228504	225 × 24	.0201	#0	90800	.415	.640	RH & N	600	400
X55-523	2695/34	.0063	#0	105500	.428	.850	RH & N	600	
8227230	19	.0745	#0	105500	.373	.91 (nom.)	OPR & N	5000	736
8023246	325 × 24	.0201	#00	130000	.462	.705	AVA	750	513
8126654	325 × 24	.0201	#00	130000	.462	.725	RH & N	600	557
8075653	259	.0227	#00	133100	.477	.750	AVA	600	593
8217302	19	.0837	#00	133100	.419	.660(nom.)	Rubber	600	630
8212752	19	.094	#000	167900	.470	1.00(nom.)	OPR & N	5000	974
8214582	4256 × 34	.0063	#000	168000	.576	.795	Neoprene	300	610
8085150	2107 × 30	.0100	#0000	212700	.627	.845	Neoprene	300	760
8075538	259	.0286	#0000	212000	.600	.850	AVC	600	875
8023248	550 × 24	.0201	#0000	220000	.623	.865	AVA	750	813
8126655	550 × 24	.0201	#0000	220000	.623	.883	RH & N	600	876
8075530	427	.0265		300000	.716	1.010	AVC	600	1233
8047997	775 × 24	.0201		313100	.732	1.05	AVA	750	1168
8077160	775 × 24	.0201		313100	.744	1.093	Rubber	600	1372
8206581	775 × 24	.0201		313100	.726	1.09	RH & N	600	1290
8221565	775 × 24	.0201		313100	.744	1.200	RH & N with Cotton Braid	600	1290
8057457	1100 × 24	.0201		444000	.894	1.197	AVA	750	1614
8126656	1100 × 24	.0201		444000	.872	1.205	RH & N	600	1775
8160268	1325 × 24	.0201		535000	.945	1.37	AVA & N	600	2150
8179320	1325 × 24	.0201		535000	.945	1.37	RH & N	600	2360
8137083	1600 × 24	.0201		636000	1.12	1.55	AVA	750	2340
8213136	1925 × 24	.0201		777700	1.12	1.56	RH & N	600	3017
8233364	1666 × 44	.002	#12	6500	.110	---	---	---	19.7

Insulation Symbols:

AV - etc. -- Asbestos Varnish Cambric
RH & N -- Heat Resistant Rubber and Neoprene
OPR & N -- Ozone Resistant Rubber and Neoprene
SCRC -- Single Conductor Rubber Covered

SECTION 27 37503D

LSG-10 Governor

3-206

LSG-10 GOVERNOR

DESCRIPTION

The Woodward LSG-10 governor is an isochronous, mechanical-hydraulic speed sensing and electro-hydraulic load sensing governor with adjustable steady state speed regulation (speed droop). It is designed for use on single or paralleled turbine or engine-driven generator sets. In order to utilize load sensing on paralleled units most of the units in the system should be equipped with similar load sensing governors. Under special conditions some improvement over control obtainable from conventional governors might also be obtained when a smaller number of units have load sensing governors. It may be used on an infinite bus with the load sensing element disabled, operating at fixed load as a conventional speed droop governor. Units using load sensing will (in effect) parallel with zero steady state speed regulation and divide load between units proportionately according to the capabilities of the respective units. Actually, speed droop is used, but the load sensing cancels it.

The stalled torque rating of the LSG-10 is 156 pound-inches transmitted through a terminal shaft with a total travel of 45 degrees and a no load to 100% load travel of 28 degrees. This is equal to 10 foot-pounds of work for full travel. Various mounting and drive shaft arrangements are available, so the governor may be used on any engine or turbine designed for use with any other Woodward governor. It has its own oil supply. Manual speed adjustment, speed droop adjustment and the load limit are mounted on the dial panel. A motor for remote speed adjustment is usually furnished. A shut-down solenoid is available.

The LSG-10 governor consists of a load sensing section and a speed sensing section which together control a hydraulic relay. The relay servo positions a terminal shaft. The speed sensing section (referred to as the "speed governor") is schematically similar to the Woodward PG governor. The speed droop, adjustable from zero to approximately 7%, is in the speed sensing section of the governor and is actuated by the speed servo rather than the terminal shaft position as is customary. The function of the speed sensing section is to provide the basic speed reference and to provide accelerating torque during speed transients.

The load sensing section (or "load governor") is an electro-hydraulic transducer consisting of a force motor mechanically connected to a pilot valve which controls flow of oil from the pump to the load servo in such a manner that a proportional relationship exists between the force motor coil current and the load servo piston position. The coil current varies linearly with generator load. The linkage ratios are chosen so that the terminal shaft will move the necessary distance required to exactly correct the fuel or steam flow for any load change which occurs.

The LS0-10 governor responds rapidly to load changes. A change in the speed of the engine or turbine always results from any change in the load, but the governor action resulting from a load change will be much faster than that resulting from a speed change. As a result, transient speed (frequency) errors are much smaller when using the LSG-10 gover-nor than when using a conventional speed governor. The resulting speed deviations are on the order of 25% to 50% of what would be obtained with speed sensing alone. The degree of improvement obtained depends greatly on the characteristics of the engine or turbine. On some prime movers the governor will maintain steady state speed within ± .1 of 1% or less of base speed. Frequency deviation can be held to a minimum as the governor will usually obtain the best performance the engine or turbine is capable of delivering. The electro-hydraulic transducer has an overall response time from electric signal to

output position of approximately .02 seconds. It should be noted that to obtain the extremely fast response of this governor following a change in load, the mass of the linkage connecting the terminal shaft of the governor to the fuel racks or gas valve of the engine or the steam valve of the turbine should be kept to a minimum. The linkage should have a minimum number of wear points. The speed and load sensing elements are independent of each other to the extent that the speed sensing section can control the engine or turbine very accurately should any trouble occur in the electrical portion of the equipment. This control would then become the equivalent of a conventional high quality hydraulic speed governor.

Electrical load sensing is obtained through the use of circuitry which detects the in-phase component of the load current for each phase of the alternator. The signals thus obtained from each phase are added and their sum is amplified by means of stable, conservatively rated silicon power transistors, and the resultant signal is supplied to the force motor coil in the governor. Electrical equipment forming part of this governing system is factory calibrated and sealed. Parallel operation with the load divided equally among units is obtained by interconnection of amplifier input signals. Although the speed sensing sections of the governors require speed droop for parallel operation, the LSG-10 operates isochronously. This results because the speed servo (to which the speed droop is referenced in this governor) always operates in the same position during steady-state, on-speed conditions, while the load servo positions the fuel racks, or gas or steam valve, at the value required to schedule the exact torque for the existing load.

Other circuits are available for DC generation and special applications. Where generator units having these governors must operate in parallel with a large power system, either for standby purposes or during transfer of load to or from a generator plant, simple auxiliary equipment to permit this is available. The Woodward Governor Company normally supplies all necessary components of these various systems. Usually, the current and potential transformers supplied by the switchboard manufacturer to power the switchboard instruments also power the load sensing portion of the governing system. The burden on each current transformer can be calculated easily since the full load secondary current is known and the full load current signal at 100% generator power factor is 1.00 to 1.15 volts. To obtain the maximum burden, divide the current signal voltage by the lowest power factor to be expected, and proceed with the calculations. It will be around 5 or 6 VA per phase. The total burden of the computer on the potential transformers is about 40 VA. The load computer and current signal resistors incorporated in this system are not located in the governor but are housed in small separate boxes, usually mounted in a switchboard cubicle.

WIRING SPECIFICATION

The standard plugs used to connect to receptacles on the governing equipment can be obtained by the engine, turbine and switchboard manufacturers from electric or electronic supply houses. As a convenience, they may be ordered from us, with color coded cables attached. There are no heavy currents in the circuits to the governing equipment. Regular switchboard wire should be used for connections from the current transformer secondaries to the resistor box and between terminal strips in the switch gear. For cord plugs use #18 or #20 stranded wire with oil resistant insulation. Solid wire may make a good connection when the installation is new, but engine vibration or other disturbances may cause failure at the soldered connections in the cord plugs.

There are three important precautions:

1. Follow the Woodward wiring diagram accurately. Don't add extra switches or other devices without discussing the matter with us.

2. Our wiring diagram specifies phase relationship between connections from the generator leads (low voltage generator) or potential transformers, and the current transformers. These must be correct.

3. The wires between the current signal resistor box and the load computer terminals (J-I, H-E and D-A of Figures 17 and 18) must connect directly to the resistor box terminals. These resistors have values of a fraction of an ohm and are accurately adjusted at the factory for rated full load current of the generator with which they are to be used. Connection at any other point in the current transformer secondary circuit will, by adding an unknown wire resistance, nullify this careful calibration and result in an improper load signal to the computer and unsatisfactory operation of the governor (see Figure 13).

INSTALLATION

When the governor is installed on the engine or turbine, care should be exercised to see that it is mounted squarely and that the drive connection is properly aligned. A gasket should be used between the base of the governor and the mounting pad. Link-age from the governor to the engine fuel pumps, or gas or steam valve, must be designed and adjusted with more care than was previously required for other governors. On each side of the governor, surrounding the terminal shaft, is a scale (Figure 1) on which are marked positions corresponding to zero and 100% of rated full load of the generator unit. The linkage must have a lever of adjustable length, and a link of adjustable length, see Figure 2. If the governor has to turn a greater or smaller amount than is indicated by the dial to change generator output from no load to full rated load, the length of the lever must be changed. If the amount of travel is correct, but both the zero and full rated load positions are high or low, the length of a connecting link must be changed. These are the only adjustments (in addition to the usual compensating needle valve adjustment) that are required. Don't attempt adjustment of the factory calibrated governor adjustments or the electrical equipment. There must be a linear relationship between governor terminal shaft travel and kilowatt output from the generator.

Be sure linkage is free of friction and lost motion. If there is a collapsible member in the linkage, perhaps for shutdown, be sure it does not yield each time the governor moves the linkage rapidly.

It is desirable to equip the engine or turbine with a separate overspeed device to prevent runaway in the event of a failure (including mechanical failure outside the governor) that would render the governor inoperative. The governor is a control, not a safety device.

INSTALLATION ADJUSTMENT

Important: Before starting the unit for the first time, remove all the electrical connector plugs from the governor, the load computer, and the trimmer. Fill the governor with oil to the upper mark on the gage. Use SAE 20 or SAE 30 oil for ordinary temperature conditions. If governor operating conditions are extremely hot, use SAE 40 or SAE 50; if extremely cold, use SAE 10. Usually the same oil being used in the engine crankcase is satisfactory for use in the governor. The oil must not contain additives which are used to free up rings, remove carbon, etc., unless a non-foaming additive is also present. The oil should not foam or sludge excessively when agitated, or form gummy deposits when heated. The unit may now be started in the usual way, controlling the governor by hand, as with any hydraulic speed governor. Open the needle valve until the unit hunts, or surges. This will speed up elimination of air

from the oil passages. After about one half minute gradually close the needle valve until the hunting just stops. Closing the needle valve farther than necessary will make the governor slow to return to normal speed after a load change. It should never be closed tight. Test the action by manually disturbing the speed of the unit. The unit should return promptly to the original steady speed with only a small overshoot. It may be necessary to add a little oil, but don't let the level go higher than the upper mark on the gage.

Experience has shown that in a new installation there are often errors in wiring to the governor. Naturally, each error must be corrected as it is found. It is easy to check for errors with a small volt-ohm-milliameter. Test fixtures similar to those shown in Figure 3 and wired as shown in Figure 4 are a great convenience, but not a necessity. Make the following tests with the engine running, with or without load. These tests are for standard governors. Write to the Woodward Governor Company for instructions covering special governors.

LOAD COMPUTER INPUT CORD PIUG: This is a female plug**.**

1. Set the meter for a scale that reads 250 or 300 volts AC (or higher) and insert the test prods in the holes marked G and C, see Figure 5. There are small letters molded in the insulation next to each hole. WARNING: Don't force the meter prods into the holes. This may damage the contacts so they will not make a good contact when plugged into the receptacle. (If you have a test fixture as shown in Figure 3, insert the input cord plug in the input receptacle, then insert the meter prods in the pin jacks marked G and C. See Figure 6.) If the generator unit has potential transformers to supply the switchboard meters and the governor, the test meter should read 110 volts. On a low voltage generator unit 120-208 volts Y connected, or 240 volts) the meter will read 208 or 220 volts. See the switchboard wiring diagram for your plant or generator set.

   You should also obtain the same reading with the test prods in terminals C and F, and in F and G. If the readings are not all the same something is wired wrong.

   On a 120-208 volt machine, make one more check. You should get a reading of 120 volts between B and C, B and F, and between B and G. This is be-cause terminal B is connected to the center (or neutral) of the Y.

2. With no generator current flowing, you should obtain no voltage from A to D, E to H, or I to J. Presence of even a small voltage here indicates something wrong.

3. Apply load to the unit in any convenient way - as much as possible, up to full rated load. Insert the test prods in terminals A and D. There should be practically no reading with the meter on a high voltage scale. Switch the meter to lower and lower voltage scales, until it is easy to read the voltage. With full rated kilowatt load, the meter should read 1.00 to 1.15 volts AC at unity power factor, or 1.25 - 1.44 volts at 80% power factor. For smaller loads, the reading should be proportionately smaller, for instance, approximately 0.50 volt at half load and unity power factor. Don't worry if these voltages are slightly off. Small meters are not very accurate at low voltages, also the loads on the 3 generator phases may not be equally balanced. This test is to check for errors in external

wiring. You should find this same voltage between terminals E and H, and between I and J if the load is equally divided among the 3 phases.

If any discrepancy is found, check between terminals A and D on the current signal resistor box. These terminals, which are on opposite ends of the resistor box, should give the same voltage as at the same terminals of the input plug. Check between terminals E and H, and between I and J in the same way.

If the above voltages are all correct, and not before, insert the input cord plug in the load computer.

You should now be able to measure the following voltages in the output receptacle mounted on the computer or in the pin jacks of a test adapter plugged into it:

a. Roughly 45-50 volts DC between d (negative) and h (positive) (amplifier power supply).

b. Zero volts DC between d(negative) and a (positive) with no load on the unit. At full load the reading will be about 12 volts, and proportionately less at smaller loads: 3 volts at one quarter load, 6 volts at half load, etc. If the reading is only one third of *hat it should be when the generator is loaded, one of the connections from the current signal resistor box to the load computer is reversed. Leave the meter connected to output terminals d and a. With a piece of wire, short circuit terminals A and D at the current signal resistor. If the meter reading drops further, the connections from these terminals to the input plug are correct. WARNING: Don't disconnect any wires at the resistor box (Figure 13); just short them with a fairly heavy wire, say No. 12. Now try shorting E and H, then I and J. If shorting any of these pairs of terminals increases the meter reading, it indicates reversed connections from here to the load computer.

If just one current signal (A to D, E to H, or I to J) is reversed, the meter will read approximately 4 volts from d (negative).to a (positive) with full load on the generator. If two are reversed, a will be negative and d will be approximately 4 volts positive. If all three are reversed, a will be negative and d will be approximately 12 volts positive. In other words, the correct full load reading of 12 volts from d (negative) to a (positive) will be decreased by 8 volts for each reversed load signal. Shorting out the incorrect current signal resistor reduces this decrease to 4 volts.

If there is a reduction in voltage for each pair of resistor terminals that is shorted, but the meter reading is appreciably lower than it should be, it is possible that two or all three of the wires to C, F and G in the computer input plug are exchanged. Shut the unit down and start ringing out the wiring. WARNING: Don't disconnect any wires at the resistor box (Figure 13) or the current transformers. The secondary of a current transformer can develop a dangerously high voltage when open circuited.

If there is a cathode ray oscilloscope available, the above checks

can be made easily at the test fixture (Figure 3) inserted between the load computer input plug and the receptacle. Since potential and current transformer secondaries will probably be grounded, and the current signal resistors may be at some point above ground, use a small properly phased isolating transformer between the 69 or 120 volt terminals B-C, etc., and the oscilloscope input. A small radio filament transformer or doorbell transformer may be used, after first checking phase relationship of its primary and secondary. Set the oscilloscope for external sweep and check for an in phase relationship.

(Approx. 69 or 120 volts)		(1.00-1.15 volts at full load)
B to C	with	D to A
B to F	with	H to E
B to G	with	J to I

Check the switchboard wiring diagram to see if terminal B leads to a grounded neutral which is probable on a low voltage generator. If so, the check could be made directly in the input plug without the test fixture.

When it has been determined that all input connections are correct as indicated by the zero and approximately 12 volts (no load and full load) between d and a on the output receptacle, the output plug may be inserted. However, if you are suspicious of the plant wiring, check all possible combinations of terminals in the output cord plug before inserting it. There should be no voltage present since, with the plugs still not inserted in the governor or the trimmer, none of the computer output plug wires should be connected to anything. Checking with an ohmmeter should show that terminals of the output plug a and b are connected by means of a Jumper in the panel wiring, as are c and e. If these external jumpers are missing, voltages tabulated below from d to b and d to c would be 35-40v.

If you have a test adapter, insert the output cord plug in it and its cord plug in the computer output. This permits making more simple checks, in case you suspect trouble in the load computer. Note that the governor and trimmer plugs still are not inserted. Temporarily, connect a 25 watt thirty-five or forty ohm resistor between output pin Jacks g(-) and H (+). You should measure approximately the following DC voltages between these test fixture pin jacks, if the input plug voltages are correct and in phase, as discussed above.

	No load	Full rated load
d(-) and a(+)	0	12
d(-) and b(+)	0	12
d(-) and c(+)	2	10-1
d(-) and e(4)	2	10-11

At no load, a current of about 25 m.a. should flow thru the resistor. At rated

generator load, the current will be somewhere near 300 milliamperes. This corresponds roughly to 1 to 12 volts, respectively, measured across the resistor, see Figure 7. These values will be far from exact, with the trimmer still not connected, but they do indicate that the entire computer assembly is functioning. Now remove the resistor. The test adapter may be left connected between the output receptacle and plug, or the plug may be inserted directly in the out-put receptacle.

The next series of wiring checks should be made at the governor plug. Connect the 35 or 40 ohm resistor between terminals A and B. A current of approximately 25 milliamperes should flow through it at no load, and 300 milliamperes at full generator load. This corresponds very roughly to one volt across the resistor at no load and 12 volts at full load from B (-) to A (+). (Similar to Figure 7) If A is not positive and B negative, the wires from load computer to governor are reversed somewhere. Note that if you use the test adapter designed for use at governor, you can insert the resistor wires in terminals A and B, the meter prods in the two black Jacks normally shorted by the jumper, and read milliamperes on the meter. Press the button to read. See Figure 8.

Determine what voltage is supposed to be supplied to the governor speed adjusting motor, and set the test voltmeter to read this value (most common values are 110 or 120 volts AC or DC). Insert the meter test prods in terminals G and F of the governor plug or the test adapter. When the speed adjusting switch on the switchboard is turned to "Raise", voltage should be indicated. There should be the same voltage across terminals G and H when the switch is turned to "Lower".

Check to be sure there is no voltage present among terminals C, D and E.

If the governor is equipped with a shutdown solenoid, determine from the governor or station wiring diagram its voltage rating and which terminals are connected to it (usually 110-120 volts, AC or DC, to terminals I and J). Determine also if the solenoid is intended to shut down the unit when energized or when deenergized. You can now check to see if the proper voltage appears at the proper terminals when the solenoid is supposed to be energized.

It should now be safe to insert the cord plug in the governor receptacle, either directly or with the proper test adapter interposed, although more probably you will want to repeat the above checks on all the governors before permanently interconnecting all the equipment. (All governor and load computer cord plugs should be inserted in their receptacles to permit checking wiring to the trimmer.) Operate the speed adjustment switch and watch to see that the speed adjustment dial on the governor turns in the proper direction.

To prevent damage to the trimmer assembly due to incorrect external wiring, the following tests may be made before inserting the connecting plug in the receptacle. Note that two, easily identified types of trimmer are used, usually depending on whether the plant is designed for four

engines or less, or for five or more.

The trimmer for four units or less consists of a small gear reduction motor which drives four potentiometers through gears. It is easily identified because it has 14 pins in its input receptacle. It is shown in Figure 9. You should measure 120 volts AC between terminals A and B of the cord plug. With no load on the unit or units, you should measure very roughly 3/4 volt DC between N(-) and F(f); N(-) and H(+); N(-) and J(+); N(-) and L(+). At full load on the engine, these voltages will be around ten. Naturally, with less than four engines, there will be one or more of the above pairs of terminals with no voltages. There should be no voltage present between any combination of computer cord plug terminals C, D and E. Another check for wiring may be made with the computer input and output cord plugs inserted (either direct or through the test adapter). You should measure at the trimmer cord plug around one or two volts DC from G(+) to F(-); from I(+) to H(-); from K(+) to J(-); and from M(+) to L(-). The voltage here is not so important but the polarity is. It should now be safe to insert the cord plug in the trimmer receptacle. One further check is to see if the trimmer motor runs. Note that limit switches stop it as the potentiometers reach either end of their travel. Remove the plug from one governor, and set the master selector switch to use that governor as the master. Be sure the 120 volt AC circuit to the trimmer is energized. Have someone watch the motor in the trimmer to see if it moves. Now connect terminals C and D at the governor cord plug together. This should cause the motor to run, unless it is already at one end of its travel so the limit switch is open. As you look past the main body of the motor, you will see four gears. These should turn clockwise. Now connect together D and E at the governor cord plug. The trimmer motor should run in the opposite direction and the four gears should turn counter-clockwise. This same test should be made, using each of the other governors in the plant as the master.

The trimmer used when there are to be more than four generating units in a plant (and under some special conditions with less than four units) is shown in Figure 10. It has just one potentiometer operated by the motor, and also includes a transformer, transistors, etc. There are 10 pins in the input receptacle. Its input cord plug may be checked for external wiring errors quite easily. As in other checks mentioned previously, the cord plug is removed from the trimmer for the following.

You should measure either 110 or 220 volts AC, approximately, between terminals G and H, H and I, and I and G. See the switchboard wiring diagram for your plant. There should be no voltage between any combination of terminals A, B and C. With no load on the generator unit, there should be, very roughly, 2 volts between D(-) and F(+), and roughly 10 volts at full load. (The same approximate readings should be obtained between D(-) and E(+).) Check operation of the trimmer motor, as described above for the four unit trimmer. Connecting C and D together in the cord plug of the governor serving as the master will cause the motor to run the brush of the potentiometer counterclockwise as you face the brush. Connecting D and E together will cause the brush to turn clockwise.

The above checks, which require only inexpensive test equipment and very little electrical knowledge, will probably discover any errors in plant wiring which might damage or prevent correct operation of the governing equipment.

For your convenience, all the above checks are tabulated here:

Test Connections No.	Place of Measurement	Load	Correct Reading	Notes
All Plugs Removed	Computer input plug:			
1	G to C C to F F to G	Off line Off line Off line	120,208 or 240V-AC See station wiring diagram	
2	B to C(see note) B to F B to G	Off line Off line Off line	120V-AC 120V-AC 120V-AC	120-208 volt Y connected generator only
3	A to D E to H I to J	Off line Off line Off line	Zero V-AC Zero V-AC Zero V-AC	
4	A to D E to H I to J	As much load as possible up to full load	1.25-1.44V-AC at rated load and 80% PF. Proportional for smaller loads	
Input plug in computer. If test adapter is used, adapter into computer and input cord plug into adapter. All other plugs still removed.	Computer output receptacle			
5	d(-) to h(+)	Off line	45 - 50V-DC	
6	d(-) to a(+)	Off line	Zero	
	d(-) to a(+)	Full load	Approximately 12V-DC	Proportionally lower voltage at less than full load

Test No.	Connections	Place of Measurement	Load	Correct Reading	Notes
7		Output cord plug (not the receptacle of computer): All combinations of terminals a to b, a to c, a to d, etc. to i to J	On line, with or without load	No voltage in any combination	If the electronic trimmer (10 wire connector, Figure 17) is used and is already plugged in for use with other units, there will be DC voltages from d(-) to c, e and j(+)which may be from 0 to perhaps 15 volts.
8	Computer input plug inserted. Test adapter between output receptacle and output cord plug. 35 to 40 ohm 25 watt resistor from g(-) to h(+) of output test adapter.	a to b c to e		Zero ohms Zero ohms	
9		Output test adapter d(-) to a(+) and also d(-) to b(+)	No load Full load	Zero V-DC 12 V-DC	Proportionately less at smaller loads
10		d(-) to c(+) and also d(-) to e(+)	No load Full load	2 V-DC 10 V-DC	Proportionately less at smaller loads.
11	Remove resistor	Resistor	No load Full load	Approx. 1 volt DC across resistor (Approx. 25 m.a.) Approx. 12 volts DC across resistor (Approx. 300 m.a.)	

Test No.	Connections	Place of Measurement	Load	Correct Reading	Notes
12	Both computer plugs still inserted	Governor cord plug or test adapter			
		35 to 40 ohm resistor from A(+) to B(-)	No load	Approx. 25 m.a. or 1 volt	
				Full load Approx. 300 m.a. or 12 volts	
	Remove resistor				
13		Governor cord plug or test adapter	Off line		
		G to F		Zero	
		G to F		Rated speed adj. motor voltage	Speed adj. switch on switchboard turned to "Raise"
		G to H		Zero	
		G to H		Rated speed adj. motor voltage	Speed adj. switch turned to "Low"
14		Any combination of C, D and E	On line any load	Zero	
15		Terminals indicated by wiring diagram for shutdown solen.	Engine not running	Rated solenoid voltage	Solenoid energized
	REPEAT ABOVE CHECK ON ALL GOVERNORS				
16	Both computer plugs and governor plugs inserted with or without test adapters.	Watch speed adjustment dial on governor	Off line or not running		Turn speed adj. switch to raise and to lower.

Test No.	Connections	Place of Measurement	Load	Correct Reading	Notes
		FOUR UNIT, POTENTIOMETER TYPE TRIMMER: 14 PIN RECEPTACLE			
	Trimmer cord plug still not inserted				
		Trimmer input plug			
17		A to B		110 - 120V-AC	
18		N(-) to F(+)	No load Full load	Approx. 3/4V-DC Approx. 10V-DC	Voltage appears at one pair of these terminals for each engine in operation
		N(-) to H(+)	No load Full load	Approx. 3/4V-DC Approx.10V-DC	
		N(-) to J(+)	No load Full load	Approx. 3/4V-DC Approx. 10V-DC	
		N(-) to L(+)	No load Full load	Approx. 3A V-DC Approx. 10V-DC	
19		Any combination of C, D and E		Zero volts	
		G(+) to F(-) I(+) to h(-) K(+) to J(-) M(+) to L(-)	Any load from zero to max.	Polarity must be correct. Reading will be approx. 1-2 volts D.C.	
	Trimmer cord plug inserted				
21	Remove plug from one governor and turn master selector switch to that unit	Observe 4 gears driven by motor		Gears turn clock-wise	C and D connected together at gov-ernor cord plug.
				Gears turn coun-terclockwise	D and E connected together at gov-ernor cord plug
22	Repeat 21 at each governor				

Test No.	Connections	Place of Measurement	load	Correct Reading	Notes
		ELECTRONIC TRIMMER FOR MORE THAN FOUR UNITS - 10 PIN CONNECTOR			
	Trimmer cord plug not inserted	Trimmer input cord plug			
23		G to H H to I I to G		110 or 220V-AC See plant wiring diagram	
24		Any combination of A, B and C		Zero volts	
25		D(-) to F(+)	No load Full load	Approx. 2V-DC Approx. 10V-DC	
	Trimmer cord plug inserted				
26	Remove plug from one governor and turn master selector switch to use that governor as the master.	Observe trimmer motor	Potentiometer brush turns counterclockwise as you face the brush	C and D connected together at governor cord plug.	
			Brush turns counterclockwise	D and E connected together at governor cord plug.	
27	Repeat 26 at each governor				

SCHEMATIC OPERATION CF GOVERNOI

Please refer to Figure 11. The main pump which forms a part of the relay (lower half of the governor) draws oil from the sump and supplies it to the spring loaded accumulators where it is stored under a pressure of 100 pounds per square inch. Very rapid servo movements are possible as the accumulators supply the necessary oil faster than the pump alone could. As the accumulator pistons move against the force of the accumulator springs, one of them uncovers a port leading back to the sump. This serves as a relief valve and limits the pressure to a value of a little over 100 psi. This pressure is supplied direct to the relay valve, and also to the pump of the pilot governor where the pressure is raised to 150 psi. Note that check valves in the suction and discharge of both pumps permit the governor drive shaft to rotate in either direction.

SPEED GOVERNOR

The speed governor portion of the LSG is identical in principle with the Wood-ward type PG. Assume that the right hand end of the serve floating lever remains fixed and the generator load is increased. The resulting decrease in governor speed below the set value will permit the speeder spring to force the flyweights, which are driven by the unit, to move inward. This lowers the pilot valve plunger and permits the pressure oil supplied by the pump to flow into the buffer piston bore. This causes the buffer piston to move to the right in the schematic.. As the oil trapped on the right side of the buffer piston is displaced, the speed governor power piston is forced upward. This movement of the buffer piston partially relieves the compression of the left hand buffer spring and increases the compression of the right hand spring. The force of the buffer springs tending to resist this movement results in a slightly higher oil pressure on the left side of the buffer piston than on the right. These unbalanced oil pressures are transmitted to the lower and upper sides of the compensation land on the pilot valve plunger. This produces an upward force on the plunger, opposing the decrease in flyweight force which had permitted the speeder spring to move the plunger down. When the speed governor power piston (which, as will be explained, moves the fuel or steam control of the engine or turbine) has moved far enough to meet the new fuel or steam requirement, the unbalanced pressures on the compensation land will have recentered the plunger, which closes the valve port and stops further power piston motion. Increase of speed to normal does not cause the flyweights to move outward and open the pilot valve ports in the opposite direction, because leakage of oil through the needle valve equalizes the pressures above and below the compensation land at the same rate that the speed returns to normal. As the pressures are equalized the springs return the buffer piston to its normal central position. Movement of the speed governor power piston is opposed by the loading piston, which, possessing less effective thrust, moves with it.

When generator load is decreased the resultant increase in governor speed causes the flyweights to move outward, raising the pilot valve plunger. The loading piston, which is under constant pressure from the governor pump, is now able to force the speed governor power piston downward, because the oil at the left of the buffer piston can now discharge to the sump. This movement reduces the fuel or steam to meet the new requirement. Again, differential pressure across the compensation land recenters the pilot valve plunger, and keeps the pilot valve

ports closed while speed decreases to normal.

The speed at which the governor controls the engine is determined by the compression of the speeder spring which opposes the centrifugal force of the fly-weights. Turning the speed adjusting knob on the governor panel, or operating the small reversible motor geared to this knob raises or lowers the left end of the speed setting lever and changes this compression. If the speed droop pivot is set by the speed droop adjustment (from the dial panel) to any position eccentric with the speed droop lever shaft, movement of the speed -governor power piston will cause the right hand end of the speed setting lever to move up or down. Upward movement to increase fuel or steam flow because of an increase in load reduces the speed setting. This decrease in speed with an increase in load is, of course, speed droop. (A more technical name for speed droop is "steady state speed regulation".) Setting the speed droop pivot concentric with the speed droop lever shaft will cause operation of the speed governor to be isochronous, that is, no change in speed setting will be produced by a change in speed governor power piston position. The reasons for various speed droop settings will be discussed later.

SPEED DROOP SETTING

The speed droop setting knob is on the left side of the panel. The speed droop knob, through a screw and linkage, adjusts the speed droop pivot pin. At "O speed droop setting, this pin is on the rotation center line of the speed governor's terminal lever. As the knob is turned, the pivot pin is moved further away from this center line. Thus, as the speed governor piston rotates its terminal lever, speeder spring loading is changes proportionally. This speed droop is in the speed section only of the governor.

A governor with speed droop may be used as a tachometer. Assume that the speed of some unit is controlled within a narrow band, say plus of minus one percent of normal by any means -- by hand control of the fuel or steam, by having its generator synchronized with a power system, or perhaps by some sort of governor (not the additional governor we are about to add to the unit for explanation only). A speed governor having 2% or more speed droop could also be installed on this engine but without connecting its output connection (power piston rod, or terminal shaft) to the fuel control. With its speed setting properly adjusted, its output connection will move with changes in engine speed, attempting to correct these changes. It can't, however, because its output isn't connected to anything. As its output connection moves, attempting to increase or decrease fuel, it will also decrease or increase its own speed setting, until its speed setting is equal to the speed at which the engine is driving it. The result is that within a speed band equal to the amount of speed droop it possesses, the output of this governor takes a definite position corresponding to the speed at which it is running. Thus, this speed droop governor acts as a tachometer, with the position of its output indicating speed.

LOAD LIMIT

The load limit knob, through a cam and linkage, acts as an adjustable stop on the relay servo piston travel. The relay servo piston can travel in the increased fuel or steam direction until it engages the load limit linkage which then mechanically centers the relay valve plunger and thus stops further movement of

the relay servo piston. Fuel or steam can not increase further, but is free to decrease.

SPEED SETTING

The speed of rotation of the governed unit is measured by the ballarms and speeder spring. A steady state condition exists when the centrifugal force produced by the ballarms exactly equals the opposing speeder spring force with the ballarms at a vertical position. The pilot valve plunger control land then covers the control port in the bushing and the speed servo is hydraulically locked in position. The lowest knob on the panel controls the speeder spring compression and consequently speed setting through linkage to the upper end of the spring. Remote speed adjustment is possible through the speed setting motor. A friction clutch between the motor and the manual adjustment permits manual adjustment and protects the motor from overload at the ends of the speed adjustment range.

Figure 20 and subsequent figures are views showing actual arrangement of all these Darts in the governor. The trimmer switches, which are mechanically operated by the speed governor Dower piston, will be explained later. The governor mechanism described thus far is the equivalent of many Woodward precision speed governors.

LOAD GOVERNOR

In the preceding, we assumed that the right hand end of the servo floating lever remained fixed during a load change, and the subsequent speed change and return of speed to normal. (See Figure 11.) Now let us assume for the moment that the left end of the servo floating lever remains fixed. The mechanism now to be described moves the right hand end accurately and extremely rapidly in response to a change in electrical load on the generator. This brings the fuel or steam control to the correct new position required to carry the new value of load.

As indicated in the simplified plant wiring diagrams, Figures 12A and 12B, connections are made from the potential and current transformers associated with the three generator phases to the load computer which forms a part of the governing equipment. The load computer (Figure 14), sensing the current and voltage in each phase, sends to the coil of a polarized solenoid in the governor a current of 25 milliamperes DC when there is no load on the generator, and 300 milliamperes at full rated kilowatt load. Please refer again to Figure 11. An increase in current through the coil will cause the permanent magnet armature of the solenoid to move upward, carrying with it the load governor pilot valve plunger. This uncovers the valve port and oil from the high pressure supply flows very rapidly into the space under the load governor power piston. This piston moves upward, overcoming the force of the loading piston to move it upward. This increases fuel or steam flow to the engine or turbine, just as an upward movement of the speed governor power piston does. Upward movement of the load governor piston causes a downward movement of the right hand end of the second restoring lever. This continues until the increased compression of the restoring spring balances the increase in solenoid force that initiated this movement, and the load governor pilot valve plunger moves down so the ports are again closed. The result of this operation is that the load governor power piston always assumes a position corresponding to the current to the solenoid coil, which is in turn proportional to kilowatt load on the generator. Since there is no problem of stability in-

volved, the governor can be designed for extremely rapid movement of the load governor power piston, about 0.01 seconds from no load to full load position.

POWER RELAY

Either the speed governor or load governor power piston moving upward against the force of the loading piston, (or the loading piston moving downward with either of the power pistons discharging through its pilot valve to the sump) can do less than one-half foot pound of work. This obviously is not enough capacity to move the control of a very large unit, so its power must be amplified. Movement of the loading piston is transmitted to the relay floating lever which uncenters the relay valve plunger so the space below the relay servo piston is connected to the 100 psi oil pressure or to the sump, resulting in an upward or downward movement of the piston. Force for the downward movement comes from the oil under constant pressure on the differential area (equal to one-half the control surface area) on the upper side of the piston. Through the relay floating lever, movement of the relay servo re-centers the relay valve. Through a connecting link and crank, the relay servo piston can turn the governor terminal shaft 45 degrees, doing ten foot-pounds of work in less than 0.04 second. Of this total travel, 28 degrees, with a work capacity of about 6-1/4 foot-pounds, is used in moving the fuel or steam control from no load to full load. (As with any hydraulic governor, the work required to move the fuel or steam control should not exceed two-thirds of the available work capacity.)

LOAD COMPU TER

We said above that the polarized solenoid, or force motor coil, of the load governor is energized by a current proportional to the load imposed on the generator. The electrical arrangement is as follows and as shown on the simplified typical wiring diagram in Figures 12A and 12B:

A factory calibrated resistor, Rcs (see Figure 13), is placed in series with the secondary of each of the three current transformers. when no load is imposed on the generator, no current flows through these resistors and there is no voltage drop across any of them. At full rated generator load and 100% power factor, the drop across each resistor is 1.00-1.15 volts. At the more common 80% power factor the voltage drop for full rated load would be 1.15-1.44 volts. At other power factors or at less than full load, the voltage drop will be in pro-portion. These three voltages comprise a signal to the load computer to tell it how much current is passing through each of the main generator leads. The four wires from the generator (Figure 12A) or the three wires from the potential transformers (Figure 12B) permit the computer to compare the phase of the three current signals with the phase of the corresponding voltages. Assuming that the generator voltage remains reasonably constant (which it does, except in very special cases), the wires leading to the force motor coil in the governor supply it with 25 milliamperes when there is no load on the generator, and 300 milliamperes at full load.

OPERATION OF THE LOAD COMPUTER

Please refer to Figure 17 which shows the wiring of the computer, and to Figure 15 which shows a portion of the wiring for one phase. The dots at one end of each transformer winding indicate polarity of the voltage at any instant. The

secondary voltages V_1 and V_2 are large compared to C_1 and C_2. The transformers are connected so that C_1 is subtracted from V_1, and C_2 is added to V_2, as indicated by the polarity dots. If the power factor is less than 100% the C and V voltages are not in phase with each other, and the resultant voltages will be R_1 and R_2. Figure 16 is a vector diagram of these voltages. R_1 and R_2 pass through the bridge rectifiers RECT 1 and RECT 2 in Figure 15. The DC voltage rectified from V_1 minus C_1 is connected to R_6 plus part of P_3. The DC voltage rectified from V_2 plus C_2 are connected to R_5 plus part of P_3.

These two DC voltages are opposite in polarity so the difference between them appears at TP3(-) and TP4(+). This DC voltage is equal to (C_1 + C_2) times Power Factor, and so is proportional to the kilowatt load on that phase of the generator. It is zero at no load, and about 4 volts at full load. (The potentiometer P3 is adjusted during factory calibration to correct for minor variations in circuit components, so that the TP3-TP4 voltage is zero at zero load.)

This circuit, in Figure 17 (and Figure 18), is repeated three times, once for each generator phase, and the output DC voltages are added, giving about 12 volts between TP1 and TP4 at full load on the generator.

The additional secondaries (V3 in Figure 15) are connected to the three phase, full wave rectifier (D25-29 in Figures 17 and 18) to supply 40 - 50 volts to the calibrated transistor amplifier.

The 0 to 12 volt signal from the three "wattmeter", or current times power factor circuits, passes through resistor R7 (Figures 17 and 18). It is affected by loading of resistors in the amplifier circuit, by operation of the trimmer, and by the 40 - 50 volt power supply, so that at no load the DC voltage from TP1 to TP5 (which can be measured between output plug terminals d and c or e) is 2 volts at no load, and approximately 10 volts at full load.

The two stage transistor amplifier is factory adjusted and sealed so that at these input voltages, the currents to the force motor coil are 25 and 300 milliamperes. The circuit is such that these currents are affected very little by power supply voltage or changing resistance of the force motor coil.

PARALLEL OPERATION

When two or more generator units are to be operated in parallel, it is desirable, within reasonable limits, to share the load among them in proportion to their capacities, and at the same speed of operation regardless of load (isochronous control). This isochronous, proportional load division can be obtained with LSG-10 governors if: (1) all the governor force motor coils receive the same current from the amplifiers in their computers, (2) the servo pistons of all the speed governors are in their midposition, and (3) the linkage from each governor to the fuel pumps or control valve of its engine or turbine is properly adjusted to obtain 0 to 100% travel for 0 to 100% load.

PARALLELING LINES

Please refer to Figure 17 or 18. Through auxiliary contacts on the circuit breaker of each running unit, computer output terminals e are connected together, and terminals d are permanently connected together. Thus the input to all the

transistor amplifiers is the same; therefore, the output to the coils of all governors is the same, fulfilling requirement (1) above.

SPEED DROOP IN LOAD DIVISION

Since they are paralleled on the same power system, all units run at the same speed. If their speed adjustments are all very similar, their speed governor servos will all be very nearly in midposition. This fulfills requirement No. 2 above. (Here, as discussed earlier, the speed governor is acting as a tachometer: its output position depends on the speed at which it is running.)

LINKAGE

Accurate adjustment of control linkage was discussed earlier. this fulfills requirement No. 3

With all three conditions met (within reasonable limits),there is isochronous operation, with load proportionately divided within those limits. The droop in the speed governors does not make itself felt because the load governors make the necessary changes in control setting to accommodate changes in load.

THE TRMMER SWITCHES

Internal mechanical adjustments of the governor are such that when there is a current of 25 milliamperes applied to the force motor coil, the speed governor servo piston has to be in its midposition to bring the load indicator mark on the side of the governor to the zero load position. These same internal adjustments also require the speed governor servo piston to remain at its mid-position to bring the load indicator to 100% when the coil current is 300 milliamperes.

Earlier in discussing schematic operation of the speed governor with speed droop, we pointed out that within a narrow range of speeds, its piston assumes a definite position for any given speed, Just like the needle of a tachometer. We also mentioned casually the trimmer switches, shown schematically in Figure 11. If the speed governor piston is required to move above its midposition because for some reason, unit speed is below the value for which the governor is set, one pair of contacts (INCREASE LOAD SIGNAL) is closed. If the piston moves below center because speed is high, the other pair of contacts (DECREASE LOAD SIGNAL) is closed.

The governor output (terminal shaft) position required to carry any given load on a particular unit changes a small amount from time to time. Differential expansion of the unit frame and control linkage, changes in weather, and other variables cause this. As a result, there are inevitably minor variations in load division between units, but these are small enough to be ignored. More important, there may be a small error in system frequency after a load change. Such an error in frequency will cause each speed governor servo piston to move above or below its midposition and close one or the other pair of trimmer switch contacts. The trimmer switches in one governor (selected as the master) cause the trimmer motor (discussed more fully later) to run and slowly turn a potentiometer in the trimmer assembly. By means of either of two circuits described later, this increases or decreases the voltage at the input of the transistor

amplifiers of all governors, causes a proportionate increase or decrease in coil current to all the governors and, therefore, a change in the energy input to all units. This gradually eliminates the small speed error that existed, and when speed is back to normal the speed governor servo pistons are back in their midpositions and the trimmer switch contacts in the master governor are open.

MASTER SELECTOR SWITCH

It is only necessary to use the trimmer switches of one governor to operate the trimmer motor which in turn readjusts all operating governors simultaneously. The master selector switch, usually located in a convenient central location on the station switchboard transfers this control to any desired governor. The switchboard manufacturer should furnish a switch, the handle of which must be pushed or pulled before it can be turned. This permits transferring master control from one running unit to another without briefly touching contacts for intermediate units.

TRIMMER

The trimmer motor is a very small, shaded pole type which turns one or more potentiometers slowly through a gear reduction. One winding of the motor is permanently connected to 110 volts, 60 cycles. The motor runs in one direction when terminals to one-half of the shaded pole winding are connected together and in the opposite direction when the other half of the winding is short circuited. Limit switches stop the motor at either end of its travel. Through either of two simple arrangements, this raises or lowers the paralleling line voltage a small amount (computer output terminals d and e which are also, of course, the inputs to the transistor amplifiers). This causes a small movement of the load governor servo pistons in the proper direction to correct the small speed error, the trimmer contacts then open, and the trimmer motor stops.

POTENTIOMETER TYPE TRIMMER

Figures 9 and 18 show the simpler of two trimmer assemblies, consisting only of the trimmer motor, geared to four potentiometers, and wired as shown, one potentiometer for each of 2, 3 or 4 load computers. The potentiometers for each computer are connected from the emitter of T112 to the negative side of the power supply, and have across them a Voltage proportional to current in the force motor coil The potentiometer slider takes a portion of this voltage, through 1M3, to the input of the amplifier. Note that the amount of trimming for a given amount of motor and potentiometer movement is almost proportional to the amount of load on the unit.

ELECTRONIC TRIMMER

When there are more than four units in a plant, the amount of wiring to the potentiometertype trimmer might be objectionable. Figures 10 and 17 show a circuit which senses the voltage already present at the amplifier input (computer output terminals d to c or e). Through computer resistor 1t13, it raises or lowers this voltage a small amount, depending on the setting of potentiometer P1 in the trimmer. As with the simpler trimmer described above, the amount of trimming that can be done depends on the amount of load on the generator.

TRIMMER CUTOUT SWITCH

In the governor section of Figures 17 and 18 there is shown a normally closed switch connected to terminal D. This is also shown operated by the load governor servo piston in Figure 11. This switch opens when load on the unit drops below approximately 20%. Variations in engine fuel pump or turbine steam valve position would probably be much greater at very small loads than at the loads normally carried, so the trimmer might easily be run all the way to one extreme or the other. There is no harm in this except that the trimmer motor would require a certain amount of time-to travel back to the necessary position should a large load increase occur. Since generator units would never be run at such small loads, except very briefly under most abnormal conditions, it is not considered objectionable to eliminate the trimming, and tolerate a possible small speed error at very small loads.

LOAD DIVISION SWITCH

With conventional governors, the operator usually closes the unit circuit breaker with the synchroscope moving in the fast direction, say about 6 revolutions per minute. This machine is 6 cycles per minute or 0.1 cycle per second faster than those already running. If the governors have about 1-1/2% speed droop (0.9 cycles out of 60), it will immediately pick up 1/9 or about 11% of its rated load. If the synchroscope is moving slower or if the governor has more speed droop, it will pick up less load when connected to the line. All operators are familiar with this. The same small pickup of load occurs with the LSG governor.

When the unit circuit breaker closes, the load governor circuit of the oncoming unit's governor is connected to that of the governors already in service. It immediately takes on approximately its proportional share of the total power plant load, and the other units give up load. But -- since the speed governor was set Just a little bit fast, it causes the oncoming unit to take on some extra load. Since there is no objection to using 3%, or even more, speed droop on a load sensing governor, this extra load beyond the unit's proportional share will be less than in the preceding example, about plus or minus 10% of its rated load. It may be desirable to change the speed setting to make the load division more exactly proportional. Normally in an attended plant this would be done with the speed setting switch. In some LSG systems it can be done semi-automatically. It requires a three pole, double throw switch marked "Load Division Switch" on the switchboard panel for each generator unit. It is spring loaded so it normally makes contact as shown in Figures 17 and 18. After the oncoming unit has run for a few minutes and reached normal operating temperature, this switch should be held manually in its other position for a short time, perhaps ten seconds. This connects the speed adjustment motor of this governor to its own trimmer contacts. Since one of the other governors is serving as a master and holding correct system speed, and since the speed adjustment of the oncoming governor was a little high, its increase load signal trimmer contacts will cause its motor to slowly reduce its speed setting. (These contacts adtually decrease the load on the unit when used in this manner.) When movement of the speed governor piston opens this trimmer switch, the governor will be at the same speed setting as the master (and all others) and it will have its proportional share of load. Naturally the load division switch should be used only when system frequency is stable at the desired value. It is also very important

to note that the load division switch should never be operated on the unit which is serving as the master.

POWER TRANSFER CONTROL

Some installations normally use purchased electric power some of the time, and transfer load to their own generator plants at other times. This may be done automatically because of failure of the purchased power source, or it may be done because the local plant provides more accurate control of frequency or voltage. In the latter case, it is desirable to synchronize the plant with the external power source, then open the tie breaker between them, so there will be no interruption of power to the load. The Woodward power transfer control permits a controlled, smooth transition. Please refer to Figure 19. When the control switch is turned to "Parallel", a source of DC voltage (either the power supply of the electronic trimmer, or a small power supply built in the transfer control itself) is used to raise the paralleling line voltage a little above 2, and hold it at that value regardless of the influence of the "wattmeter" action of the load computers. Thus, when the unit circuit breaker is closed, the load governor servo piston moves to a position which causes the unit to pick up a small amount of load, perhaps 5 or 10%. After the necessary number of units have been synchronized, the control knob is turned in the "Raise" direction, and all units will pick up load in proportion to their capacities. When the wattmeter shows zero power flowing through the tie breaker, the breaker is opened. Since the wattmeter circuits of all the load computers are now delivering the same voltage to the paralleling lines as is the load transfer control, the control switch is turned to "Normal" which disconnects the power transfer control from the paralleling lines. The governors now function normally to control the units. This control is also very convenient when transferring the load back to the external power source.

SHUTDOWN SOLENO ID

When required, the LSG-10 governor is furnished with a shutdown solenoid mounted on the cover. By means of suitable linkage, it raises the relay valve plunger which causes the relay servo piston to move all the way to the fuel-off position. A direct current solenoid is normally furnished. When the supply is alternating current, two small silicon diodes are burnished to permit using the DC solenoid.

Four arrangements are available, as specified:

1. Energize to shut down. No latch.

2. For use when the shutdown voltage may not be maintained long enough to be sure the unit will come to a complete stop, a latch is furnished. This holds the solenoid armature in the shutdown position, and must be released manually before the unit can be re-started.

3. Energize to run. No latch.

4. When current to hold the shutdown solenoid in the run position is taken from the unit itself, a starting latch is furnished. The solenoid can then be manually latched in the run position. When current is applied to the solenoid, its armature moves a small additional distance in the run direction, and this releases the starting latch.

OPERATING PROCEDURES

The operation of a plant with LSD governors is very little different than with conventional hydraulic governors with which power plant men are already familiar. These new governors are much easier to use, but you should use the methods described below, not some of the old and some of the new together. There are at least six operating conditions. In general, the following instructions apply to steam turbines as well as internal combustion engines.

PROCEDURE NO. 1

ADDING A UNIT TO THOSE ALREADY RUNNING

Start the unit and allow it to warm up as instructed by the manufacturer. Use the speed adjusting knob and load limit as you would with any hydraulic speed governor. This need not be changed. Before closing the unit circuit breaker, be sure to turn the load limit up to its maximum position.

Using the speed adjusting knob, or the speed adjusting motor switch on the switchboard, match the speed of the unit to that of the line and close the breaker, all in the usual way. The load sensing mechanism will cause the unit to take on approximately its share of load, and the other units will give up this amount of load. It is not necessary to go from unit to unit readjusting load balance as often was necessary with conventional speed governor systems.

If the load division is only fairly good after synchronization, let the oncoming unit run for five or ten minutes to reach normal operating temperature. Then rebalance the load with the speed setting switch or the load division switch. The load should now remain divided quite accurately among all units.

If system frequency is not quite correct, adjust it by means of the speed adjusting knob of the unit which is acting as the master. You can also use the speed adjusting motor, but it is easier to make a small adjustment manually. If you make more than a very small change in speed setting, operate the load division switches on all the other units for a few seconds. DON'T EVER OP-ATE THE LOAD DIVISION SWITCH OF THE UNIT WHICH IS SERVING AS THE MASTER.

If you are going to take the unit that is serving as the master off the line, turn the master selector switch to a position corresponding to some other unit on the line. (If the plant uses a time and frequency controller instead of the trimmer switches in some one of the governors, it is not necessary to operate the master selector switch -- in fact there may not even be a master selector switch.)

PROCEDURE NO. 2

SHUTTING DOWN A UNIT

To take a unit off the line, just open the breaker. Don't unload the unit first. If you unload the unit before opening the breaker, frequency will drop, and will Jump up when the breaker is opened. If you leave the load on

the unit and just open the breaker, there will be almost no noticeable deviation in frequency. The unit may now be shut down with the load limit or by some other method as recommended by the unit manufacturer.

PROCEDURE NO. 3

STARTING A PLANT THAT HAS BEEN SHUT DOWN

The speed droop should be set the same on all governors, about 5 on the dial unless special instructions have been received.

Start the units as instructed by the manufacturer. If you leave the speed adjustment settings as they were when the plant was shut down, they will' be almost correct, but the units may run just a little slow until they reach operating temperature. This is because many units require more fuel or steam to run at normal speed when cold than when warm. As you prefer, you may reset the speed adjustment as each unit is started, then re-set again when they warm up, or you may leave the speed as it is and wait a few minutes for the units to come to operating temperature. Match the speed of each unit to the speed of the first one in the usual way and close the breakers. Apply the load to the plant. After a few minutes, when the units have reached operating temperature, check system frequency and, if necessary, adjust the speed setting of all units to correct frequency while maintaining equal load division. If the system has a trimmer, reset frequency by adjusting the speed setting of the master governor only. Now, if necessary, rebalance load on all other units with their speed setting switches or load division switches.

PROCEDURE NO. 4

TRANSFERRING THE LOAD FROM A UTILITY OR OTHER LARGE SYSTEM TO THE LOCAL PLANT

Unless special equipment is provided, a generator unit with an LSG governor cannot be operated in parallel with a large power system. The load sensing mechanism would cause it to move instantly to either the minimum or maximum fuel position. For this reason, the power transfer control shown in Figure 19 is required. After starting the unit or units that are to carry the load, turn the control knob all the way to the left and turn the switch to "Parallel" position. The units may now be synchronized to the line in the usual, way, and each will take on a small amount of load. After they are all synchronized, turn the control knob slowly to the right. All the units will take on load, each in proportion to its size. Continue to pick up load until the switchboard instruments show that the local plant is carrying all the load, and no power is being taken from the utility system. Open the circuit breaker between the plant and the utility. Turn the control switch to "normal". Check system frequency, and if necessary, adjust it at the governor which is serving as the master. Operate the load division switch of all units except the master for a few seconds. After the units have warmed up to normal operating temperature, re-check speed.

To transfer power back to the utility system, turn the control switch to "adjust". Now turn the control knob left or right as required to bring the needle of the meter to zero, in the middle of the scale. Turn the control switch to "Parallel". Energize the synchroscope or synchronizing lights. Now turn the control knob up (right) or down to control frequency of the plant. After paralleling, turn the control knob to the left to unload all the units simultaneously, after which the breaker connecting the plant to the utility

may be opened, or the breakers of the individual units may be opened.

Normally the power transfer control is furnished with a removable handle which is inserted in the switch only when the load is to be transferred to or from the plant.

PROCEDURE No. 5

SINGLE UNIT OPERATION

When only one unit is to be run at a time, and when there is no trimmer connected, the speed droop can be set at 5 or zero. Adjust frequency with the speed adjustment in the usual way. In a plant which has a trimmer, always leave the speed droop setting at 5, even when only one unit is to be run.

ALTERNATE OPERATING PROCEDURES -- NO TRIMMER USED

Where there is a very linear relationship between governor terminal shaft travel and kilowatt output from the generator, all governors can be set with speed droop at about 5 and the frequency will be maintained without the need for a trimmer. Even if there is some nonlinearity, the frequency error can be reduced by setting one governor in the plant for zero droop. If there is any frequency error, its speed governor will change the fuel or steam setting of that one unit to correct it. Since the load governor section of all the governors will be in the same position, this additional movement of the one governor will cause a comparatively small unbalance in the load division between units. Normally this load division error will be small enough to be ignored, but if desired the operator can correct it by making a very small change in the speed setting of the governors with speed droop. This method of operation has the advantage of simplifying the equipment required, yet it gives excellent control and places a negligible burden on the operators. It has the additional advantage, in the case of experienced operators, of being very similar to the procedures they have always used.

ANOTHER ALTERNATIVE

Operate the plant as described above with zero speed droop on one governor. A single knob can be placed on the switchboard to modify by a small amount the electric signal and hence the position of all the load governor servo pistons. When the unit wattmeters indicate more load division error than is desired, a small adjustment of this one control will correct it.

As in the use of the trimmer to correct small frequency errors, these two methods of manually correcting small load division errors are required to compensate for small changes in fuel or steam requirements under various conditions, non-linearity in fuel pumps, or gas or steam valves, or inaccuracies in linkage from the governor to the mechanism it controls.

MAINTENANCE

The service life of any well built hydraulic governor depends primarily on the cleanliness of the oil put in it and the degree of roughness in the dive from the unit to the governor. For long, trouble-free governor life, keep the governor clean, and at frequent intervals check the tightness of any chain and the mesh of gears which transmit rotation to the governor drive shaft. Once a year (oftener

in dusty locations) remove the governor from the unit and flush it thoroughly with fuel oil, kerosene or any other solvent that will not damage oil seals, gaskets or paint; remove magnetic pipe plug from front of governor and clean it off. It is very important to flush out all of the solvent, so it won't mix with the oil and form deposits. This can be done by first filling the governor with the oil that is to be used in It. Next, set the governor on two blocks on a bench and turn the drive shaft several turns by hand to pump the oil into all the passages. Then pour out this oil and, with the governor upside down, turn the drive shaft several revolutions by hand. To do a good Job, repeat this flushing with clean oil to eliminate all of the solvent, then put the governor back on the engine and fill with clean new oil. If a very light oil, such as SAE 5, is available in the same type as the heavier oil to be used in the governor in regular service, it would be excellent for flushing out the solvent. As mentioned earlier in this bulletin, the same oil as that used in the engine crankcase is probably as good as any other to use in the governor. We suggest that a smoothly curved pitcher having no seams, to avoid accumulations of dirt, be used when adding oil to the governor.

OVERHAUL AND TROUBLE SHOOTING

Part of the price one pays for the superior control obtained from a speed and load sensing governor is increased difficulty in overhaul and especially in adjustment. We do not recommend that power plant personnel or engine specialists do any work on these governors beyond cleaning and checking to determine in what part of the equipment any trouble lies. Experience with over a half million governors indicates that they almost never stop working suddenly, unless they have been badly neglected. If such a failure should occur, it is doubtful if any assortment of spare parts would be adequate to make repairs. In general, governors wear gradually and give an indication of their condition in the form of slowly deteriorating control. Further deterioration is at a slow enough rate so it should be possible to obtain an exchange or replacement governor, even in the most remote plant.

PLACES WHERE TROUBLE MAY OCCUR AND HOW TO LOCATE THEM

1. LINKAGE - If a governor which was originally satisfactory gradually starts to hunt or becomes sluggish or inaccurate in its operation, and the trouble is not due to dirt, it may be due to general wear within itself, or it may be due to friction or lost motion in the linkage from the governor to the fuel pumps. It is easy to look for and to correct linkage troubles, so do this first.

2. NO LOAD SENSING ON THE SYSTEM - There are at least two easy ways to tell if the load sensing is not functioning. If the governors are set to have speed droop, as is usually the case, system frequency will increase as load gradually decreases, and frequency will decrease as load increases. On large load changes, the governors will not move as rapidly as usual and the temporary speed change will be larger than it should be.

3. NO LOAD SENSING ON ONE UNIT - With the unit on the line and carrying load, remove the connector plug at the governor. If the load governor is functioning, the indicator on the side of the governor will jump toward zero load position and the load shown by the unit wattmeter will go toward zero. When the plug is replaced, fuel or steam will be applied again and the unit will pick up load.

   You will also notice if there is trouble with the load sensing mechanism of one governor only because it won't pick up its share of load when it is paral-

leled with the line. (If you want to use the unit for power, without waiting to correct the load sensing trouble, remove the cord plugs from the computer, then just pick up the desired amount of load in the usual way with the speed adjusting motor switch. It will act like any governor with speed droop in a plant where another unit or units maintain constant frequency.)

With the engine running, but not connected to the bus, touch two wires from 6 to 12 volts of flashlight batteries to terminals A(+) and B(-) in the governor receptacle. The governor terminal shaft will turn rapidly toward the 100% load position. This will cause the speed to increase momentarily, but the speed governor will immediately return it to normal. When you remove the battery wires, the terminal shaft will Jump toward the no load position, and again the speed governor will quickly return it to the correct value. NOTE: Use small flashlight batteries, as suggested, so that if you accidentally touch the wrong contacts, you won't burn them up, as you would if you used a storage battery. This indicates that the mechanism in the governor itself is functioning. If there is no response to application of voltage to governor terminals A and B, check between them with an ohmmeter. A reading of 35 to 40 ohms is about right. Check visually for broken wires inside the governor, without doing any disassembling.

4. COMPUTER - If the above check indicates that the load governor is working correctly, it is apparent that it is not receiving current from the load computer. Parallel the engine with the line and use the speed adjustment to pick up half load or more. Check the input plug to the computer, as described under installation instructions, then check computer output. Use the test adapter, with the output cord plugged into it, so that terminals a and b and c and e will be jumpered together. Even without this, of course, you could check for voltage between d and a, and between d and h. If the voltage between d and a varies with generator load, but the voltage from d to c does not, the a-b jumper is open somewhere outside the computer. If d to c voltage varies with load, but d to e does not, the c to e jumper is open.

   If all of the above checks indicate satisfactory operation, connect a 35 or 40 ohm, 25 watt resistor from g to h. This should be done with the plug at the governor removed. You should measure across this resistor a voltage that will vary between about 1 and 12 volts as generator load varies from zero to full load. If this is normal and the load governor was working properly, insert the resistor in the plug that normally goes in the governor receptacle to see if the current reaches this point.

5. TRIMMERS - Thorough testing has shown that the potentiometers used in both types of trimmer will last for years, but they could eventually give trouble. The shaft bearing may wear out or seize, or there may be wear and failure of the brush or the resistance windings. These sources of trouble should be easy to locate. In an emergency, suitable temporary potentiometers could undoubtedly be secured at a local electronic supply house. However, the type we furnish have been thoroughly life-tested. Install the now one in the same manner the old one was installed. Be sure the limit switches open their contacts before the brush reaches either end. In the four potentiometer arrangement, be sure all the brush arms are synchronized, so one does not reach the end of its stroke before the others do.

Depending on engine characteristics, excellent control can usually be obtained with the trimmer removed from service entirely. Remember, the trimmer is only used to correct small speed errors caused by variations in fuel control position required to carry a given load. If the trimmer is the potentiometer type (identified by its 14 wire connector plug) and is to be unplugged and removed from service for any length of time, connect a temporary 500 ohm 10 watt resistor to the wires leading to output terminals d and i, and a 3000 ohm 10 watt resistor between the wires leading to d and j of each load computer.

If the trimmer is the electronic type (identified by its 10 wire connector plug) and it is to be removed from service, connect a temporary 3000 ohm 10 watt resistor between the wires leading to output terminals d and j of each load computer. (This resistor is always used in plants where there is only one engine, and hence no trimmer.)

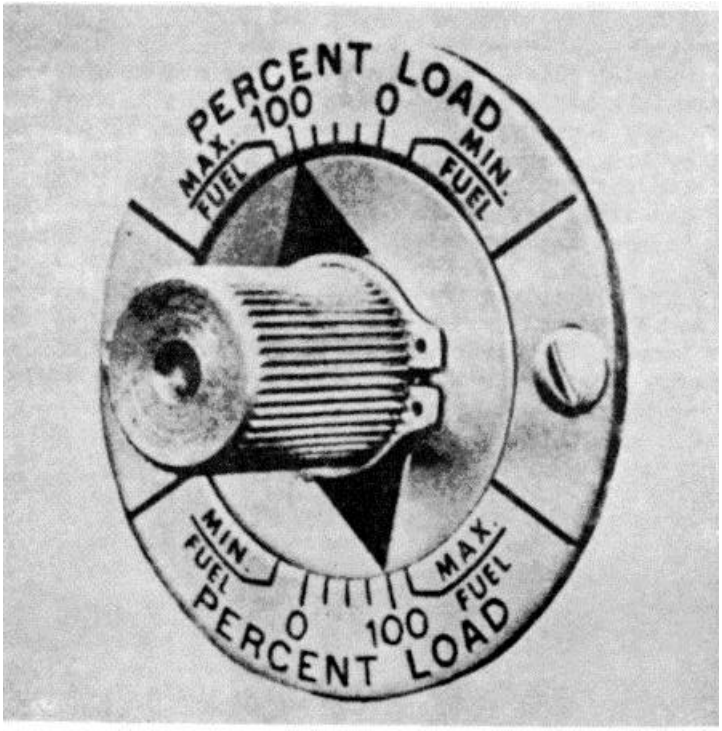


FIGURE 1

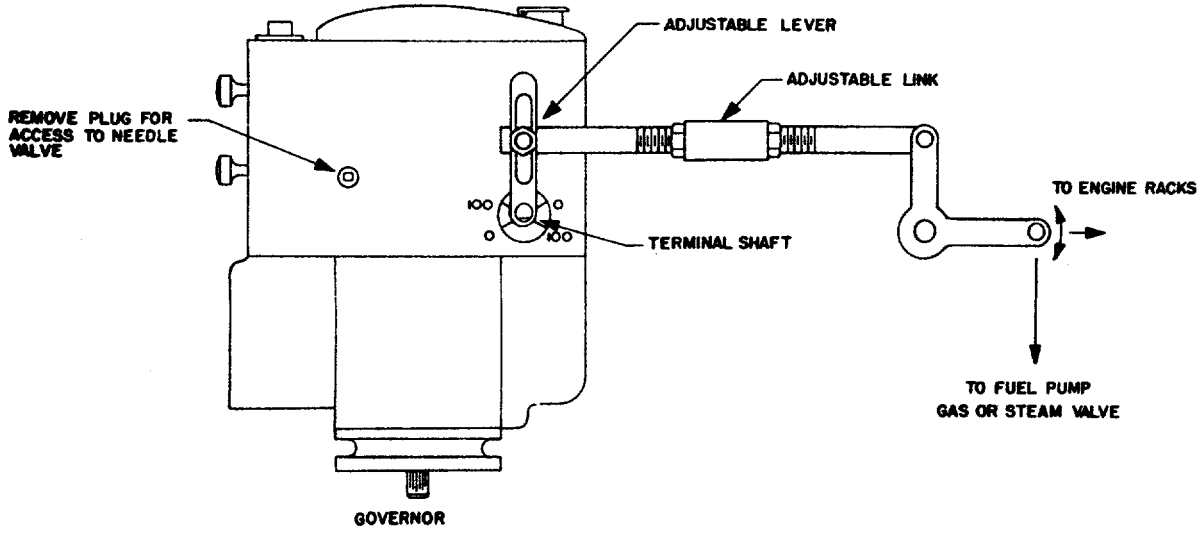


FIGURE 2

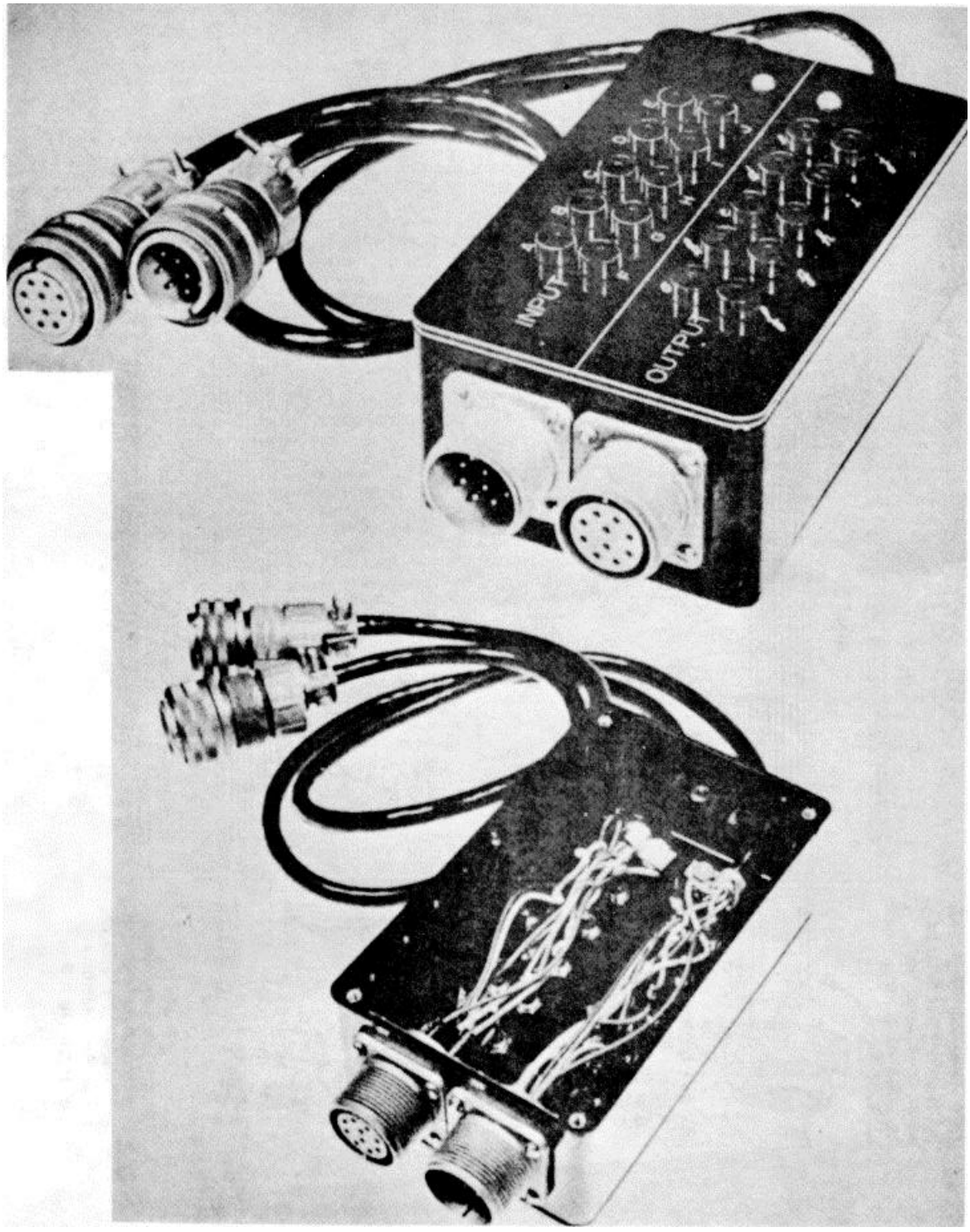


FIGURE 3

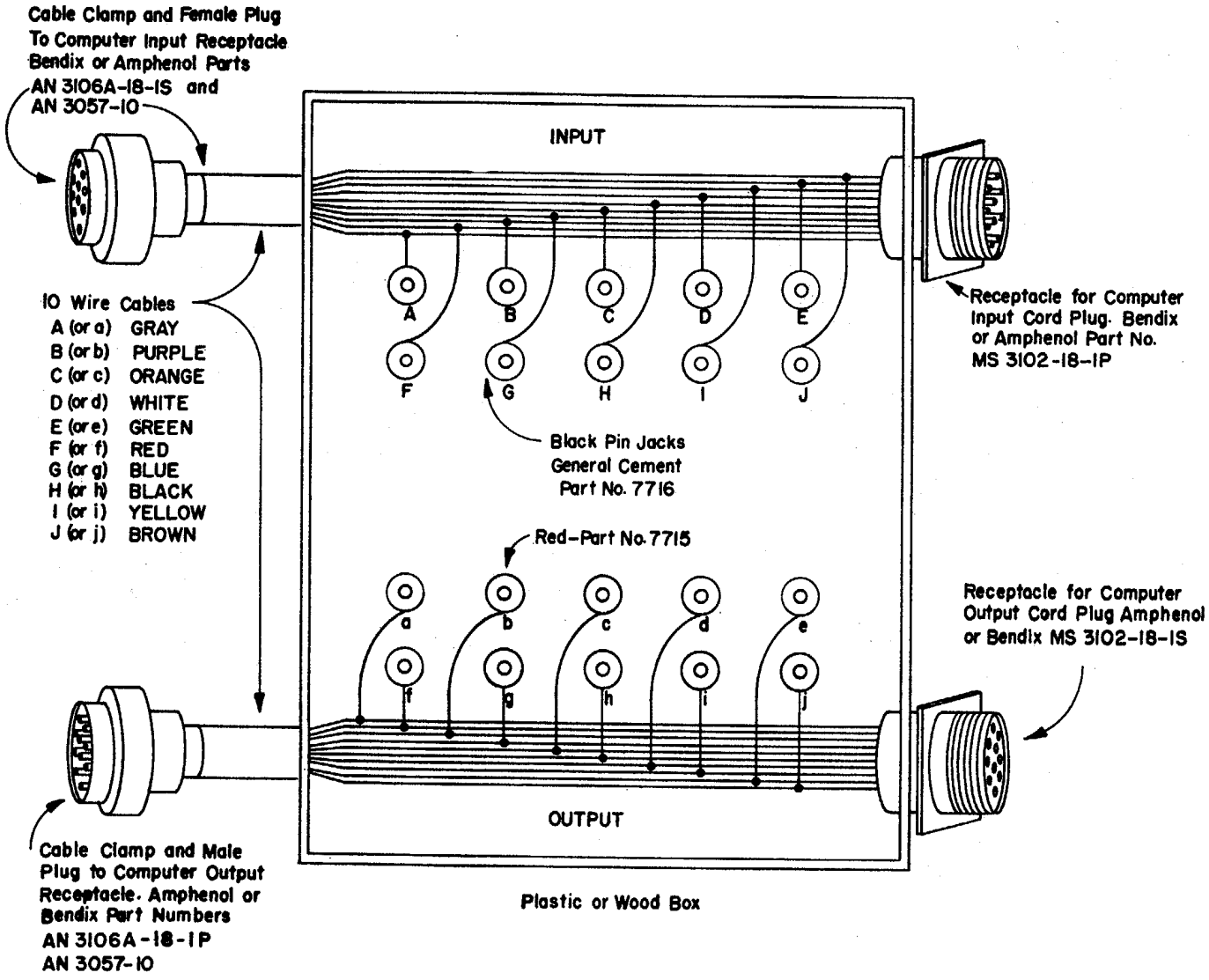

Cable Clamp and Female Plug
To Computer Input Receptacle
Bendix or Amphenol Parts
AN 3106A-18-1S and
AN 3057-10
INPUT
10 Wire Cables
A (or a) GRAY
B (or b) PURPLE
C (or c) ORANGE
D (or d) WHITE
E (or e) GREEN
F (or f) RED
G (or g) BLUE
H (or h) BLACK
I (or i) YELLOW
J (or j) BROWN
A
B
C
D
E
F
G
H
I
J
Receptacle for Computer
Input Cord Plug. Bendix
or Amphenol Part No.
MS 3102-18-1P
Black Pin Jacks
General Cement
Part No. 7716
Red-Part No. 7715
a
b
c
d
e
f
g
h
i
j
Receptacle for Computer
Output Cord Plug Amphenol
or Bendix MS 3102-18-1S
OUTPUT
Cable Clamp and Male
Plug to Computer Output
Receptacle. Amphenol or
Bendix Part Numbers
AN 3106A-18-1P
AN 3057-10
Plastic or Wood Box

FIGURE 4

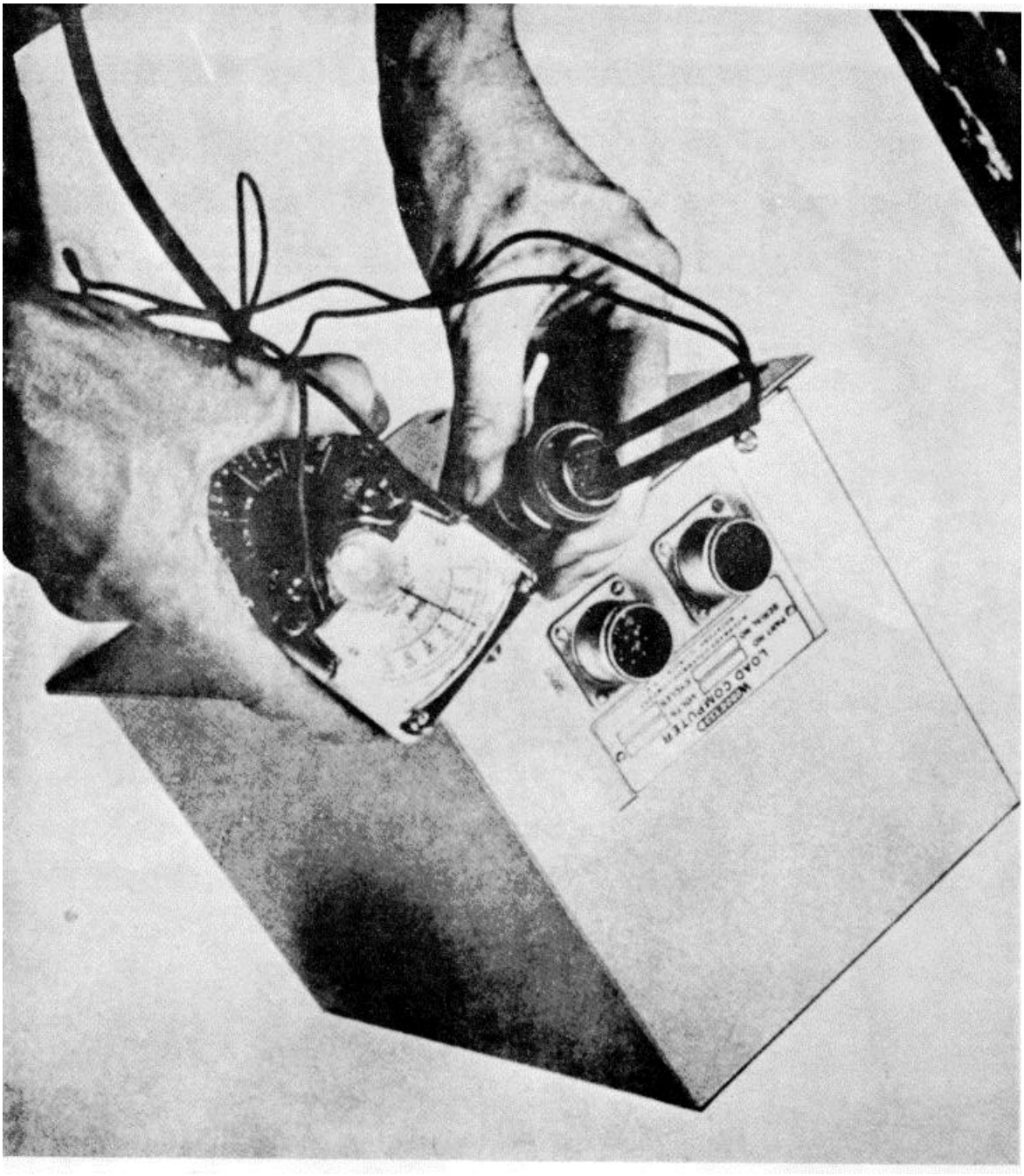


FIGURE 5

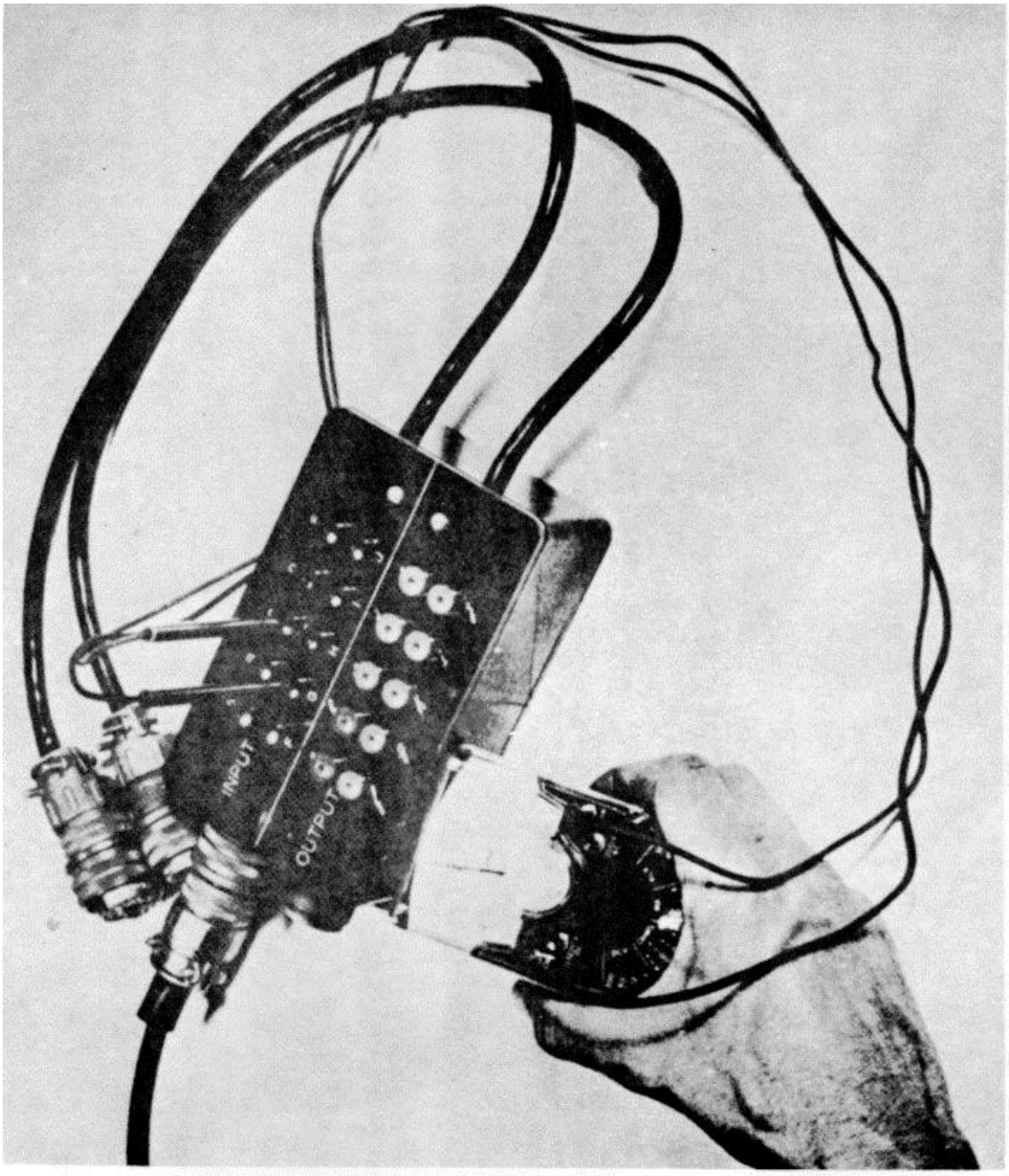


FIGURE 6

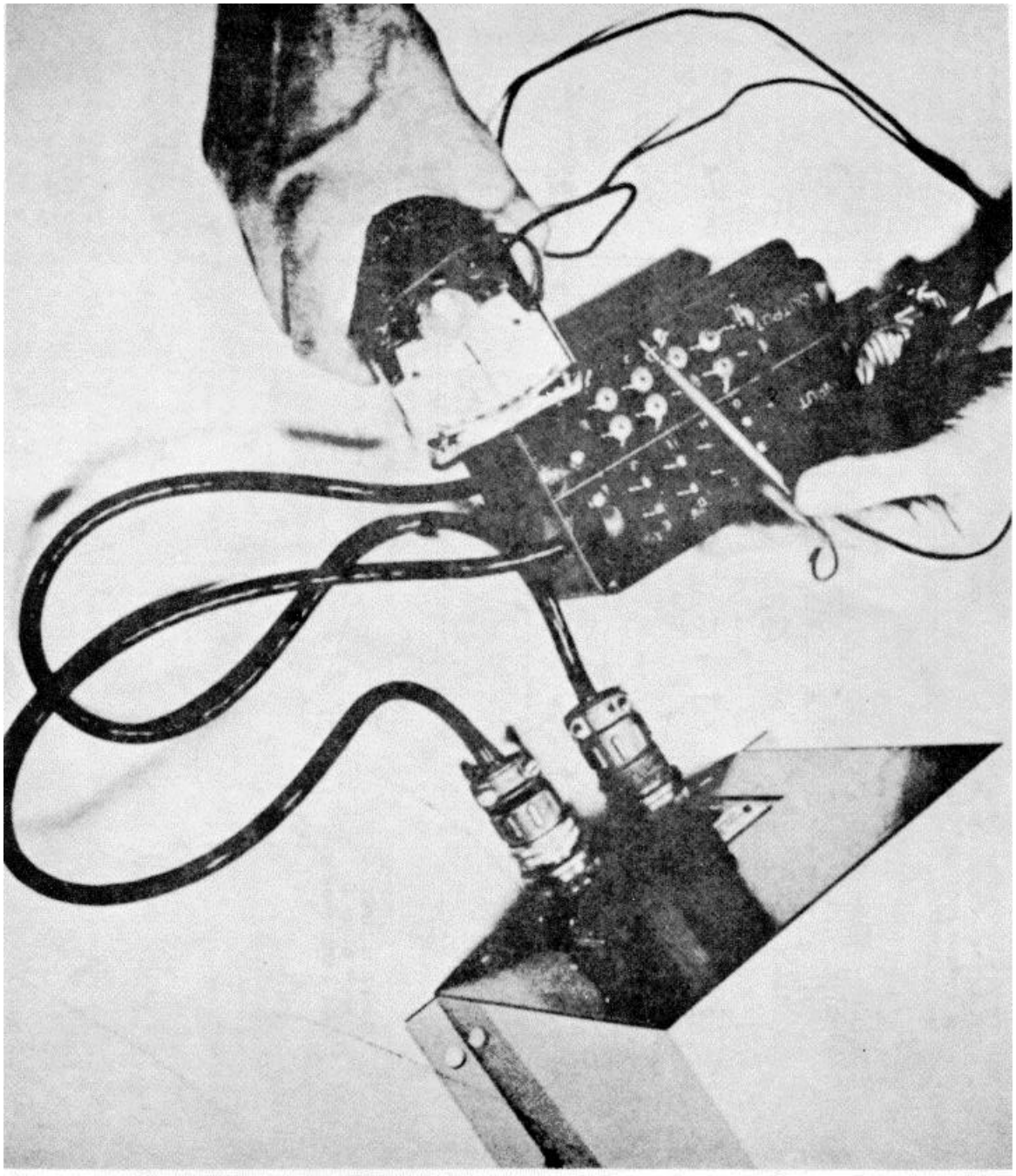


FIGURE 7

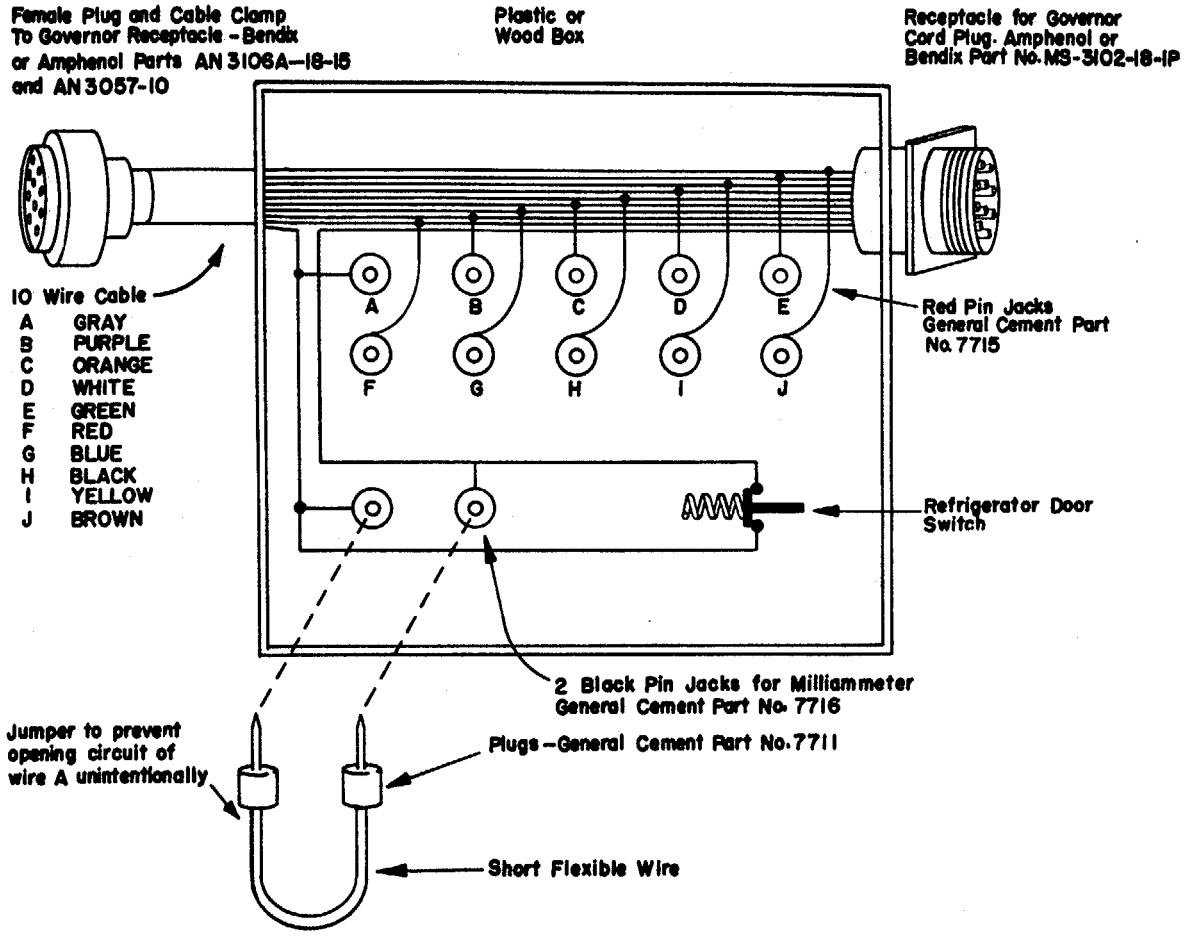

Female Plug and Cable Clamp
To Governor Receptacle - Bendix
or Amphenol Parts AN 3106A-18-15
and AN 3057-10
Plastic or
Wood Box
Receptacle for Governor
Cord Plug. Amphenol or
Bendix Part No. MS-3102-18-1P
10 Wire Cable
A GRAY
B PURPLE
C ORANGE
D WHITE
E GREEN
F RED
G BLUE
H BLACK
I YELLOW
J BROWN
A
B
C
D
E
F
G
H
I
J
Red Pin Jacks
General Cement Part
No. 7715
Refrigerator Door
Switch
2 Black Pin Jacks for Milliammeter
General Cement Part No. 7716
Jumper to prevent
opening circuit of
wire A unintentionally
Plugs - General Cement Part No. 7711
Short Flexible Wire

FIGURE 8

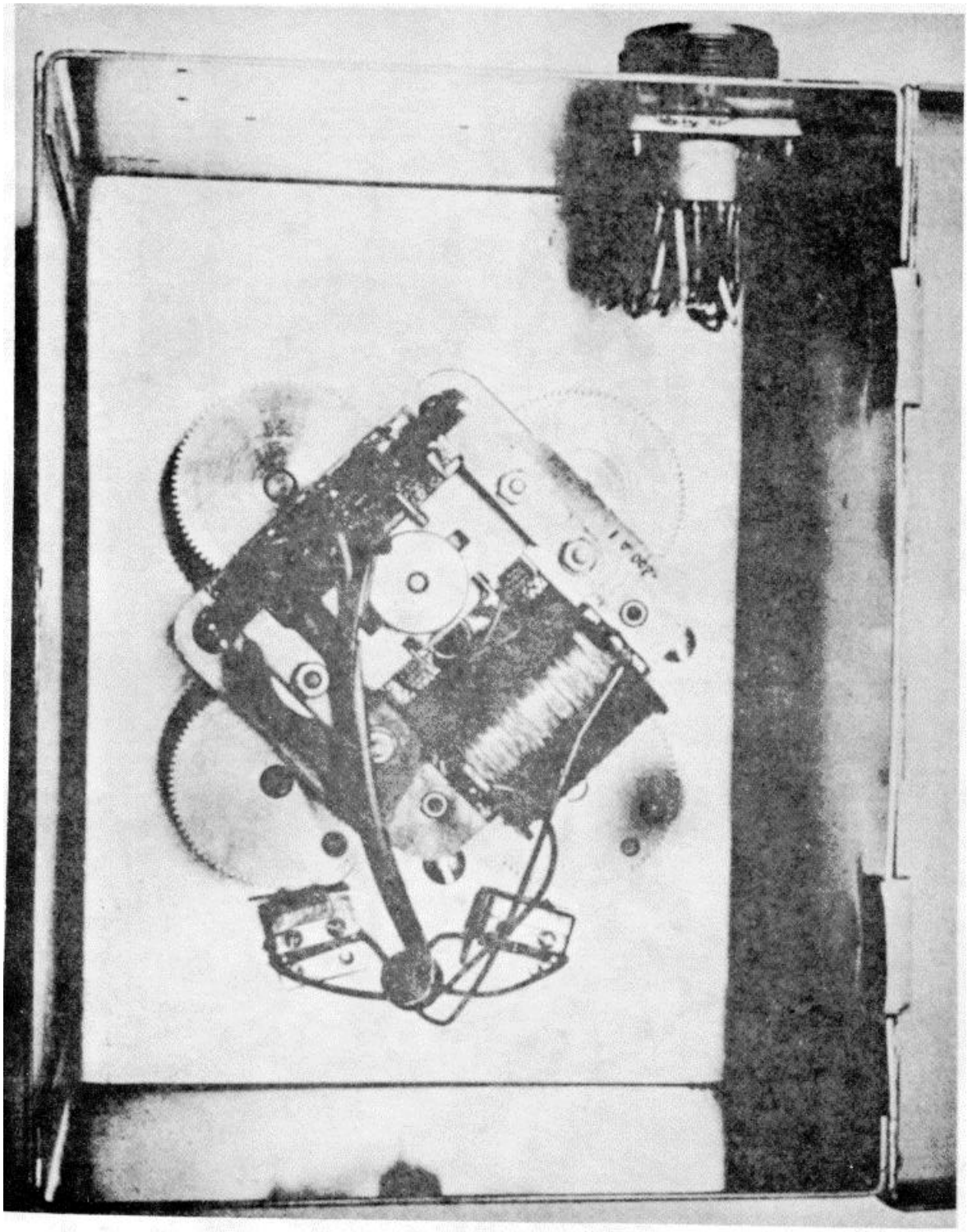


FIGURE 9A

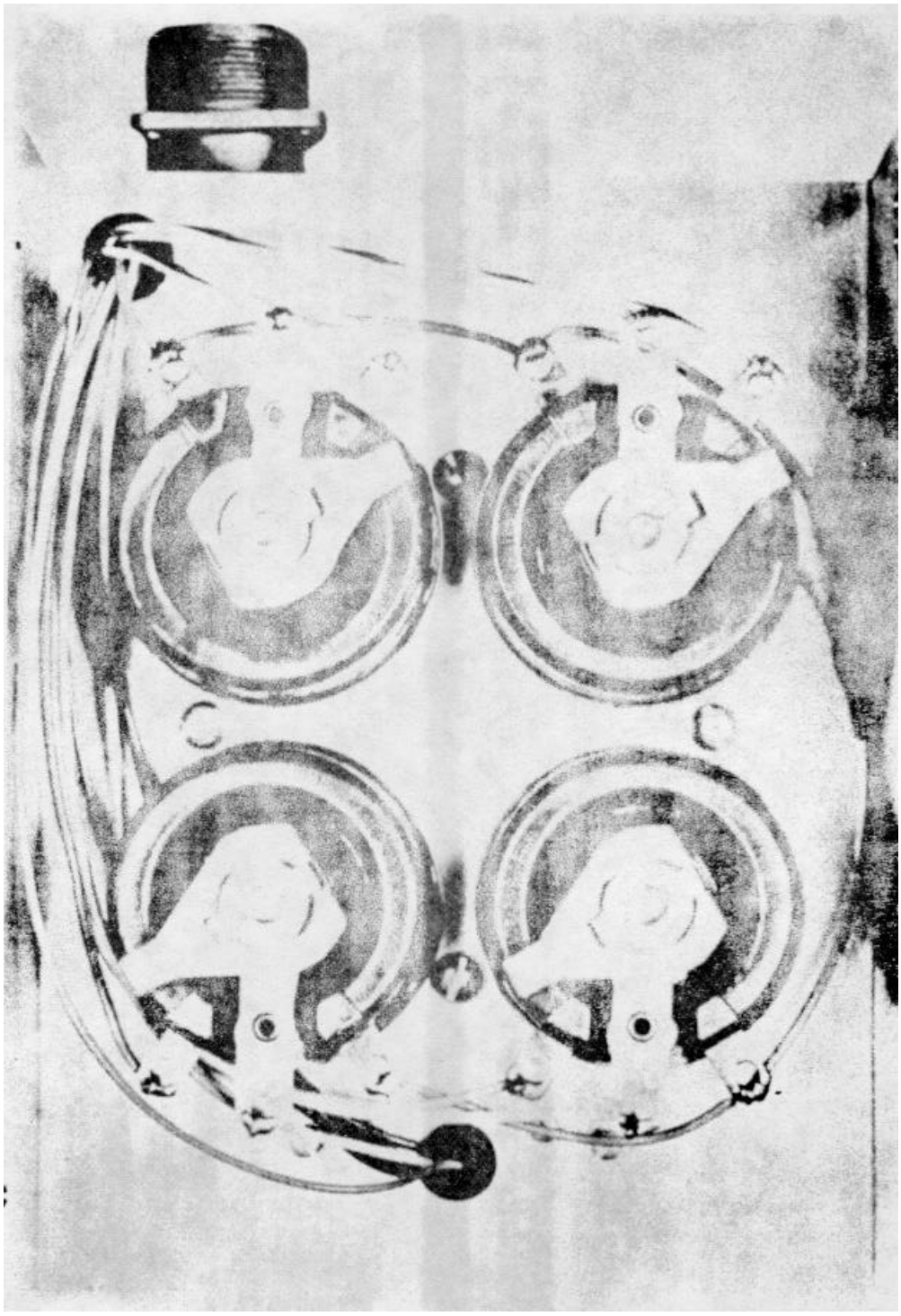


FIGURE 9B

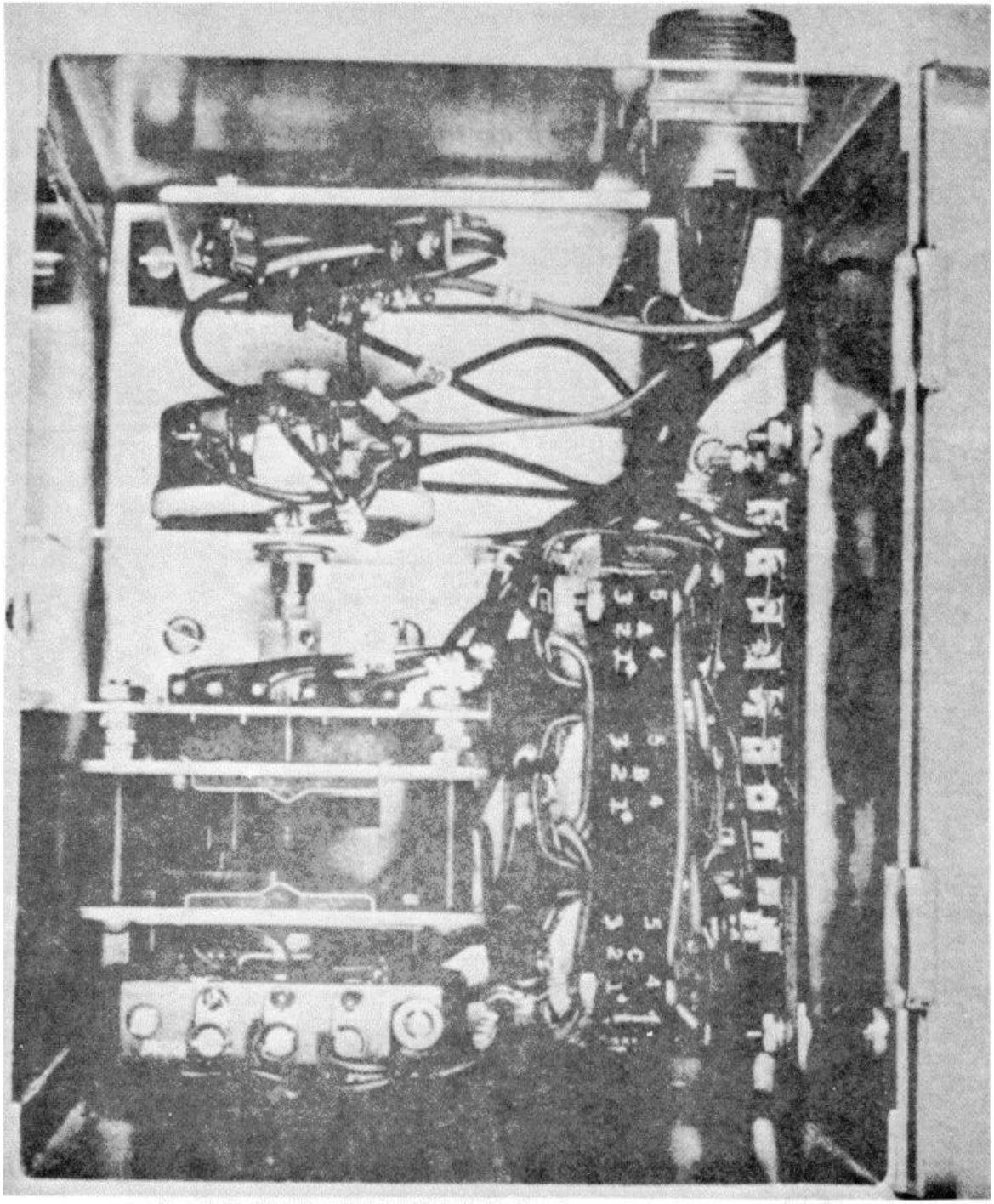


FIGURE 10

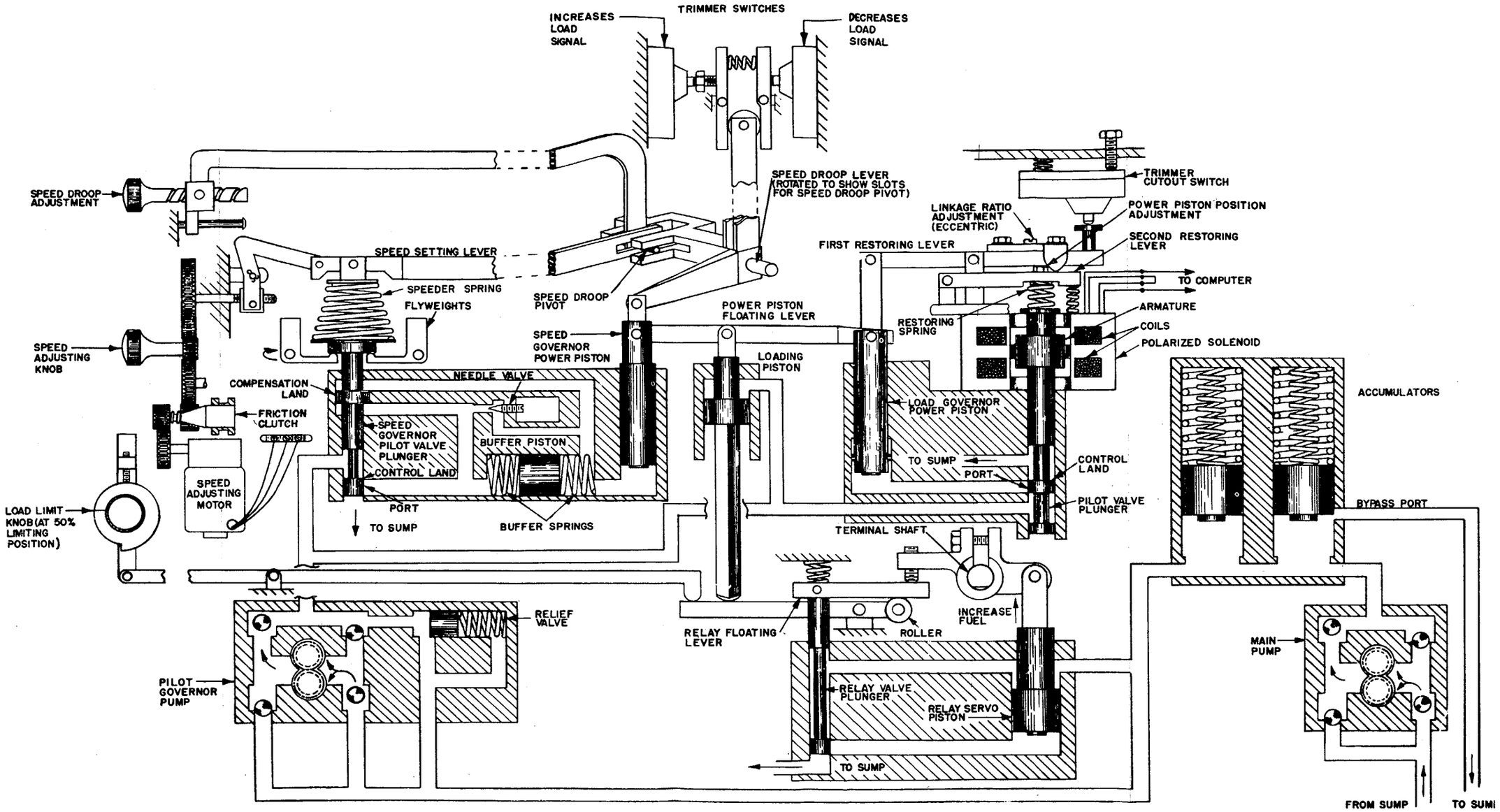
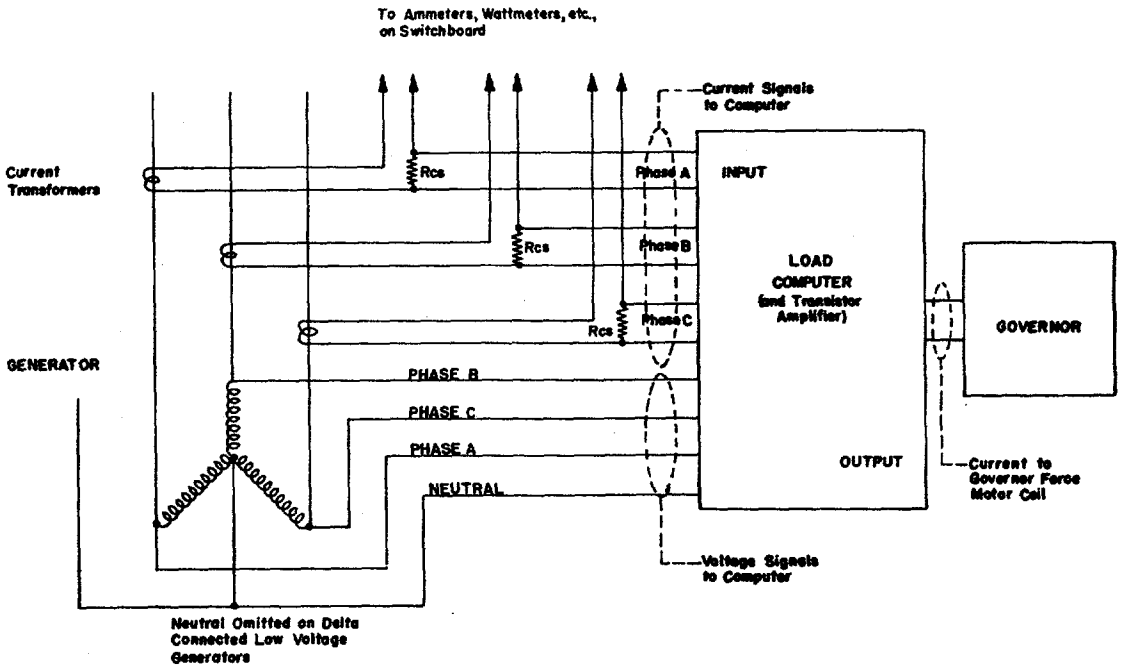

INCREASES LOAD SIGNAL
TRIMMER SWITCHES
DECREASES LOAD SIGNAL
SPEED DROOP ADJUSTMENT
SPEED DROOP LEVER (ROTATED TO SHOW SLOTS FOR SPEED DROOP PIVOT)
TRIMMER CUTOUT SWITCH
LINKAGE RATIO ADJUSTMENT (ECCENTRIC)
POWER PISTON POSITION ADJUSTMENT
SECOND RESTORING LEVER
FIRST RESTORING LEVER
SPEED SETTING LEVER
SPEEDER SPRING
FLYWEIGHTS
SPEED DROOP PIVOT
TO COMPUTER
ARMATURE
COILS
POLARIZED SOLENOID
POWER PISTON FLOATING LEVER
RESTORING SPRING
SPEED ADJUSTING KNOB
SPEED GOVERNOR POWER PISTON
LOADING PISTON
NEEDLE VALVE
COMPENSATION LAND
FRICTION CLUTCH
LOAD GOVERNOR POWER PISTON
ACCUMULATORS
SPEED GOVERNOR PILOT VALVE PLUNGER
BUFFER PISTON
TO SUMP
CONTROL LAND
PORT
SPEED ADJUSTING MOTOR
CONTROL LAND
PORT
PILOT VALVE PLUNGER
BYPASS PORT
LOAD LIMIT KNOB (AT 50% LIMITING POSITION)
TO SUMP
BUFFER SPRINGS
TERMINAL SHAFT
RELIEF VALVE
INCREASE FUEL
RELAY FLOATING LEVER
ROLLER
MAIN PUMP
PILOT GOVERNOR PUMP
RELAY VALVE PLUNGER
RELAY SERVO PISTON
TO SUMP
FROM SUMP
TO SUMP

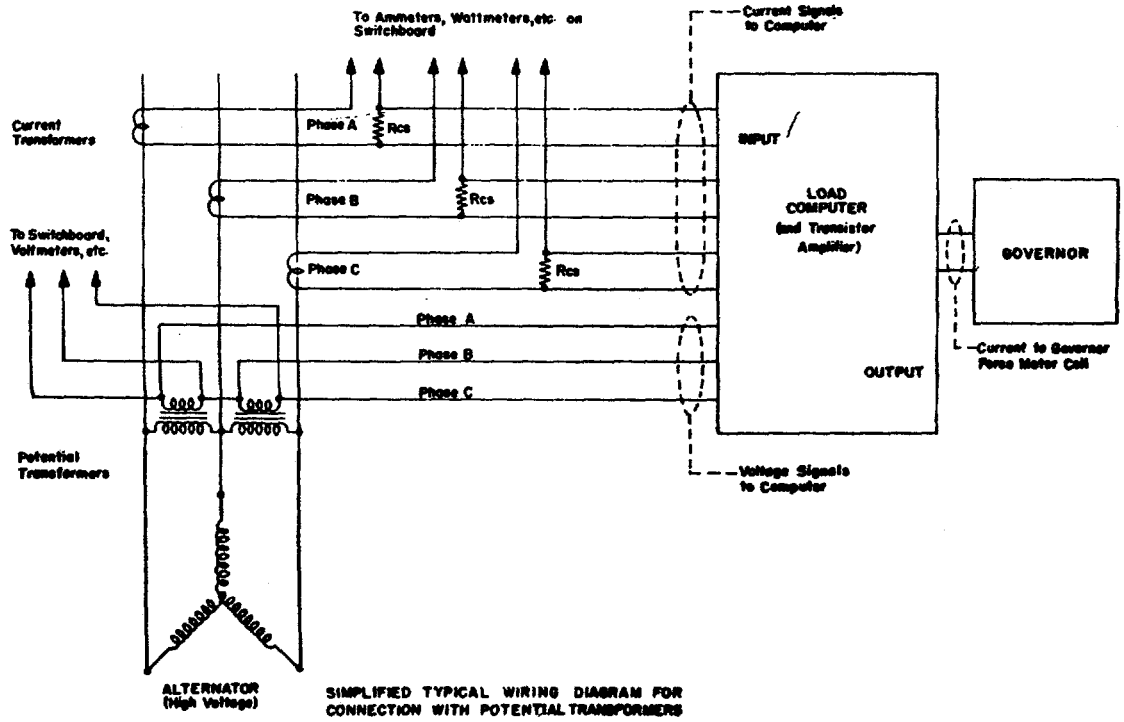
FIGURE 11



SIMPLIFIED TYPICAL WIRING DIAGRAM FOR
LOW VOLTAGE(120-208V Y Connected, or 3 Wire
120or 240 V Δ) Generator

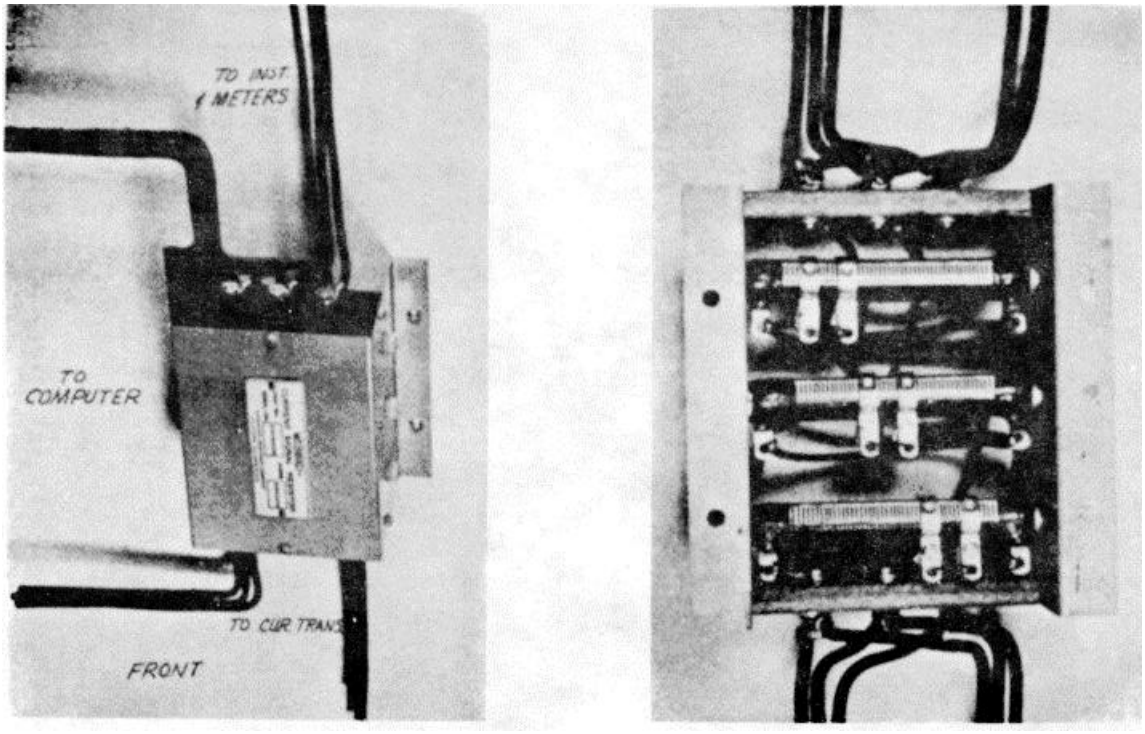
FIGURE 12A

FIGURE 12A

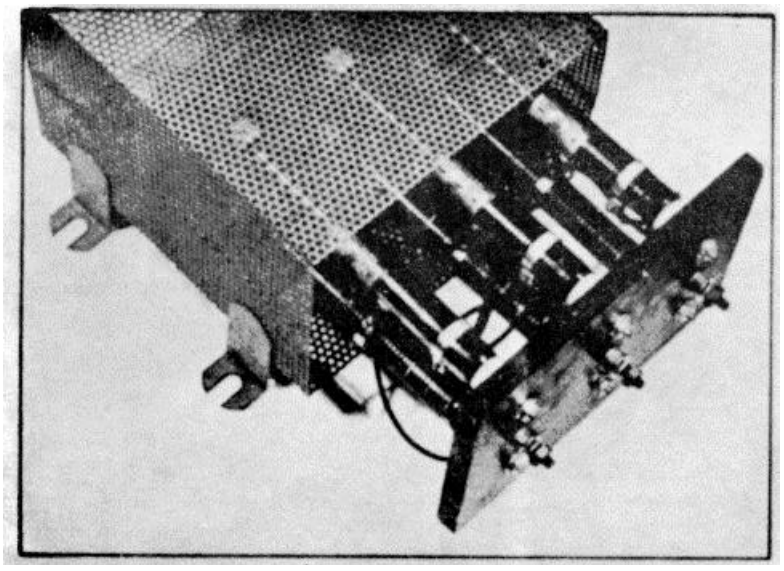


SIMPLIFIED TYPICAL WIRING DIAGRAM FOR
CONNECTION WITH POTENTIAL TRANSFORMERS

FIGURE 12B



New Style Resistor Box



Old Style Resistor Box

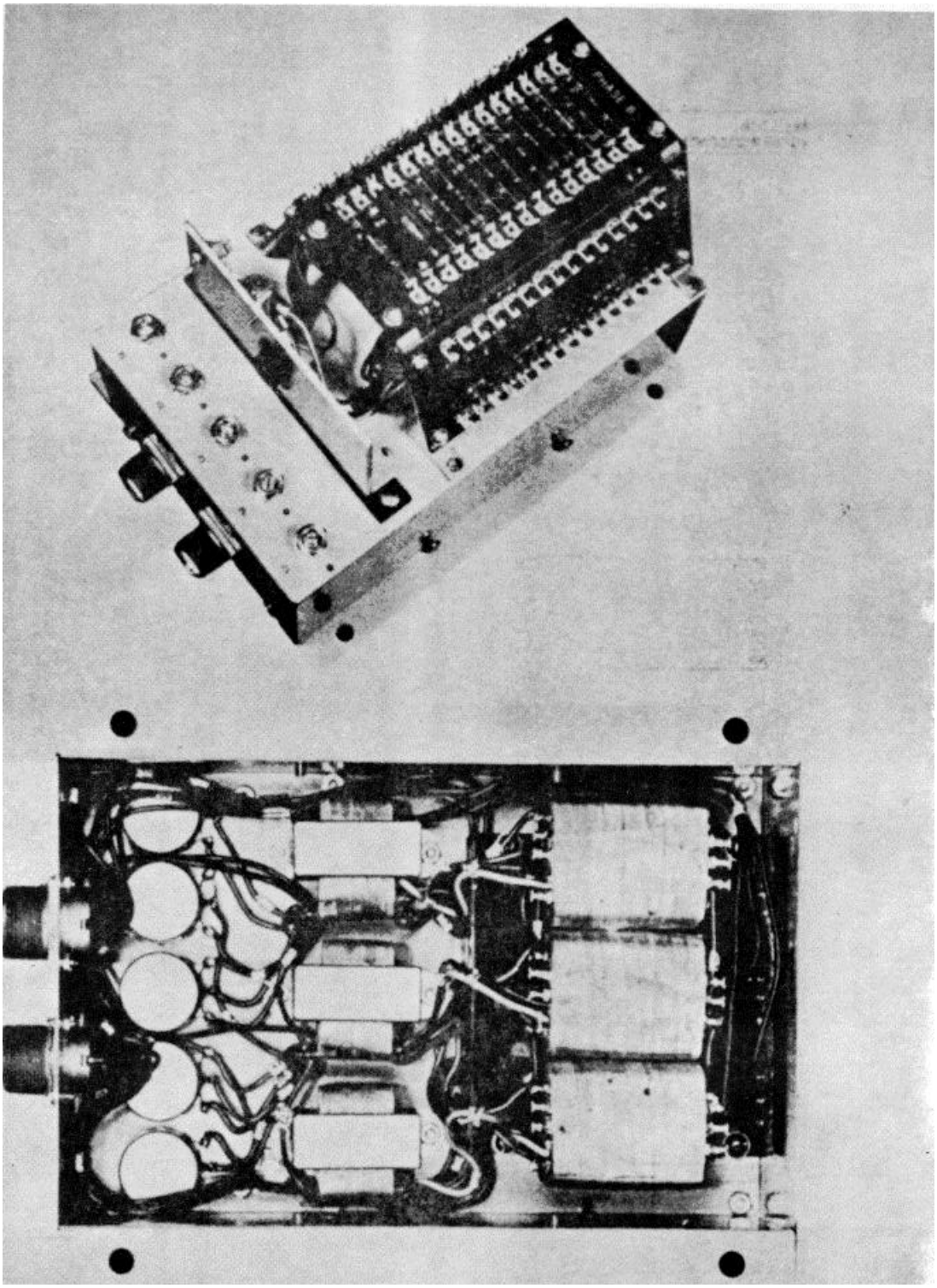


FIGURE 14

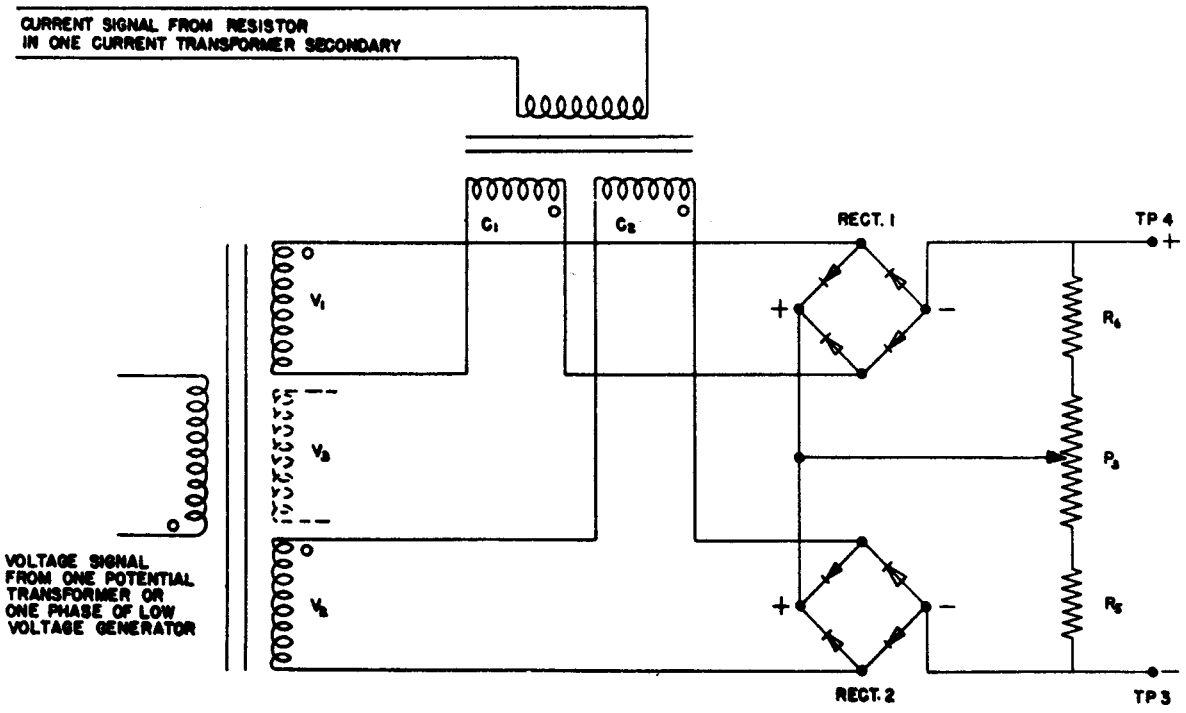


FIGURE 15

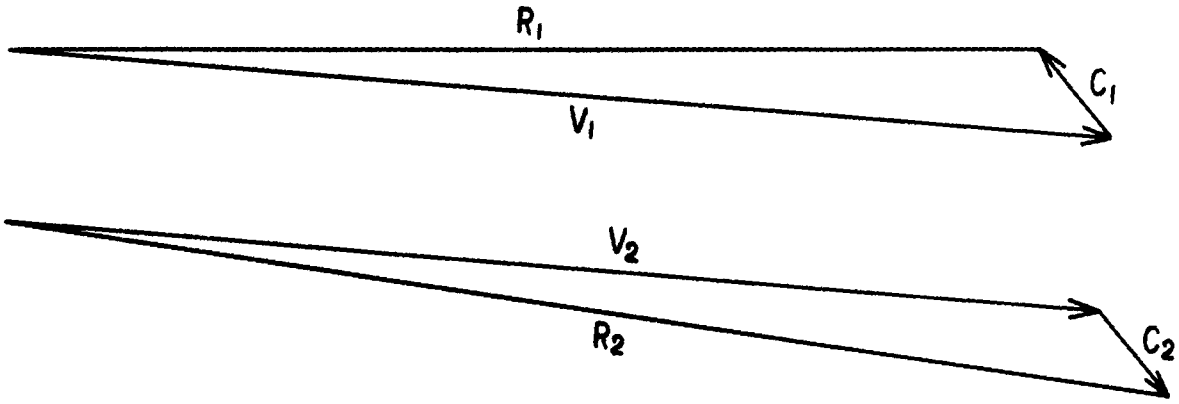


FIGURE 16

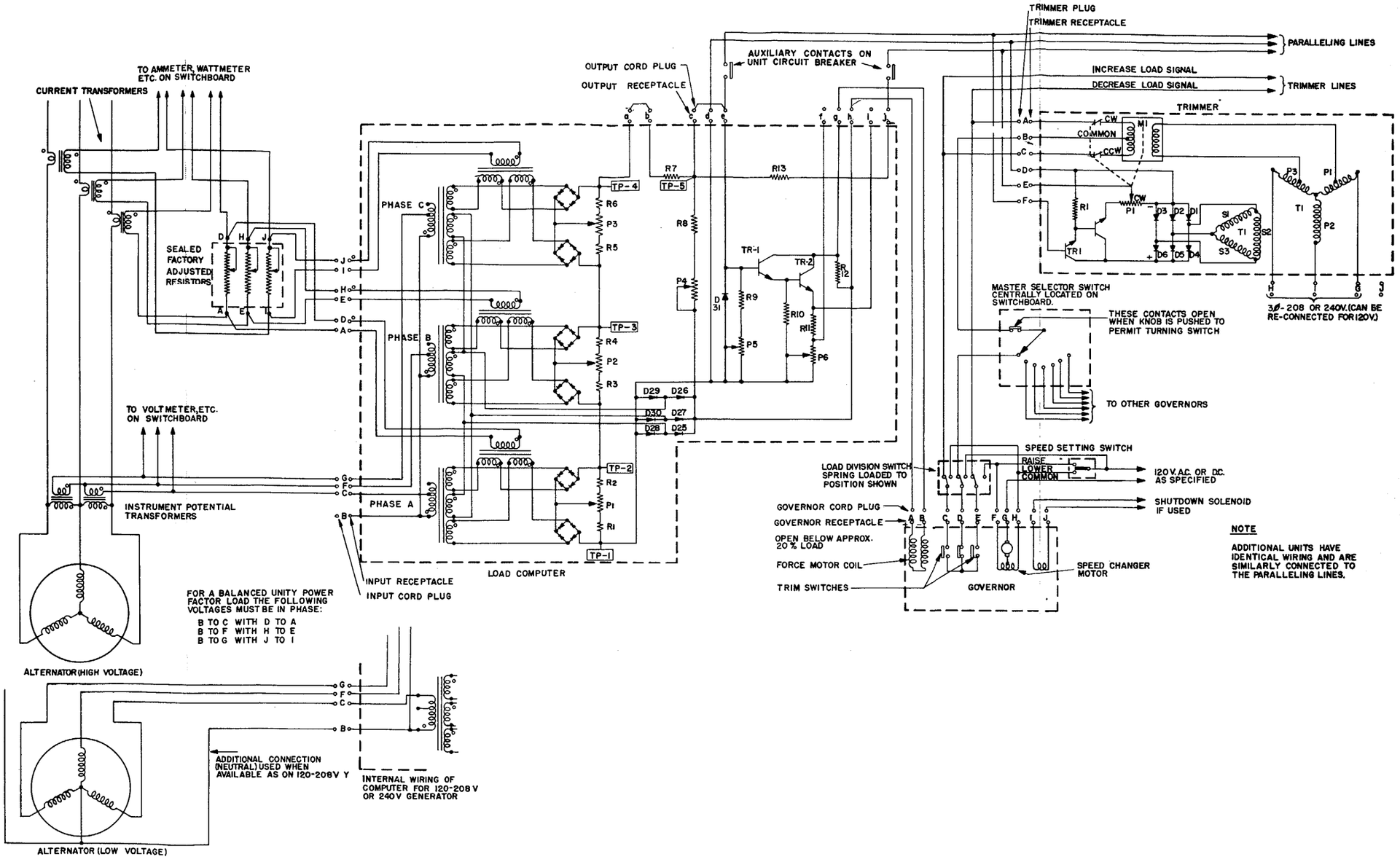

TRIMMER PLUG
TRIMMER RECEPTACLE
PARALLELING LINES
AUXILIARY CONTACTS ON UNIT CIRCUIT BREAKER
OUTPUT CORD PLUG
OUTPUT RECEPTACLE
INCREASE LOAD SIGNAL
DECREASE LOAD SIGNAL
TRIMMER LINES
TRIMMER
TO AMMETER, WATTMETER ETC. ON SWITCHBOARD
CURRENT TRANSFORMERS
SEALED FACTORY ADJUSTED RESISTORS
PHASE C
PHASE B
PHASE A
TP-4
TP-5
TP-3
TP-2
TP-1
R7
R13
R8
P4
R6
P3
R5
R4
P2
R3
R2
P1
R1
TR-1
TR-2
R12
R9
R10
R11
P5
P6
D31
D29
D26
D30
D27
D28
D25
TO VOLTMETER, ETC. ON SWITCHBOARD
INSTRUMENT POTENTIAL TRANSFORMERS
INPUT RECEPTACLE
INPUT CORD PLUG
LOAD COMPUTER
FOR A BALANCED UNITY POWER FACTOR LOAD THE FOLLOWING VOLTAGES MUST BE IN PHASE:
B TO C WITH D TO A
B TO F WITH H TO E
B TO G WITH J TO I
ALTERNATOR (HIGH VOLTAGE)
ADDITIONAL CONNECTION (NEUTRAL) USED WHEN AVAILABLE AS ON 120-208V Y
INTERNAL WIRING OF COMPUTER FOR 120-208 V OR 240V GENERATOR
ALTERNATOR (LOW VOLTAGE)
COMMON
CW
CCW
M1
R1
P1
D3
D2
D1
S1
T1
S2
S3
P3
P2
TR1
D6
D5
D4
3Ø - 208 OR 240V. (CAN BE RE-CONNECTED FOR 120V.)
MASTER SELECTOR SWITCH CENTRALLY LOCATED ON SWITCHBOARD.
THESE CONTACTS OPEN WHEN KNOB IS PUSHED TO PERMIT TURNING SWITCH
TO OTHER GOVERNORS
SPEED SETTING SWITCH
RAISE
LOWER
COMMON
120 V.A.C. OR D.C. AS SPECIFIED
SHUTDOWN SOLENOID IF USED
LOAD DIVISION SWITCH SPRING LOADED TO POSITION SHOWN
GOVERNOR CORD PLUG
GOVERNOR RECEPTACLE
OPEN BELOW APPROX. 20 % LOAD
FORCE MOTOR COIL
TRIM SWITCHES
GOVERNOR
SPEED CHANGER MOTOR
NOTE
ADDITIONAL UNITS HAVE IDENTICAL WIRING AND ARE SIMILARLY CONNECTED TO THE PARALLELING LINES.

FIGURE 17

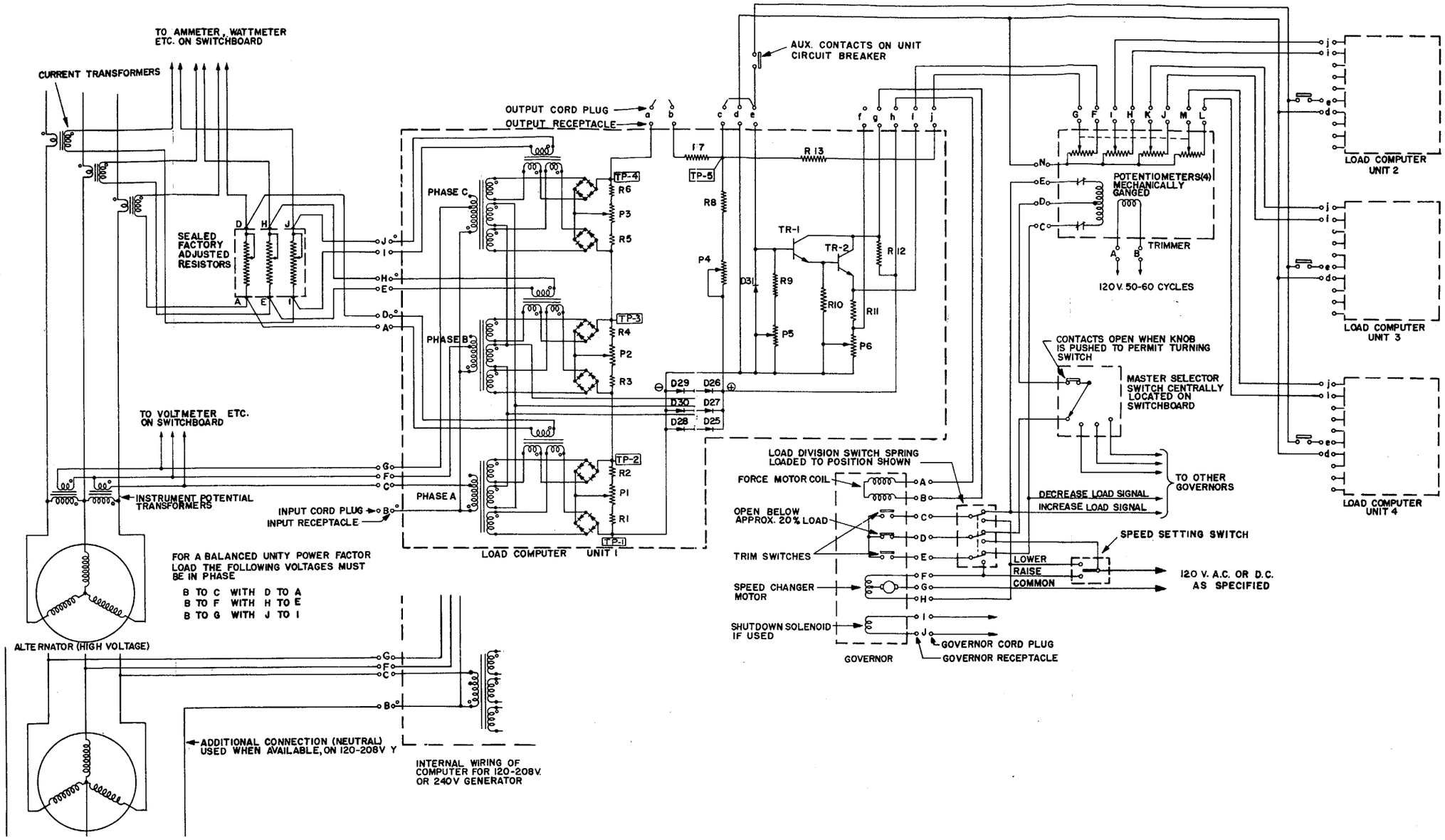

TO AMMETER, WATTMETER ETC. ON SWITCHBOARD
CURRENT TRANSFORMERS
AUX. CONTACTS ON UNIT CIRCUIT BREAKER
OUTPUT CORD PLUG
OUTPUT RECEPTACLE
SEALED FACTORY ADJUSTED RESISTORS
PHASE C
PHASE B
PHASE A
TP-4
TP-3
TP-2
TP-1
TP-5
R6
P3
R5
R4
P2
R3
R2
P1
R1
R7
R13
R8
P4
R9
P5
R10
R11
P6
R12
TR-1
TR-2
D31
D29
D26
D30
D27
D28
D25
POTENTIOMETERS(4) MECHANICALLY GANGED
TRIMMER
120 V. 50-60 CYCLES
LOAD COMPUTER UNIT 2
LOAD COMPUTER UNIT 3
LOAD COMPUTER UNIT 4
CONTACTS OPEN WHEN KNOB IS PUSHED TO PERMIT TURNING SWITCH
MASTER SELECTOR SWITCH CENTRALLY LOCATED ON SWITCHBOARD
TO OTHER GOVERNORS
DECREASE LOAD SIGNAL
INCREASE LOAD SIGNAL
SPEED SETTING SWITCH
LOWER
RAISE
COMMON
120 V. A.C. OR D.C. AS SPECIFIED
TO VOLTMETER ETC. ON SWITCHBOARD
INSTRUMENT POTENTIAL TRANSFORMERS
INPUT CORD PLUG
INPUT RECEPTACLE
LOAD COMPUTER UNIT 1
LOAD DIVISION SWITCH SPRING LOADED TO POSITION SHOWN
FORCE MOTOR COIL
OPEN BELOW APPROX. 20% LOAD
TRIM SWITCHES
SPEED CHANGER MOTOR
SHUTDOWN SOLENOID IF USED
GOVERNOR
GOVERNOR CORD PLUG
GOVERNOR RECEPTACLE
FOR A BALANCED UNITY POWER FACTOR LOAD THE FOLLOWING VOLTAGES MUST BE IN PHASE
B TO C WITH D TO A
B TO F WITH H TO E
B TO G WITH J TO I
ALTERNATOR (HIGH VOLTAGE)
ADDITIONAL CONNECTION (NEUTRAL) USED WHEN AVAILABLE, ON 120-208V Y
INTERNAL WIRING OF COMPUTER FOR 120-208V. OR 240V GENERATOR

FIGURE 18

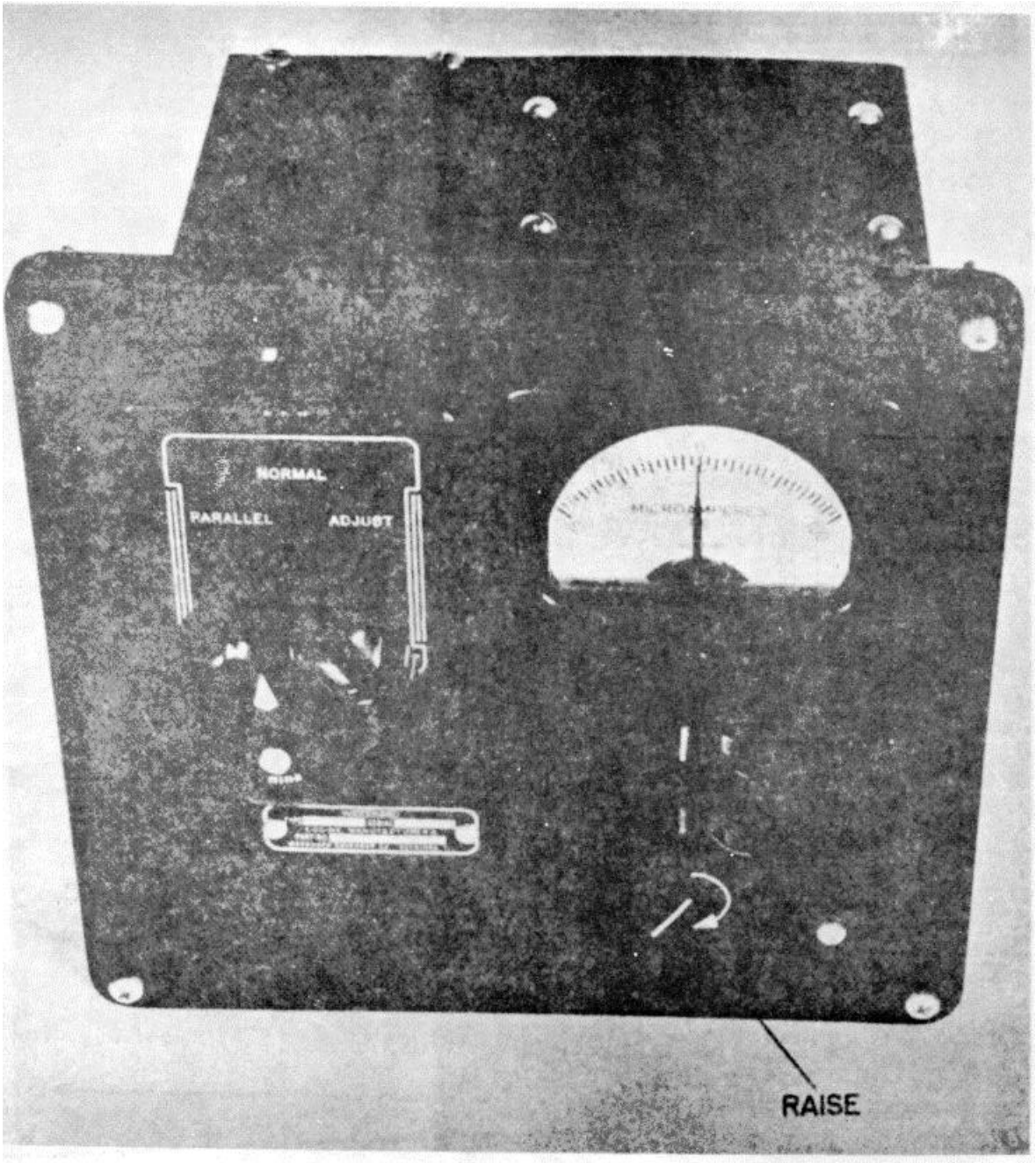


FIGURE 19

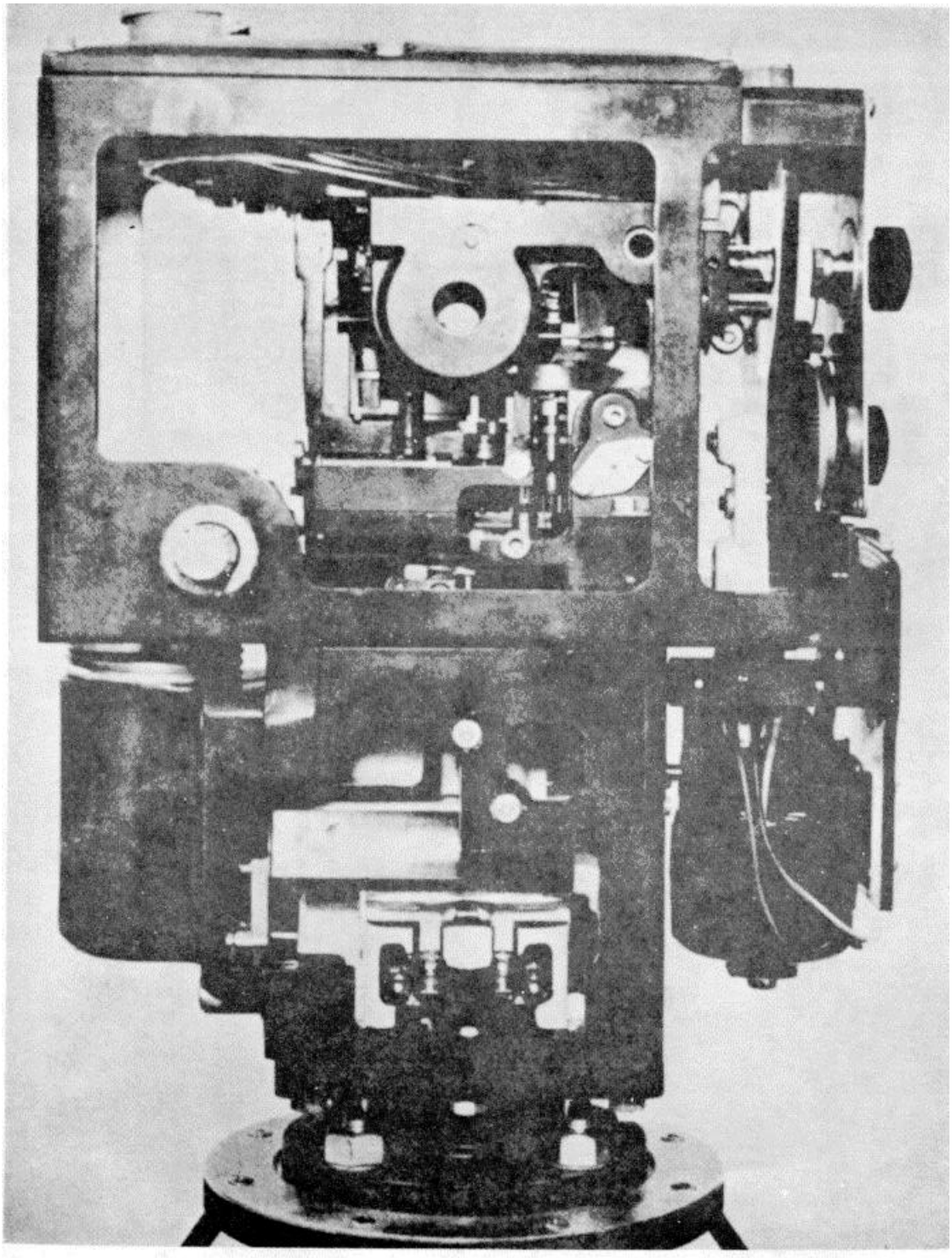


FIGURE 20A

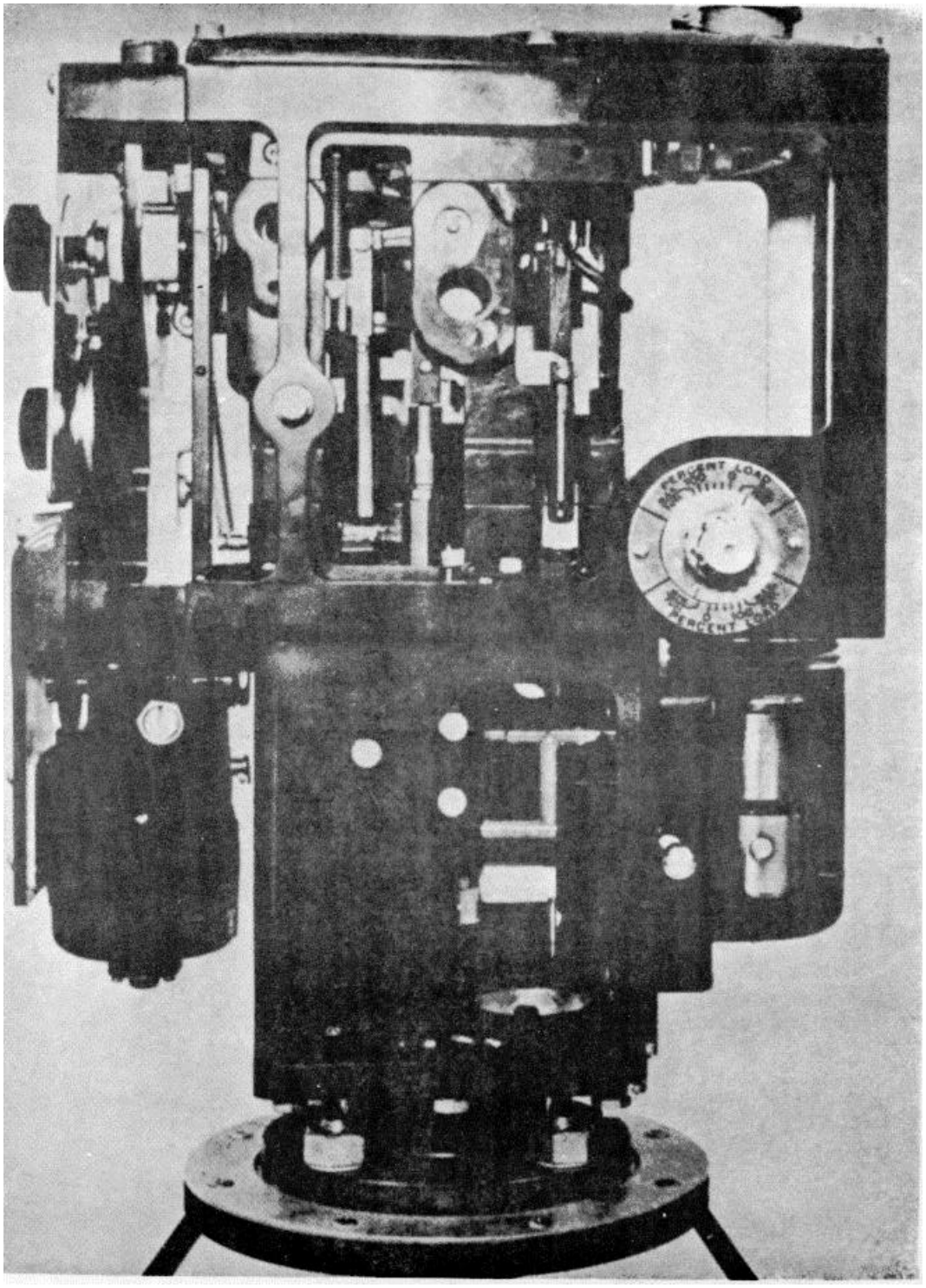


FIGURE 20B

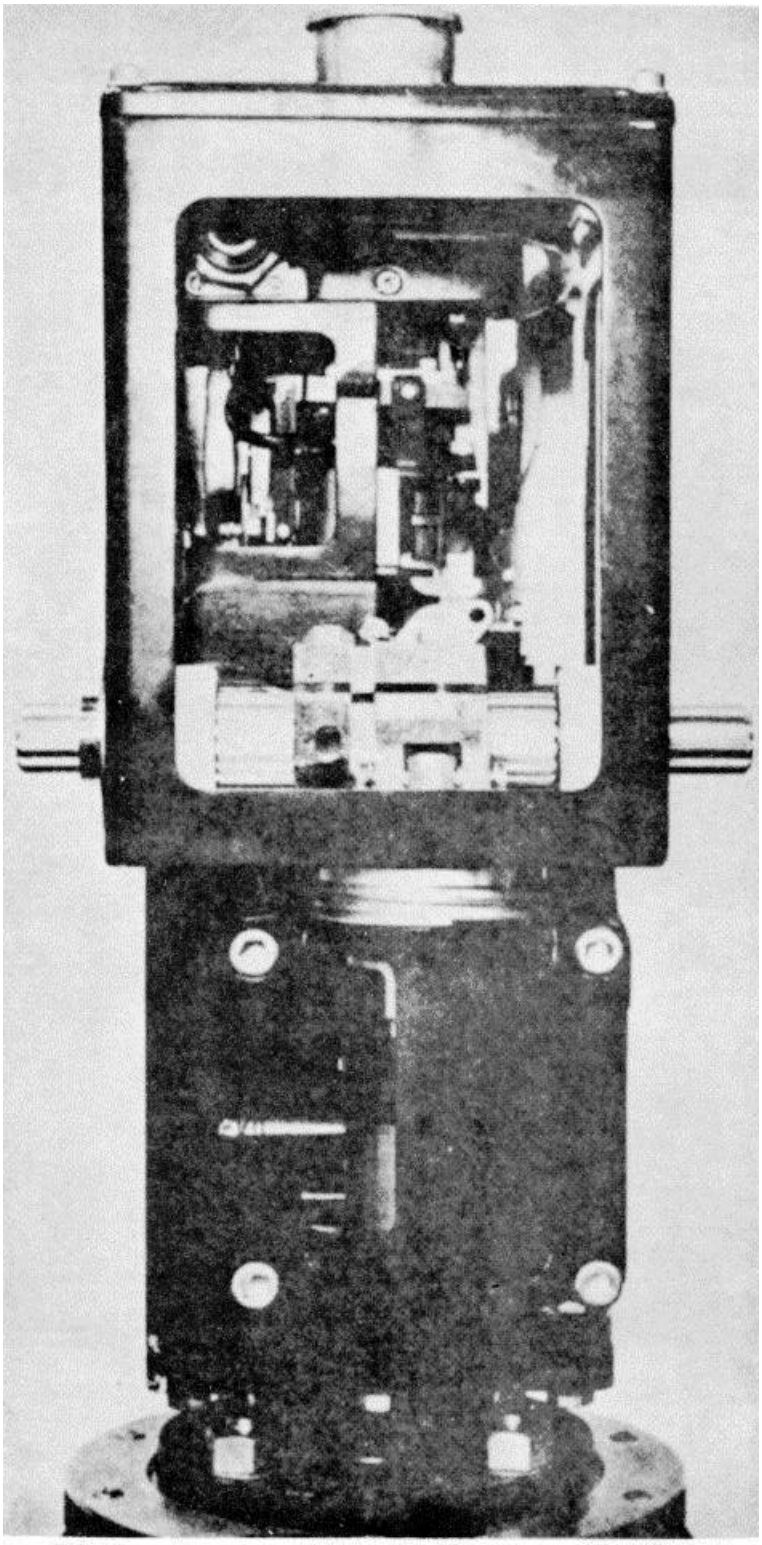
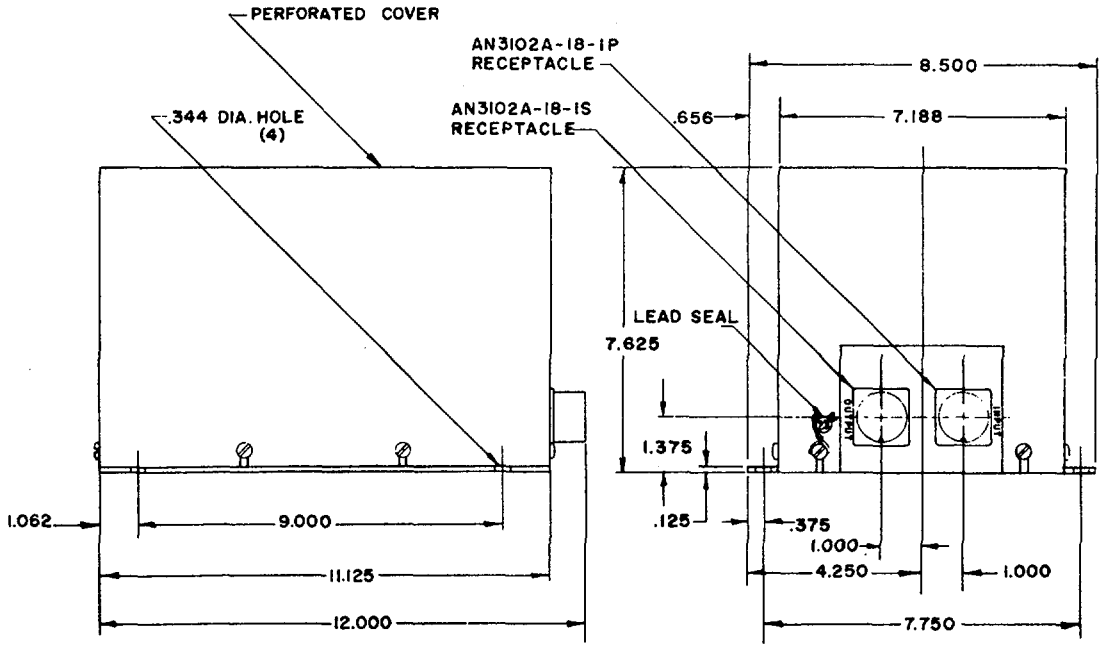


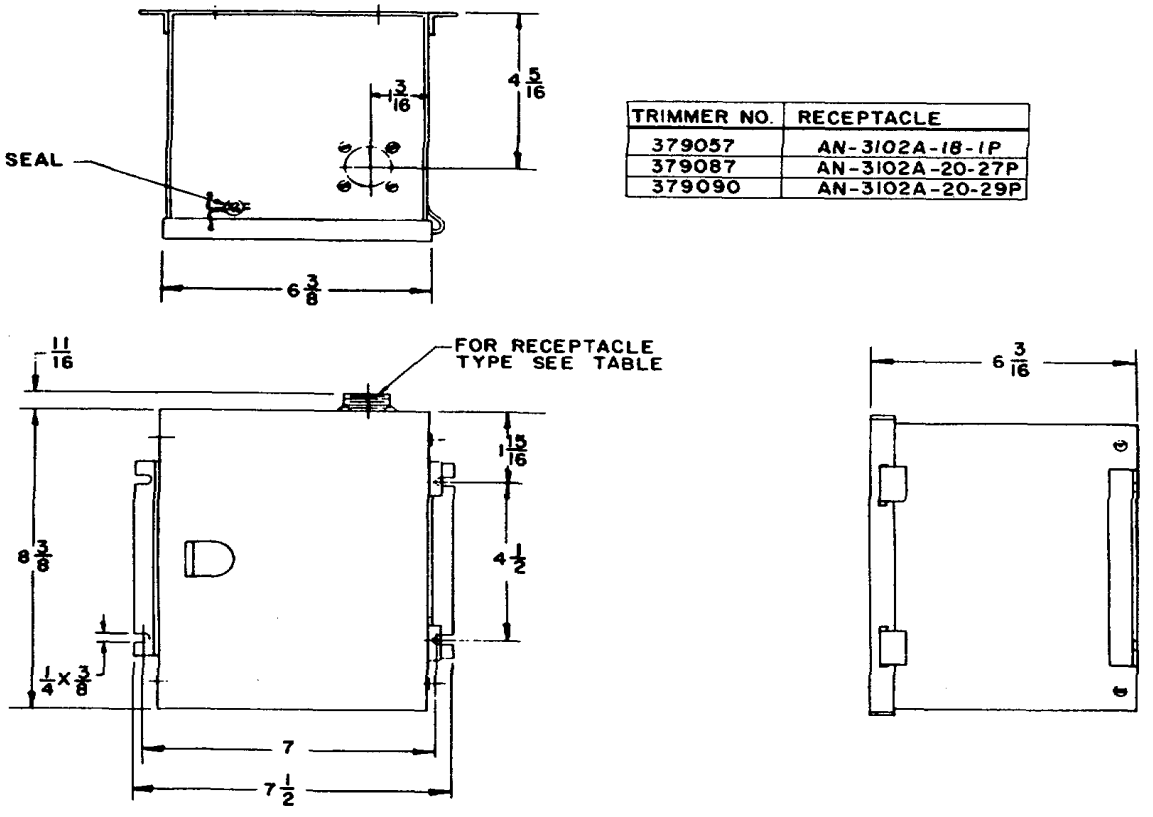
FIGURE 20C

FIGURE 21 NOT APPLICABLE



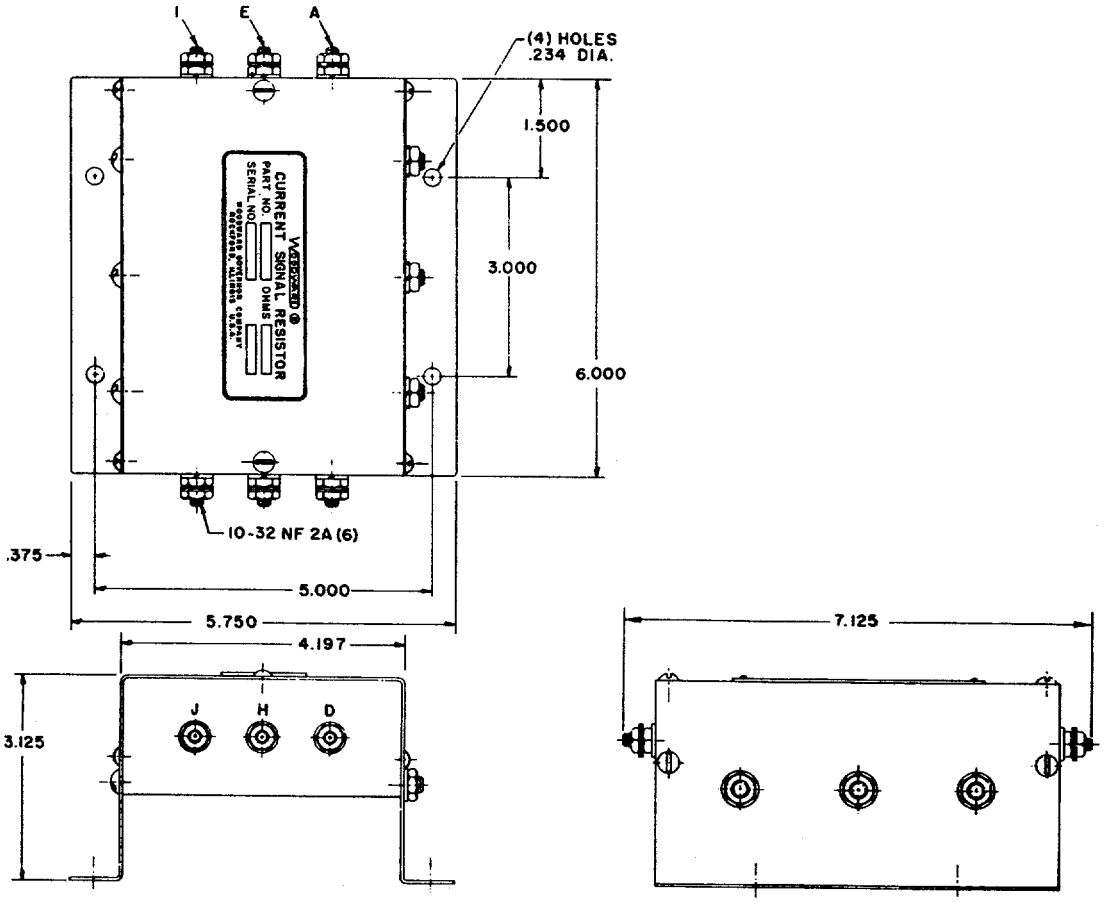
Computer Box

FIGURE 23



Trimmer Box

FIGURE 24



Resistor Box

FIGURE 25

SECTION 28A

INSTRUCTIONS FOR 5 KV AND 15 KV
METAL-CLAD SWITCHGEAR WITH CIRCUIT BREAKERS
(5 KV RATED 4.16, MAXIMUM DESIGN 4.76 KV)
(15 KV RATED 13.8 KV, MAXIMUM DESIGN 15 KV)

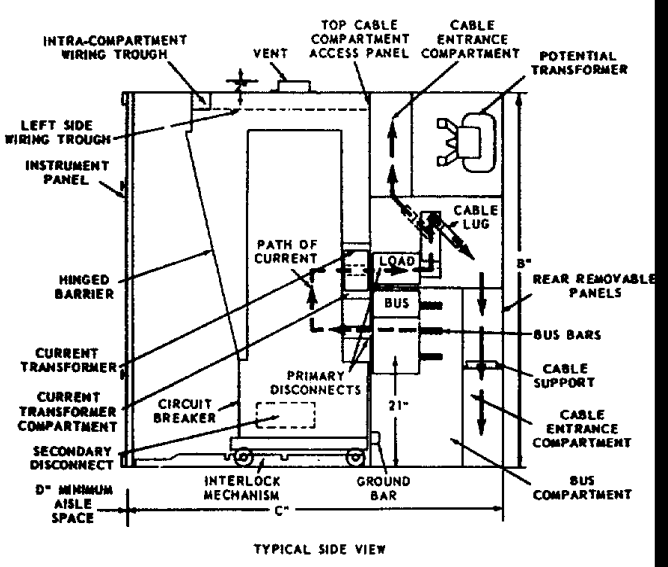


Fig. A - 5-kv Breaker Unit

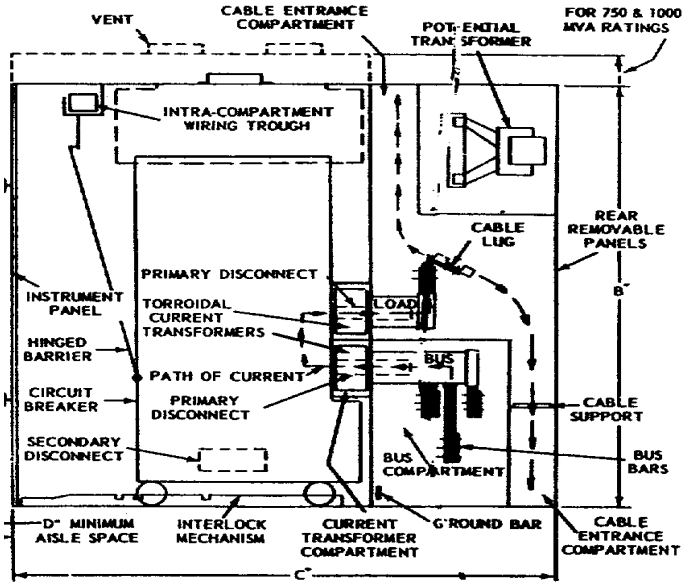


Fig. B - 15-kv Breaker Unit

Note that upfeed and downfeed are available in the standard cubicle; the *potential transformers are trunnion-mounted and the torroidal current transformer* front *access*

TABLE 1.

BREAKER RATINGS					STRUCTURAL DIMENSIONS						
Breaker Type (Mva)	Rated Kv	Max. Design Kv	Cont. Current Amps.	Wt.	Type	Fig.	A Width (in.)	B Height (in.)	C Depth (in.)	D Drawout Aisle (in.)	Wt.
MA-75 ①	4.16	4.76	1200	1070	DF	A	26	72	74	50	1200
MA-150 ②	4.16	4.76	1200	1070	DJ	A	26	72	74	50	1200
MA-150 ②	4.16	4.76	2000	1140	DJ	A	26	72	74	50	1200
MA-250 ③	4.16	4.76	1200	1070	DM	A	26	72	74	50	1200
MA-250 ③	4.16	4.76	2000	1140	DM	A	26	72	74	50	1200
MA-350	4.16	4.76	1200	1200	DN	A	26	72	74	50	1200
MA-350	4.16	4.76	3000	1800	DN	B	36	92	94	66	1800
MB-250	7.2	8.25	1200	1660	FM	B	36	92	94	66	1800
MB-250	7.2	8.25	2000	1750	FM	B	36	92	94	66	1800
MB-500	7.2	8.25	1200	1685	FO	B	36	92	94	66	1800
MB-500	7.2	8.25	2000	1775	FO	B	36	92	94	66	1800
MC-150	13.8	15.0	600	1660	FJ	B	36	92	94	66	1800
MC-150	13.8	15.0	1200	1660	FJ	B	36	92	94	66	1800
MC-250	13.8	15.0	1200	1660	FM	B	36	92	94	66	1800
MC-250	13.8	15.0	2000	1750	FM	B	36	92	94	66	1800
MC-500	13.8	15.0	1200	1720	FO	B	36	92	94	66	1800
MC-500	13.8	15.0	2000	1810	FO	B	36	92	94	66	1800
MC-750	13.8	15.0	1200	3000	FQ	B	36	100	105	77	2000
MC-750	13.8	15.0	2000	3000	FQ	B	36	100	105	77	2000
MC-1000	14.4	15.5	1200	3000	FR	B	36	100	105	77	2000
MC-1000	14.4	15.5	3000	3600	FR	B	36	100	105	77	2000

Dimensions subject to change on special units.

① When applied at a service voltage of 2.3 kv, this breaker has an **interrupting** rating of 50 mva.

② When applied at a service voltage of 2.3 kv, this breaker has an interrupting rating of 100 mnva.

③ When applied at a service voltage of 2.3 kv, this breaker has an interrupting rating of 150 mvo

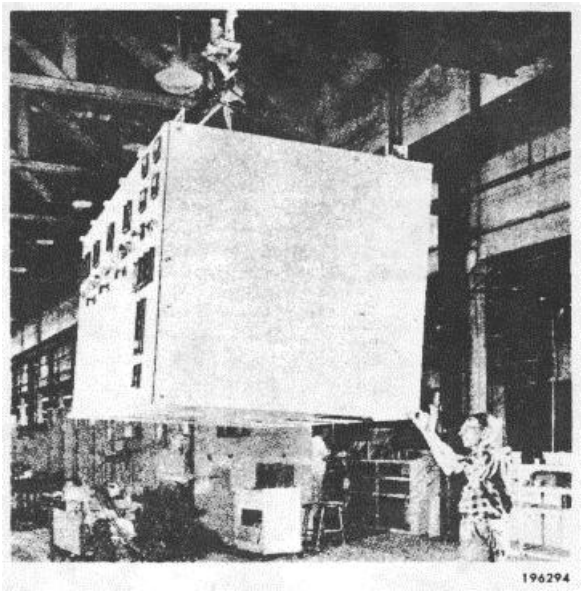
DRAWINGS AND WIRING DIAGRAMS

All drawings and wiring diagrams required during the installation process are furnished in advance to the customer. These drawings and wiring diagrams will include any changes originated by the purchaser during manufacture and any changes to corrections by the supplier necessary to insure proper installation and operation of the equipment.

RECEIVING

UNLOADING

Each shipping group of the switchgear assembly is securely blocked and braced for shipment. It is crated, boxed, or covered depending on shipping conditions. Whatever the method of shipment, every precaution is taken to insure its safe arrival. If special handling is required, it is so indicated. All moving parts are blocked but, because relatively delicate instruments are included, care must be taken to avoid rough handling. Two shipping channels with lifting holes are bolted to the top of the indoor switchgear assembly to facilitate handling. On single unit assemblies, lifting eyebolts may be furnished instead. If cranes or other lifting means are not available, the group can be rolled into position. To help in placing rollers under the skids and removing them and the skids after positioning, lifting jacks can be used, see Figure 1. Jacking bars, supplied with each switchgear group, must be bolted to the side frames of one or two units in the group. Then, jacks placed beneath the jacking bars are used to raise or lower the group. Either one end individually or both ends simultaneously can be raised or lowered. After removing the rollers and skids, lower the group slowly (do not drop it as the impact may damage delicate instruments). Under no circumstances should the shipping channels be removed from the top of the units until the equipment is installed in its final location and the rollers and skids have been removed.



Lifting channels atop metal-clad switchgear facilitate handling by crane.

Except in the case of a one or two unit group, mount the jacking bars on the in between units, never on the ends. This will enable rolling a group up against one that has already been positioned and, in addition, avoid stressing the end frames.

Because of the absence of bottom rear cross members, the units may be easily rolled into place after the cable has been pulled in or primary conduit stubbed up.

ACCESSORIES

The following accessories are crated separately:

1. Split plug jumper for testing breaker when breaker is out of but adjacent to cubicle.
2. Manual racking-in lever. (15 kv only.)
3. Four jacking bars.
4. Pothead compound, insulating tape, touch-up paint as required for installation.
5. Equipment specified for remote mounting may also be included.

STORING

If switchgear is not to be erected immediately, uncrate, inspect and store in a *clean, dry location.*

If space heaters are supplied with a particular order, energize the space heaters as in the final installation to eliminate condensation, which will occur whether the unit is stored or in operation in some locations.

Space heaters are not considered standard equipment with indoor switchgear. (Recommend 500 watts per unit.) If this type has to be stored indoors, space heat-

ers mounted inside the cubicles must be applied to prevent condensation. Standard indoor units are not drip-proof and therefore should be stored indoors. If indoor units must be stored outdoors, adequate covering must be provided together with a heat source of approximately 500 watts per unit distributed between breaker and bus compartments and mounted inside the cubicles to prevent condensation.

Batteries should be connected to a charger and never be left in dead storage.

INSTALLING

CONDUIT

Conduit for power and control connections may be in-stalled in the areas indicated on the General Arrangement Drawings and Floor Plan with due regard for the ease of training the cables in the switchgear. Conduit ends should be about one inch (maximum 1h") above the finished floor to prevent washing water from soak-ing cables. They should also be capped and taped to keep out moisture and vermin.

FOUNDATIONS

Whether the switchgear is to be installed on an exist-ing floor or on a new floor, dimensions of sill channels and anchor bolts should be in accordance with the General Arrangement and Floor Plan. Refer to Figure 2 for recommended sill channel mounting of indoor installations.

ERECTION

The proper erection method depends on whether the units are shipped as one complete group or in two or more sections. In any case, the General Arrangement Drawing will indicate the shipping groups. Units are assembled and wired exactly as they are to be arranged in the final installation. Prior to shipment to the job site, the lineup is separated into the appropriate size shipping groups and crated for shipment.

SINGLE GROUPS

The unit is brought to the site, being handled as instructed under "UNLOADING." Before placing on the previously installed sill channels, make sure the channels have been checked with a level. After the channels have been found to be level, the unit is placed in its final position and bolted or welded to the sill channel as in Figure 2.

MULTIPLE GROUPS

When a shipment is made in two or more groups, the procedure to be followed is, in general, the same as that for single groups. However, individual groups must be carefully aligned and set as closely as possible. The fronts of the groups are aligned first and then bolted together.

After erecting either single or multiple groups, check with a plumb bob, or similar device, to be certain each group is vertical and has not shifted during handling. The breaker units of each shipping group have been checked and marked at the factory. The plumb bob lining up to within plus or minus Me inch of the factory marked plumb" insures alignment. Refer Figure 3. If any shipping group units have shifted during shipment and are out of plumb, the following correction procedure is recommended:

(a) Loosen bolts holding-the lifting channels to the group of units.
(b) Loosen, but do not remove, bolts holding the "plumb" marked unit to its adjacent unit. Ad-just until plumb bob is within plus or minus we inch of the factory marked "plumb." It may be necessary to loosen bolts in successive adjacent units to attain the necessary plumb.
(c) Tighten all bolts holding units to each other.
(d) Remove lifting channels.
(e) Check each breaker shutter operating mechanism for proper operation.

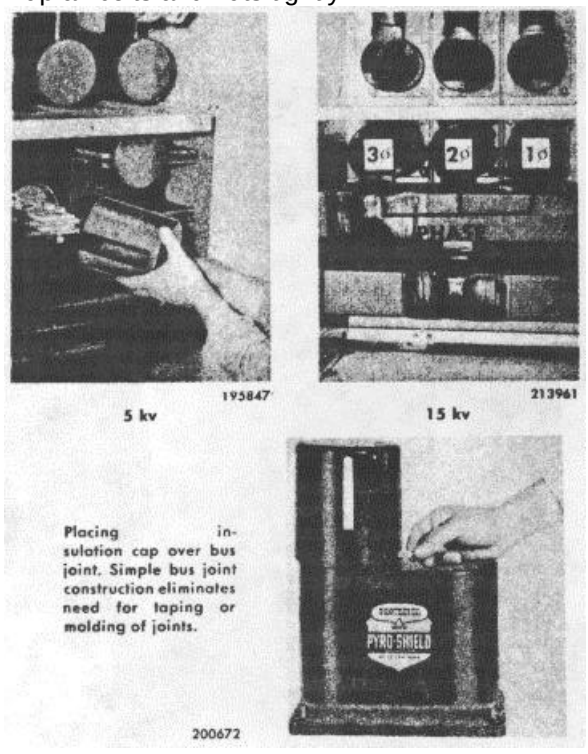
Secondary inter-group wiring at shipping breaks is then connected as tagged, and as shown on the Master Wiring Diagram, Figure 13.

ELECTRICAL CONNECTIONS

BUS BAR JOINTS

This type of joint is connected as shown in Figure 10

Before placing the insulator cap over the bus joint, draw up all bolts and nuts tightly.



195847
5 kv
213961
15 kv

Placing insulation cap over bus joint. Simple bus joint construction eliminates need for taping or molding of joints.

200672

INSULATION CAPS

After bolting the main bus to the primary connectors, the molded insulator cap is placed over the joint and fastened by means of a reusable nylon rivet. Upon insertion, the rivet prongs compress to enter. Simply using a small hammer, the blow drives the center pin through the hollow shank. The center pin wedges the prongs apart for positive lock and the cap is fastened to the base assembly. To remove the rivet, the
center is driven through the hollow shank. The rivet is removed and then the joint can be disassembled. 15 kv joints are taped. See Fig. 10.

PRIMARY CABLE CONNECTIONS

Before primary cable connections are made, phase rotation will have to be considered. Viewed from the breaker drawout side, phase 1 is at the left, phase 2 in the center, and phase 3 at the right.

When the bus bars are arranged horizontally and parallel to the breaker drawout side, phase 1 is toward the front of the assembly, phase 2 is in the center, and phase 3 in the rear.

When bus bars are arranged above one another, phase 1 is at the top, phase 2 in the center, and phase 3 at the bottom.

Phasing is furnished this way unless otherwise marked on the installation drawings transmitted prior to shipment of the switchgear.

Relays and meters are connected for a phase rotation of 1, 2, 3. This means that the voltage of phase 1 reaches its maximum value 120 degrees ahead of the voltage of phase 2, and the voltage of phase 2 reaches its maximum value 120 degrees ahead of the voltage of phase 3. Lines to the switchgear must be connected accordingly to insure correct meter and relay operation.

POTHEAD CONNECTIONS

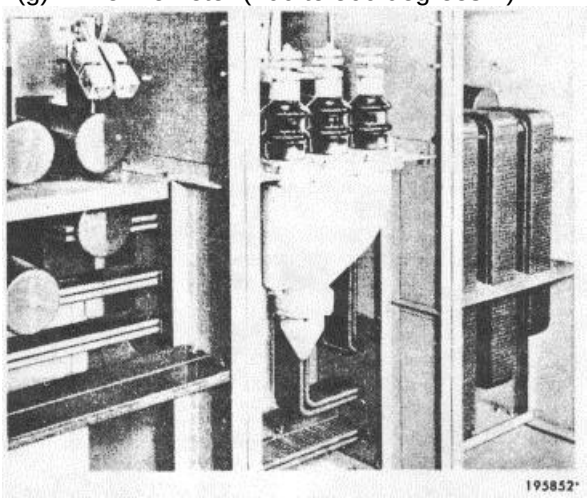
(Lead Covered Cable)

The following material, with the exception of the insulation compound and tarred rope, is not included with the switchgear unless covered by the contract, but is needed to properly install pothead connections:

(a) Insulating compound.
(b) Solder (50-50) for connectors.
(c) Solder (60-40) for wiping joints.
(d) Stearine for solder and wiping flux.
(e) Varnished cambric tape for reinforcing cable conductor insulation and for stress relief cones. (Rubber tape is used on rubber insulated cables.)
(f) Copper tinsel braid for stress relief cones, if required.
(g) Dry cotton tape.
(h) Tarred rope for filling clamp-type cable glands.

Tools and Equipment required for installing potheads:

(a) Kit of cable jointer tools including hacksaw, knife, and wrenches.
(b) Blow torch.
(c) Gasoline furnace for heating solder and compound.
(d) Solder pot and ladle.
(e) Melting vessel for melting compound.
(f) Funnel, filling and vent pipes for compounding.
(g) Thermometer (200 to 500 degrees F).



Typical rear view of Switchgear showing assembled bus joint, and from left to right feeder unit with cable lug connectors, feeder with pothead, and bus tie unit.

Note the following general instructions:

(a) The conductor insulation and internal parts of the pothead should be kept clean and free of moisture.
(b) Avoid all sharp bends in all insulated conductors.
(c) Remove lead sheath carefully to avoid cutting the insulation. The last few layers should be torn off to prevent cutting the individual conductor insulation.
(d) If temperature is below 15 degrees F, cable must be warmed prior to bending. Potheads should al-ways be heated to prevent compound from congealing too quickly on cold surfaces. Avoid direct application of heat on porcelains or on parts with porcelain inserts.
(e) Follow carefully the instructions shown in Figures 5 and 6. In all cases avoid the formation of air and gas pockets.
(f) Fill the potheads with compound from the bottom up to allow compound to rise evenly and force air up and out at the top, eliminating voids. Clean off all surplus and spilled compound.
(g) After pothead has cooled, re-tighten all bolts to make sure of positive tightness of all joints.

INSTRUCTIONS FOR RECLAMATION OF A POTHEAD

Following procedure can be used if cable is going to be replaced:

Steps 1- Cut off cable at base of pothead.
2- Remove upper pothead connections.
3- Remove pothead from cubicle.
4- Remove top cap nuts and vent screw as well as pipe plug in lower pothead body.

5 - Pothead can now be placed in an oven with temperature of approx. 150 degrees C and left in oven until all compound drains. 6-When completely drained remove, disassemble and clean thoroughly with suitable solvent.

7- IMPORTANT: It is recommended that new compound be used to refill pothead after reassembling as the dielectric strength of the old compound may be reduced by contaminants.

8 - New gaskets must be used for reassembling. 9--It may be necessary to obtain new wiping sleeves or packing glands and studs depending on new cable size to be used. If new cable will be smaller than that re-moved, stud and wiping sleeve or packing gland will have to be replaced with new. If new cable will be larger, then holes may be opened to desired size and original stud and sleeve or gland can be reused. 10-To refill, same procedure can then be followed as if this were a new pothead. The instructions given for this refilling are in complete detail in Switchgear Instruction Books furnished with every installation. For removing potheads where existing cable is to be reused:

Steps 1- Remove upper pothead connections.

2- Remove top cap nuts and vent screw as well as bottom pipe plug.

3- Shield cable at base of pothead with asbestos or other heat insulating material as safety feature to avoid damage to cable insulation.

4- Now using a blow torch or other heating device heat body of pothead sufficient to melt compound and drain into bucket.

5 - Heat well around drain plug at bottom to start compound flow.

6 - CAUTION: Do not apply flame directly to porcelain insulators as they may crack and if sufficient heat should travel to the top it could melt compound in insulator.

7- When drained, pothead can be removed, disassembled and cleaned with suitable solvent.

Then follow instructions given in Steps No. 7, 8, 9 and 10, above.

PACKING, WIPING SLEEVE GLANDS AND SUPPORTS

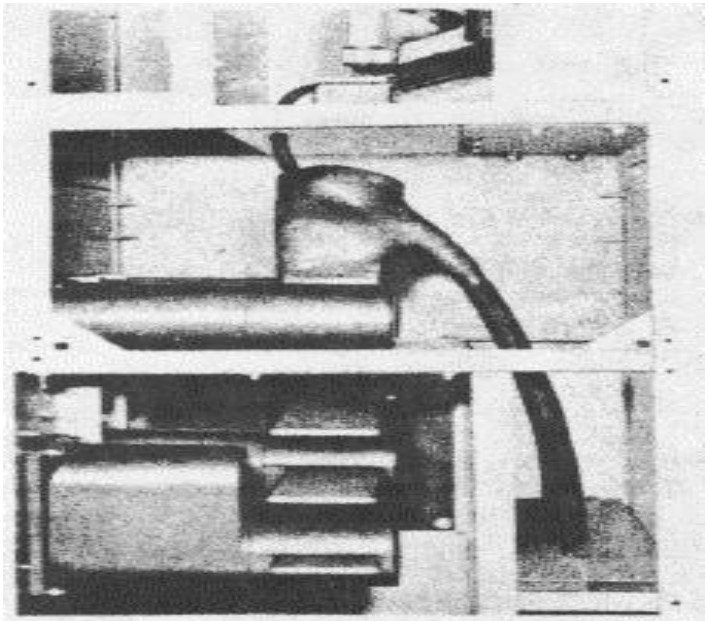
When packing glands are furnished, cut the gland to suit the outside diameter of the cable, and pack as shown for the clamp-type terminals. (Figure 5.)

TAPING JOINTS

When supports of insulating material are furnished, the supports should be cut for the cable O.D. and suit ably clamped.

Upon completing the primary cable connections (Figs. 5, 6, and 8) all untaped high voltage connector joints should be insulated. After connections are made, the joints are wrapped with AC no-corona tape. Use approximately two feet of this copper mesh tape to form a regular surface (not necessarily a straight surface) over the bolt heads.

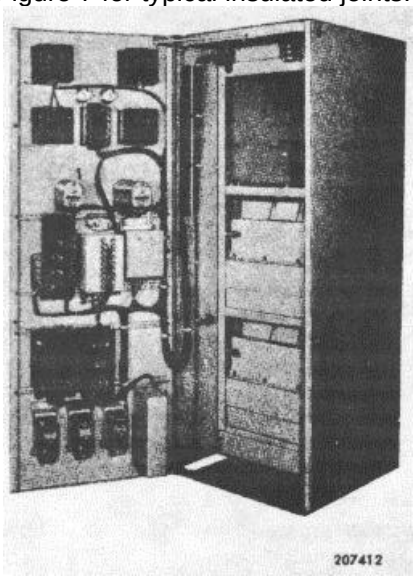
Wrap joints with three layers of Empire cloth sheet 0.010 inches thick (approximately six ft long), wide enough so that edges overlap adjoining insulation about



Typical cable compartment showing cable in downfeed direction. Refer to Figure 7 for cable joint insulation instructions.

three inches, and long enough to overlap ends three inches. Stagger the overlapping of the ends as much as possible and tie the layers firmly with bias cut yellow Empire cloth tape 0.010 inches thick by z/ inches wide (approximately 30 ft long).

Make this insulation operation with the Empire cloth twice for satisfactory insulation for 5.0 and 7.5 kv equipment, and three times for 15 kv equipment. Use six sheets of 0.010 inches thick Empire cloth per joint for 5.0 and 7.5 kv, and nine sheets for 15 kv. Then tape joints with one layer half wrapped electrical tape (one roll). See Figure 7 for typical insulated joints.



Typical auxiliary door open to secondary control wiring.

SECONDARY WIRING

All secondary wiring is carefully installed and tested at the factory for electrical and mechanical soundness. Customer's connections are made to terminal blocks and/or secondary disconnect blocks as shown on Master Wiring Diagrams, Figure 13.

If special connections are made, such as the inclusion of contacts on remote devices, wired terminal blocks are provided for this purpose. See Figure 9 for typical control cable connection.

GROUND CONNECTION

A common ground bus is incorporated in all units for properly grounding the equipment after installation.

The ground bus extending thru the switchgear is accessible in the primary cable area of the left hand end of unit.

Provision for connecting this ground bus must be made so that a reliable ground connection is obtained. Consult latest National Electrical Code for ground connection standards.

TEMPORARY GROUNDS

It is recommended that no work be done on current carrying parts until these parts have been disconnected from the system and solidly grounded. One method of solidly grounding the high voltage circuit is by use of a grounding device. This device is placed in a cubicle in the same manner as a breaker and provides a path to ground. It is furnished only when specified in the contract.

STANDARD EQUIPMENT

CIRCUIT BREAKER

GENERAL

Metal-clad switchgear is a combination of circuit breakers, disconnecting devices, instrument transformers, relays, meters and instruments together with their interconnections and enclosures which are so arranged in an electrical circuit as to open and close that circuit when desired with full safety to. the operator.

A most important component of metal-clad switch-gear is the air magnetic power circuit breaker, in which the circuit interruption takes place in an intense electromagnetic field.

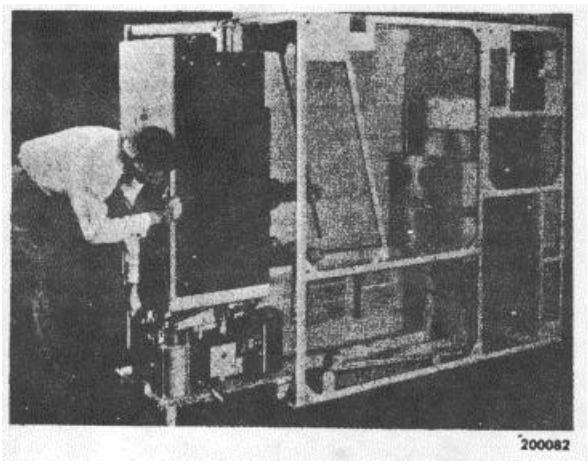
The stationary element of the metal-clad switchgear unit and the removable element (circuit breaker) are built to master jigs so that circuit breakers of the same rating are interchangeable with each other. All removable elements of like rating are checked with one stationary element, and each stationary element is checked with the same removable element to insure complete inter-changeability between elements of like rating.

Each switchgear unit, from the main bus to the cable terminals, is divided into compartments with access barriers for personnel safety. All conductors are insulated with flame-retardant materials. This together with compartmentation permits inspection and maintenance with a minimum of exposure to dangerous potentials.

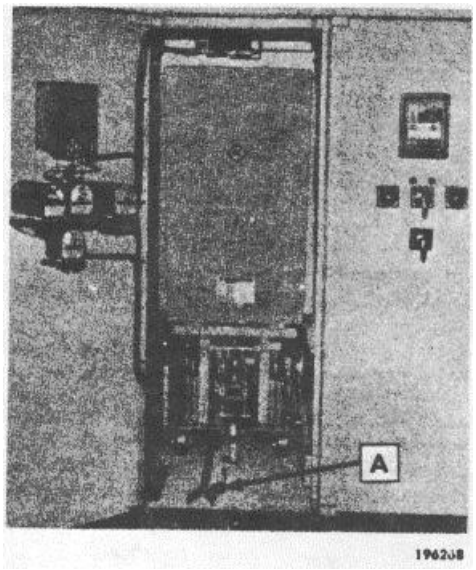
INSERTING THE BREAKER

After the breaker has been inspected and prepared as instructed in the circuit breaker instruction book, it can be inserted into the unit. If the breaker is furnished with a special nameplate identifying it with a definite unit or units, do not place it in any other unit. This limitation is sometimes necessary because special de-vices have been furnished on that particular breaker. When no such special nameplate is used, the breaker can be used in any unit of same rating.

To insert breaker, first line up the breaker directly in front of breaker unit so that the wheels match the chamfered floor edge tracks designed for easy entrance. The positive, straight line, in and out movement of the breaker is assured by the guide track assembly mounted on the floor of the unit. This track has a funnel type entrance and simply connects the mating guide bar on the base of the breaker as it enters the unit.



Just lining the breaker wheels in front of the chamfered ways in the floor is a oil that is necessary before pushing breaker into unit.



Breaker in concealed position. Stop plate interlock (A) prevents insertion of 1200 ampere breaker in 2000 ampere cubicle or 2000 ampere breaker in 1200 ampere cubicle.

MECHANICAL INTERLOCKS

Allis-Chalmers horizontal drawout switchgear has breaker interlocks that prevent:

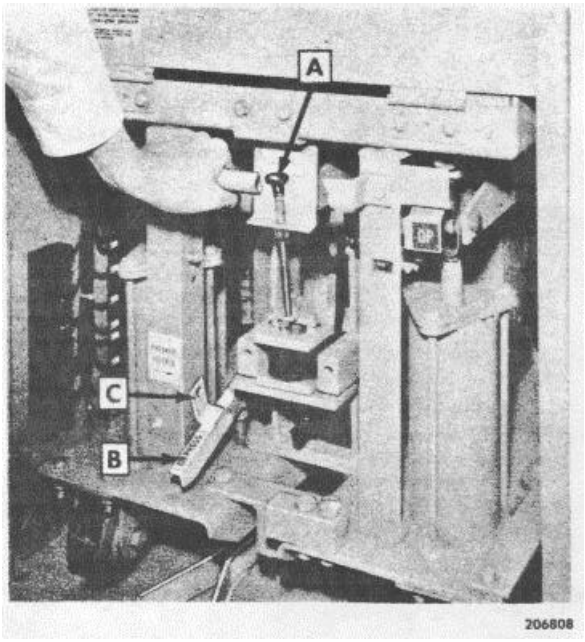
Movement of the circuit breaker to or from the connected position when it is in the closed position. Closing of the circuit breaker unless the primary disconnecting devices are in full contact or separated by a safe distance.

The main interlock is the right wall of the guide track fixed to the floor of the breaker compartment. A cam-follower, mounted under the breaker and connected to the trip mechanism, rides on this bar. The breaker can be closed only if this cam-follower is in the lower (dis-connected, test, or operating) position. When the follower is in the upper position, the breaker is trip-free-it cannot be closed or held in the closed position electrically or mechanically. The circuit breaker cannot be moved to any other position from any one position (disconnected, test, or operating) without first depress-ing the position release pedal "B."

Depressions in the compartment interlock bar are provided for the disconnected, test, and operating positions. When the breaker is in the disconnected position, the primary disconnects are separated and the shutters are completely closed. However, when the breaker is in the test position, the secondary disconnects are still making contact.

Control (or secondary) circuit connections between the stationary and removable elements are made by means of automatic, self-aligning, multi-contact, slip type connectors. Contact surfaces are mounted in the stationary element and the fingers on the removable element. The contact surfaces on the stationary element are recessed to prevent accidental short circuiting of the control circuits. Contact fingers, mounted on the removable element, are designed to assure a positive contact pressure. Low contact resistance is secured by the wiping action of the curved fingers which wipe on the flat surfaces of the stationary portion. Padlocking is accomplished by matching holes in the breaker frame with those in the release pedal arm. In the padlocked position, the release pedal will be half-way down, the breaker will be trip-free and the inter-lock cam follower will still restrain the breaker in any of the three positions within the unit.

The shutters are counterbalanced. This results in smooth, trouble free operation. The circuit breaker in movement in either direction operates directly on the shutter operating lever arm which is pivoted at the

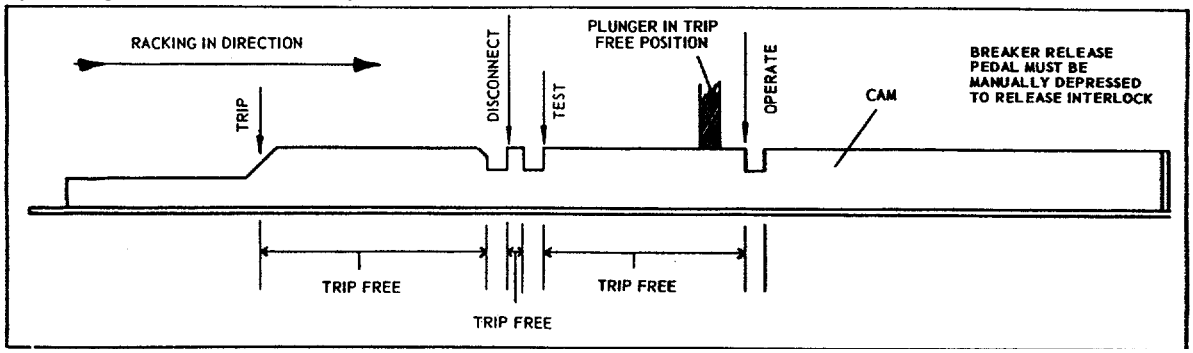


Breaker being inserted into breaker unit. 20-inch guide follower on breaker base rates with guide track on unit floor to self-align breaker in unit. (A) Breaker Manual Trip Button; (B) Position Release Foot Pedal; (QC Padlock Provision.

right inside front of the breaker compartment. A cam follower on the shutter operating lever arm mates with a follower track on the breaker which serves to raise the lever arm to open the shutter blades and lower the lever arm to close the shutter blades.

RACKING INSTRUCTIONS for 5-KV BREAKER

Insertion of the breaker into the unit to the disconnected position is accomplished without the operator having to do anything more than push the breaker into position. The breaker will come to a stop in the dis connected position when the breaker cam follower is forced into the depression of the interlock. The position release pedal must be manually depressed to raise the cam follower to permit movement of the breaker to test position. Here again, the release pedal must be de pressed to permit movement of breaker toward the connected position. The breaker will come to a stop when the primary breaker fingers strike the primary stud in



Guide track and interlock mechanism.

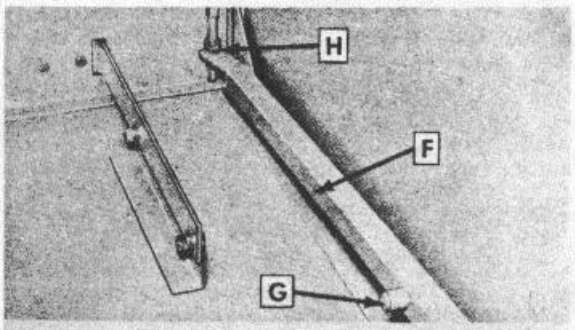
the tube mounted on structure baseplate. To move the breaker to the fully connected position, a lever bar must be used.

The pivot point of the lever bar is inserted into its mating hole in the fulcrum angle mounted on the compartment floor slightly to the right of the center of the breaker. A short upward stroke of the crank levers the breaker into the full operating position. Only when the breaker is in full operating position and the cam follower in the corresponding depression can the breaker be closed.

To withdraw the breaker, the fulcrum pin of the lever bar is inserted into its mating hole in the breaker carriage. Pivoting about the fulcrum angle on the floor (after depressing the breaker position release button) with a short downward stroke quickly withdraws the breaker.

RACKING INSTRUCTIONS for 15-KV BREAKER

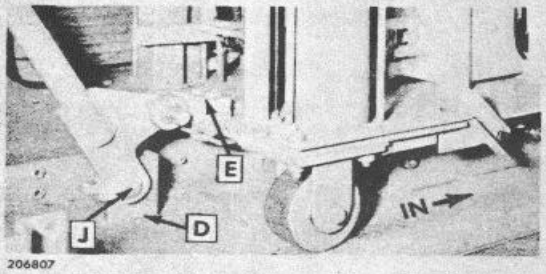
Once the breaker has been manually pushed into the unit, the racking lever may be used to easily move the breaker in and out. To use the racking lever, the pivot point of the lever is inserted into its mating hole on the lower front edge of the breaker. For moving the breaker into the connected position, the pawl on the end of the lever is placed towards the operator, and for re-moving the breaker the pawl is placed away from the operator. The pawl engages a rack on the floor of the cubicle, and a single pumping of the racking lever moves the breaker into the desired position.



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Cam follower (G) on shutter lever arm (F) mates with cam on breaker frame to positively open and close shutters. Adjusting nuts (H) insure free, easy shutter operation.

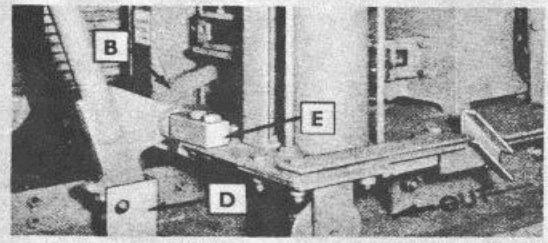
Closeup of lever bar during breaker insertion. Lever bar pin "J" is inserted into mating hole of floor fulcrum angle "D." With lever bar pinion bearing against the breaker bearing block "E," a short upward stroke of the bar engages the breaker in the "CONNECTED" position.



206807

5 KV BREAKER

Inserting wheel spindle extension of lever bar into left side hole of breaker bearing block "E" and pivoting against outside of fulcrum angle "D" on floor, a short downward stroke of bar racks breaker out. The release pedal "B" must be manually depressed to move breaker. After breaker moves, release the release pedal "B," pull breaker with lever bar until it automatically stops in "TEST" position.

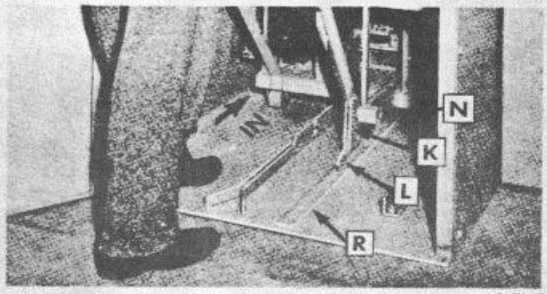


206809

5 KV BREAKER

Inserting the lever pivot "K" into hole in breaker frame "N" and placing pawl "L" to engage floor rack "R" a pumping action of lever will move breaker to the desired position. In disconnected, test or connected positions the release pedal "B" must be manually depressed to move breaker. After breaker moves, release the release pedal "B" and continue racking of breaker to desired position.

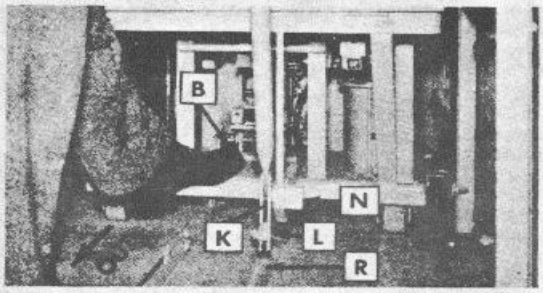
15 KV BREAKER



207167

To rack breaker into connected position place pawl "L" towards the operator.

15 KV BREAKER



207163

To remove breaker place pawl "L" away from operator.

RACKING INSTRUCTIONS—LEVER BAR

RACKING SAFETY MEASURES

After the breaker has been initially inserted into the connected position, rack the breaker out and check the length of engagement of primary contact fingers over the straight portion of contact surface on the stationary contacts. The contact point of the fingers should travel a minimum of % inch over the straight portion of the stationary contacts. This can be checked by applying putty inside the cluster of fingers before the breaker is inserted. Then, after the breaker is racked in and out, measure the distance from the contact points of the fingers to the depression in the putty made by the ends of the stationary contacts and compare this to the length of the bevel on stationary contacts.

If the unit is not energized from either the cable or bus sides, rack the breaker in, close and trip it electrically (provided auxiliary power is available) to check closing and tripping circuits.

Rack the breaker out to the test position and check to make sure it can be closed and tripped electrically in this position. The secondary contact device used with this type of breaker is such that contact is maintained up to this test position, enabling closing and tripping electrically without using a plug jumper.

Check the ground contacts to be sure they make in both test and operating positions.

CAUTION: Before inserting the breaker for *the first time*, make absolutely sure the bus is not energized. Rack the breaker in slowly, at the same time observing the following:

1. Guide track engages properly.
2. Secondary contacts have good contact alignment.
3. Ground contacts properly aligned and make good contact.
4. Shutters operate properly.
5. Breaker primary contacts enter insulators and make properly with stationary primary contacts.
6. Interlocking, that prevents a closed breaker from being moved to or from the connected position, functions properly.

POTENTIAL TRANSFORMERS

Potential transformers are mounted on a carriage which rotates in trunnions to provide the convenience of automatic disconnection when withdrawing the potential transformers for test or inspection.

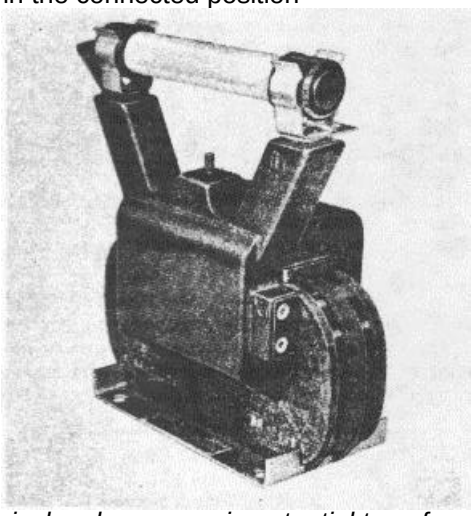
The drawout carriage for the potential transformers can be located in the top rear compartment of a standard breaker unit at a convenient shoulder height location or in an auxiliary unit. Mounted on a base which pivots in a pair of trunnions, the pivoted base is easily rotated 180 degrees to the test or disconnect position.

While pivoting from the connected to the disconnected position, the transformer primary windings and transformer mounted current limiting fuses are automatically grounded to remove any charge from the windings. When the transformers are in the test or disconnect position, the base acts as the protective barrier between the stationary primary contacts and the operator. The weight is so distributed that a minimum amount of effort is needed to revolve the carriage.

To disconnect the transformers, the following operation is followed:

1. Knurled screws holding the door are loosened and the hinged panel swung open.
2. Pulling the handle downward rotates 180 deg., disconnecting the transformer the carriage placing the fuses outside the unit for safe replacement

The potential transformers are shipped mount, the unit and in the connected position



Typical cod epoxy resin potential transformer.

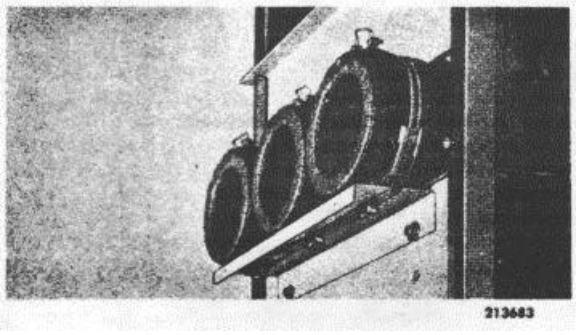
CONTROL POWER TRANSFORMERS

The control power transformers are stationary mounted and the primary fuses are mounted on a trunnion mounted carriage in the same manner as the potential transformer

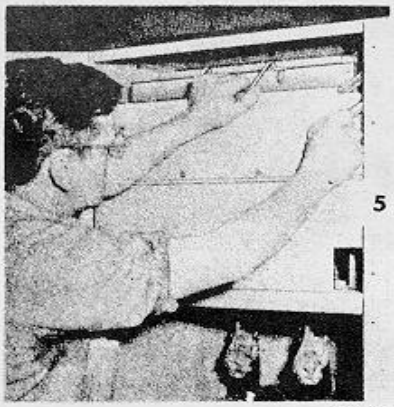
An interlocked circuit breaker is furnished on the secondary side of the control power transformer to prohibit disconnecting of the transformer unless the circuit breaker is open Only when the circuit breaker is opened (disconnecting the load from the transformer) can the fuse carriage be rotated from the connected position.

CURRENT TRANSFORMERS

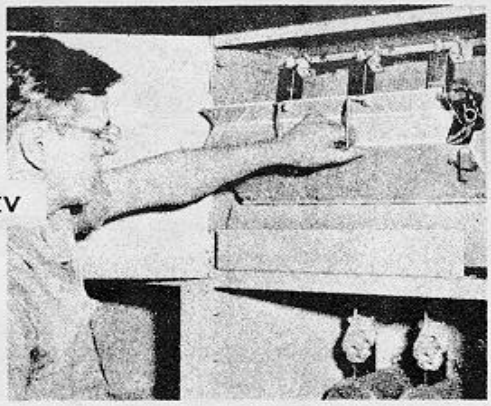
Current transformers, with high ratio, are of the torroidal type mounted in the circuit breaker compartment in front of the plate which supports the high voltage disconnect.



View of bottom of support plate beneath current transformers showing strap supports. Protective cover has been removed.

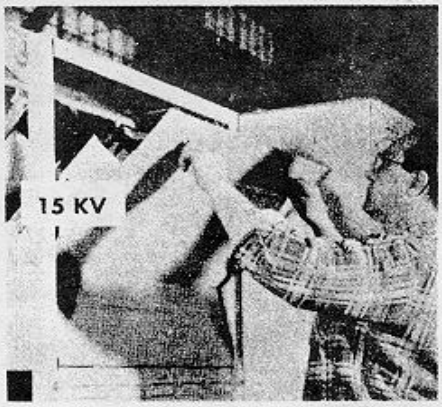


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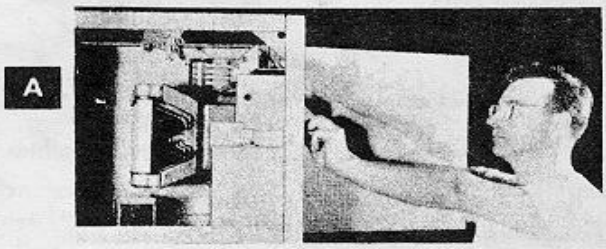
206811

Potential transformers are trunnion mounted at shoulder height in the rear of the breaker unit. Door can be hinged from either side.

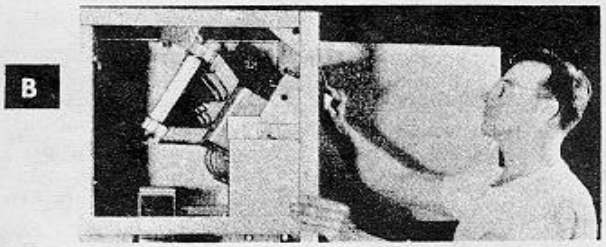


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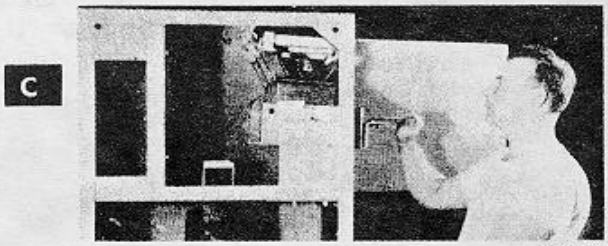
15 kv trunnion-mounted potential transformer carriage installed in feeder unit. Primary end of fuse is wiped by static ground contacts. Note steel barriers between operator and primary compartment.



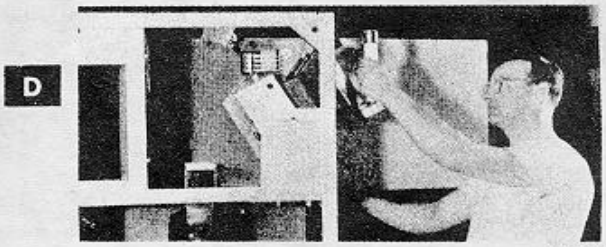
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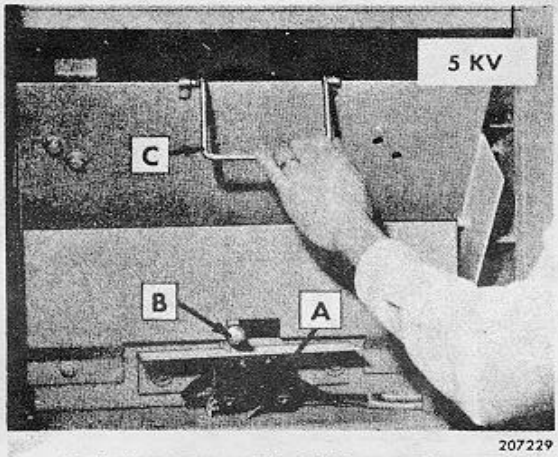
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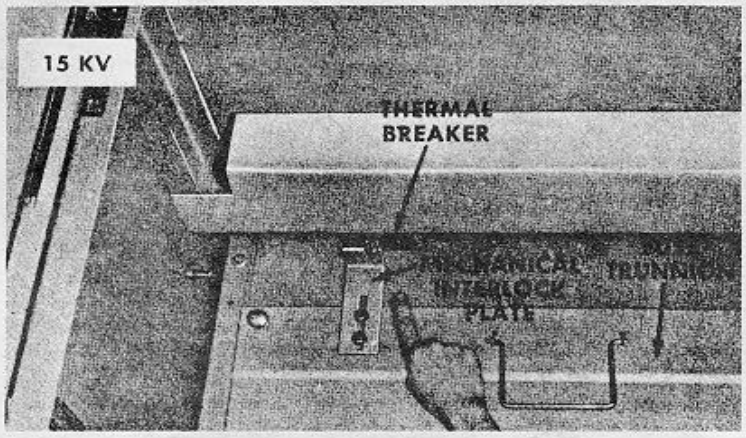
Picture (A) shows potential transformer in connected position with operator about to rotate trunnion mounted carriage; (B) fuse strikes grounding strap to remove static charge; (C) beryllium copper contacts also strike grounding strap; and (D) carriage is rotated to completely disconnected position, placing fuses outside unit for safe and convenient removal and replacement.

CONTROL POWER INTERLOCK

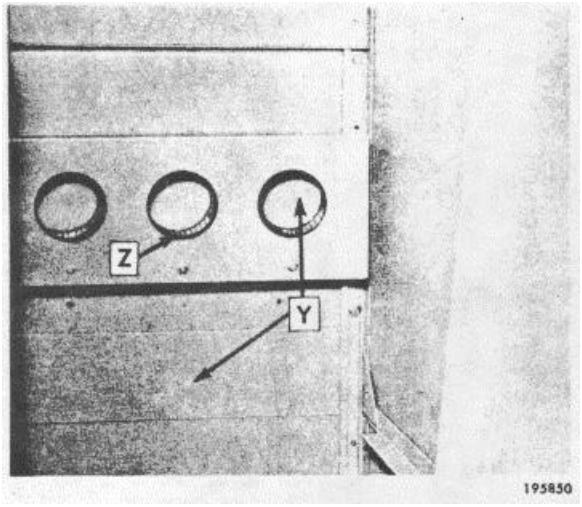


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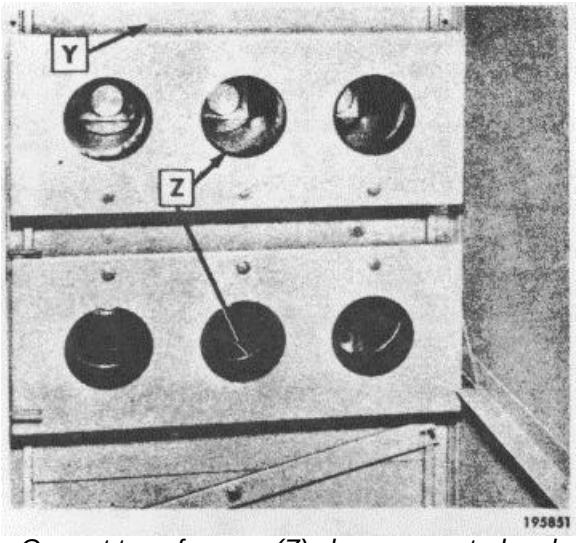
Interlock arrangement for 4.16 kv control power transformer fuse carriage. Thermal breaker must be opened prior to rotating trunnion. Note full steel barrier just above thermal breaker.



Trunnion mounted fuses for the stationary mounted control power transformer are mechanically interlocked with secondary thermal breaker to prevent load break.



Automatic shutters (Y) in closed position behind current transformers. Current transformers (Z) shown mounted on load side only.



Current transformers (Z) shown mounted on both bus and load side. Shutter (Y) blocked open to show disconnect studs.

Current Transformers (Continued)

The primary bushings of the circuit breaker serve as the primary bar of the current transformer. Therefore, removing the circuit breaker actually removes the primary bar. It is possible to test the current transformers without removing them from the unit while maintaining maximum operator safety.

In as much as the shutters are located behind the current transformers, testing of transformers located on the bus side can be accomplished without bus de-energization.

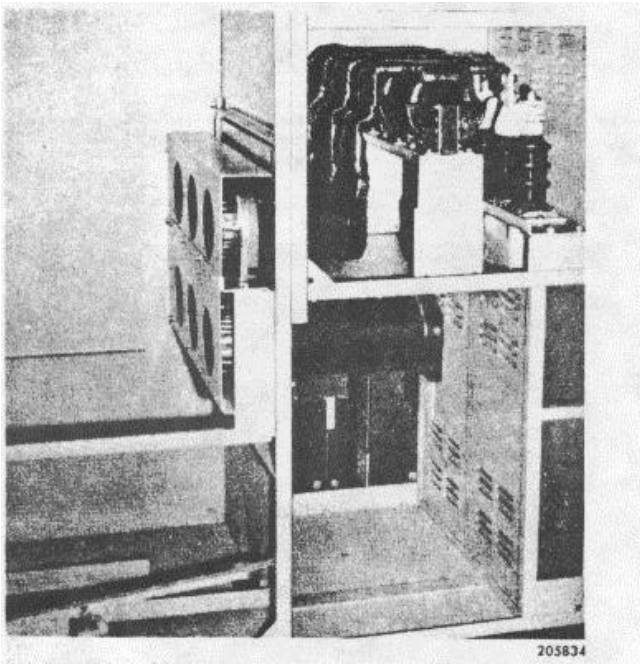
Removal of the current transformer covers is accomplished by removing cover bolts accessible from the circuit breaker compartment

Current transformers with low ratios are of the wound type and are mounted in a separate compartment with a suitable device for terminating power cables

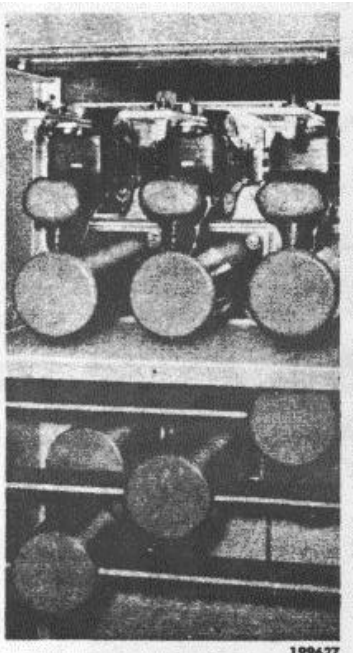
Built to NEMA and AIEE standards, each current transformer has a nameplate on which is included its type, serial number and rating. If it is necessary to contact the factory in regard to these transformers, include the nameplate information and identify the unit in which the transformer is mounted.

Current transformers should not be operated with secondaries open-circuited.

15 kv unit showing the wound type current transformers mounted with downfeed pothead.



15 kv unit showing the wound type current transformers mounted with download pothead



5-kv unit showing the wound type current transformer mounted for downfeed cable.



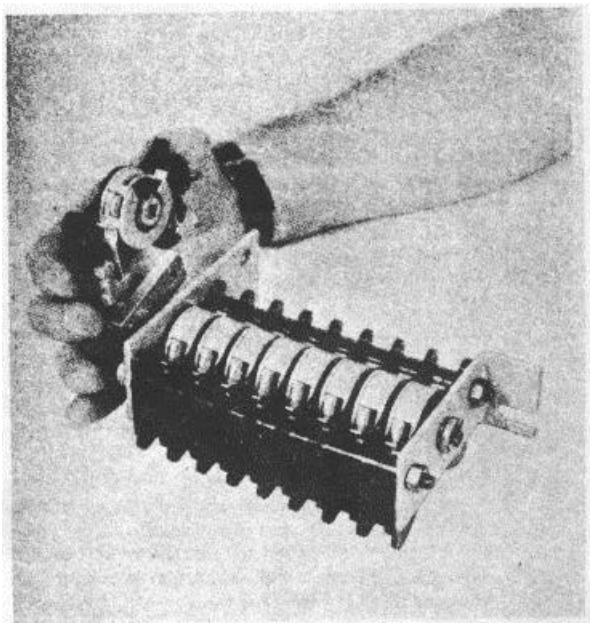
Wound type current transformer, Type DW.

SPECIAL EQUIPMENT

KEY INTERLOCK

When specified, a key interlock can be supplied to prohibit closing a breaker only when it is in the operating position. The interlock bar is attached to the guide bar. In the operating position, the lock bolt is extended, raising the cam follower bar, locking the breaker in the trip-free position. Then the key is removed to release disconnects or associated equipment for operation.

This interlock is cleared for normal breaker operation by returning disconnects, etc., to normal operating position and inserting the key into its lock, permitting withdrawal of the bolt and lowering of the cam follower bar.



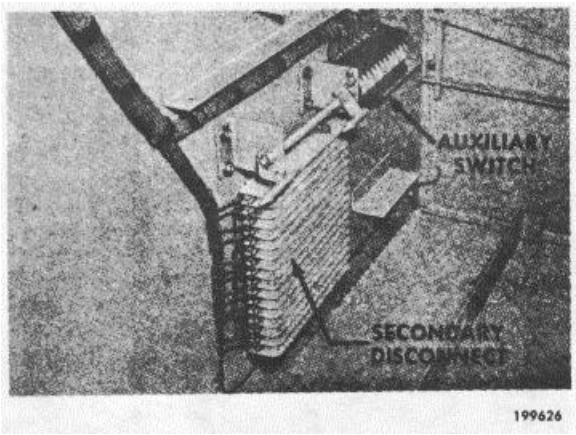
Only a pair of pliers is necessary to adjust each Q-10 auxiliary switch stage. Each point of a stage can be individually adjusted in 15 degree steps.

STANDARD ACCESSORIES

TESTING DEVICE

When specified, a plug jumper is supplied so that a breaker can be operated (tested) outside its compartment with the control switches on the instrument panel. This plug jumper is used to bridge -with a flexible cable- the secondary disconnects so that the breaker can be electrically closed and tripped. Refer to Figure 12 for plug jumper connection instructions.

If desired, a pushbutton can be supplied on the device attached to the breaker for operation at the breaker.



Cell mounted Q-10 auxiliary switches are operated by notched lug welded directly to the breaker mechanism main crank.

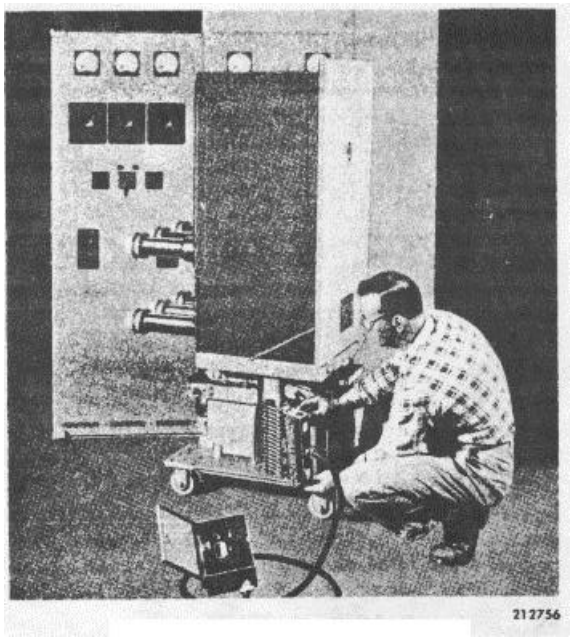
EXTRA AUXILIARY SWITCHES

When specified, extra auxiliary switches - in addition to the eight standard switches on the breaker - can be easily accommodated on the stationary structure. These switches are operated by a notched lug welded directly to the breaker mechanism main crank. Every standard structure and circuit breaker is designed to accommodate this feature.

Eight, twelve and sixteen stages can be furnished.



Test device for testing breaker outside unit with switchgear control power.



Attaching lug jumper of the Test Device to the breaker.

INSPECTION and TESTING

INSTALLATION, INSPECTION AND TESTING

Before the equipment is put in service a thorough inspection and test are made. If any defects are found, correct them immediately.

Check the following points:

1. High voltage connections properly insulated.
2. Electrical disconnecting contacts, machined parts, shutter, etc., checked for lubrication and operation.
3. Blockings, supports and other temporary ties re-moved from breakers, instruments, relays, etc.
4. Proper fuses correctly placed.
5. Temporary wiring jumpers (used on the secondaries of current transformers tied to external devices, as shown on wiring diagrams) removed.
6. Ground connections properly made.
7. Incoming primary and secondary connections properly made and checked for shorts or undesired grounds.
8. All equipment, removed during assembly, replaced.
9. Relays coordinated with other relays, etc., on the system. Refer to relay instruction book before making any adjustments. Consult local power company before making any connections to their power supply.
10. Storage battery fully charged and provided with recharging facilities.
11. Interlocks performing properly.
12. Circuit breakers checked and prepared per instruction books

LUBRICATION

It is essential that switchgear be lubricated carefully and properly to insure that all operating parts work freely, and to guard against corrosion. Lubricate moving parts - shutter guides, bearings, tilt-out transformer trunnions, etc. - with “Lubriplate” AERO Grease, or equal. Use of lubricants not suitable for the application will make mechanisms very difficult to operate. Remove all old grease and relubricate annually, or oftener if required.

Electrical contact-all stationary silver-surfaced contacts are to be lubricated with "Lubriplate” AERO *prior* to use.

1. Wipe contacts clean.
2. Apply AERO to contact surfaces.
3. Wipe off excess grease, leaving a thin film.

Remove all old grease and relubricate annually, or oftener if required.

When lubricating contacts, it is important to avoid getting grease on the insulation.

For the above procedure, a tube of AERO grease (A-C Part No. Q-108428) is included with each shipment of switchgear.

Where corrosive atmospheres are encountered, coat all unpainted metallic surfaces generously with AERO Lubriplate or equal. When grease becomes contaminated by the corrosive atmosphere, remove it and apply a new coat.

For specific lubricating instructions on circuit breakers, refer to the breaker instruction book.

FINAL TESTING

1. A megger test is made on the high voltage circuit to be sure that all connections made in the field are properly insulated. A megger test is also advisable on the control circuit.
2. A dielectric test, if possible, should be made on the high voltage circuit for one minute at one of the following voltages corresponding to the rated volts of the equipment. (Potential transformers, control transformers, lightning arresters, surge capacitors, are disconnected during this test.)

RATED KV	TEST KV	DC
5.0	14.3	20.2
7.5	14.3	20.2
15.0	27.0	38.2

A dielectric test on secondary and control circuits should be made at 1200 volts. The above voltages are in accord with NEMA Standards.

3. With breaker in the test position make the following tests on each unit.
   (a) Trip and close the circuit breaker with the control switch.
   (b) Trip the breaker by passing sufficient amps (or volts) through the coils of protective relays. © Trip and close the breaker from any remote control positions.
   (d) Operate auxiliary deices.
   (e) Test the phase sequence of polyphase high voltage circuits, particularly those used for motor starting.

(f) Check aging resistor setting of rectifier operated breakers. This aging resistor should be set so that a maximum amount of resistance is in the circuit and still permits breaker closing at 190 volts ac minimum control voltage. The dc voltage across the closing coil should be at least 90 volts at this minimum voltage setting. The rectifier is mounted on the breaker.

OPERATION and MAINTENANCE

OPERATION

When the equipment is placed in service for the first time all circuit breakers should be open and all control circuits energized. The primary incoming power source is then connected to the switchgear bus by closing the circuit breaker, disconnect switch or other means provided. The incoming power source should be at the lowest voltage possible, and then gradually brought up to normal. Let equipment stand energized for several minutes before connecting the load. Check instruments, relays, etc., during this period.

When connecting the load, connect one unit at a time with as small a load as possible on the feeder. Again, wait several minutes before connecting the next load, meanwhile observing operation of instruments, relays, etc. When it has been determined that there are no defects, the normal load may be connected.

Check the following during the first week of operation: over-heating of primary and secondary circuits, satisfactory operation of all instruments, relays, etc.

MAINTENANCE

Thorough inspections at periodic intervals are important to satisfactory operation. The frequency of inspection and maintenance depends on installation conditions and can be determined only by experience and practice.

Make these inspections at least once every year—more frequently if local conditions require.

Conditions affecting maintenance are:

Weather and atmosphere.

Unusual number of operations.

Experience of operating and maintenance personnel.

Special operating requirements.

After the frequency of inspection has been determined, cover the following points:

(a) Inspect switchgear interior for accumulation of dust, dirt, etc. Remove dust from all insulators.

(b) Check instrument and control switches and inspect their contacts.

(c) Examine indicating lamps and replace all those that are burned out.

(d) Check test block contacts for loose connections.

(e) Inspect bus bars and connections to see that they are in proper condition. If they are over-heating, check for poor or loose connections, or for overload.

(f) Check for proper condition of instrument transformers. Replace burned out fuses, if any. Check primary and secondary connections.

(g) Examine automatic shutters for proper operation.

(h) Examine all safety interlocks.

(i) Maintain circuit breakers as called for in circuit breaker instruction book.

CORROSIVE ATMOSPHERES

This switchgear is designed to give top performance when installed in normal indoor or outdoor locations. Where abnormal conditions are encountered - such as corrosive atmospheres—special precautions must be taken to minimize their effect. Exposed metallic surfaces-non-insulated bus bars, disconnect switches, primary and secondary disconnecting contacts, wire ends, instrument terminals, etc.- must be protected. Lubricate contact surfaces with a generous coat of AERO “Lubriplate” or other equally non-hygroscopic grease. If this kind of grease is not available, petroleum jelly can be used. Other exposed members can be protected with a coat of glyptol lacquer or any other corrosion-resisting paint.

When old grease becomes dirty, wipe the parts clean and apply new grease immediately.

TOUCH-UP PAINT

Matching paint, one pint per three units, thinned and ready for use, is supplied with each order for touching up any scratches, etc., made during installation. Inspect the surface and retouch where necessary. Paint is furnished in spray-on one pint cans.

RELAYS AND INSTRUMENTS

To insure satisfactory relay and instrument operation, covers of these devices should not be left off for a period longer than is necessary. When a cover has been broken, cover the device temporarily and replace broken glass as soon as possible.

SPACE HEATER OPERATION

Outdoor switchgear is furnished with two space heaters in each cubicle. The space heaters are controlled by thermostats mounted inside the cubicle. The thermostats are factory-set to cut in and out at definite temperatures (open 110 ±5F, close 100 ±5F). Where humid conditions exist, be sure to turn on these heaters well in advance of energizing the equipment to insure that the insulation is dry.

Instructions for use:

Select location of lacking bars from table. At these locations remove two “Y2 bolts now bolting units together. Then bolt lacking bars in place using longer ½” bolts supplied with bars. After removing jacking bars replace original bolts.

Shipping channels (lift channels) must be bolted in place when jacking.

It is preferred that all four jocks be raised simultaneously. If this is not possible then raise the two jacks on one end simultaneously.

Jacking bar bolting locations (facing front):

5 units: Front R.H. I# & 4 - Rear R.H. 01 & 4
4 units: Front R.H. I# & 3 - Rear R.H. #1 & 3
3 units: Front R.H. #1 & 2 - Rear R.H. &1 & 2
2 units: Front L.H. a 1 R.H. 2 - Rear L.H. I1 R.H. #2
1 units: Front L.H. & R.H. - Rear L.H. & R.H.
6 units: Front R.H. #1 & 3 & 5 - Rear R.N. #1 & 3 & 5
7 units: Front R.H. 1 & 3 & 6 - Rear R.H. 1I & 3 & 6

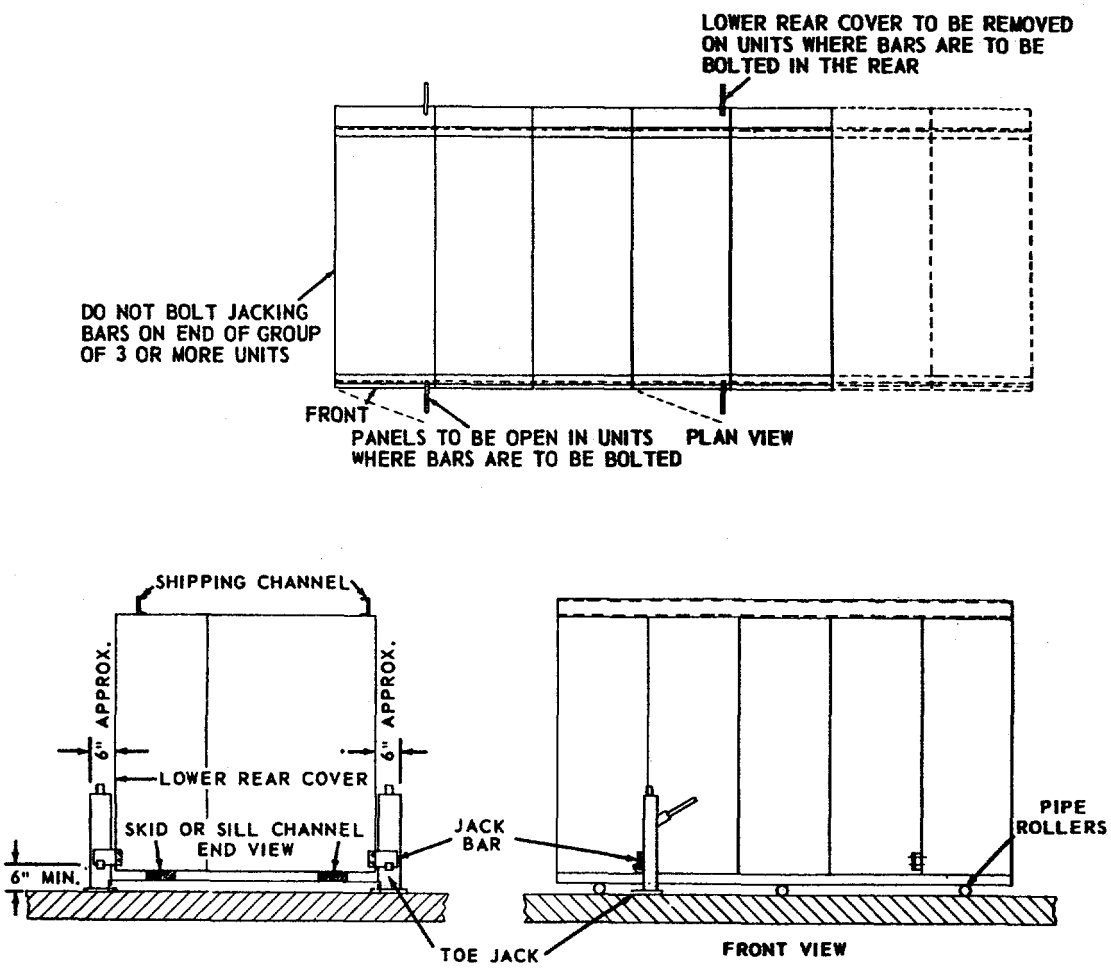
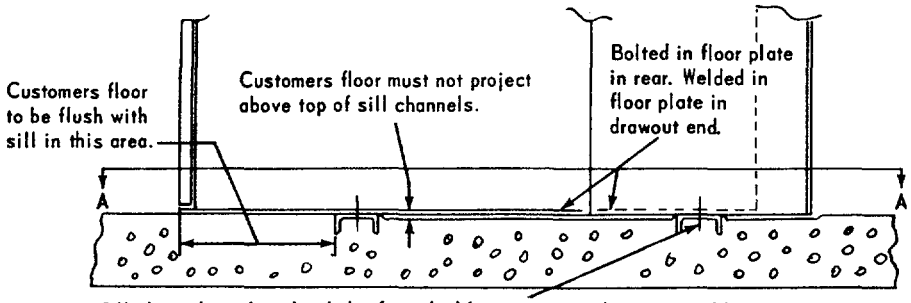
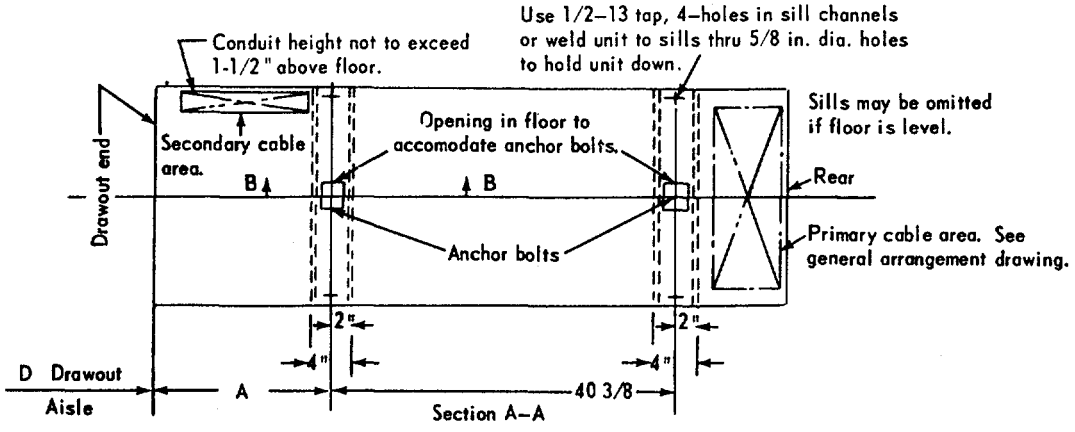


Fig. 1 - Jacking device





BREAKER TYPE (MVA)	D (In.)	A (In.)
MA 75, 150, 250	50	20⅝
MA 350	66	20⅝
MB-MC 150, 250, 500	66	20
MC 750, 1000	77	31

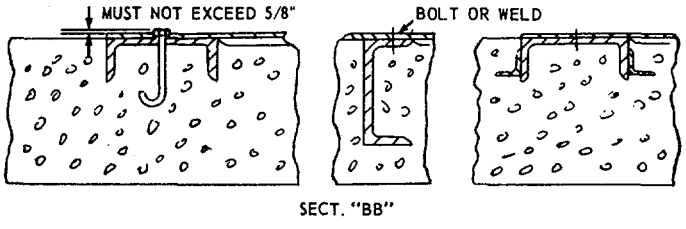


Fig. 2- Indoor floor plan (above) and indoor sill channel mounting (below).

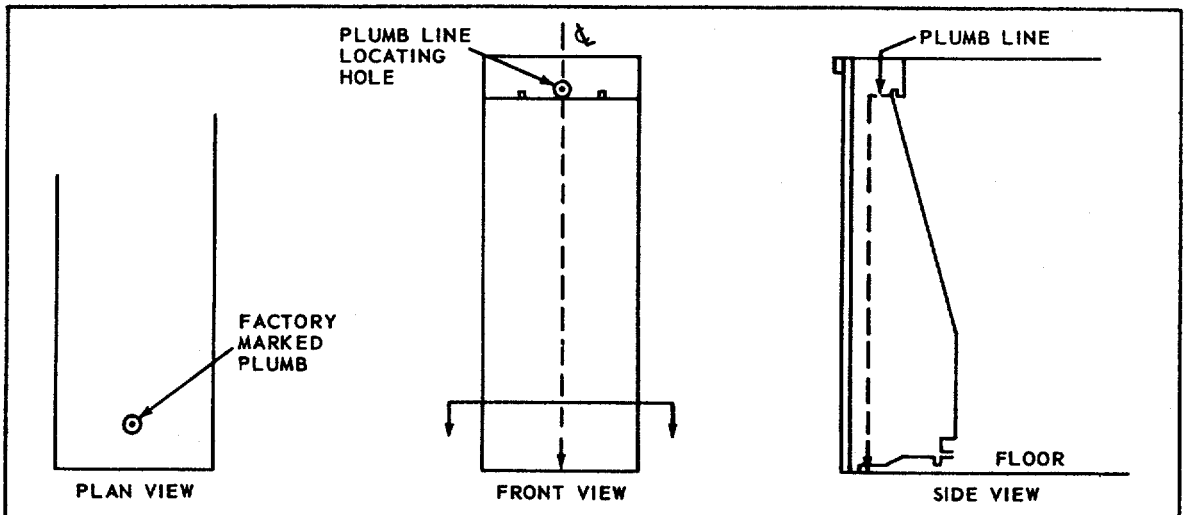


Fig. 3 — Correct method of plumbing units.

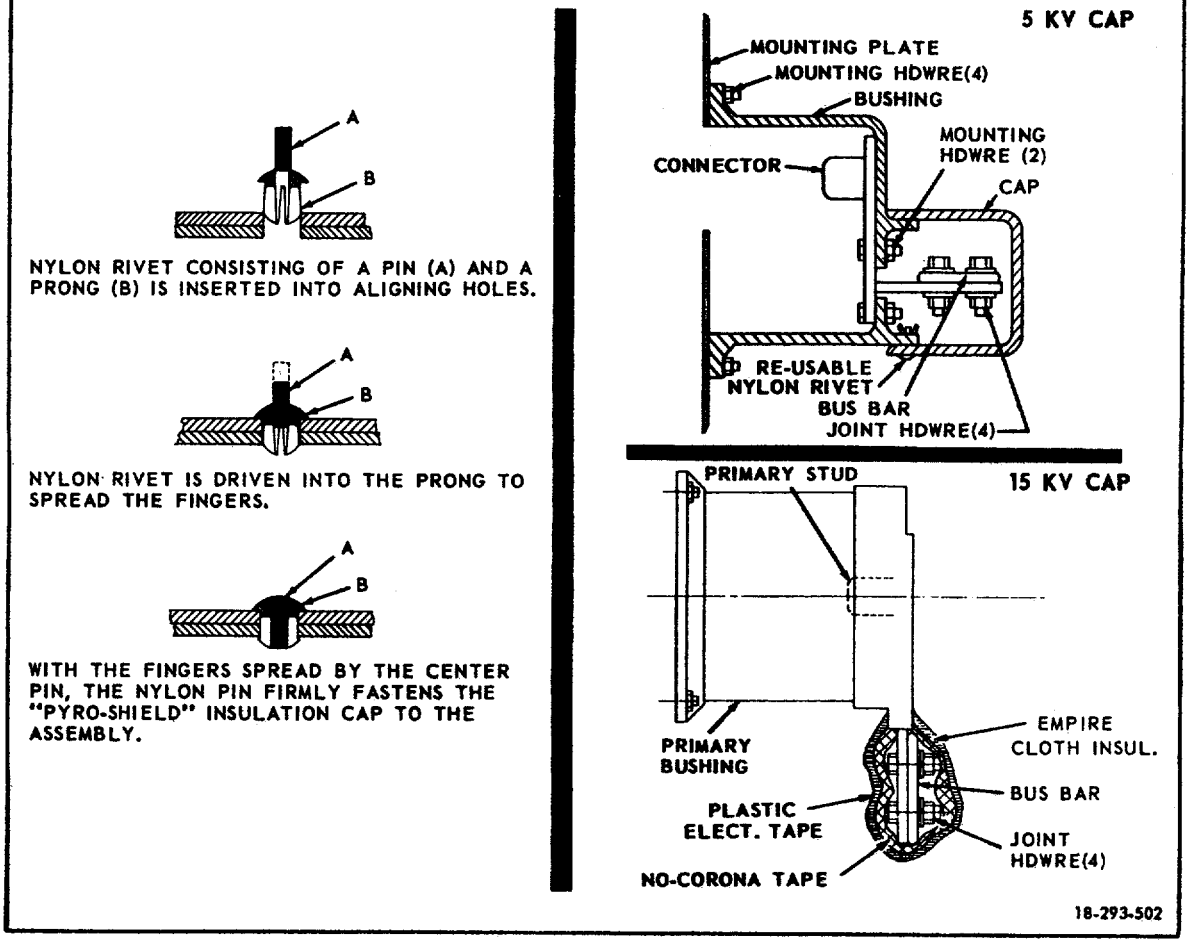


Fig. 4 - Bus joint using "Pyro-Shield" insulation caps (side) views).

POTHEADS FOR METAL-CLAD SWITCHGEAR

Potheads for Metal-Clad Switchgear must be coordinated with other switchgear components to meet space, dielectric, momentary current, and thermal current require-ments.

In standard Switchgear units, the pothead mounting is such that the pothead may be removed from the mounting without disassembly of the pothead. Each three conductor, or group of three single conductor potheads, is on a separate mounting plate. The plate,

besides serving as a mounting, separates the current transformer compartment from the cable compartment. The potheads are mounted in such a manner that the customer can, if he desires, make his cable connection outside of the unit or on the floor of the unit. He may also make his cable installation in the mounted position. There is sufficient distance between the entrance of the pothead and the floor of the unit to permit dropping the pothead body over the cable to make the stress cones.

Different sizes of pothead bodies are not furnished to match the various cable sizes within an installation. One three conductor body is furnished to take all cable sizes up to approximately 750 mcm. One single conductor body is furnished to take all cable sizes up to approximately 1000 mcm. This permits the installation of larger cable if the loads outgrow originally selected cable sizes.

Three conductor potheads have their entrances off-set, so that if two potheads are mounted in one unit the off-sets are in opposite directions. This provides more space to work when wiping lead to the wiping sleeve of the pothead and lead of the cable.

Potheads are an integral part of switchgear and there fore are required to stand the same tests as other metal clad switchgear components. The following are dielectric tests required to meet switchgear standards.

Table 1

Voltage Rating	Low Frequency RMS	Impulse Crest 1.5x40 MS Positive or Negative
7.2 KV 13.8 KV	26 KV 36 KV	75 KV 95 KV

STRESS RELIEF CONES

Stress relief cones increase the strength of the cable insulation against puncture at the end of the grounded shielding. They increase the overall internal dielectric strength and reliability of the cable termination. Stress cones are recommended for all shielded cables and the higher voltage single conductor lead covered cables. Belling out lead sheath is usually sufficient for lower voltage lead covered cables.

On paper or varnished cambric insulated cables, a double cone is built up of half lapped varnished cambric tape. The lower slope is wrapped with cop-per tinsel braid, tucked under the bell at end of lead sheath and soldered to the lead sheath and/or to the cable shielding tape. On rubber insulated cables, the double cone may be built up of dry varnished cambric tape and shielded with standard copper tinsel braid as above.

STEP A - Preparing the Cable

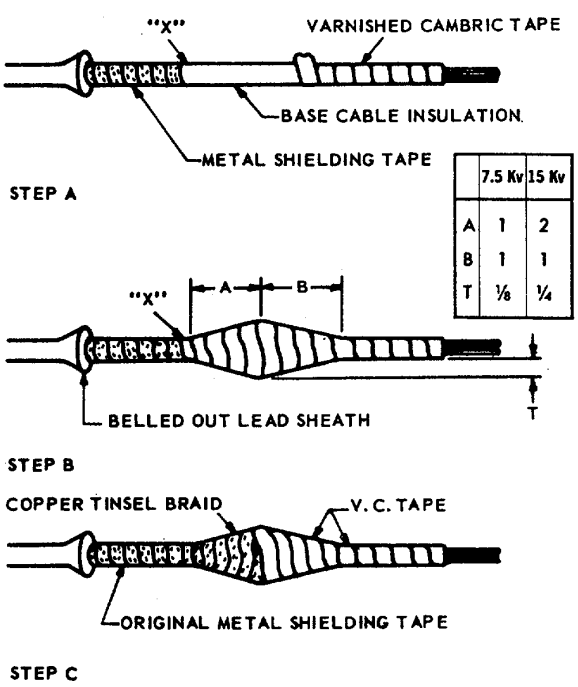
Determine length of each conductor to extend from position of wiping sleeve or packing gland to point of connection to the stud terminal. Establish location of stress relief cone on the cable so that it will be approximately in the center of the pothead body. Remove shielding and conducting tapes down to bottom of stress cone (point X). Bare the end of the conductor and solder to stud terminal.

STEP B - Building the Stress Relief Cone

Starting at the terminal end, wrap varnished cloth tape, half lapped down to the edge of the metal shielding tape. Continue wrapping back and forth until the double cone of proper diameter is obtained. Finish by wrapping the final layer of tape on the conductor and on up to the stud terminal. If varnished cambric tape is used, and the cable is varnished cambric or paper insulated, first brush flushing oil on the cable insulation and on each layer of tape. Use long rolls of varnished cambric tape to minimize the number of splices. Wrap tightly. If tape breaks, unwrap enough to locate splices near the connector end of the cone.

STEP C - Shielding

Starting slightly below the middle of the double cone, apply copper tinsel braid to the lower half. Wrap so that the upper edge is even and continue wrapping down the cone - over cable shielding or tuck under lead sheath. Solder the tinsel braid between turns and to shielding. Solder shielding to lead sheath or to ground connecting wire.



TYPICAL CABLE AND TAPED POTHEAD CONNECTIONS.

INSTALLATION INSTRUCTIONS

1. Check cable gland and stud to see that they fit cable. These items may be furnished with pilot holes only. Drill out if necessary with a clearance of approximately 1/16" over size of cable sheath and conductor, respectively.
2. Slide cable gland, cable gland gasket, and pothead body down over cable.
3. Train cable into proper position allowing sufficient length to make connections.
4. Mark cable sheath approximately 1 to 1l/" above the bottom of the gland.
5. Remove lead sheath from the cable to point marked, being careful not to damage insulation. Bell out lead sheath as shown in Fig. 3. For braided cables remove braid down to point "X."
6. Remove belt insulation (outer layers of insulation around all conductors) from the cable to point "X" above the lead bell.
7. Fan out conductors into final position avoiding sharp bends (3 conductor only). Cut off conductors to proper length to fit into studs. Remove cable insulation from end of conductor at least ¼" longer than depth of hole in stud.
8. Solder cables solidly into the studs. (For voltages above 7, 500 stress cones should be made up on cables as shown in Fig. 3.)
9. Install studs in insulators with gaskets and key washers in place. Bolt insulators firmly to their mounting plate. Tighten nut next to key washers on studs.
10. Bolt the pothead body up against insulator plate with

gasket in place.

11. Bolt cable gland to pothead body with gasket in place.

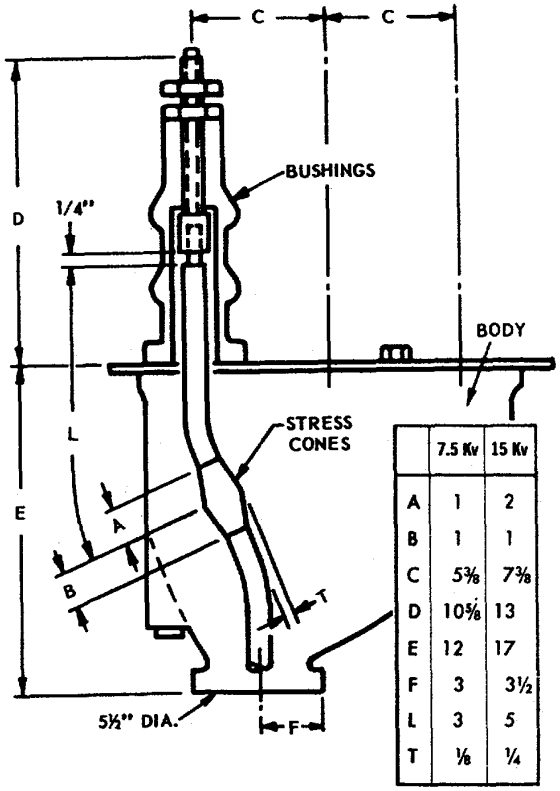
12a. *For Upright Pothead* (Cable leading down). Wipe joint between cable and wiping sleeve, or pack stuff-ing box, and pull up tight to seal against cable sheath.

12b. *For Inverted Pothead* (Cable leading up). Wipe joint between cable and wiping sleeve, inserting a greased wire next to cable sheath if wiping sleeve gland is used. After wiping, remove greased wire to provide an air vent when filling pothead with compound. If packing gland is used, do not pack until after filling.

13a. *Filling Upright Pothead.* Remove vent screws from top of studs. Insert standpipe into pothead body and extend it above highest point of pothead. Melt compound per instructions and fill body until compound reaches vent. Keep standpipe hot and full until compound in body solidifies. Remove standpipe and insert plug and gasket.

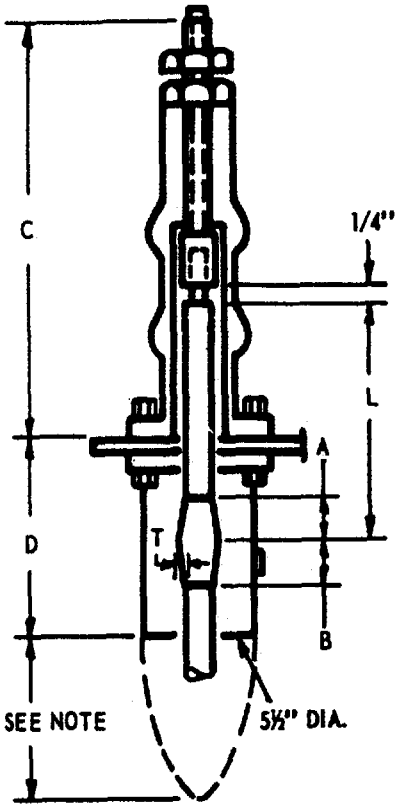
13b. *Filling Inverted Pothead.* Do not remove vent screws in studs. Make sure these are tight. Venting is provided by hole left in wiped joint or through packing space, depending on type of gland used. Insert stand-pipe into filling hole in insulator mounting plate and extend standpipe above highest point of pothead. Melt compound per instructions and fill body until compound reaches vents. Keep standpipe hot and full until compound in body solidifies. Remove standpipe and insert filling hole plug and gasket. Solder up hole in wiped joint, or insert packing, and tighten

clamp to seal joint between cable and pothead body.



	7.5 Kv	15 Kv
A	1	2
B	1	1
C	5⅜	7⅜
D	10⅝	13
E	12	17
F	3	3½
L	3	5
T	⅛	¼

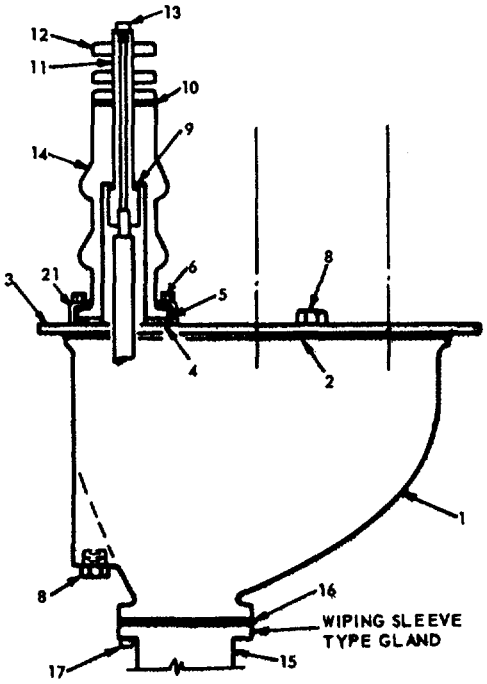
Fig. 5 - three-conductor potheads.

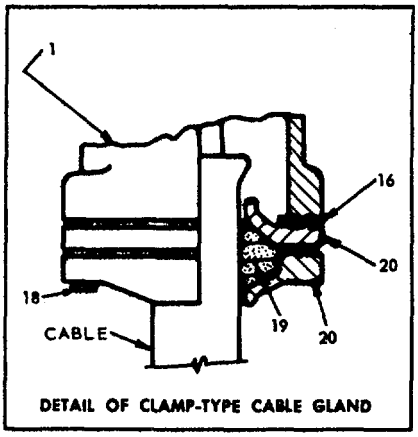


	7.5 Kv	15 Kv
A	1	2
B	1	1
C	10⅝	13
D	5¾	5¾
L	3	5
T	⅛	¼

Note: Gland Dimensions
Clamp Type—1⅞"
Wiping Sleeve—4¾"

Fig. 6 - Single conductor potheads.

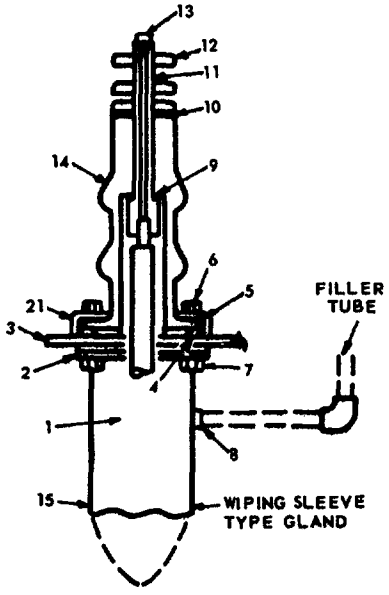




DETAIL OF CLAMP-TYPE CABLE GLAND

MAXIMUM CABLE FOR POTHEADS

Single cable entering porcelain..... 2 1/2" O.D.
Bare cable entering connectors ....1 3/8" max., 1/4" min. O.D.
Cable entering wiping sleeve..... 3 1/4" O.D.
Cable entering conduit support..... 3 3/4"
Cable entering packing ring..... 3"



PARTS LIST

Item	Name	**Conductors	Dwg. or "Q" No.
1	Pothead Body	(3C)	18-446-161-001
		(3C)	18-446-206-001 *
		(1C)	18-446-151-001②
		(1C)	18-230-399-001①
2	Gasket	(3C)	18-240-443-001
		(3C)	18-240-252-001 *
		(1C)	18-140-471-001
3	Support Plate	(3C)	18-172-856-001
		(3C)	18-178-221-001 *
		(1C)	18-172-856-001
		(1C)	18-178-221-001 *
4	Gasket		18-140-469-001
5	Gasket		18-140-469-002
6	Cap Screw ⅜ x 2¼	(1C)	Q-0035416
	Screw (Brass)	(3C)	Q-0035417
	Lock Washer		Q-0047373
	Washer (Brass)		14-104-595-018
7	Hex Nut ⅜		Q-0085265
8	Pipe Plug 1"		18-140-574-001
	Gasket		18-140-469-005
	1" Washer		Q-0086666
9	Gasket		18-140-469-003
10	Gasket		18-140-469-004
	Key Washer		18-140-468-001
11	Stud Terminal		18-270-769-002
12	Hood Nut		18-631-859-006
13	Vent Screw		Q-0085696
	Washer		Q-0086818
	Gasket		18-140-469-006
14	Insulator		18-340-068-001
			18-339-129-001 *
15	Wiping Sleeve	(1C)	18-230-399-001
		(3C)	18-261-493-001
16	Gasket		18-160-750-001
17	Cap Screw ⅜" x 1"		Q-0086198①
18	Cap Screw ⅜ x 1½		Q-0085445②
19	Hemp Rope		(Tarred)
20	Packing Ring		18-261-494-001
21	Insulator Support		18-240-300-001

*Denotes 15 kv part, all other Nos. are common to both 7.5 kv and 15 kv.
**(1C) Single Conductor; (3C) Three Conductor.
① Wipe ② Clamp

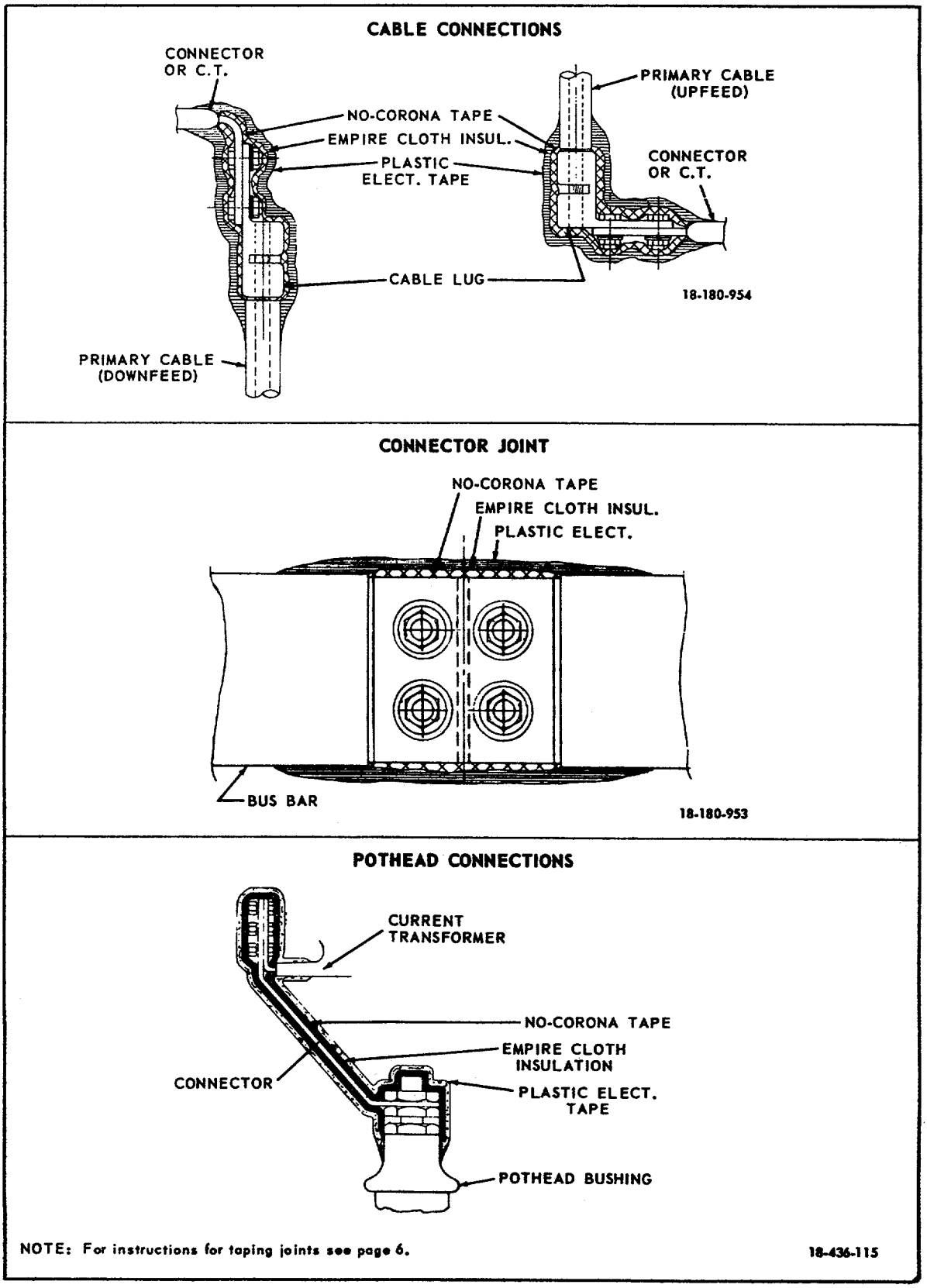


Fig. 7 - Instruction for taping joints.

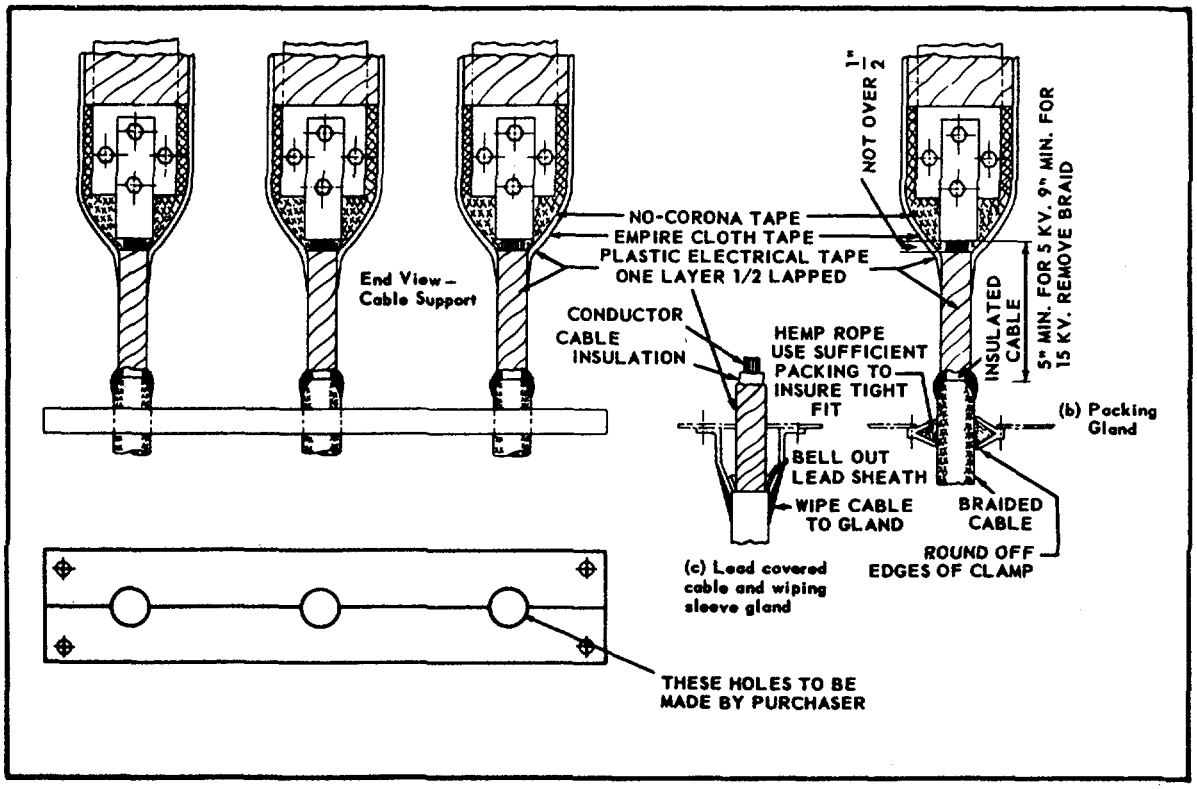


Fig. 8 - Primary cable connections.

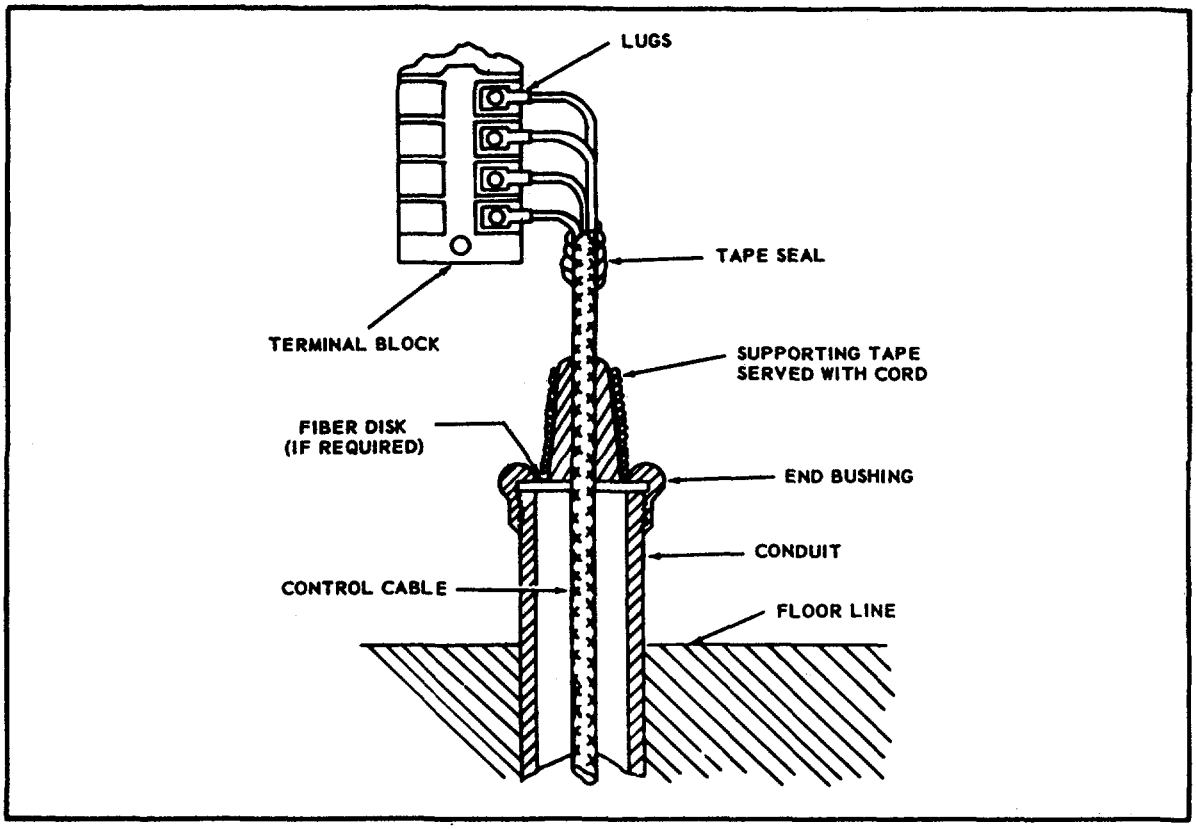


Fig. 9 - Secondary control cable connections.

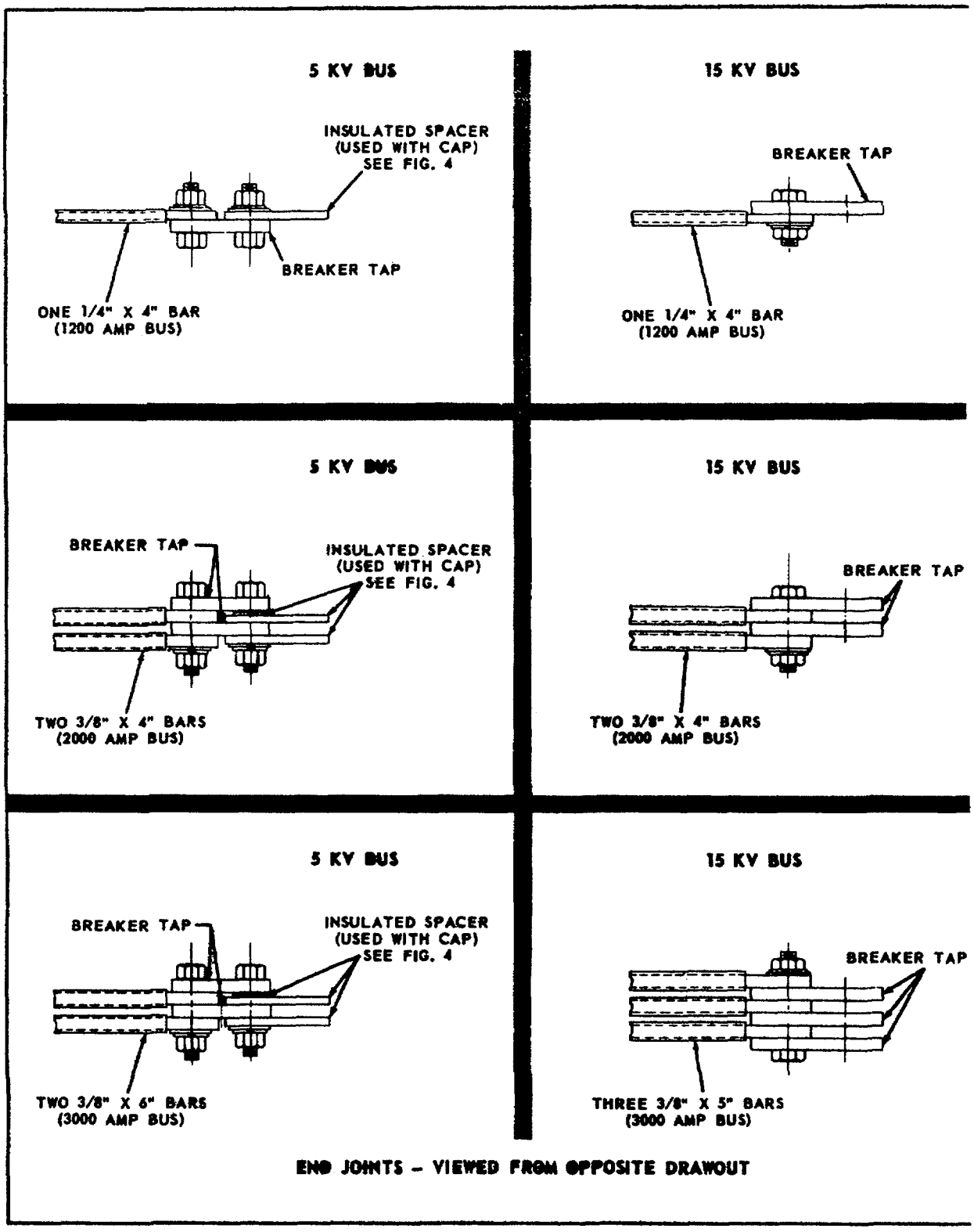
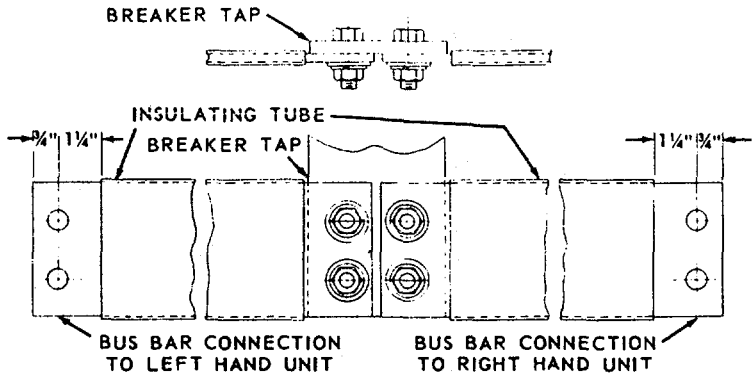
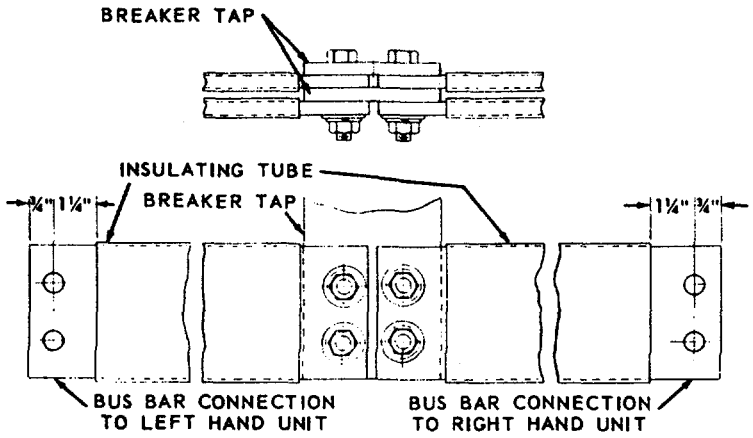
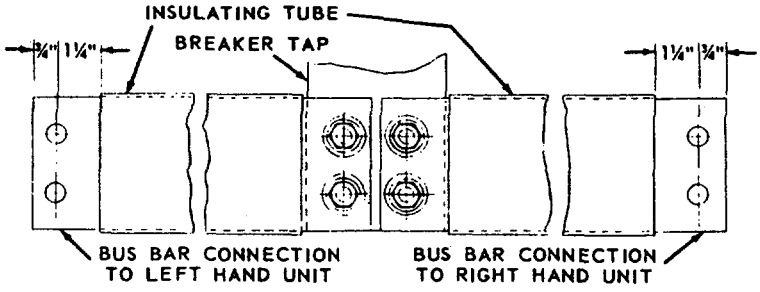


Fig. 10 - Bus bar splicing.







(5 OR 15 KV BUS)
THRU BUS – VIEWED FROM OPPOSITE DRAWOUT

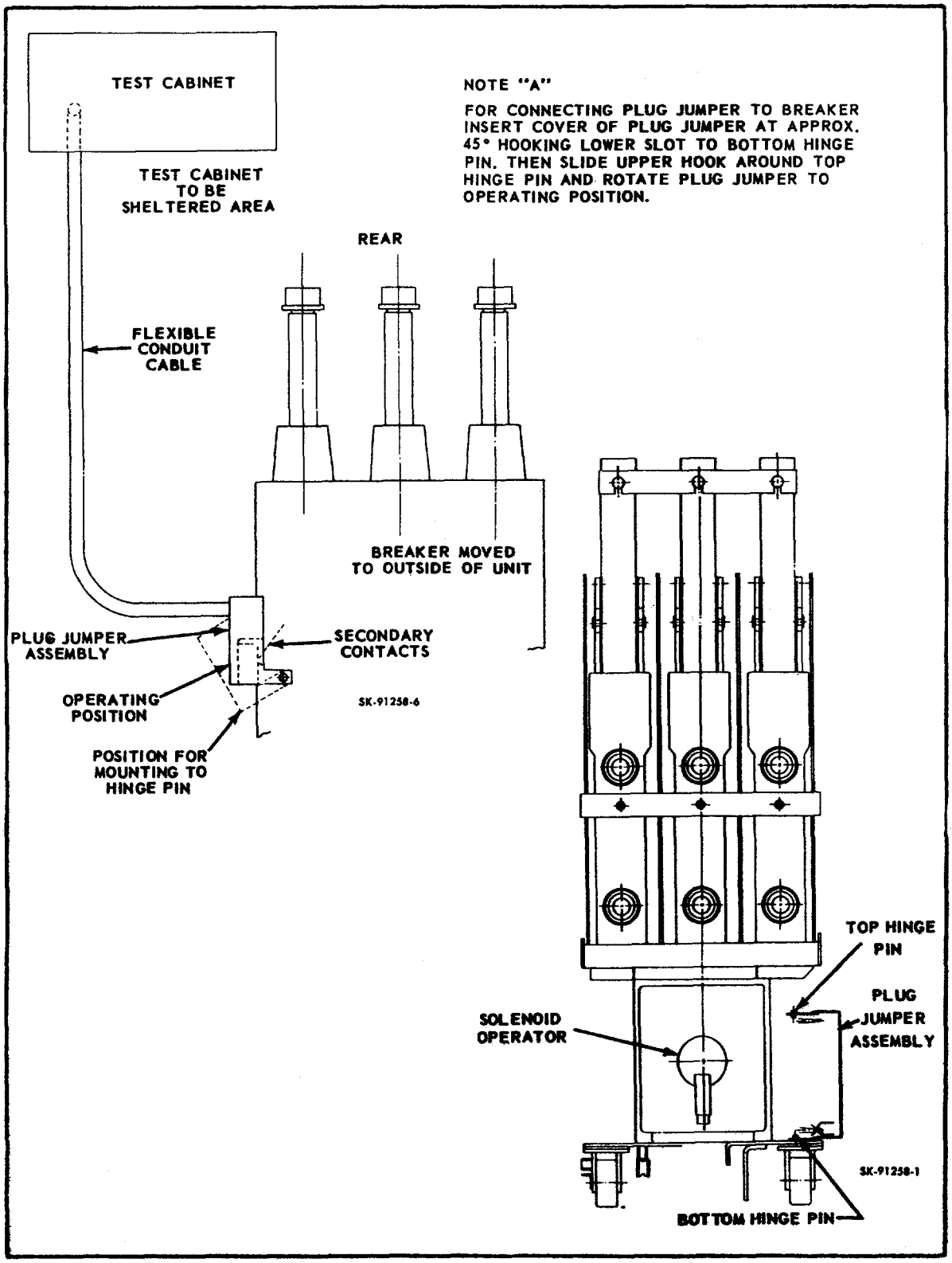


Fig. 11 - Test control cabinet

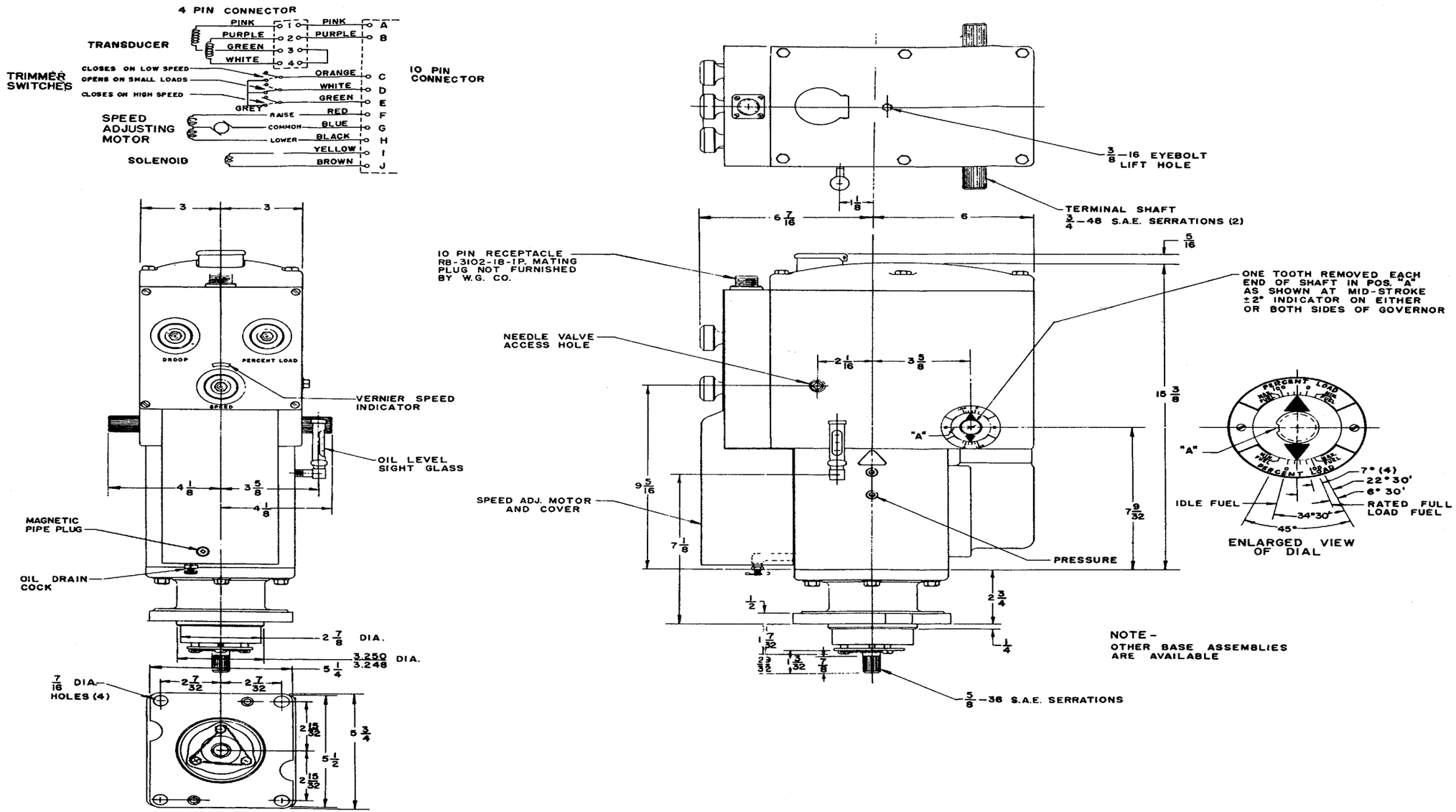

4 PIN CONNECTOR
PINK
PURPLE
GREEN
WHITE
TRANSDUCER
TRIMMER SWITCHES
CLOSES ON LOW SPEED
OPENS ON SMALL LOADS
CLOSES ON HIGH SPEED
GREY
SPEED ADJUSTING MOTOR
RAISE
COMMON
LOWER
SOLENOID
ORANGE
WHITE
GREEN
RED
BLUE
BLACK
YELLOW
BROWN
10 PIN CONNECTOR
A
B
C
D
E
F
G
H
I
J
3
3
DROOP
PERCENT LOAD
SPEED
VERNIER SPEED INDICATOR
OIL LEVEL SIGHT GLASS
4 1/8
3 5/8
4 1/8
MAGNETIC PIPE PLUG
OIL DRAIN COCK
2 7/8 DIA.
3.250
3.248 DIA.
5 1/4
7/16 DIA. HOLES (4)
2 7/32
2 7/32
2 15/32
5 1/2
2 15/32
5 3/4
3/8-16 EYEBOLT LIFT HOLE
1/8
TERMINAL SHAFT
3/4-48 S.A.E. SERRATIONS (2)
6 7/16
6
5/16
10 PIN RECEPTACLE RB-3102-18-1P. MATING PLUG NOT FURNISHED BY W.G. CO.
ONE TOOTH REMOVED EACH END OF SHAFT IN POS. "A" AS SHOWN AT MID-STROKE ±2° INDICATOR ON EITHER OR BOTH SIDES OF GOVERNOR
NEEDLE VALVE ACCESS HOLE
2 1/16
3 5/8
"A"
15 3/8
9 5/16
7 1/8
SPEED ADJ. MOTOR AND COVER
7 9/32
PRESSURE
1/2
2 3/4
1/4
1 7/32
2 3/32
1 3/32
7/8
5/8-36 S.A.E. SERRATIONS
PERCENT LOAD
MAX. FUEL
MIN. FUEL
7° (4)
22° 30'
6° 30'
IDLE FUEL
RATED FULL LOAD FUEL
34° 30'
45°
ENLARGED VIEW OF DIAL
NOTE -
OTHER BASE ASSEMBLIES ARE AVAILABLE

Figure 22

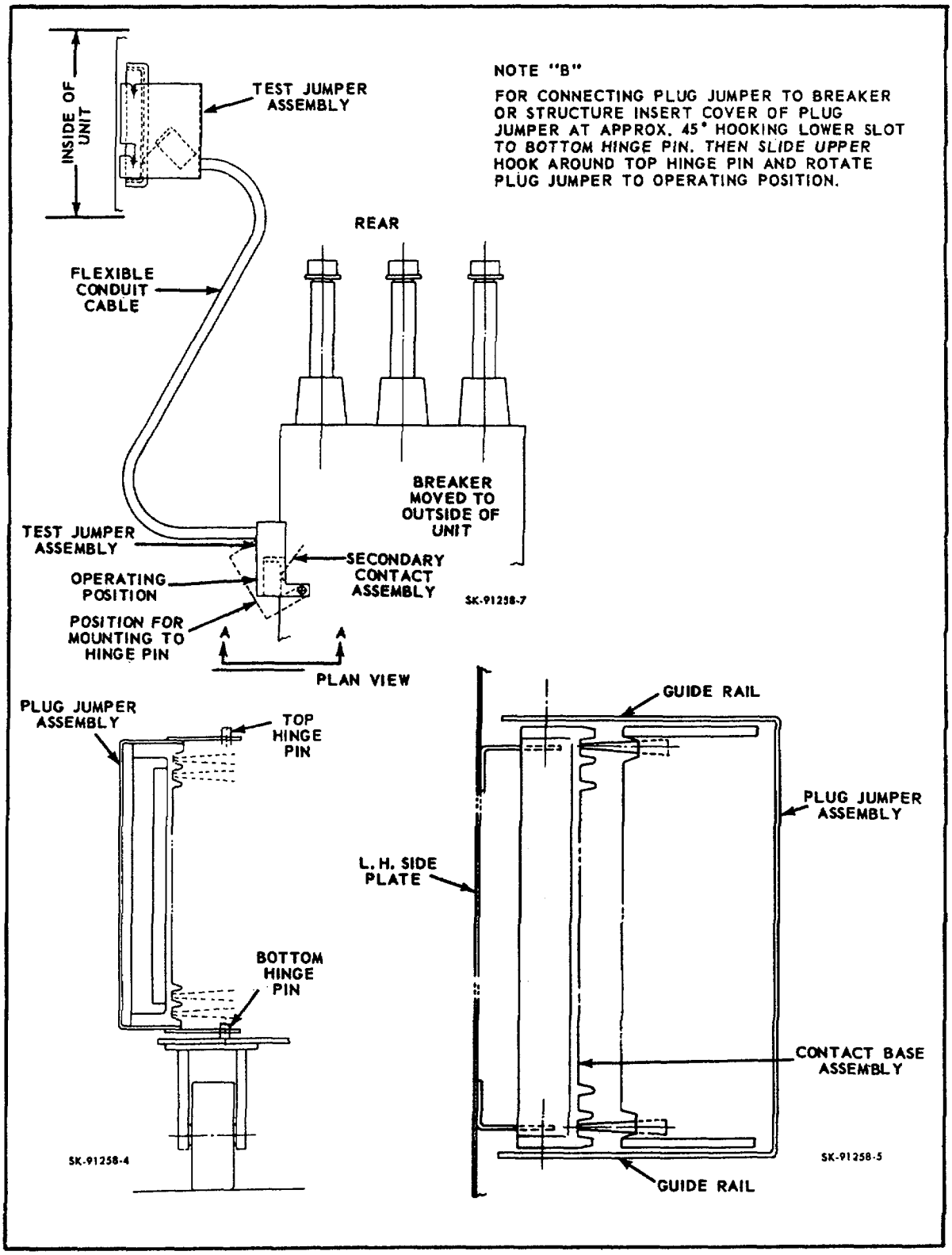
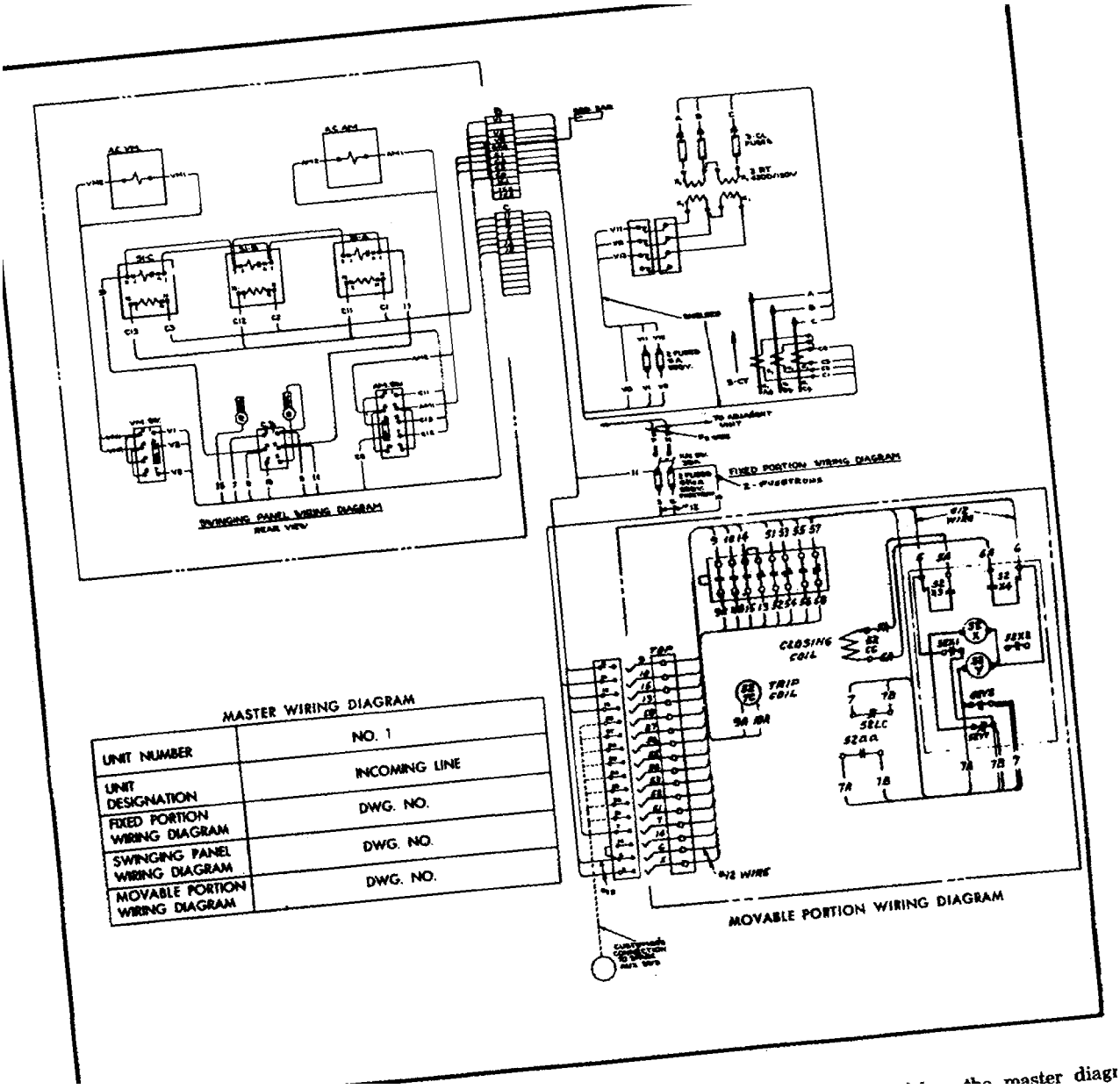


Fig. 12 - Plug jumper.



Wiring diagrams are made up in sections corresponding to the various parts of the units. Separate drawings are provided for the fixed portions, movable portions, panels, etc.

A master diagram is provided tabulating the standardized section drawings identifying them as to unit and part concerned, and showing wiring interconnections between units and external secondary connections. Use applicable wiring diagram for completing wiring when these portions are installed.

To trace wiring, the master diagram and all the diagrams listed on the master diagram must be at hand. The same terminal blocks, knife switches, fuse blocks, etc. may be shown on more than one section diagram. Where this is done the item will be identified. On the typical diagrams of this drawing, knife switch "A" is shown on both the master diagram and the fixed portion diagram. To check complete wiring for this item both section drawings must be referred to.

All jumpers noted as temporary should be removed by the customer upon installation and completion of the wiring.

Fig. 13 - Master wiring diagrams.
(Including instructions for using wiring diagrams.)

SECTION 28B 18X9587B

INSTRUCTIONS FOR RECEIVING, INSTALLATION; INSPECTION, CONNECTION, AND TEST OF THE METAL-CLAD SWITCHGEAR WITH CIRCUIT BREAKERS 5 KV AND 15KV

GENERAL

INTRODUCTION

These instructions cover the installation, operation and maintenance of horizontal drawout, metal-clad switchgear. Described are standard construction details of the switchgear, auxiliary equipment and necessary accessories. Special mechanical and electrical devices, in accordance with purchase order requirements, are covered by supplementary instructions submitted with this instruction book.

Standard ratings are in accordance with NEMA, IEEE and ASA requirements. The power circuit breakers associated with this switchgear are listed along with ratings in table below.

Typical Side Views

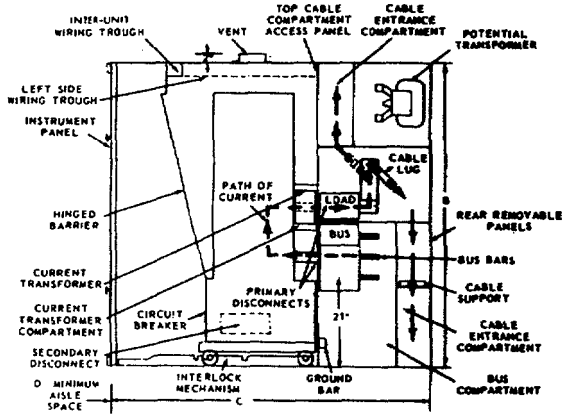


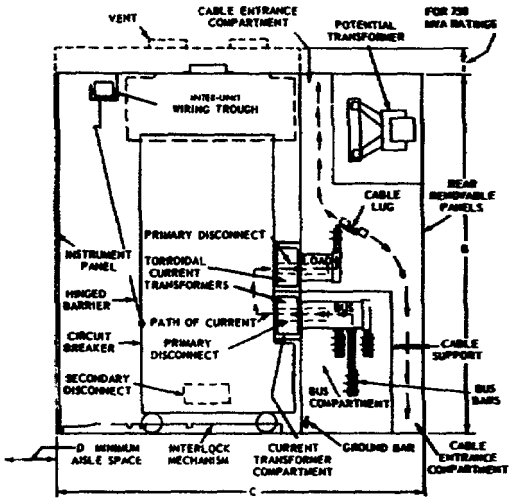
Fig. A - 5-kv Breaker Unit.

RECEIVING

UNLOADING

Each shipping group of the switchgear assembly is securely blocked and braced for shipment. It is crated, boxed, or covered--depending on shipping conditions. Whatever the method of shipment, every precaution is taken to insure its safe arrival. If special handling is require, it is so indicated. All moving parts blocked but because relatively delicate instruments are included, care must be taken to avoid rough handling

Two shipping channels with lifting holes are bolted to the top of the indoor switchgear, assembly to facilitate handling. On single unit assemblies, lifting eyebolts may be furnished instead. If cranes or other lifting means are not available, the group can be rolled into position.



BREAKER RATINGS					STRUCTURAL DIMENSIONS (in.)						
Breaker Type(mva)	Rated Kv	Max. Design Kv	Cont. Current (amps)	Weight (lbs)	Type	Fig.	A Width	B Width	C Width	D Drawout Aisle	Weight (lbs)
MA-75	4.16	4.76	1200	875	DF	A	26	72	74	50	1200
MA-250	4.16	4.76	1200	875	DM	A	26	72	74	50	1200
MA-250	4.16	4.76	2000	900	DM	A	26	72	74	50	1200
MA-350	4.16	4.76	1200	925	DN	A	26	72	74	50	1200
MA-350	4.16	4.76	2000	950	DN	A	26	72	74	50	1200
FA-350	4.16	4.76	3000	2000	DN	8	36	92	94	66	1800
FB-500	7.2	8.25	1200	1400	FO	8	36	92	94	66	1800
FB-500	7.2	825	2000	1425	FO	B	36	92	94	66	1800
FC-500	13.8	15.0	1200	1400	FO	B	36	92	94	66	1800
FC-500	13.8	15.0	2000	1425	FO	B	36	92	94	66	1800
FC-750	13.8	15.0	1200	1450	FQ	B	36	92	94	66	1800
FC-750	13.8	15.0	2000	1475	FQ	B	36	92	94	66	1800
FC-1000	13.8	15.0	1200	3300	FR	8	36	100	105	77	2000
FC-1000	1 ;3.8	15.0	3000	3450	FR	B	36	100	105	77	2000

At 2.3 kv MA 75 = mva, MA-250 = 150, MA-350 = 200 mva.

Lifting jacks can be used to help in placing rollers under the skids and to remove the rollers and the skids after positioning. After removing the rollers and skids, lower the group slowly (do not drop it as the impact may damage delicate instruments). Under no circumstances should the shipping channels be removed from the top of the units until the equipment is installed in its final location and the rollers and skids have been removed.

Because of the absence of bottom rear cross members, the units may be easily rolled into place after the cable has been pulled in or primary conduit stubbed up.

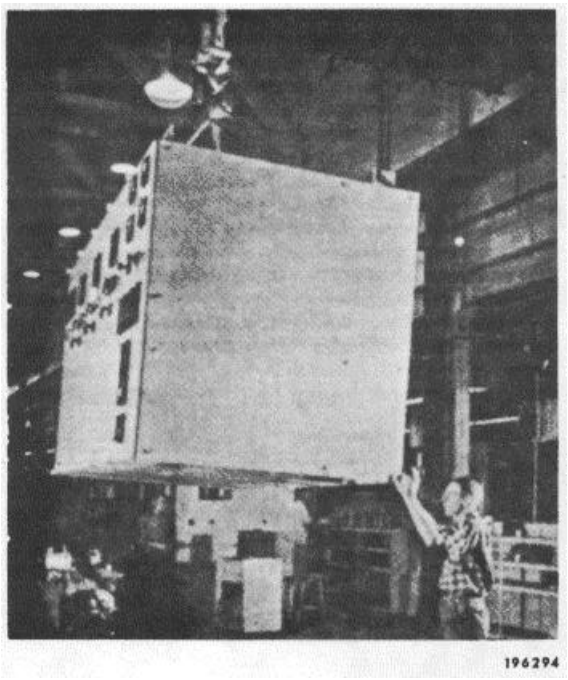


Fig. 1 - Top-mounted lifting channels facilitate handling by crane.

ACCESSORIES

The following accessories are crated separately:

1. Test device for testing breaker when it is out of but adjacent to cubicle.
2. Manual closing and racking lever.
3. Fifth wheel to facilitate moving breaker when outside of cubicle.
4. Arc chute support.
5. Spring charging crank (for stored energy operated breakers).
6. Pothead compound and touch-up paint, as required for installation.
7. Test plug, less cable, for drawout relays and watthour meters. Equipment specified for remote mounting may also be included.

SHIPMENT INSPECTION

As soon as possible after uncrating, inspect the equipment for any damage that may have occurred in transit. Check the shipping manifest to be certain all items have been received.

STORING

When switchgear is not to be erected immediately, uncrate, inspect and store in a clean, dry location.

When space heaters are supplied with an order, energize the space heaters, as in the final installation, to eliminate condensation. In some locations, condensation occurs whether the unit is stored or in operation.

Space heaters are not considered standard equipment with indoor switchgear (recommended 500 watts per unit). When indoor switchgear not equipped with space heaters is stored indoors, space heaters must be applied inside the cubicles to prevent condensation. Standard indoor units are not drip-proof and therefore should be stored indoors. If indoor units must be stored outdoors, adequate covering must be provided together with a heat source of approximately 500 watts per unit distributed between breaker and bus compartments and mounted inside the cubicles to prevent condensation.

Batteries should be connected to a charger and never be left in dead storage.

INSTALLING

CONDUIT

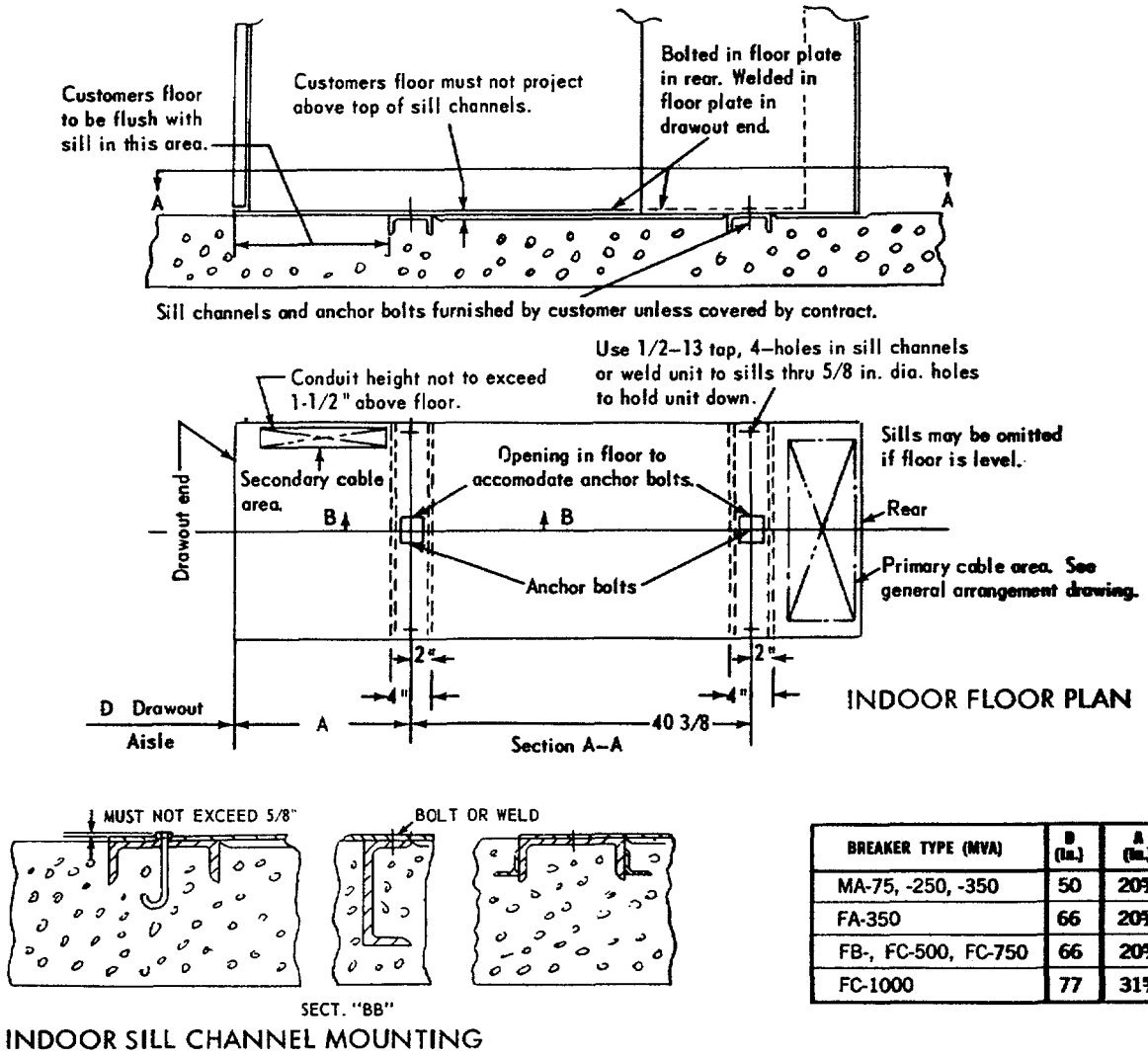
Conduit for power and control connections may be installed in the areas indicated on the General Arrangement Drawings and Floor Plan with due regard for the ease of training the cables in the switchgear. Conduit ends should be about one inch (maximum 1 1/2 in.) above the finished floor to prevent washing water from soaking cables. They should also be capped and taped to keep out moisture and vermin.

FOUNDATIONS

Dimensions of sill channels and anchor bolts should be in accordance with the General Arrangement and Floor Plan whether the switchgear is to be installed on an existing floor or a new floor. Refer to Figure 2 for recommended sill channel mounting of indoor installations.

ERECTION

The proper erection method depends on whether the units are shipped as one complete group or in two or more sections. In any case, the General Arrangement Drawing will indicate the shipping groups. Units are assembled and wired exactly as they are to be arranged in the final installation. Prior to shipment to the job site, the lineup is separated into the appropriate size shipping groups and crated for shipment.



BREAKER TYPE (MVA)	D (In.)	A (In.)
MA-75, -250, -350	50	20⅝
FA-350	66	20⅝
FB-, FC-500, FC-750	66	20⅝
FC-1000	77	31⅝

Fig. 2 - Typical floor plan and sill channel mounting.

SINGLE GROUPS

The unit is brought to the site, being handled as instructed under "UNLOADING." Before placing on previously installed sill channels, make sure the channels are level. After the channels are level, the unit is placed in its final position and bolted or welded to the sill channel. (Figure 2.)

MULTIPLE GROUPS

When a shipment is made in two or more groups, the procedure is, in general, the same as for single groups. However, individual groups must be carefully aligned and set as closely as possible. The fronts of the groups are aligned first and then bolted together.

After erecting single or multiple groups, check with a plumb bob, or similar device, to be certain each group is vertical and has not shifted during handling. The breaker units of each shipping group have been checked and marked at the factory. The plumb bob lining up to within plus or minus 1/16-inch of the factory marked "plumb" insures alignment. (Figure 3.)

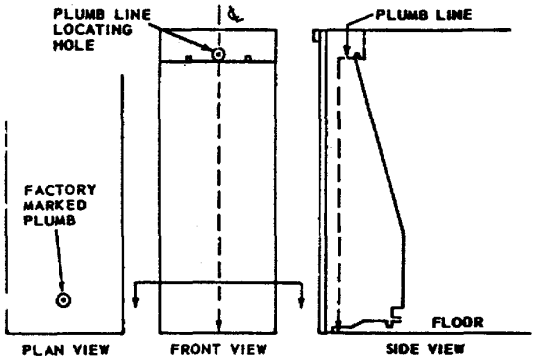


Fig. 3- Correct method of plumbing units..

If any shipping group units have shifted during shipment and are out of plumb, the following correction procedure is recommended.

(a) Loosen bolts holding the lifting channels to the group of units.

(b) Loosen, but do not remove, bolts holding the "plumb" marked unit to its adjacent unit. Adjust until plumb bob is within plus or minus 1/16 inch of the factory marked "plumb." It may be necessary to loosen bolts in successive adjacent units to attain the necessary plumb.

(c) Tighten all bolts holding units to each other.

(d) Remove lifting channels.

(e) Check each breaker shutter operating mechanism for proper operation.

Secondary inter-group wiring at shipping breaks is then connected as tagged. (Figure 4.)

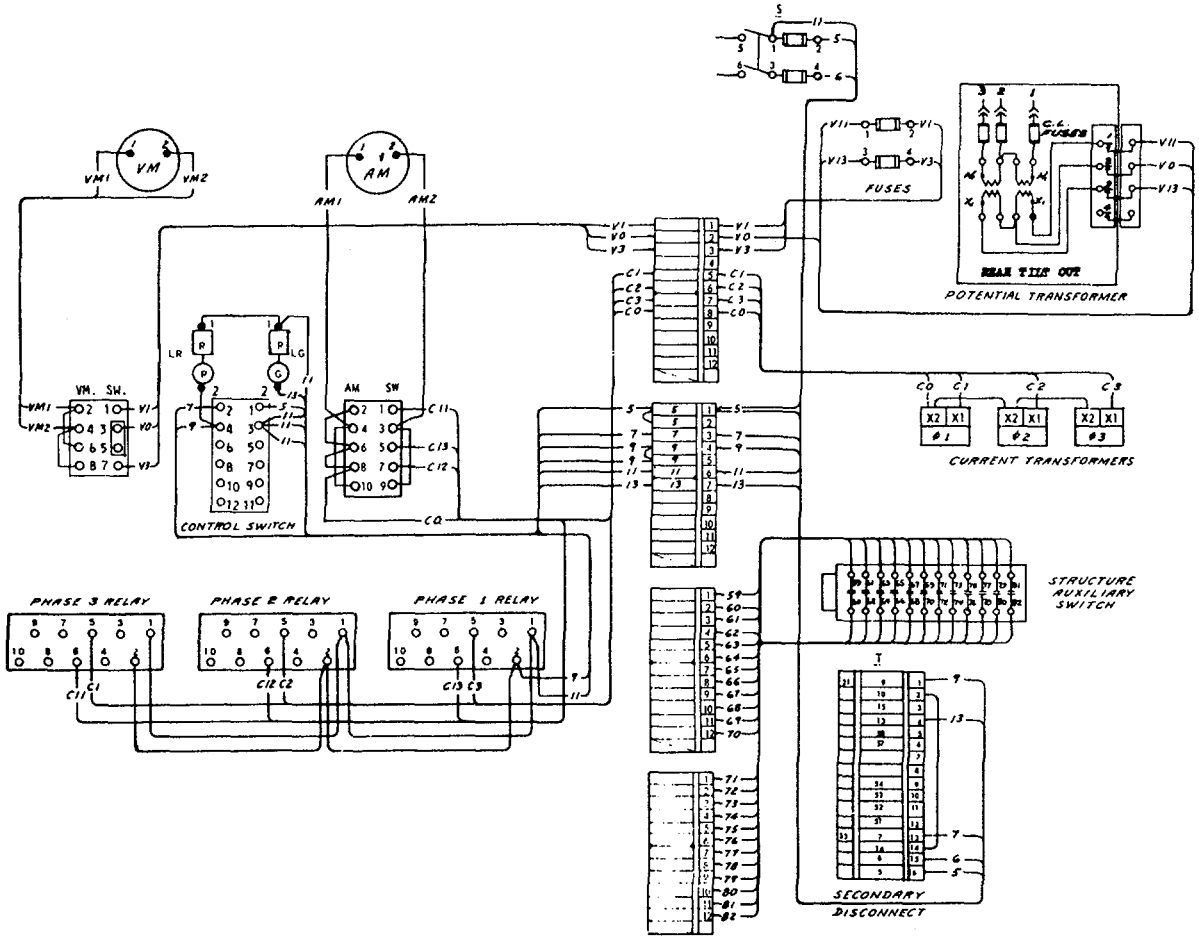
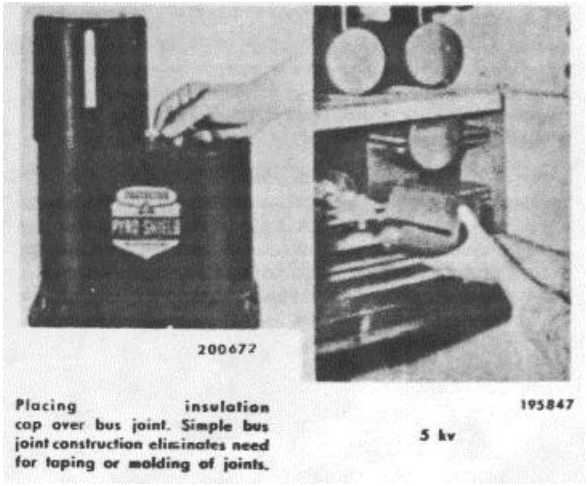


Fig. 4 - Typical Wiring Diagram.

ELECTRICAL CONNECTIONS

BUS BAR JOINTS

This type of joint is connected as shown in Figure 5. Before placing the insulator cap over the bus joint, draw up all bolts and nuts tightly.



Placing insulation cap over bus joint. Simple bus joint construction eliminates need for taping or molding of joints.

INSULATION CAPS

After bolting the main bus to the primary connectors, the molded insulator cap is placed over the joint and fastened by means of a reusable nylon rivet. Upon insertion, the rivet prongs compress to enter. Using a small hammer, drive the center pin through the hollow shank. The center pin wedges the prongs apart for positive lock, and the cap is fastened to the base assembly. To remove the rivet, the center is driven through the hollow shank. The rivet is removed and the joint can be disassembled. (Figure 6.)

Molded polyvinyl boots are used to insulate bus joints of 13.8-kv switchgear. (Figure 7.)

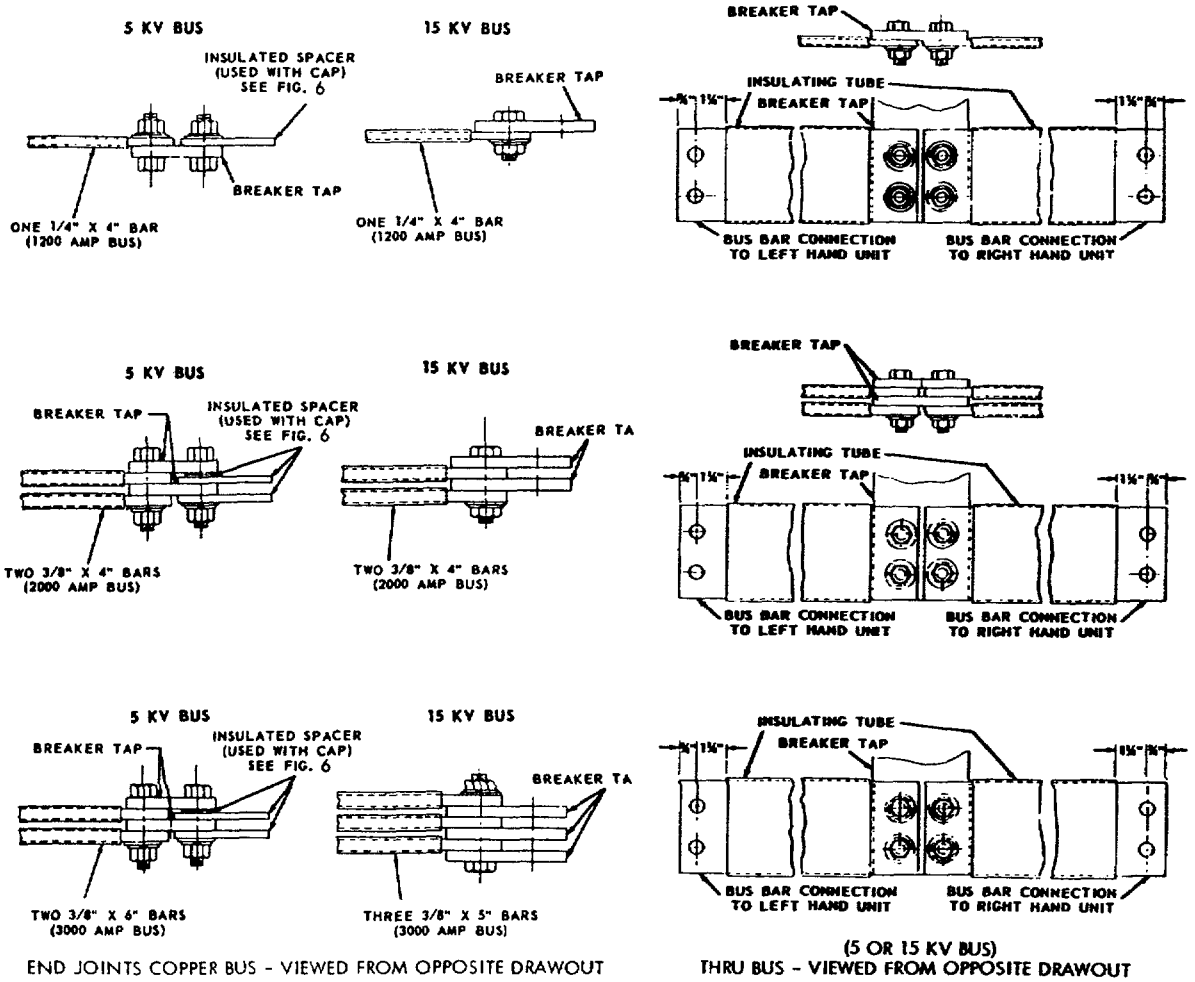


Fig. 5 – Bus bar splicing.

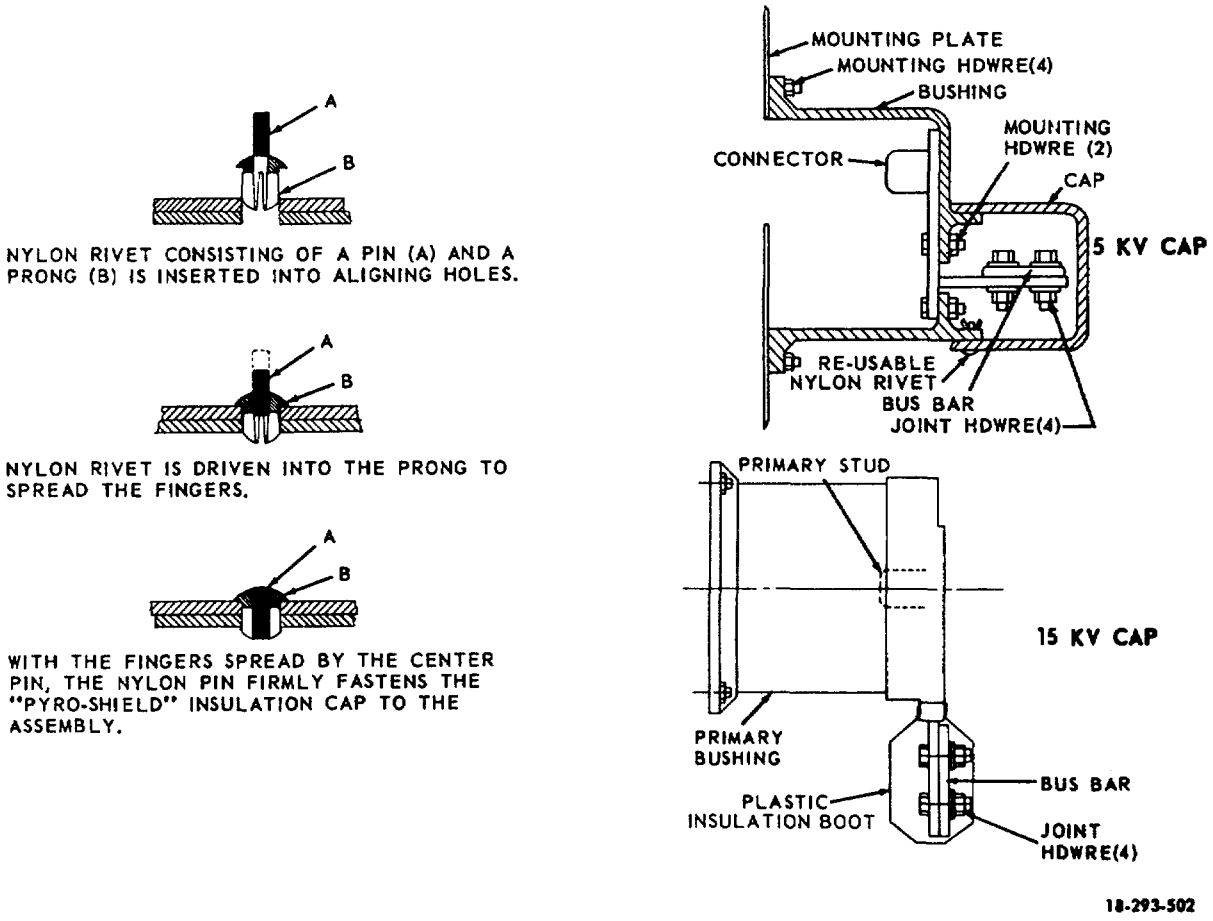


Fig. 6-- Bus joint using

PRIMARY CABLE CONNECTIONS

Before primary cable connections are made, phase rotation must be considered. Viewed from the breaker drawout side, phase 1 is at the left, phase 2 in the center, and phase 3 at the right.

When the bus bars are arranged horizontally and parallel to the breaker drawout side, phase 1 is toward the front of the assembly, phase 2 is in the center, and phase 3 in the rear.

When bus bars are arranged above one another, phase 1 is at the top, phase 2 in the center, and phase 3 at the bottom.

Phasing is furnished this way unless otherwise marked on the installation drawings transmitted prior to shipment of the switchgear.

Relays and meters are connected for a phase rotation of 1, 2, 3. This means that the voltage of phase 1 reaches its maximum value 120 degrees ahead of the voltage of phase 2, and the voltage of phase 2 reaches its maximum value 120 degrees ahead of the voltage of phase 3. Lines to the switchgear must be connected accordingly to insure correct meter and relay operation.

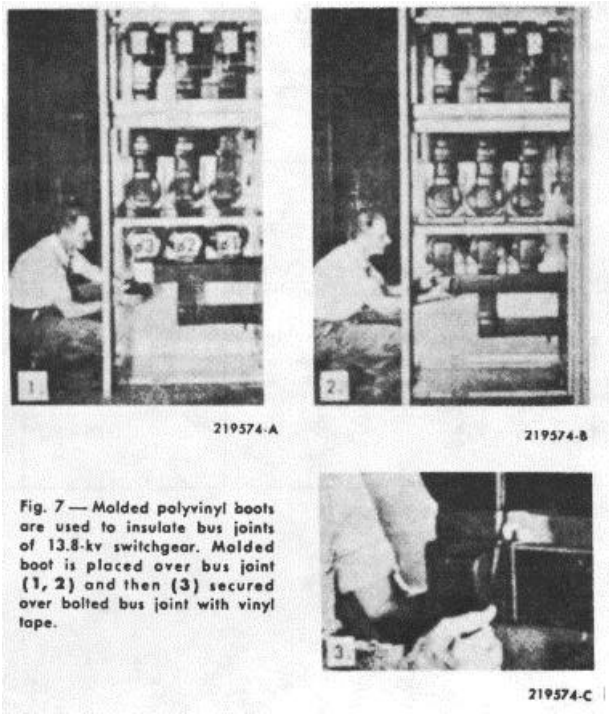
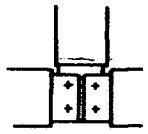
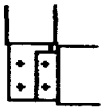
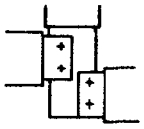
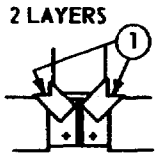
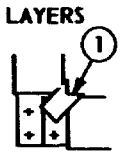
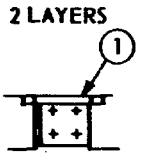
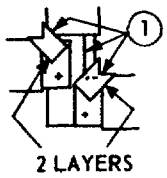
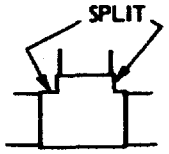
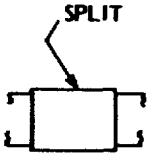
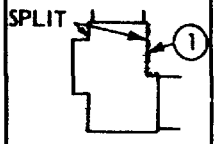
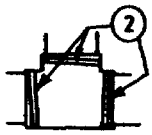
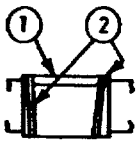
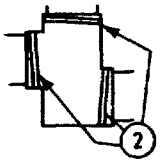
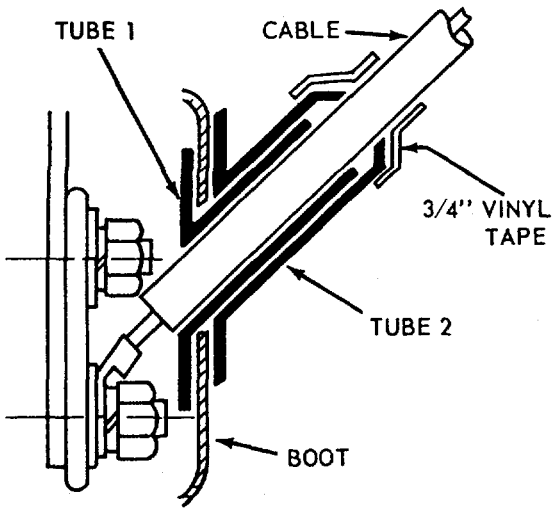


Fig. 7 — Molded polyvinyl boots are used to insulate bus joints of 13.8-kv switchgear. Molded boot is placed over bus joint (1, 2) and then (3) secured over bolted bus joint with vinyl tape.

	T CONNECTION	L CONNECTION	THRU CONNECTION	OFFSET CONNECTION
STEP 1 Make bus bar joints as instructed. Observe carefully the required placement of bolts through the joint.				
STEP 2 Place two layers of 2-inch wide black vinyl tape [1] in corners or over edge as shown, one on top of the other. Form a sharp corner over the bus bar tape or tubing. The ends of the tape should extend equally over the front and back of the joint.				
STEP 3 Place the plastic boot on the joint and align to produce the minimum gap at the split. Locate the split over the 2-inch wide black vinyl tape.				
STEP 4 Apply single layer ½ lap ¾-inch wide maroon vinyl tape [2] as shown to hold the boot in place. On the thru-connection, place a third layer of the 2-inch black vinyl tape over the split before securing the boot with the ¾-inch tape.				



INSULATION BOOT INSTALLATION WITH A CABLE CONNECTION
(except Thru-Connection) *

Step 1 Cut a one-inch diameter hole in the center of the insulation boot for the specified joint (except thru-connection).

Step 2 Slide insulation tube number 2 onto cable from the joint connection end.

Step 3 Slide boot onto the cable from the joint connection end through the one-inch hole cut in the center.

Step 4 Slide insulation tube number 1 onto the cable from the joint connection end.

Step 5 Strip cable insulation and make connection to joint.

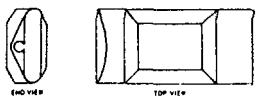
Step 6 Slide tube 1 tight against joint.

Step 7 Fit boot over the joint. Tube 1 will pass through the hole in the boot, tube 2 will remain outside of the boot.

Step 8 Holding boot tight up against the joint, slide tube 2 tight up against the outside of the boot.

Step 9 Tape the end of tube 2 to the cable with one layer of 3/4-inch wide maroon vinyl tape.

*NOTE: At Thru-Connection Joints where a cable is to be installed, a boot will be supplied to fit over the cable. Make the cable connection as instructed and install the boot in the same manner as shown on the front side of this sheet.



BOOT FOR THRU-CONNECTION WITH CABLE

CAULKING MATERIAL

"Scotchcast" Number 214 resin (or equal) is required to caulk the air gaps around bus bars at the bus supports.

MIXING

The resin is furnished in two parts. Each part should be thoroughly mixed before combining. Mixing proportions are 5 parts "A" to 1 part "B" by weight. The combined parts should be completely mixed by mechanical means until the color is uniform. Avoid excessive whipping as it introduces air into the mixture.

POT LIFE

A batch will remain manageable for 45 minutes to an hour and a half. It can readily be used with a spatula for the first 45 minutes.

CURING TIME

The resin will gel at room temperature in four to eight hours. Complete cure is 24 hours at room temperature.

APPLICATION PROCEDURE

The compound handles much like peanut butter. It is readily applied with a spatula and remains in the exact place it is applied. Apply the resin to make a continuous fillet completely around the bus bar insulation at the support, as shown in the following figures. Care must be taken to insure that all air voids between the tubing and support are completely filled with resin.

AMOUNT REQUIRED

Each caulked support requires 1/6-pound of resin for each phase, or 1/2-pound for a three-phase arrangement.

WHERE APPLIED

Apply to all metal-clad switchgear and bus ducts rated 15kv. Also apply to Types P and Q switch units with insulated bus when included in metal-clad lineups. All three phases are to be caulked as described above.

ILLUSTRATIONS OF CAULKED AIR GAPS ON BUS BAR SUPPORTS

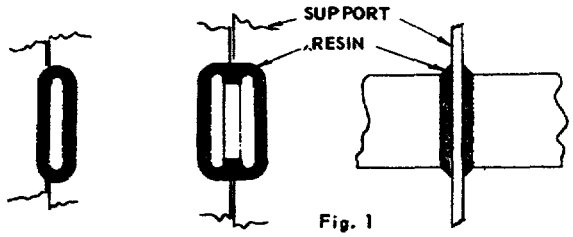


Fig. 1

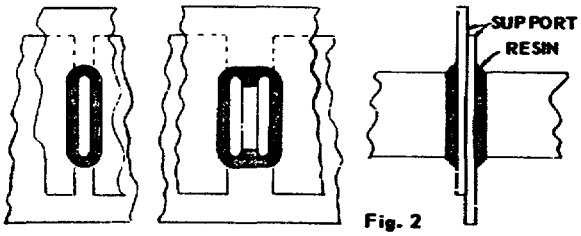


Fig. 2

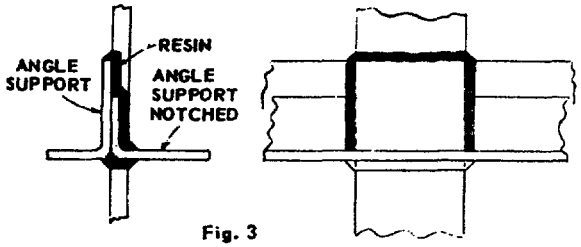


Fig. 3

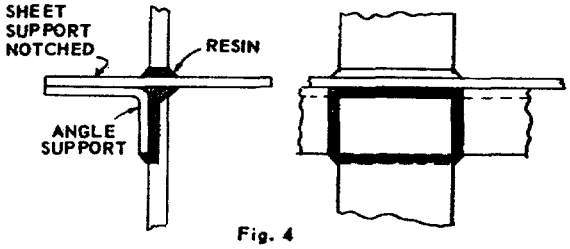


Fig. 4

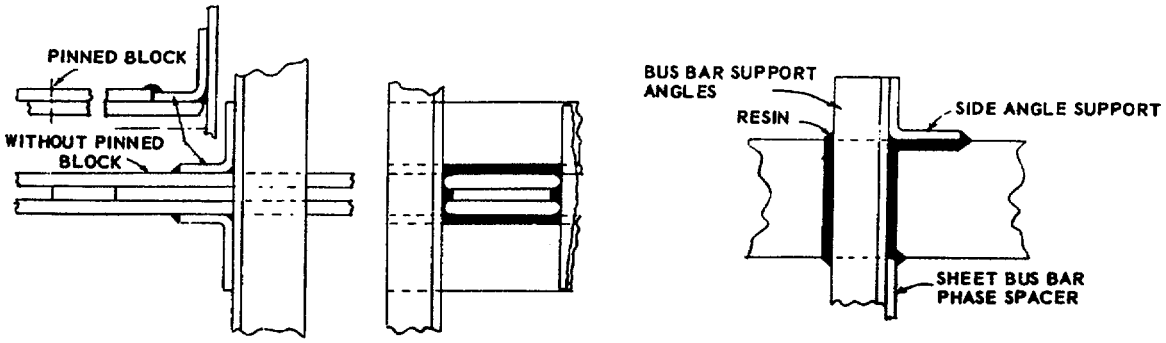


Fig. 5

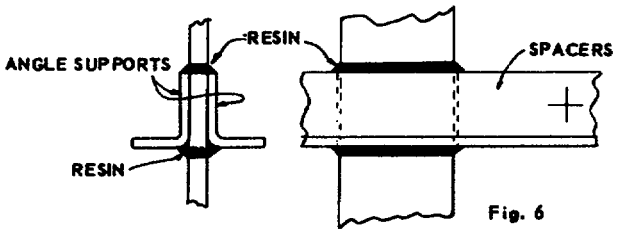


Fig. 6

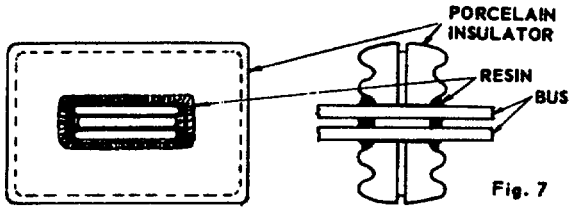


Fig. 7

Use resin to form a complete ring between the porcelain insulator and bus insulating tube. This operation must be performed on both sides of the porcelain insulator. It is not necessary to completely fill the void within the insulator or between bus bars.

POTHEAD CONNECTIONS.
(Lead Covered Cable)

The following material, with the exception of the insulation compound and tarred rope, is not included with the switchgear unless covered by the contract, but is needed to properly install pothead connections:

(a) Insulating compound.
(b) Solder (50-50) for connectors.
(c) Solder (60-40) for wiping joints.
(d) Stearine for solder and wiping flux.
(e) Varnished cambric tape for reinforcing cable conductor insulation and for stress relief cones. (Rubber tape is used on rubber insulated cables.)
(f) Copper tinsel braid for stress relief cones, if required.
(g) Dry cotton tape.
(h) Tarred rope for filling clamp-type cable glands.

Tools and equipment required for installing potheads:

(a) Kit of cable jointer tools including hacksaw, knife, and wrenches.
(b) Blow torch.
(c) Gasoline furnace for heating solder and compound.
(d) Solder pot and ladle.
(e) Melting vessel for melting compound.
(f) Funnel, filling and vent pipes for compounding.
(g) Thermometer (200 to 500 degrees F).

Note the following general instructions:

(a) The conductor insulation and internal parts of the pothead should be kept clean and free of moisture.
(b) Avoid sharp bends in insulated conductors.
(c) Remove lead sheath carefully to avoid cutting the insulation. The last few layers should be torn off to prevent cutting the individual conductor insulation.
(d) If temperature is below 15 degrees F, cable must be warmed prior to bending. Potheads should always be heated to prevent compound from congealing too quickly on cold surfaces. Avoid direct application of heat on porcelains or on parts with porcelain inserts.
(e) Follow carefully the instructions shown in Figures 11 and 12. In all cases avoid the formation of air and gas pockets.
(f) Fill the potheads with compound from the bottom up to allow compound to rise evenly and force air up and out at the top, eliminating voids. Clean off all surplus and spilled compound.
(g) After pothead has cooled, re-tighten all bolts to make sure of positive tightness of all joints.

INSTRUCTIONS FOR RECLAMATION OF A POTHEAD

Following procedure can be used if cable is going to be replaced:

Steps 1 - Cut off cable at base of pothead.
2 - Remove upper pothead connections.
3 - Remove pothead from cubicle.
4 - Remove top cap nuts and vent screw as well as pipe plug in lower pothead body.
5 - Pothead can now be placed in an oven with temperature of approx. 150 degrees C and left in oven until all compound drains.
6 - When completely drained remove, disassemble and dean thoroughly with suitable solvent.
7 - IMPORTANT: It is recommended that new compound be used to refill pothead after reassembling as the dielectric strength of the old compound may be reduced by contaminants.
8 - New gaskets must be used for reassembling.
9 - It may be necessary to obtain new wiping sleeves or packing glands and studs, depending on new cable size to be used. If new cable will be smaller than that removed, stud and wiping sleeve or packing gland must be replaced with new. If new cable will be larger, then holes may be opened to desired size and original stud and sleeve or gland can be reused.
10- To refill, same procedure can then be followed as if this were a new pothead.

For removing potheads where existing cable is to be reused:

Steps 1 - Remove upper pothead connections.
2 - Remove top cap nuts and vent screw as well as bottom pipe plug.
3 - Shield cable at base of pothead with asbestos or other heat insulating material as safety feature to avoid damage to cable insulation.
4 - Using a blow torch or other heating device, heat body of pothead sufficiently to melt compound and drain into bucket.
5 - Heat well around drain plug at bottom to start compound flow.
6 - CAUTION: Do not apply flame directly to porcelain insulators as they may crack, and if sufficient heat should travel to the top it could melt compound in insulator.
7 - When drained, pothead can be removed, disassembled and cleaned with suitable solvent.

Then follow instructions given in Steps No. 7, 8, 9 and 10, above.

PACKING, WIPING SLEEVE GLANDS AND SUPPORTS

When packing glands are furnished, cut the gland to suit the outside diameter of the cable, and pack as shown for the clamp-type terminals. (Figure 11.)

TAPING JOINTS

When supports of insulating material are furnished the supports should be cut for the cable OD. and suitably clamped.

Upon completing the primary cable connections (Figs. 11, 12, and 14), untaped high voltage connector joints should be insulated. After connections are made, the joints are wrapped with no-corona tape. Use approximately two feet of this copper mesh tape to form a regular surface (not necessarily a straight surface) over the bolt heads.

Wrap joints with three layers of Empire cloth sheet 0.010 inches thick (approximately six ft long), wide enough so that edges overlap adjoining insulation about three inches, and long enough to overlap' ends three inches. Stagger the overlapping of the ends as much as possible and tie the layers firmly with bias cut yellow Empire cloth tape 0.010 inches thick by 3/4 inches wide (approximately 30 ft long).

Make this insulation operation with the Empire cloth twice for satisfactory insulation for 5.0 and 7.5 kv equipment, and three times for 15 kv equipment. Use six sheets of 0.010 inches thick Empire cloth per joint for 5.0 and 7.5 kv, and nine sheets for 15 kv. Then tape joints with one layer half wrapped electrical tape (one roll). See Figure 8 for typical insulated joints.

POTHEADS

Potheads must be coordinated with other switchgear components to meet space, dielectric, momentary current, and thermal current requirements.

In standard switchgear units, the pothead mounting is such that the pothead may be removed from the mounting without disassembly of the pothead. Each three conductor pothead, or group of three single conductor potheads, is on a separate mounting plate. The plate, in addition to serving as a mounting, separates the current transformer compartment from the cable compartment.

The potheads are mounted in a manner that the customer can, if he desires, make his cable connection outside the unit or on the floor of the unit. He may also make his cable installation in the mounted position. There is sufficient distance between the entrance of the pothead and the floor of the unit to permit dropping the pothead body over the cables to make the stress cones.

Different sizes of pothead bodies are not furnished to match the various cable sizes within an installation. One three conductor body is furnished to take all sizes up to approximately 750 mcm. One single conductor body is furnished to take all cable sizes up to approximately 1000 mcm. This permits the installation of larger cable if the loads outgrow originally selected cable sizes.

Three conductor potheads have their entrance off-set, so that if two potheads are mounted in one unit the off-sets are in opposite directions. This provides more space to work when wiping lead to the wiping sleeve of the pothead and lead of the cable.

Potheads are an integral part of switchgear and 'therefore are required to stand the same tests as other metal-clad switchgear components. The following are dielectric tests required to meet switchgear standards.

Table 1

Voltage Rating	Low Frequency RMS	Impulse Crest 1.5 x 40MS Positive or Negative
7.2 KV	26 KV	75 KV
13.8 KV	36 KV	95 KV
5 KV	19 KV	60 KV

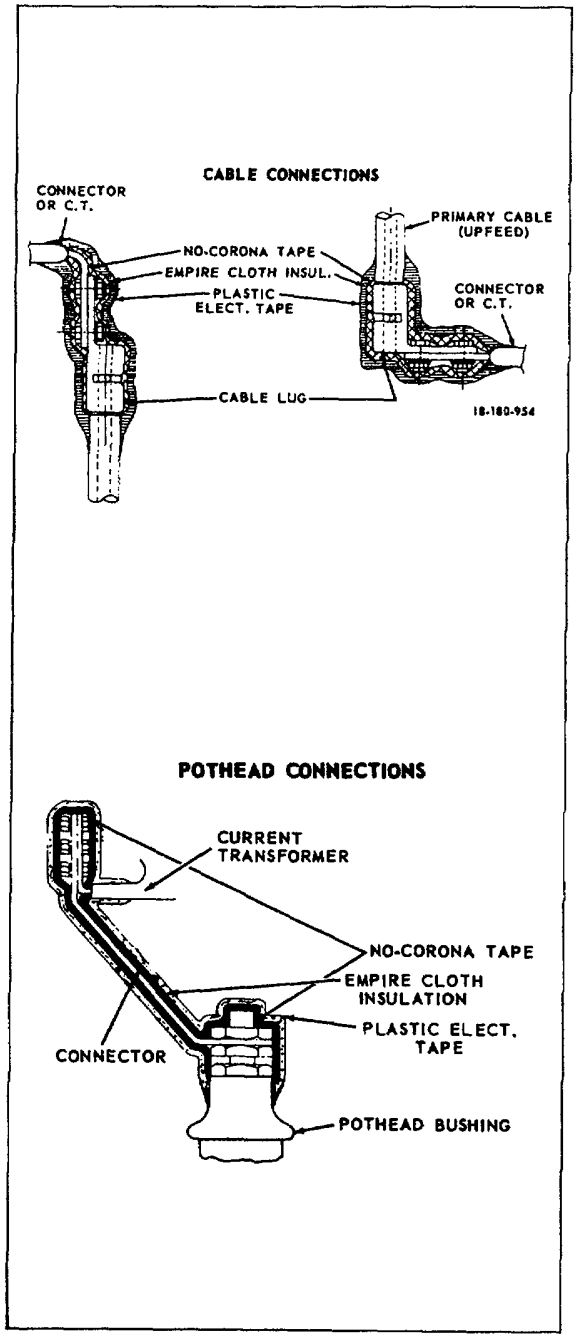


Fig. 8 – Instructions for taping joints.

STRESS RELIEF CONES

Stress relief cones increase the strength of the cable insulation against puncture at the end of the grounded shielding. They also increase overall internal dielectric strength and reliability of the cable termination. Stress cones are recommended for all shielded cables and the higher voltage single conductor lead covered cables. Belling out lead sheath is usually sufficient for lower voltage lead covered cables.

On paper or varnished cambric insulated cables, a double cone is built up of half lapped varnished cambric tape. The lower slope is wrapped with copper tinsel braid, tucked under the bell at end of lead sheath and soldered to the lead sheath and/or to the cable shielding tape. On rubber insulated cables, the double cone may be built up of dry varnished cambric tape and shielded with standard copper tinsel braid as above.

STEP A – Preparing the Cable

Determine length of each conductor to extend from position of wiping sleeve or packing gland to point of connection to the stud terminal. Establish location of stress relief cone on the cable so that it will be approximately in the center of the pothead body. Remove shielding and conducting tapes down to bottom of stress cone (point X). Bare the end of the conductor and solder to stud terminal.

STEP B – Building the Stress Relief Cone

Starting at the terminal end, wrap varnished cloth tape, half lapped down to the edge of the metal shielding tape. Continue wrapping back and forth until the double cone of proper diameter is obtained. Finish by wrapping the final layer of tape on the conductor and on up to the stud terminal. If varnished cambric tape is used, and the cable is varnished cambric or paper insulated, flushing oil should first be brushed on the cable insulation and on each layer of tape. Use long rolls of varnished cambric tape to minimize the number of splices. Wrap tightly. If tape breaks, unwrap enough to locate splices near the connector end of the cone.

INSTALLATION INSTRUCTIONS

1. Check cable gland and stud to see that they fit cable. These items may be furnished with pilot holes only. Drill out if necessary with a clearance of approximately 1/16 inch over size of cable sheath and conductor, respectively.
2. Slide cable gland, cable gasket, and pothead body down over cable.
3. Train cable into proper position allowing sufficient length to make connections.
4. Mark cable sheath approximately 1 to 1'/2 inches above the bottom of the gland.
5. Remove lead sheath from the cable to point marked, being careful not to damage insulation. Bell out lead sheath as shown in Figure 9. For braided cables remove braid down to point "X."
6. Remove belt insulation (outer layers of insulation around all conductors) from the cable to point "X" above the lead bell.
7. Fan out conductors into final position avoiding sharp bends (3 conductor only). Cut off conductors to proper length to fit into studs. Remove cable

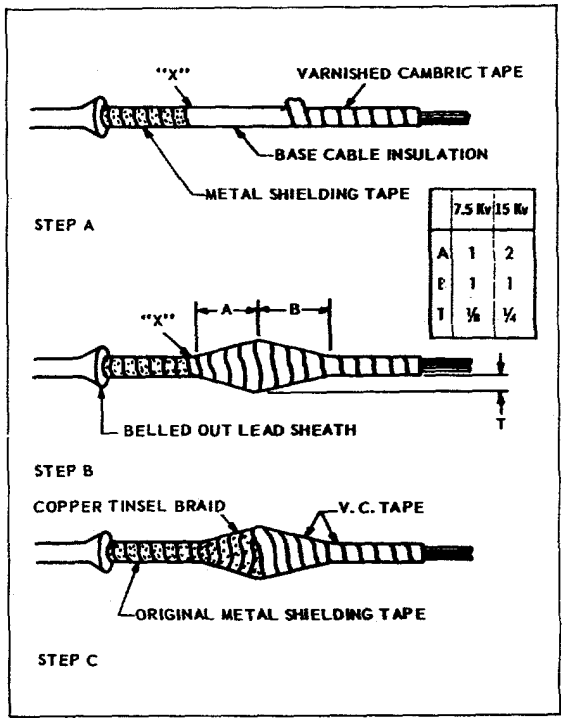


Fig. 9- Typical cable and taped pothead connections..

STEP C – Shielding

Starting slightly below the middle of the double cone, apply copper tinsel braid to the lower half. Wrap so that the upper edge is even and continue wrapping down the cone--over cable shielding or tuck under lead sheath. Solder the tinsel braid between turns and to shielding. Solder shielding to lead sheath or to ground connecting wire.

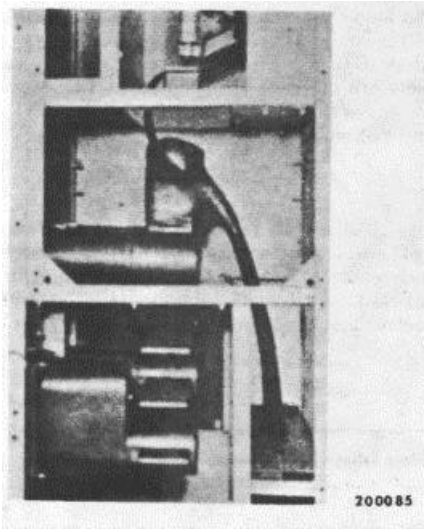


Fig. 10 – Typical cable compartment showing cable in downfeed direction. Refer to Figure 8 for cable joint insulation instructions.

insulation from end of conductor at least 1/4 inch longer than depth of hole in stud.

8. Solder cables solidly into the studs. (For voltages above 7, 500 stress cones should be made up on cables as shown in Figure 9.)
9. Install studs in insulators with gaskets and key washers in place. Bolt insulators firmly to their mounting plate. Tighten nut next to key washers on studs.
10. Bolt the pothead body up against insulator plate with gasket in place.
11. Bolt cable gland to pothead body with gasket in place.

12a. *For Upright Pothead* (Cable leading down). Wipe joint between cable and wiping sleeve, or pack stuffing box, and pull up tight to seal against cable sheath.

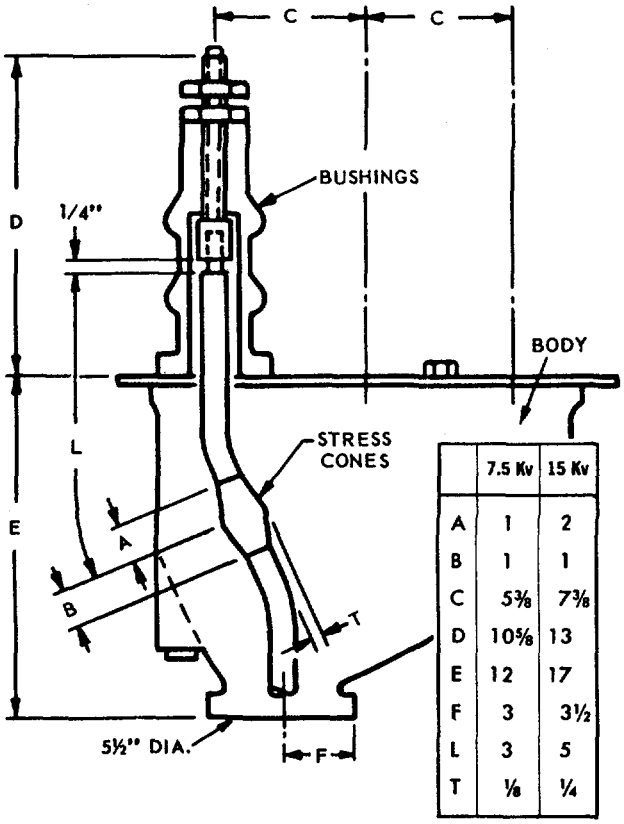
12b. *For Inverted Pothead* (Cable leading up). Wipe joint between cable and wiping sleeve, inserting a greased wire next to cable sheath if wiping sleeve gland is used. After wiping, remove greased wire to provide an air vent when filling pothead with compound. If packing gland is used, do not pack until after filling.

13a. *Filling Upright Pothead.* Remove vent screws from top of studs. Insert standpipe into pothead body and extend it above highest point of pothead. Melt compound per instructions and fill body until compound reaches vent. Keep standpipe hot and full until compound in body solidifies. Remove standpipe and insert plug and gasket.

13b. *Filling Inverted Pothead.* Do not remove vent screws in studs. Make sure these are tight. Venting is provided by hole left in wiped joint or through packing space, depending on type of gland used. Insert standpipe into filling hole in insulator mounting plate and extend standpipe above highest point of pothead. Melt compound per instructions and fill body until compound reaches vents. Keep standpipe hot and full until compound in body solidifies. Remove standpipe and insert filling hole plug and gasket. Solder up hole in wiped joint, or insert packing, and tighten clamp to seal joint between cable and pothead body.

MAXIMUM CABLE SIZE FOR POTHEADS

Single cable entering porcelain	2 1/2" O.D.
Bare cable entering connectors	1 3/8" max., 1/4" min. O.D.
Cable entering wiping sleeve	3 1/4" O.D.
Cable entering conduit support	2 3/4" O.D.
Cable entering packing ring	3" O.D.



	7.5 Kv	15 Kv
A	1	2
B	1	1
C	5⅜	7⅜
D	10⅝	13
E	12	17
F	3	3½
L	3	5
T	⅛	¼

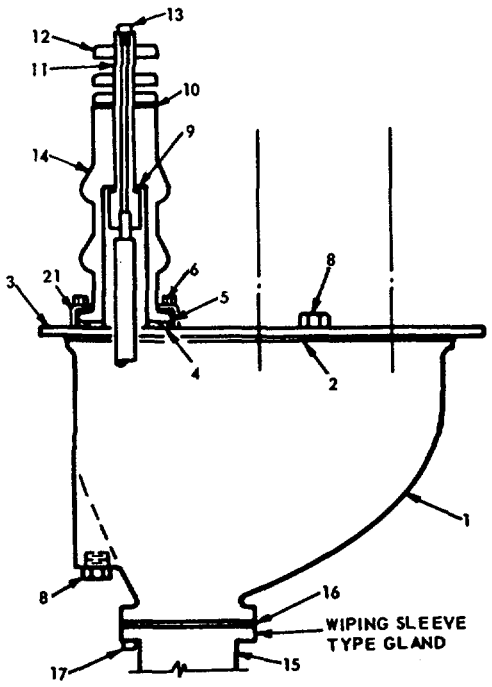
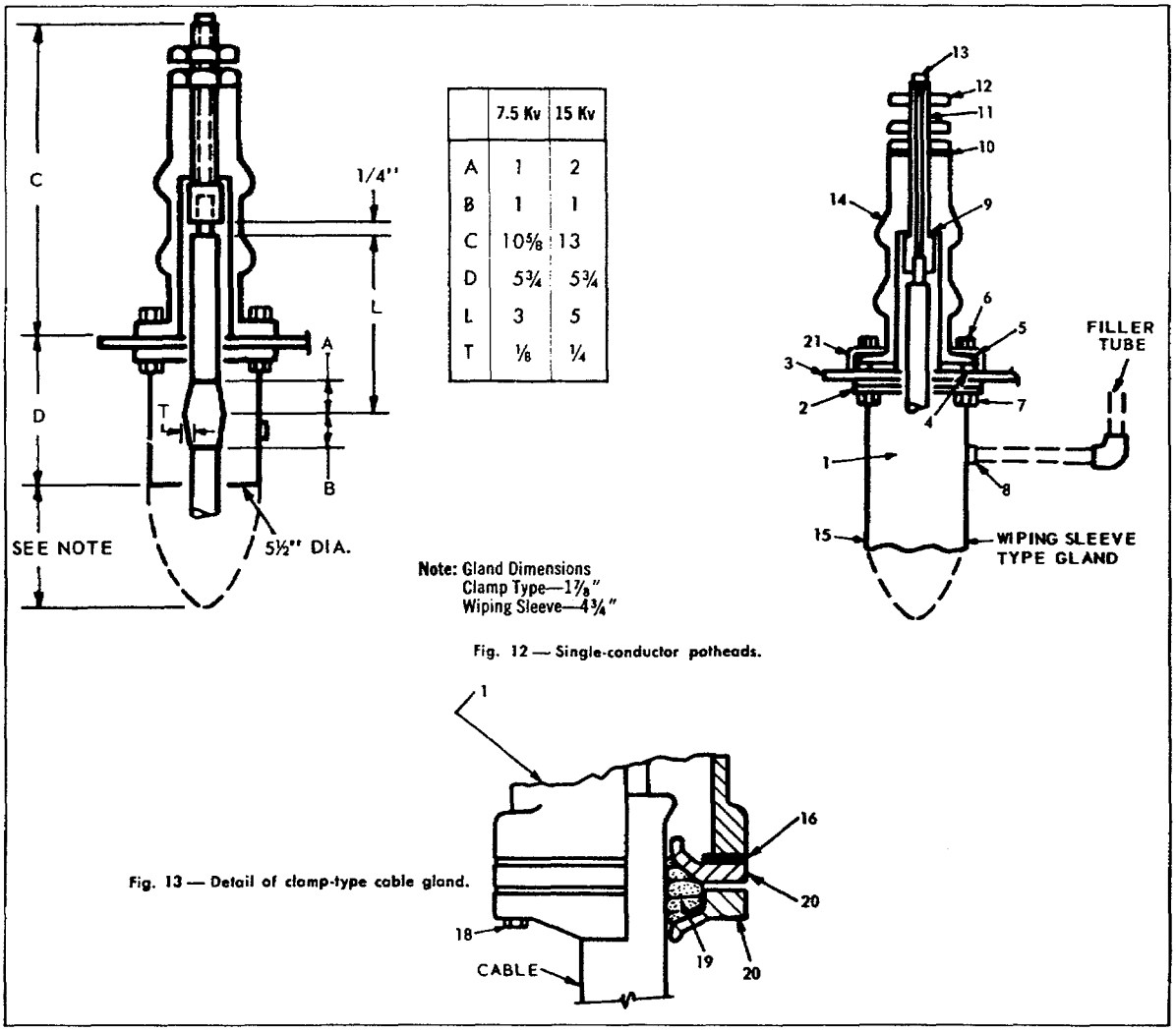


Fig. 11 – Three-conductor potheads.



	7.5 Kv	15 Kv
A	1	2
B	1	1
C	10⅝	13
D	5¾	5¾
L	3	5
T	⅛	¼

Fig. 12 — Single-conductor potheads.

Fig. 13 — Detail of clamp-type cable gland.

PARTS LIST (Figs. 11, 12, 13)

Item	Name	**Con-ductors	Dwg. No.
		(3C)	18-446-161-001
1	Pothead Body	(3C)	18-446-206-001*
		(1C)	18-446-151-001②
		(1C)	18-230-399-001①
2	Gasket	(3C)	18-240-443-001
		(3C)	18-240-252-001*
		(1C)	18-140-471-001
		(3C)	18-172-856-001
3	Support Plate	(3C)	18-178-221-001*
		(1C)	18-172-856-001
		(IC)	18-178-221-001*
4	Gasket		18-140-469-001
5	Gasket		18-140-469-002
6	Cap Screw 3/8" x 2 1/4"	(1C)	00-611-345-476
	Screw (Brass)	(3C)	00-655-017-036
	Lock Washer		00-655-059-200
	Washer (Brass)		14-104-595-018
7	Hex Nut 3/8"		00-631-059-106
8	Pipe Plug 1"		00-711-497-006
	Gasket		18-140-469-005
	1" Washer		00-651-027-480
9	Gasket		18-140-469-003
10	Gasket		18-140-469-004
	Key Washer		18-140-468-001
11	Stud Terminal		18-270-769-002
12	Hood Nut		18-631-859-006
13	Vent Screw		00-615-471-417
	Washer		00-615-007-196
	Gasket		18-140-469-006
14	Insulator		18-363-987-001
			18-363-734-001*
15	Wiping Sleeve	(1C)	18-230-399-001
		(3C)	18-261493-001
16	Gasket		18-160-750-001
17	Cap Screw 3/8" x 1"		00-611-289-466①
18	Cap Screw 3/8" x 1 1/2"		00-611-289-470②
19	Hemp Rope		(Tarred)
20	Packing Ring		18-261-494-001
21	Insulator Support		18-240-300-001

* Denotes 15 kv part, all other Nos. are common to both 7.5 kv and 15 kv.
** (1C) Single Conductor; (3C) Three Conductor.
① Wipe ②Clamp

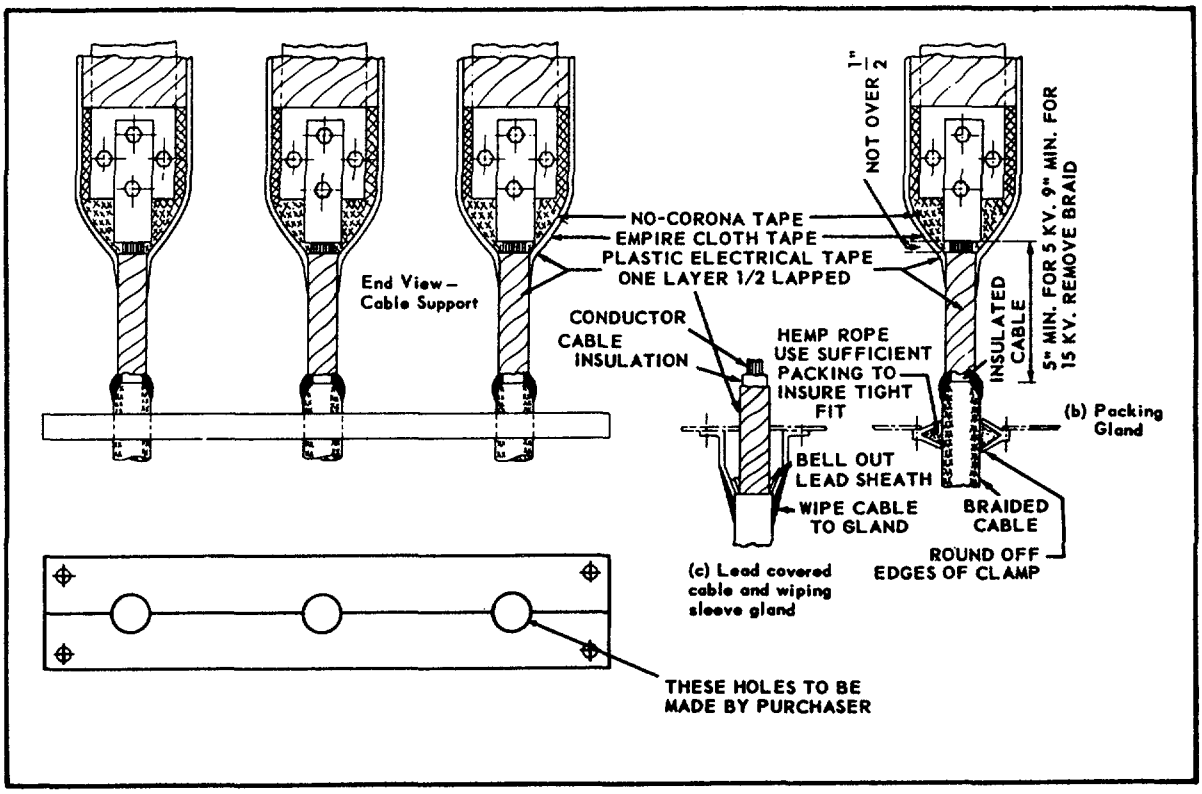


Fig. 14 – Primary cable connections.

SECONDARY WIRING

Secondary wiring is carefully installed and tested at the factory for electrical and mechanical soundness, and connections are made to terminal blocks and/or secondary disconnect blocks as shown on typical wiring diagram, Figure 4.

If special connections are made, such as the inclusion of contacts on remote devices, wired terminal blocks are provided for this purpose. See Figure 15 for typical control cable connection.

GROUND CONNECTION

A common ground bus is incorporated in all units for properly grounding the equipment after installation.

The ground bus extending thru the switchgear is accessible in the primary cable area of the left hand end of the unit.

Provision for connecting this ground bus must be made in a manner that a reliable ground connection is obtained. Consult latest National Electrical Code for ground connection standards.

TEMPORARY GROUNDS

It is recommended that no work be done on current carrying parts until these parts have been disconnected from the system and solidly grounded. One method of solidly grounding the high voltage circuit is by use of a grounding device. This device is placed in a cubicle in the same manner as a breaker and provides a path to ground. It is furnished only when specified in the contract.

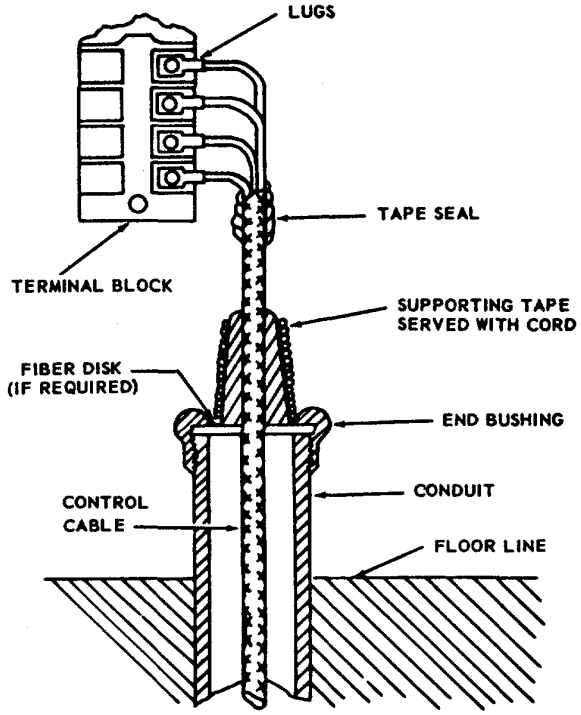


Fig. 15 – Secondary control cable connections.

STANDARD EQUIPMENT

CIRCUIT BREAKER

General

The stationary element (cubicle) of metal-clad switchgear and the removable element (circuit breaker) are built to master jigs so that circuit breakers of the same rating are interchangeable. All removable elements of like rating are checked with the applicable stationary element jig, and each stationary element is checked with the applicable removable element jig to insure complete interchangeability between elements of like rating.

Each switchgear unit, from the main bus to the cable terminals, is divided into compartments with access barriers for personnel safety. All conductors are insulated with flame-retardant materials. This, together with compartmentation, permits inspection and maintenance with a minimum of exposure to dangerous potentials.

INSERTING THE BREAKER

After the breaker has been inspected and prepared as instructed in the circuit breaker instruction book, it can be inserted into the unit. If the breaker is furnished with a special nameplate identifying it with a definite unit or units, do not place it in any other unit. This limitation is sometimes necessary because special devices have been furnished on that particular breaker. When no such special nameplate is used, the breaker can be used in any unit of same rating.

To insert breaker, first line up the breaker directly in front of breaker unit. The positive, straight-line, in-and-out movement of the breaker is assured by the guide track assembly (Fig. 17) mounted on the floor of the unit. This track has a funnel-type entrance and simply connects the mating guide bar on the base of the breaker as it enters the unit.

MECHANICAL INTERLOCKS

The horizontal drawout switchgear has breaker interlocks that prevent:

Movement of the circuit breaker to or from the connected position when it is in the closed position.

Closing of the circuit breaker unless the primary disconnecting devices are in full contact or separated by a safe distance.

The main interlock is the right wall of the guide track fixed to the floor of the breaker compartment. A cam-follower, mounted under the breaker and connected to the trip mechanism, rides on this bar. The breaker can be closed only if this cam-follower is in the lower (test or operating) position. When the follower is in the upper position, the breaker is trip-free it cannot be closed or held in the closed position electrically or mechanically. The circuit breaker cannot be moved to any other position from any one position (disconnected, test, or operating) without first depressing the position *i* release pedal.

Depressions in the compartment interlock bar are provided for the disconnected, test, and operating positions. When the breaker is in the disconnected position, the primary disconnects are separated and the shutters are completely closed. However, when the breaker is in the test position, the secondary disconnects are still making contact.

Control (or secondary) circuit connections between the stationary and removable elements are made by means of automatic, self-aligning, multi-contact, slip type connectors. Contact surfaces are mounted in the stationary element and the fingers on the removable element. The contact surfaces on the stationary element are recessed to prevent accidental short circuiting of the control circuits. Contact fingers, mounted on the removable element, are designed to assure a positive contact pressure. Low contact resistance is secured by the wiping action of the curved fingers which wipe on the flat surfaces of the stationary portion.

Padlocking is accomplished by matching holes in the breaker frame with those in the release pedal arm. In

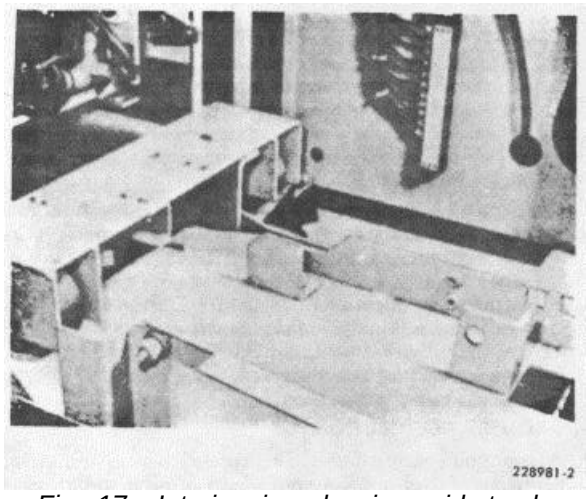


Fig. 17 – Interior view showing guide track.

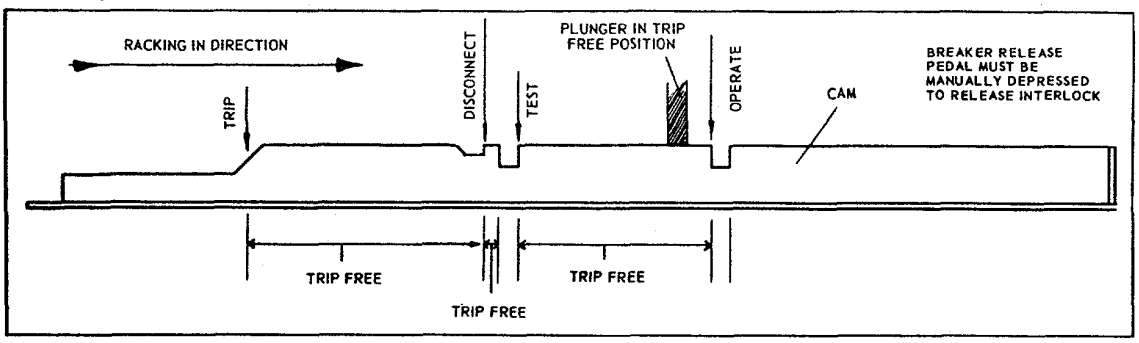


Figure. 16 – Guide track and interlock mechanism.

the padlocked position, the release pedal will be halfway down, the breaker will be trip-free and the interlock cam follower will still restrain the breaker in any of the three positions within the unit.

The shutters are counterbalanced. This results in smooth, trouble-free operation. The circuit breaker in movement in either direction operates directly on the shutter operating lever arm which is pivoted at the right inside front of the breaker compartment. A cam follower on the shutter operating lever arm mates with a follower track on the breaker which serves to raise the lever arm to open the shutter blades and lower the lever arm to close the shutter blades.

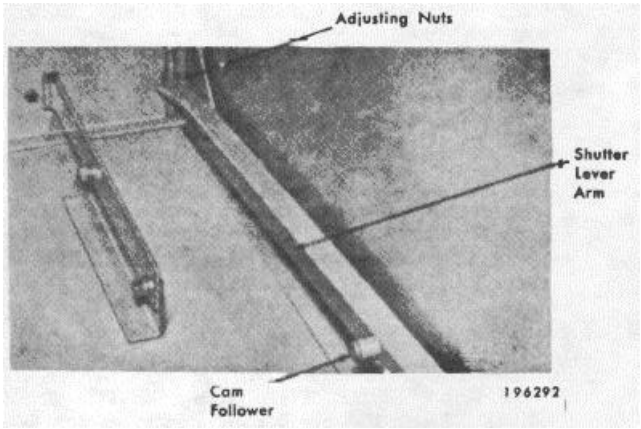


Fig. 18 – Cam follower on shutter lever arm mates with cam on breaker frame to positively open and close shutters. Adjusting nuts insure free, easy shutter operation.

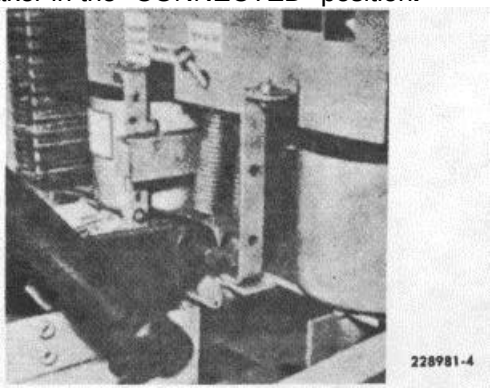
RACKING INSTRUCTIONS for 5-KV BREAKER

Insertion of the breaker into the unit to the disconnected position is accomplished without the operator having to do any thing more than push the breaker into position. The breaker will come to a stop in the disconnected position when the breaker cam follower is forced into the depression of the interlock. The position release pedal must be manually depressed to raise the cam follower to permit movement of the breaker to test position. Here again, the release pedal must be depressed to permit movement of breaker toward the connected position. The breaker will come to a stop when the primary breaker fingers strike the primary stud in the tube mounted on structure baseplate. To move the breaker to the fully connected position, a lever bar must be used (Figures 19, 20).

The pivot point of the lever bar is inserted into its mating hole in the fulcrum angle mounted on the compartment floor slightly to the right of the center of the breaker. A short upward stroke of the crank levers the breaker into the full operating position. Only when the breaker is in full operating position and the cam follower in the corresponding depression can the breaker be closed.

To withdraw the breaker, the fulcrum pin of the lever bar is inserted into its mating hole in the breaker carriage. Pivoting about the fulcrum angle on the floor (after depressing the breaker position release button) with a short downward stroke quickly withdraws the breaker.

Closeup of lever bar during breaker insertion. Lever bar pin is inserted into mating hole of floor fulcrum angle. With lever bar pinion bearing against the breaker bearing block, a short upward stroke of the bar engages the breaker in the "CONNECTED" position**.**



Inserting wheel spindle extension of lever bar into left side hole of breaker bearing block and pivoting against outside of fulcrum angle on floor, a short downward stroke of bar racks breaker out. The release pedal must be manually depressed to move breaker. After breaker moves, release the release pedal, pull breaker with lever bar until it automatically stops in "TEST" position.

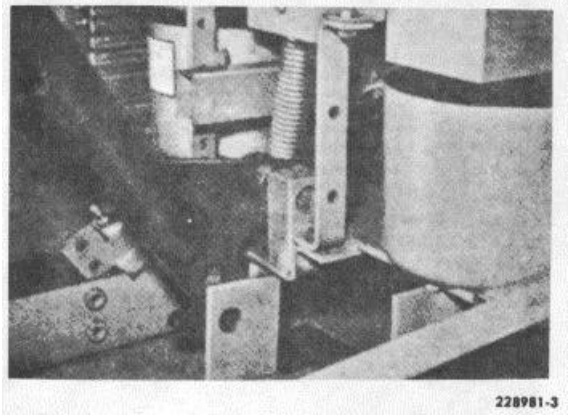


Fig. 19 – Racking instructions for 5-kv breaker. Top picture shows method of placing breaker in fully connected position and lower picture, shows method used track breaker out of connected position .

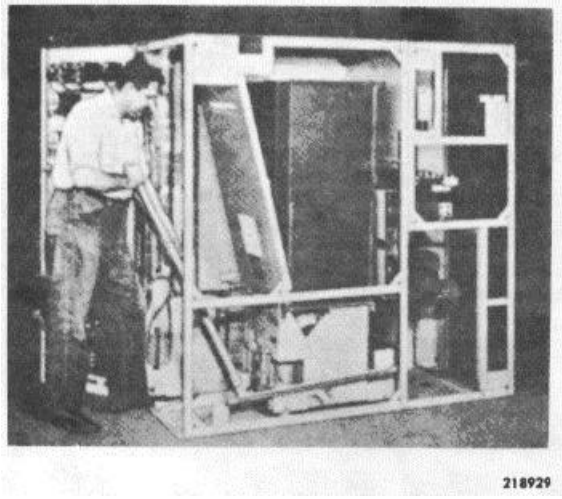


Fig. 20 – Levering-in action places 5-kv breaker in operating position

RACKING INSTRUCTIONS for 15-KV BREAKER

To insert the breaker into the cubicle, visually center the breaker at the front of the cubicle. The breaker may be manually pushed far enough into the cubicle to enable the racking lever pawl to engage the racking strip on the cubicle floor. Insert the pin on the lever into the horizontal hole at the bottom of the breaker frame. The racking lever pawl should engage the racking strip with the pawl pointing toward operating personnel. By "pumping" the lever handle, the breaker will travel toward the disconnect, test and connected positions.

To remove the breaker, reverse the pawl to point away from operating personnel and operate the lever as described above.

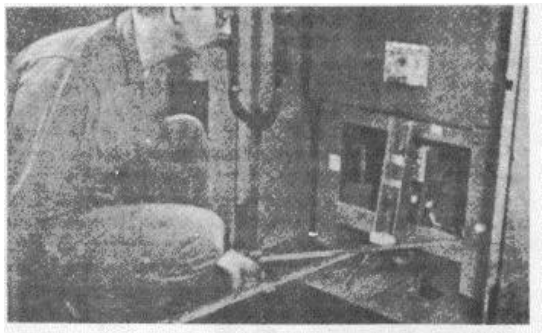
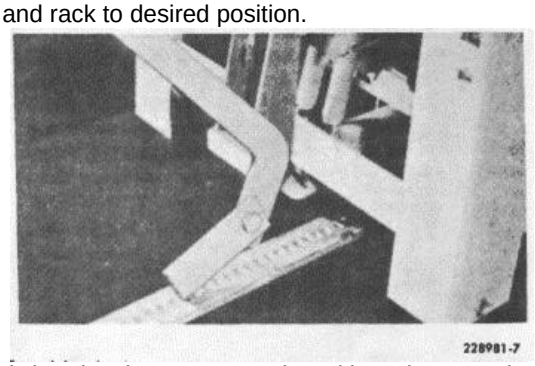


Fig. 21 228981-9

It is desirable to use a rack extension on indoor equipment when the customer's floor is not flush with the cubicle floor. The extension helps personnel move the breaker from the aisle into the cubicle by rocking. Ears on the extension are hooked behind cubicle frame angles. In disconnected test or connected positions, the release pedal must be manually depressed to move breaker. After breaker moves, release the pedal and rack to desired position.



To rack breaker into connected position place pawl towards the operator.



To remove breaker place pawl away from operator.

Fig. 22 – Racking of 15-kv breaker.

RACKING SAFETY MEASURES

The rack extension is provided to facilitate movement of the breaker outside the cubicle in a manner to line up the breaker with the cubicle guide bar.

After the breaker has been initially inserted into the connected position, rack the breaker out and check the length of engagement of primary contact fingers over the straight portion of contact surface on the stationary contacts. The contact point of the fingers should travel a minimum of 1/8 inch over the straight portion of the stationary contacts. This can be checked by applying putty inside the cluster of fingers before the breaker is inserted. Then, after the breaker is racked in and out, measure the distance from the contact points of the fingers to the depression in the putty made by the ends of the stationary contacts and compare this to the length of the bevel on stationary contacts.

If the unit is not energized from either the cable or bus sides, rack the breaker in and close and trip it electrically (provided auxiliary power is available) to check dosing and tripping circuits.

Rack the breaker out to the test position and check to make sure it can be closed and tripped electrically in this position The secondary contact device used with this type of breaker is such that contact is maintained up to this test position, enabling closing and tripping electrically without using a plug jumper.

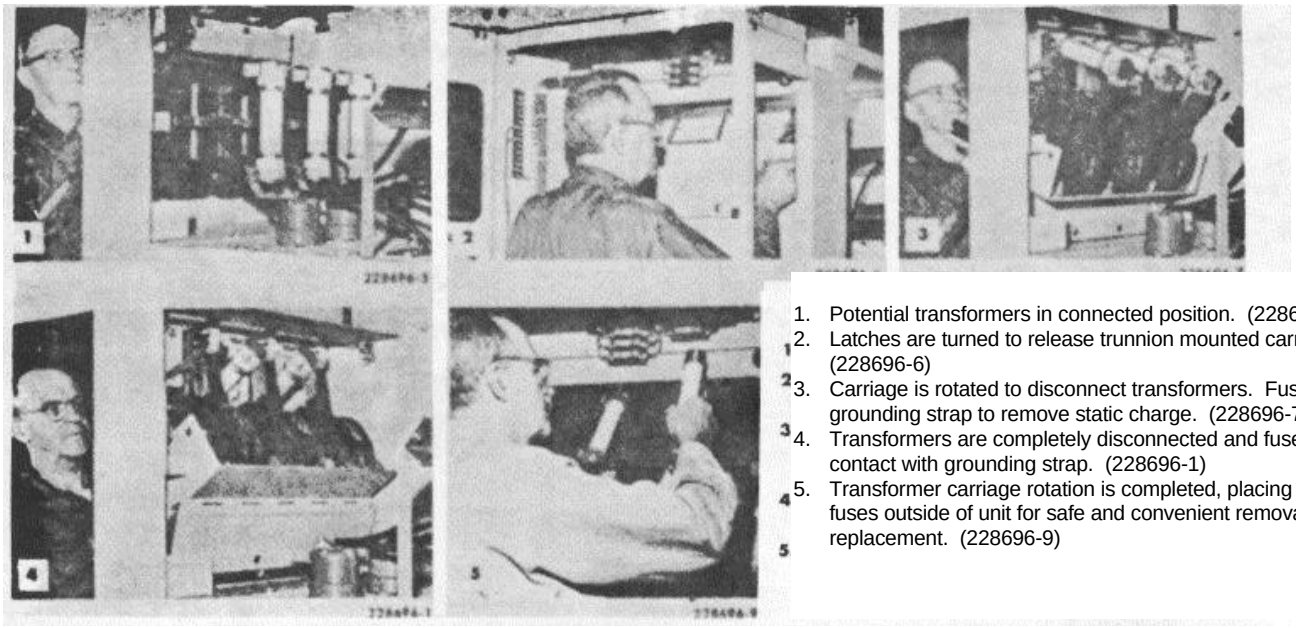
Check the ground contacts to be sure they make in both test and operating positions.

CAUTION: BEFORE INSERTING THE BREAKER FOR *THE FIRST TIME,* MAKE ABSOLUTELY SURE THE BUS IS NOT ENERGIZED. Rack the breaker in slowly, at the same time observing the following:

1. Guide track engages properly.
2. Secondary contacts have good contact alignment.
3. Ground contacts properly aligned and make good contact.
4. Shutters operate properly.
5. Breaker primary contacts enter insulators and make properly with stationary primary contacts.
6. Interlocking, that prevents a closed breaker from being moved to or from the connected position, functions properly.



Fig. 23 228981-11



1. Potential transformers in connected position. (228696-5).
2. Latches are turned to release trunnion mounted carriage. (228696-6)
3. Carriage is rotated to disconnect transformers. Fuse strikes grounding strap to remove static charge. (228696-7)
4. Transformers are completely disconnected and fuses are in contact with grounding strap. (228696-1)
5. Transformer carriage rotation is completed, placing grounded fuses outside of unit for safe and convenient removal and replacement. (228696-9)

POTENTIAL TRANSFORMERS

Potential transformers are mounted on a carriage which rotates in trunnions to provide the convenience of automatic disconnection when withdrawing the potential transformers for test or inspection.

The drawout carriage for the potential transformers can be located in the top rear compartment of a standard breaker unit at a convenient shoulder height location or in an auxiliary unit. Mounted on a base which pivots in a pair of trunnions, the pivoted base is easily rotated 180 degrees to the test or disconnect position.

While pivoting from the connected to the disconnected position, the transformer primary windings and transformer mounted current limiting fuses are automatically grounded to remove any charge from the windings. When the transformers are in the test or disconnect position, the base acts as the protective barrier between the stationary primary contacts and the operator. The weight is so distributed that a minimum amount of effort is needed to revolve the carriage.

To disconnect the transformers -

5 KV Units

1. Turn knurled screws holding the door and swing hinged panel open.
2. Turn latches – one at each side – to release trunnion mounted carriage.
3. Using handle, pull carriage down to rotate 180 degrees. This disconnects transformers and grounds the fuses. Fuses are now accessible for removal or replacement.

15 KV Units

1. Rotate T-handles – one on each side – to release trunnion mounted carriage.
2. Repeat step 3, above.

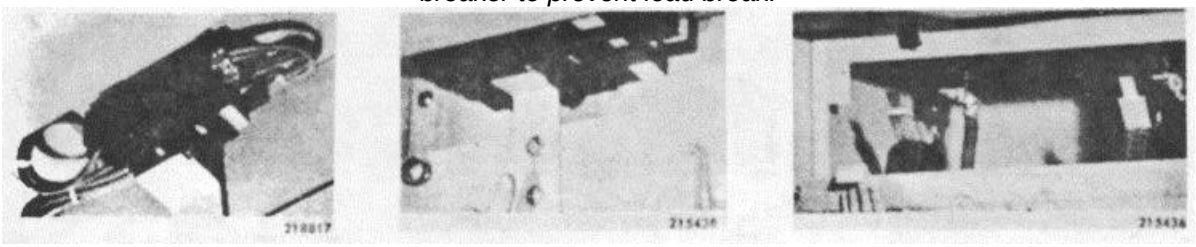
Potential transformers are shipped mounted in the unit and in the connected position.

CONTROL POWER TRANSFORMERS

Control power transformers are stationary mounted and the primary fuses are mounted on a trunnion mounted carriage in the same manner as the potential transformers.

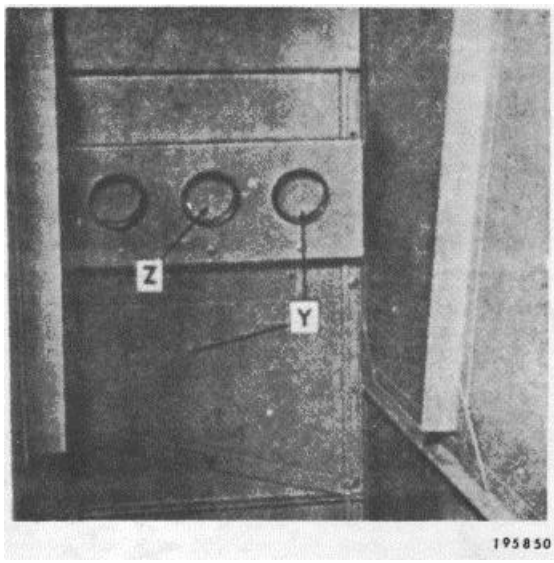
An interlock circuit breaker is furnished on the secondary side of the control power transformer to prohibit disconnecting the transformer unless the circuit breaker is open. Only when the circuit breaker is opened (disconnecting the load from the transformer) can the fuse carriage be rotated from the connected position.

Fig. 24 – Trunnion mounted fuses for the stationary-mounted control-power transformer are mechanically interlocked with secondary thermal breaker to prevent load break.

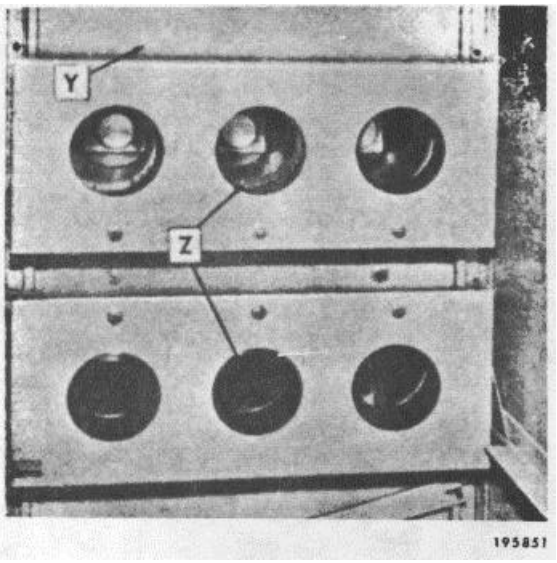


When the secondary breaker is closed, rotation of carriage is prevented as engages breaker toggle

When the secondary breaker is open (left), rotation of carriage is possible (right).



Automatic shutters (Y) in closed position behind current transformers. Current transformers (Z) shown mounted on load side only.



Current transformers (Z} shown mounted on both bus and load side. Shutter (Y) blocked open to show disconnect studs.

Fig. 25

CURRENT TRANSFORMERS

Current transformers, with high ratio, are of the torroidal type mounted in the circuit breaker compartment in front of the plate which supports the high voltage disconnects.

The primary bushings of the circuit breaker serve as the primary bar of the current transformer. Therefore, removing the circuit breaker actually removes the primary bar. It is possible to test the current transformers without removing them from the unit while maintaining maximum operator safety.

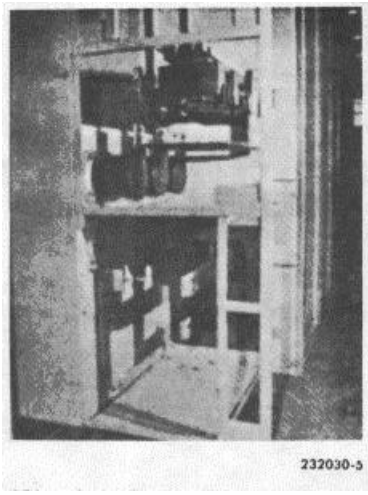
Inasmuch as the shutters are located behind the current transformers, testing of transformers located on the bus side can be accomplished without bus deenergization.

Removal of the current transformer covers is accomplished by removing cover bolts accessible from the circuit breaker compartment.

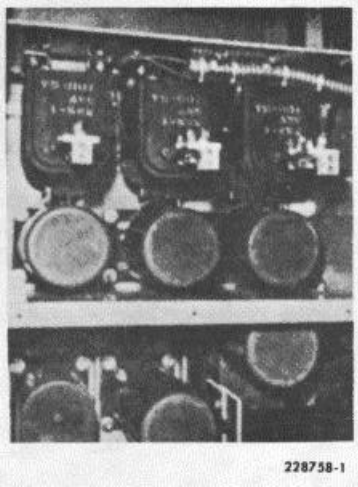
Current transformers with low ratios are of the wound type and are mounted in a separate compartment with a suitable device for terminating power cables.

Built to NEMA and IEEE standards, each current transformer has a nameplate on which is included its type, serial number and rating. If it is necessary to contact the factory in regard to these transformers, include the nameplate information and identify the unit in which the transformer is mounted.

Current transformers should not be operated with secondaries open-circuited.

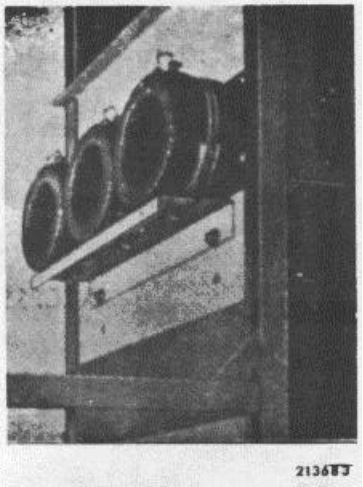


15-kv unit showing wound type current transformers arranged for upfeed connection.



5-kv unit showing the wound type transformers mounted for downfeed Cable.

Fig. 26



View of bottom of support plate beneath current transformers showing strap supports. Protective cover has been removed.

Fig. 27

SPECIAL EQUIPMENT

KEY INTERLOCK

When specified, a key interlock can be supplied to prohibit closing a breaker only when it is in the operating position. The interlock bar is attached to the guide bar. In the operating position, the lock bolt is extended, raising the cam follower bar, locking the breaker in the trip-free position. Then the key is removed to release disconnects or associated equipment for operation.

This interlock is cleared for normal breaker operation by returning disconnects, etc., to normal operating position and inserting the key into its lock, permitting withdrawal of the bolt and lowering of the cam follower bar.

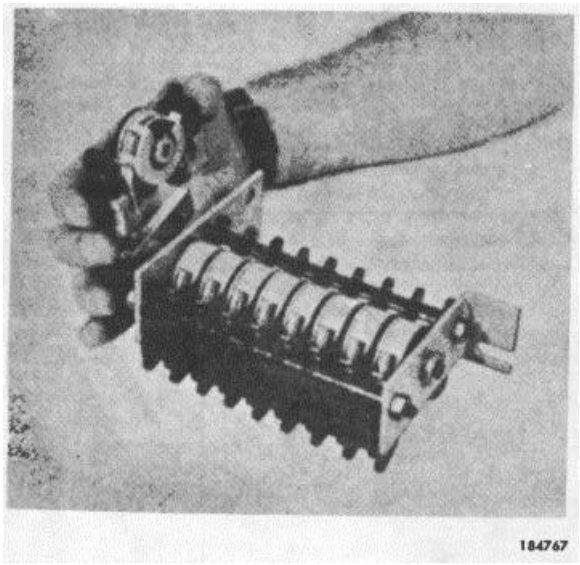


Fig. 28 – Only a pair of pliers is necessary to adjust each Q-10 auxiliary switch stage. Each point of a stage can be individually adjusted in 15 degree steps.

STANDARD ACCESSORIES

TESTING DEVICE

When specified, a plug jumper is supplied so that a breaker can be operated (tested) outside its compartment with the control switches on the instrument panel. This plug jumper is used to bridge--with a flexible cable -the secondary disconnects so that the breaker can be electrically closed and tripped. Refer to Figure 31B for plug jumper connection instructions.

If desired, a pushbutton can be supplied on the device attached to the breaker for operation at the breaker.

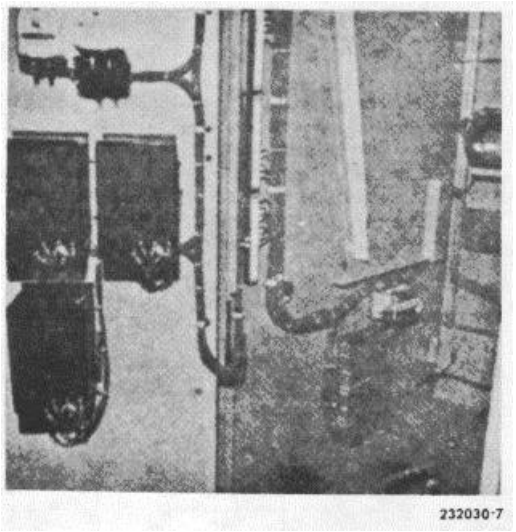


Fig. 29 – Cell mounted Q-10 auxiliary switches are operated by notched lug welded directly to the breaker mechanism main crank.

EXTRA AUXILIARY SWITCHES

When specified, extra auxiliary switches – in addition to the eight standard switches on the breaker – can be easily accommodated on the stationary structure. These switches are operated by a notched lug welded directly to the breaker mechanism main crank. Every standard structure and circuit breaker is designed to accommodate this feature.

Eight, twelve and sixteen stages can be furnished.

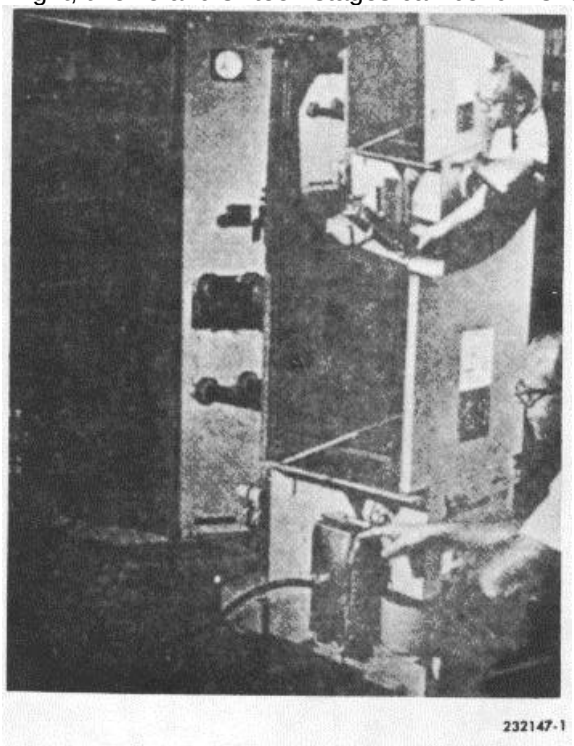


Fig. 30 – Test device for testing breaker outside unit with switchgear control power.

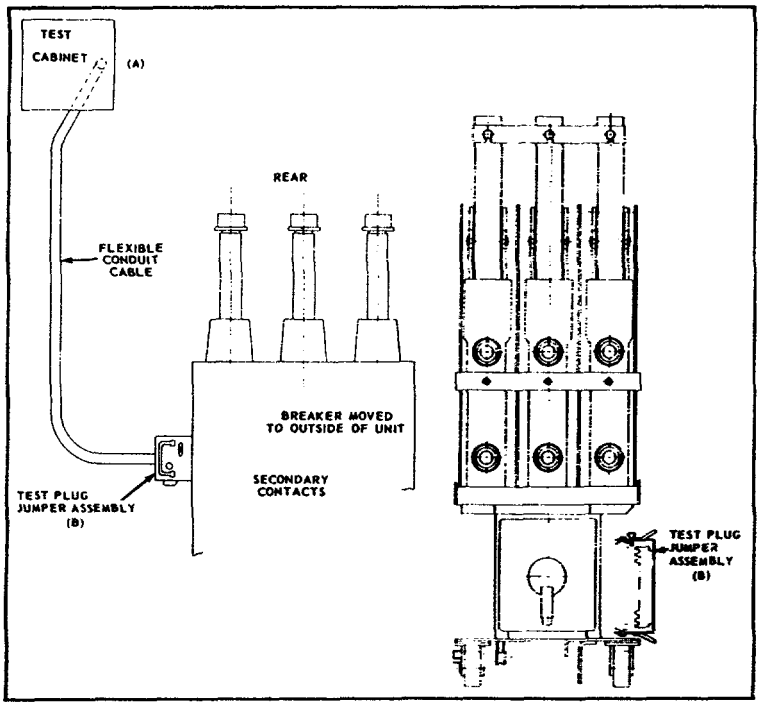


Fig. 31B - Optional test control cabinet.

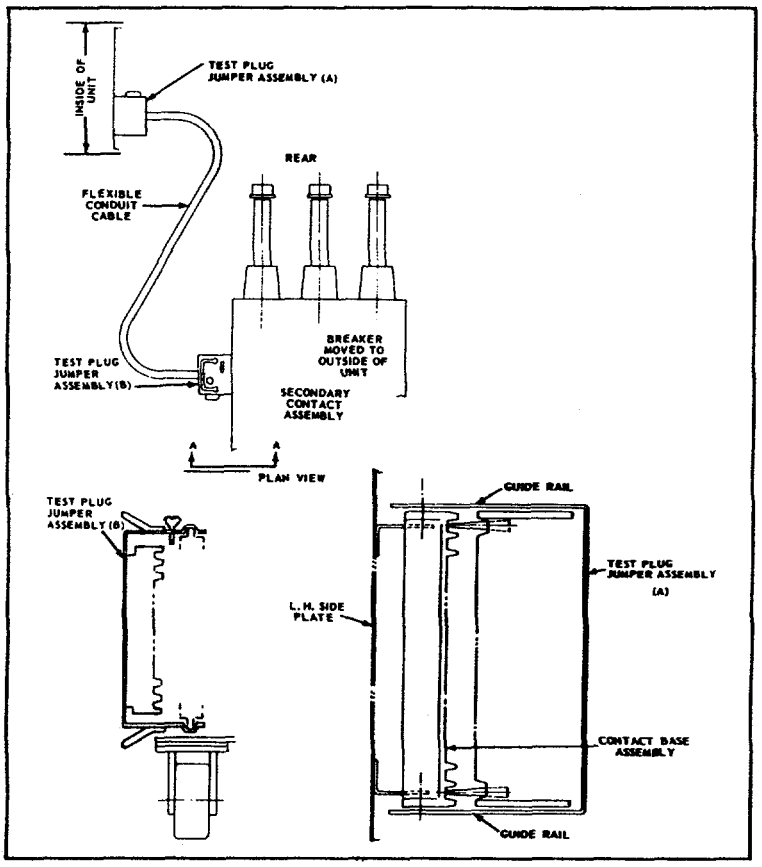


Fig. 31A – Plug jumper.

INSPECTION and TESTING

INSTALLATION, INSPECTION AND TESTING

Before the equipment is put in service, it must be thoroughly inspected and tested. Correct any defects immediately.

Check the following points:

1. High voltage connections properly insulated.
2. Electrical disconnecting contacts, machine parts, shutter, etc., checked for lubrication and operation.
3. Blockings, supports and other temporary ties removed from breakers, instruments, relays, etc.
4. Proper fuses correctly placed.
5. Temporary wiring jumpers (used on the secondaries of current transformers tied to external devices, as shown on wiring diagrams) removed.
6. Ground connections properly made.
7. Incoming primary and secondary connections properly made and checked for shorts or undesired grounds.
8. All equipment, removed during assembly, replaced.
9. Relays coordinated with other relays, etc., on the system. Refer to relay instruction book before making any adjustments. Consult local power company before making any connections to their power supply.
10. Storage battery fully charged and provided with recharging facilities.
11. Interlocks performing properly.
12. Circuit breakers checked and prepared per instruction books.

LUBRICATION

It is essential that switchgear be lubricated carefully and properly to guard against corrosion and to insure that all operating parts work freely.

Lubricate moving parts – shutter guides, bearings, tilt-out transformer trunnions, etc. – with "Lubriplate" AERO Grease, or equal. Use of lubricants not suitable for the application will make mechanisms very difficult to operate. Remove all old grease and relubricate annually, or oftener if required.

Electrical contact – all stationary silver-surface contacts are to be lubricated with "Lubriplate" AERO *prior to use.*

1. Wipe contacts clean.
2. Apply AERO to contact surfaces.
3. Wipe off excess grease, leaving a thin film.

Remove all old grease and relubricate annually, or oftener if required.

When lubricating contacts, it is important to avoid getting grease on the insulation.

For the above procedure, a tube of AERO grease is included with each shipment of switchgear.

Where corrosive atmospheres are encountered, coat all unpainted metallic surfaces generously with AERO Lubriplate or equal. When grease becomes contaminated by the corrosive atmosphere, remove it and apply a new coat.

Refer to breaker instruction book for specific lubricating instructions on circuit breakers.

FINAL TESTING

1. A megger test is made on the high voltage circuit to be sure that all connections made in the field are properly insulated. A megger test is also advisable on the control circuit.
2. A dielectric test, if possible, should be made on the high voltage circuit for one minute at one of the following voltages corresponding to the rated volts of the equipment. (Potential transformers, control transformers, lightning arresters, surge capacitors, are disconnected during this test.)

Rated KV	Test KV	DC
5.0	14.3	20.2
7.5	14.3	20.2
15.0	27.0	38.2

A dielectric test on secondary and control circuits should be made at 1200 volts. The above voltages are in accord with NEMA Standards.

3. With breaker in the test position make the following tests on each unit.
   (a) Trip and close the circuit breaker with the control switch.
   (b) Trip the breaker by passing sufficient amps (or volts) through the coils of protective relays.
   (c) Trip and close the breaker from any remote control positions.
   (d) Operate auxiliary devices.
   (e) Test the phase sequence of polyphase high voltage circuits, particularly those used for motor starting.
   (f) Check aging resistor setting of rectifier operated breakers. This aging resistor should be set so that a maximum amount of resistance is in the circuit and still permits breaker closing at 190 volts ac minimum control voltage. The dc voltage across the closing coil should be at least 90 volts at this minimum voltage setting. The rectifier is mounted on the breaker.

OPERATION and MAINTENANCE

OPERATION

When the equipment is placed in service for the first time all circuit breakers should be open and all control circuits energized. The primary incoming power source is then connected to the switchgear bus by closing the circuit breaker, disconnect switch or other means provided. The incoming power source should be at the lowest voltage possible, and then gradually brought up to normal. Let equipment stand energized for several minutes before connecting the load. Check instruments, relays, etc., during this period.

When connecting the load, connect one unit at a time with as small a load as possible on the feeder. Again, wait several minutes before connecting the next load, meanwhile observing operation of instruments, relays, etc. When it has been determined that there are no defects, the normal load may be connected.

Check the following during the first week of operation: over-heating of primary and secondary circuits, satisfactory operation of all instruments, relays, etc.

MAINTENANCE

Thorough inspections at periodic intervals are important to satisfactory operation. The frequency of inspection and maintenance depends on installation conditions and can be determined only by experience and practice.

Make these inspections at least once every year – more frequently if local conditions require.

Conditions affecting maintenance are:

Weather and atmosphere.

Unusual number of operations.

Experience of operating and maintenance personnel.

Special operating requirements.

After the frequency of inspection has been determined, cover the following points:

(a) Inspect switchgear interior for accumulation of dust, dirt, etc. Remove dust from all insulators.

(b) Check instrument and control switches and inspect their contacts.

(c) Examine indicating lamps and replace all those that are burned out.

(d) Check test block contacts for loose connections.

(e) Inspect bus bars and connections to see that they are in proper condition. If they are overheating, check for poor or loose connections, or for overload.

(f) Check for proper condition of instrument transformers. Replace burned out fuses, if any. Check primary and secondary connections.

(g) Examine automatic shutters for proper operation.

(h) Examine all safety interlocks.

(i) Maintain circuit breakers as called for in circuit breaker instruction book.

CORROSIVE ATMOSPHERES

This switchgear is designed to give top performance when installed in normal indoor or outdoor locations. Where abnormal conditions are encountered – such as corrosive atmospheres – special precautions must be taken to minimize their effect. Exposed metallic surfaces – non-insulated bus bars, disconnect switches, primary and secondary disconnecting contacts, wire ends, instrument terminals, etc. – must be protected. Lubricate contact surfaces with a generous coat of AERO "Lubriplate" or other equally non-hygroscopic grease. If this type of grease is not available, petroleum jelly can be used. Other exposed members can be protected with a coat of glyptol lacquer or any other corrosion-resisting paint.

When old grease becomes dirty, wipe the parts clean and apply new grease immediately.

TOUCH-UP PAINT

Matching paint, one pint per three units, thinned and ready for use, is supplied with each order for touching up any scratches, etc., made during installation. Inspect the surface and retouch where necessary. Paint is furnished in spray-on one pint cans.

RELAYS AND INSTRUMENTS

To insure satisfactory relay and instrument operation, covers of these devices should not be left off for a period longer than is necessary. When a cover has been broken, cover the device temporarily and replace broken glass as soon as possible

SPACE HEATER OPERATION

Outdoor switchgear is furnished with one space heater in each cubicle. The space heaters are controlled by thermostats mounted inside the cubicle. The thermostats are factory-set to cut in and out at definite temperatures (open 110 $\pm$ 5Fclose 100 $\pm$ 5F). Where humid conditions exist, be sure to turn on these heaters well in advance of energizing the equipment to insure that the insulation is dry.

INSTRUCTION BOOK

SECTION 29.

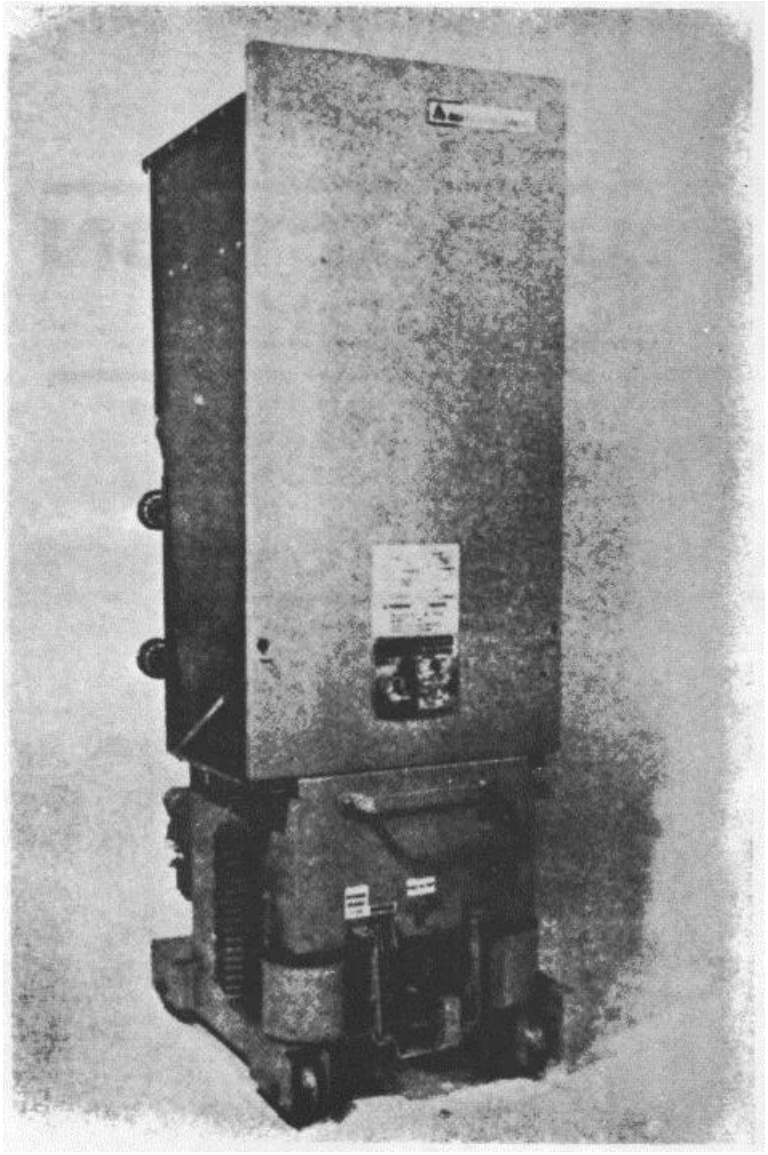
TYPE "D" MOVABLE PORTION MA-75/150/250B

RUPTAIR MAGNETIC POWER CIRCUIT BREAKER

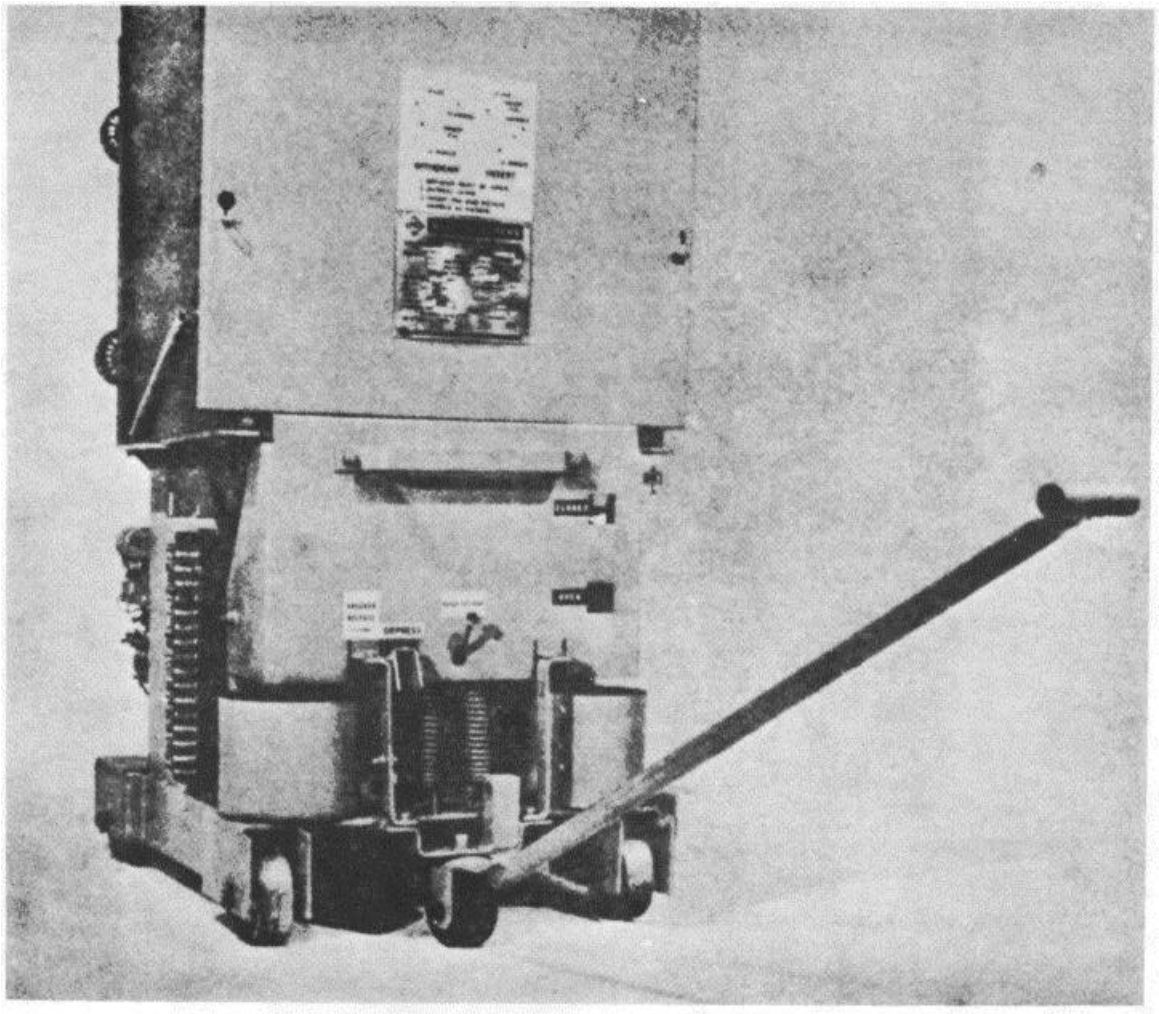
AND AUXILIARY EQUIPMENT (SOLENOID OPERATOR)

No. BWX-6631-4

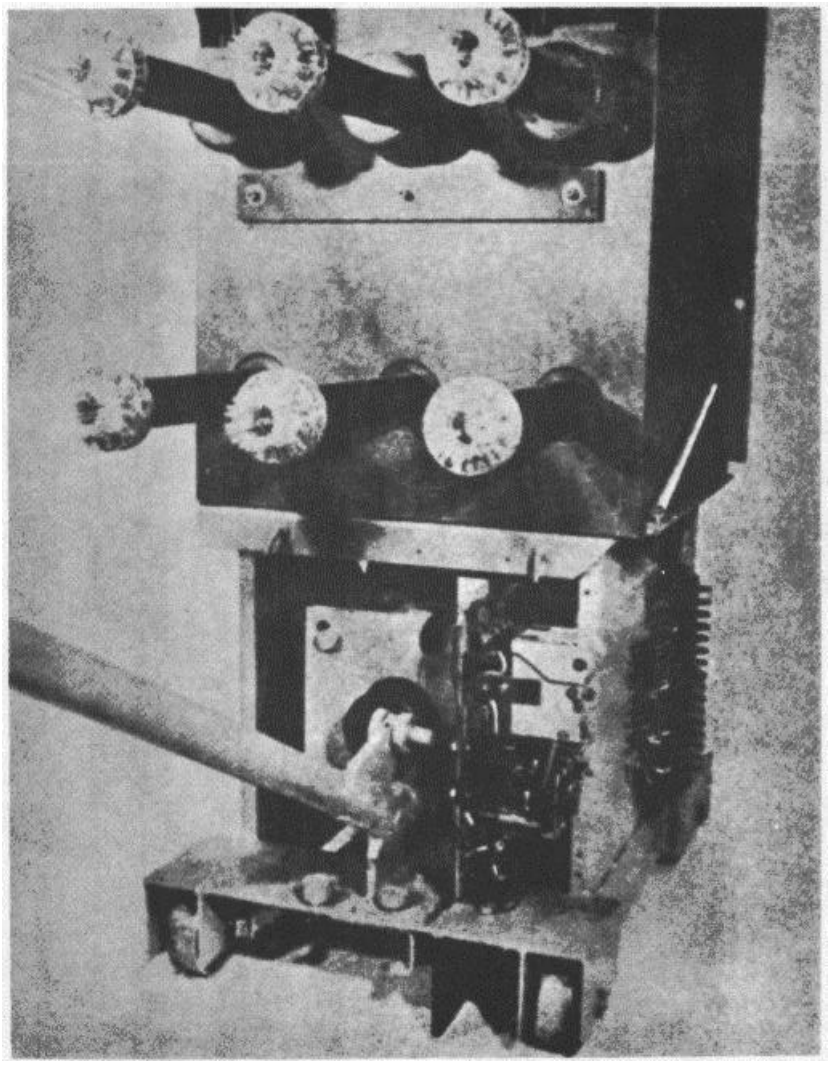
3-314



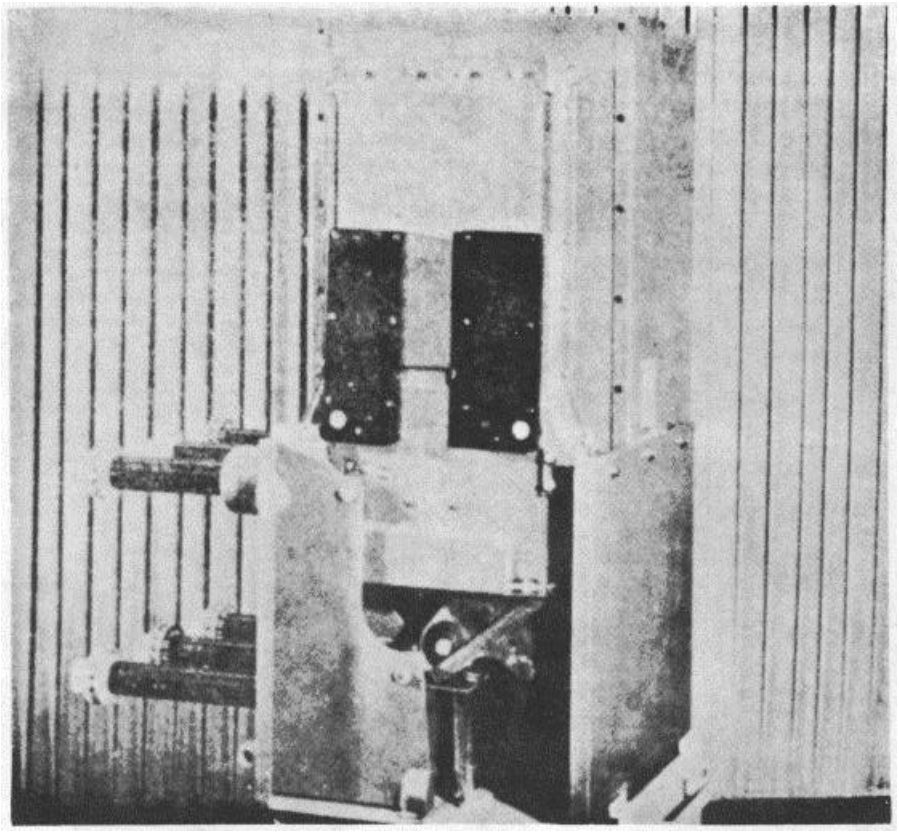
205393 **Front side view of Type D 4.16 kv., 1200 Amp., Air Magnetic Circuit Breaker**



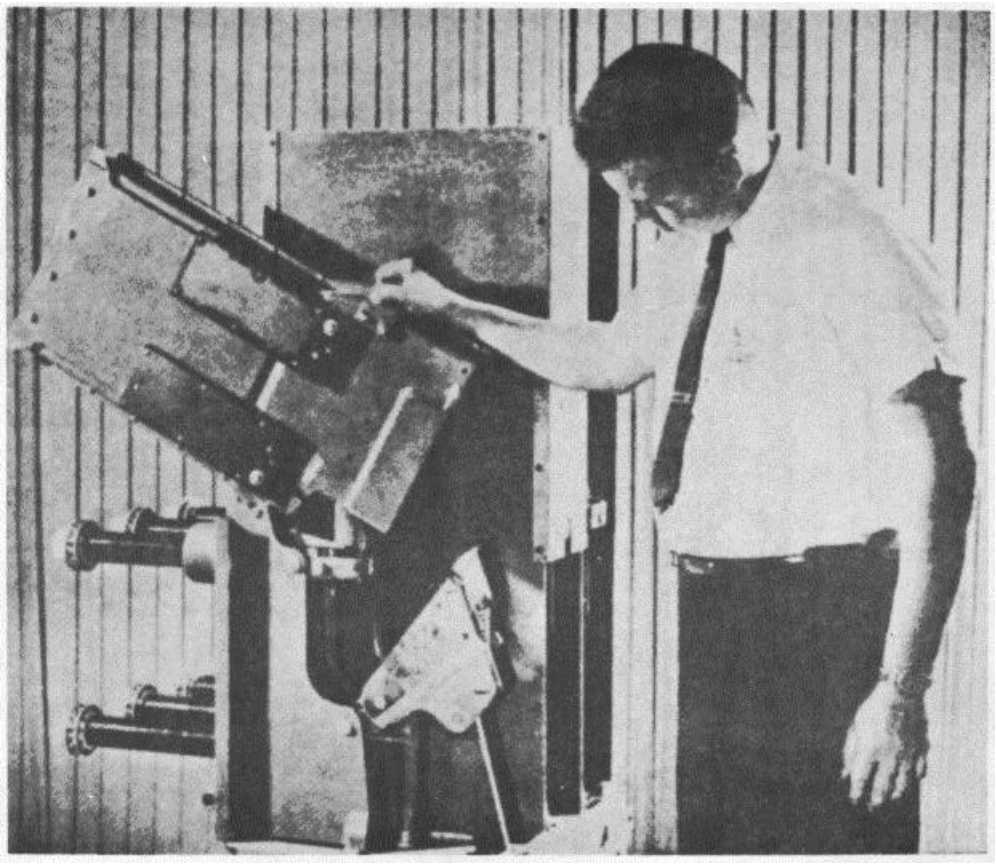
205394 View shows application of fifth wheel on Type D Air Magnetic Circuit Breakers



205392 View shows application of manual closing device on Type D Air Magnetic Circuit Breaker



217530 Side view of Type D, 4.16 kv, 1200 Amp., Air Magnetic Circuit Breaker, Outer Phase Barrier Removed.



217525 Arc Chute Assembly of Type D, 4.16 kv, 1200 Amp., Air Magnetic Circuit Breaker is tilted back for easy assembly of contacts.

SUBSECTION I. DESCRIPTION

1.1 GENERAL

The Allis-Chalmers RUPTAIR movable portion consists of a magnetic circuit breaker for metal-clad switchgear application, with auxiliary equipment suitably arranged for best function and easy installation. As part of standard equipment, each order is furnished with one maintenance closing device for solenoid operated breakers or a charging crank for stored energy operated units.

The RUPTAIR magnetic circuit breaker differs essentially from oil breakers and air-blast breakers in that it does not depend on any stored medium such as oil or compressed air for arc interruption. The component parts of the breaker are mounted in a structural steel frame. The operator, the operating shaft, and connecting links are mounted on the lower section of the breaker frame and are well shielded. The horizontal terminal studs, which are insulated with flame retardent tubing, extend through the breaker bracket and support the other parts of the electrical circuit. Interruption occurs within the arc chute assemblies which are mounted at the top, over the contact structures.

1.2 METHOD OF ARC INTERRUPTION

Interruption is accomplished in air at atmospheric pressure, with the aid of a self-induced magnetic blowout field and air draft. At the time the trip coil is energized, current is being carried through the main contacts.

As the movable contact assembly separates from the stationary contact assembly, the current transfers very quickly from the main contacts to the arcing contacts, thus keeping the main contact erosion to a minimum. (For breakers equipped with tertiary contacts, the current transfers from the mains, to the tertiary and then to the arcing contacts.) As the movable contact assembly continues its stroke, the arcing contacts part, drawing a power arc, which is transferred first to the stationary end arc runner then to the moving end arc runner. The transfer of the arc to the arc runners establishes the full flow of current through the blowout coils, setting up the magnetic field which, in accompaniment with natural thermal effects of the heated arc, the configuration of the current carrying circuit, etc., tend to force the arc upward into the barrier stack. The cool surfaces of the barrier stack cool and deionize the arc, while the "Vee" slots in the stack reduce its cross section and elongate it.

The arc runners are made of wide, heavy material for maximum heat dissipation and to minimize metal vaporization. To facilitate interruption of low currents, a puffer assembly provides a movement of air through the contact area to aid the magnetic field in moving the arc into the barrier stack. All of the above effects work together to increase the resistance of the arc and enable it to be extinguished at an early current zero.

SUBSECTION 2. ADJUSTMENTS

2.1 GENERAL

The breaker has been completely set up, adjusted and tested at the factory.

Adjustments should not have to be made nor fastenings tightened when the breaker is received. If there is visible damage or breakage due to shipment, storage or installation, the adjustments should be checked and corrected, if necessary, before breaker is operated electrically.

Manual operation (use maintenance closing device) of breaker should be used for preliminary operation to see that all parts are free and work smoothly. The bushings and other insulating parts should be clean and dry. All contact surfaces should be inspected to see that they are clean and smooth. (Do not dress silver surfaces). Removal of all phase barriers and removal or raising of arc chute assemblies gives access to breaker for checking adjustments.

CAUTION: BEFORE REMOVING ANY PART, MAKE SURE THAT THE BREAKER AND ITS OPERATING MECHANISM IS DISCONNECTED FROM ALL ELECTRIC POWER AND THAT THIS BREAKER IS IN THE OPEN POSITION.

SUBSECTION 3. SOLENOID OPERATOR

3.1 SOLENOID OPERATOR (Fig. 4)

A solenoid operator is an integral part of this type of breaker unit.

(For breakers equipped with the stored energy closer, see separate instruction book.) It is mounted in the lower section of breaker and is contained within the breaker frame. The operator is furnished with a mechanically trip-free mechanism consisting of a 4-bar toggle linkage so designed as to provide quick and positive tripping at any position of the closing stroke. The operator mechanism is of low inertia, capable of quick acceleration, and it is equipped with a low energy trip device and opening coil designed to provide high speed release of the trip mechanism upon energization of the trip coil.

3.2 CLOSING (Fig. 4 & 13)

Figure 13 shows the mechanism of the operator in the open position. Points "B", "F", "G" and "H" are fixed centers about which crank arms (2) and (3), link (6), trip latch (9), and prop latch (10) rotate respectively. Center "E" is a temporarily fixed center, being restrained by stop (11) and latch (9) as long as latch (9) is. in position.

The closing force is applied by armature (4-4, 13-12) to toggle roll (4-15, 13-D). The toggle roll moves toward the right forcing the toggle linkage (4-101, 13-5) and (4-102, 13-4) to an on center or in line position, thus rotating crank arms (4-73, 13-2) and (4-74, 13-3) counterclockwise about pin (4-64, 13-B). Movement of crank arm (4-73, 13-2) upward forces link (1-47, 13-1) to move upward thus rotating the disconnect arm counterclockwise closing the breaker and charging the breaker opening springs (1-31, 13-7) and the reset spring (4-91, 13-8).

When toggle links (4-101, 13-5) and (4-102, 13-4) reach their final positions, prop latch (4-97, 13-10) drops behind toggle roll (4-15, 13-D) to lock the mechanism in the closed position as shown in Figure 14. After closing the breaker armature (4-4, 14-12) returns to its normal position. Manual closing is as described except that armature (4-4, 13-12) is activated manually through the manual closing device.

3.3 OPENING (Fig. 4 and 15)

Opening of the breaker is accomplished either manually or electrically. Manually the breaker is tripped by pushing on the trip button (1-43) which rotates the trip latch (4-27, 15-9) in a clockwise direction. Latch roll (4-15A, 15-E) is released enabling link (4-70, 15-6) to rotate clockwise about pin (4-69, 15-F). Since the restraining force on opening spring (1-31, 15-7) is now released they act to rapidly open the breaker contacts. Reset spring (4-91, 15-8) then acts to return the mechanism to the normal open position shown in Figures 4 and 13.

Electrical tripping is as previously described except that trip latch (4-27, 15-9) is rotated by the trip pin (4-17A, 15-13) which is actuated by the shunt trip coil (4-17, 15-14).

The tripping action previously described can take place at any time during a closing operation, either manual or electrical, and regardless of whether or not the armature is energized. Thus the mechanism is electrically and mechanically trip-free in any position.

3.4 AUXILIARY EQUIPMENT

The auxiliary equipment consists of a secondary transfer device, control relay, auxiliary switch and closing rectifier as required. These are mounted on the lower portion of the breaker. The secondary finger contacts are wired such that when movable portion is moved into test or operating position in the cubicle the finger contacts engage the stationary contacts to complete the control circuit for operation of the breaker.

3.5 AUXILIARY SWITCH (Fig. 11)

The auxiliary switch (1-15) has been adjusted at the factory and should normally not require further adjustment. Each rotor (11-3) can be adjusted individually in steps of 15 degrees merely by pressing the contact to one side against the spring and rotating it within its insulated rotor housing until it snaps into the desired position.

3.6 LIMIT SWITCH (Fig. 4)

The limit switch (4-18) is located on the front of the operator frame and contains both the "a-a" and "b-b" stages of limit switch contacts. The switch has been adjusted before leaving the factory and should require no further adjustment. Adjustment is made by bending the spring steel switch arm.

On the FB-500 and the FC-750 breakers the stop screw (4-76) should be adjusted so that with the breaker open and the arm (4-77) against the stop screw (4-76), the "b-b" contact is closed with 1/32 to 1/64 overtravel left in the limit switch.

3.7 LATCH CHECK SWITCH (Fig. 4)

The latch check switch (4-1) is mounted on the bottom of the operator frame. The switch makes contact near the end of the reset travel of the lower link of the four bar linkage. Adjustment is made by moving the switch.

NOTE: The latch check switch may be jumped out or omitted except when the unit is used with a recloser relay.

3.8 INTERLOCK PLUNGER (Fig. 1)

The foot lever (1-20) operates the interlock plunger (1-18) as well as the trip latch. Depressing the lever trips the breaker and raises plunger (1-18) sufficiently to release the breaker allowing it to be

moved in the cubicle. The interlock is in proper adjustment when the plunger (1-18) is positioned to 1-11/16 to 1-13/16 above the floor line, and causes tripping of breaker contacts when it is raised to a level not more than 2-1/16 above the floor line. The latch tripping rod associated with the foot lever should be clear of the trip latch (4-27) by 1/32 to 1/16.

3.9 TRIP LATCH (Fig. 4)

The trip latch (4-27) is in proper adjustment when the latch roll (4-15-A) engages it at a point 1/8 to 3/16 from the bottom edge of the latch face (4-27). Changes in adjustment are made by positioning stop screw (4-65). Note that this adjustment affects the clearance between the trip pin (4-17A) and the trip latch (4-27) (see Section 3.10). The latch roll stop screw (4-75) should be positioned such that the latch roll will have a clearance of 1/64 to 3/64 between the latch roll and the latch face with breaker in open position.

3.10 TRIPPING SOLENOID

The tripping solenoid (4-17) has been adjusted in the factory and should require no further adjustment. If readjustment is required it should be made only when the trip latch bite is in correct adjustment (see Section 3.9).

The travel of the trip armature should be such that slow manual actuation will trip the breaker and have 1/16 to 3/32 after travel. Adjustment is made by shimming the trip solenoid with spacers, item 16.

With the coil deenergized there should be 3/32 to 5/32 clearance between the trip pin (4-17A) and the trip latch (4-27). Adjustment is made by raising or lowering the hex nut (4-76).

3.11 PROP LATCH (Fig. 4)

The prop latch (4-97) is normally adjusted such that it engages the toggle roll (4-15) at a point 1/8 to 3/16 from the bottom edge of the latch. Adjustment is made by using spacers (4-99).

With the breaker closed and armature (4-4) held with maintenance closing device against pole head (4-72), the armature must push the toggle roll (4-15) to a point which will provide a clearance of 1/64 to 3/64 with the prop latch (4-97), and 1/32 to 3/32 clearance to stop (4-59). These settings have been made at the factory and should not require readjustment. Adjustment is made by changing the effective plunger length with washers (small) (4-11) between the plunger (4-6) and the armature (4-4).

SUBSECTION 4. DISCONNECT SECTION

4.1 BREAKER MECHANISM

The breaker mechanism consists essentially of movable contact arms and insulating links which connect the contact arms to the operator mechanism.

4.2 CONTACTS (Fig. 3)

The stationary contact structure of each phase is made up of two sets of contacts; main current carrying, and arcing, which are mounted on the upper bushing stud. The movable contacts are attached to contact arms that pivot from the end of the lower bushing stud. Transfer areas of current carrying contacts are silver plated and contact surfaces are of silver-tungsten alloy. The main current carrying contacts are finger type and engage with a wiping action. The arcing contacts are butt type. All contacts are backed by steel springs giving positive contact pressure when engaged.

4.2A SERVICING CONTACTS

The frequency of contact inspection depends on the severity of service to which the breaker is subjected. There are two areas which normally require service inspection:

A. Stationary and moving main and arcing contacts. Badly pitted or burned contacts should be replaced.

B. Hinge joints. Remove the disconnect arms as a unit by removing screw (3-24), nut (3-14) and spring washers (3-23). Carefully inspect all contact surfaces. Silver washers (3-25) and adjacent surfaces should be clean and free of roughness or galling. Lubricate washers (3-25) and mating surfaces by rubbing in microfine dry graphite, used sparingly. Remove excess graphite. Reassemble, adjusting hinge joint pressure as described in Section 4.5.

4.3 BREAKER TIMING

Check the contact adjustment and breaker timing, also check adjustments of auxiliary equipment and see that it functions properly. A comparison of breaker timing at any period of maintenance with that taken when the breaker was new will immediately indicate a condition of maladjustment or friction should the timing vary more than 1/2 cycle on opening or 2 cycles on closing with the same coils. A hole is provided in the movable contact arm for the purpose of attaching a speed analyzer connection.

4.4 ARCING CONTACT HINGE JOINT (Fig. 3)

The arcing contact hinge joint is in proper adjustment when each spring washer (3-15) is deflected approximately 0.015 inches.

This adjustment is obtained by tightening nut (3-4) until all parts just touch, then tighten the nut 3/4 to 1 turn more.

4.5 CONTACT PRESSURE OF HINGE JOINT (Fig. 3)

The hinge joint contact pressure is in proper adjustment when a pull of from 7 to 9 pounds on the 5 kv, and from 5 to 7 pounds on the 15 kv is required to move the disconnect toward the open position. This measurement is obtained as follows:

Remove pin (1-46) and detach link (1-47) from the disconnect arms (3-18) and (3-19). Move the disconnect to a position just short of "contact make". Attach a spring scale to the disconnect 8-1/2 inches on the 5 kv, and 10-1/2 inches on the 15 kv, above screw (3-24), and in a direction perpendicular to the longest edge of the disconnect arm. Measure the pull to move the disconnect toward the open position.

Adjustment is made by tightening (or loosening) nut (3-14).

Before attaching link (1-47) to disconnect arms (3-18) and (3-19), check contact alignment (section 4.6) and contact lead (section 4.7).

4.6 CONTACT ALIGNMENT (Fig. 3)

The contacts are an integral part of the bushing assemblies and are carefully aligned with the upper and lower bushings before shipment and no further adjustment should normally be necessary.

The horizontal pairs of main contact fingers in each phase should '"make" with the moving contact simultaneously. (Note: Contacts on different phases should not necessarily "make" simultaneously, they can vary as much as 1/32 inches.)

If not already detached, remove pin (1-46) and detach link (1-47) from disconnect arms (3-18) and (-19).

On MA-75/150B and FC-150/250/500 Breakers Detach arcing contact (3-10) from yoke (3-2) by removing pin (3-26). Move the disconnect toward the closed position until it just touches a main contact finger (See Fig. 3, View A-A, main contacts engaging). Dimension c should then be no greater than .020 inches, with one contact touching.

On MA-250/350B, FB-250/500 and FC-750 Breakers Remove pin (1-46) and detach link (1-47) from disconnect arms (3-18) and (3-19) of two phases only. With the maintenance closing device, move the disconnects of the remaining phase toward the closed position until a main contact finger (3-11) is touched. Dimension c should then be no greater than .020 inches, with one contact touching.

Adjustment is made by loosening two nuts (3-22) and rotating the contact assembly. Alignment (dimension c) should be checked after tightening nuts (3-22).

Alignment is checked and adjusted on each phase separately. Be sure there are no binds between contacts (3-11) preventing proper wiping action with the disconnect arms.

Attach arcing contact (3-10) to yoke (3-2), if detached, but check contact lead (section 4.7), before attaching link (1-47) to disconnect arms (3-18) and (3-19).

4.7 CONTACT LEAD (Fig. 3)

Contact lead is adjusted on breakers in the factory and should normally not require further adjustment. It should, however, be checked on each phase separately and only with contact alignment on the phase in correct adjustment (see section 4.6).

The arcing contacts (3-9, 10, 27, 28) should "make" before the main contacts. Measure and adjust each phase separately as follows:

If not already detached, remove pin (1-46) to detach link (1-47) from disconnect arms (3-18) and (3-19). Move the disconnect toward the closed position until the arcing contacts just touch (See Fig. 3, View A-A, arcing contact engaging.)

The shortest gap between the bottom contact fingers (3-11) and the contact on the disconnect arms (3-18) and (3-19) should be 7/32 to 1/4 inches. (Dimension b in View A-A of Fig. 3.) Adjustment is made by opening or closing the gap with nut (3-1).

Reconnect link (1-47) to disconnect arms (3-18) and (3-19) using pin (1-46).

4.8 CONTACT STROKE (Fig. 3)

Contact stroke should be checked and adjusted only when the contacts are in proper alignment (see Section 4.6).

In order to ensure proper wiping action and contact pressure, the stroke of the disconnect must be maintained in proper adjustment. Check and adjust as follows:

With the breaker latched, dimension a in View A-A of Fig. 3, on the top pair of fingers should be 1/8 to-3/16". Adjustment is made with the breaker in the open position by increasing or decreasing the effective length of link (1-47) by means of nuts (1-10). Each phase is adjusted individually.

Trip the breaker open and check to see that dimension d is 4 $\pm$ 1/8 inches on the 5 kv, and 6 $\pm$ 1/8 inches on the 15 kv on-all three phases. (On breakers with more than four contacts per phase, dimension d is still measured to the second from top contact.)

Adjustment for dimension d is made by first removing pin (1-33) on each puffer. After loosening nut (1-42), increase (or decrease) effective length of rod end (1-40) by screwing (or unscrewing) it into piston stem (1-44). Adjust rod ends (1-40) on both puffers the same amount. Tighten nuts (1-42), replace pin (1-33), and check dimension d.

SUBSECTION 5. ARC CHUTE ASSEMBLY

5.1 ARC CHUTE ASSEMBLY (Fig. 2 & 3)

Each arc chute consists of a flame retardent envelope-which provides phase isolation for interruption and venting of the by-product gases of interruption. The arc chute contains:

a) The transfer stack consisting of refractory plates. It aids the transfer of the arc terminal from the stationary end arcing contact (3-9) to the stationary end runner (2-4).

b) The stationary end arc runner (2-4) and moving end arc runner (2-3) to which the arc terminals transfer from the arcing contacts. The arc runners form paths for the arc terminals to travel up the arc chute.

c) The stationary end blowout coil (2-15) and moving end blowout coil (2-13) which connect their respective arc runners to the top and bottom bushings. The current in these coils creates the magnetic flux which passes through cores (2-18), pole pieces (2-22) and the space between the pole pieces. The action of this flux on the arc forces the arc up the barrier stack.

d) The barrier stack (2-23) consisting of a number of refractory plates with "Vee Shaped" slots cemented together. The barrier stack cools, squeezes and stretches the arc to force a quick interruption.

e) The barrier (2-1) containing coolers (2-28) through which the by-product gases of interruption pass. The barrier completes the cooling and deionizing of the arc products.

Arc chutes are normally tilted (see Section 5.3) to expose contact area of the breaker and/or to replace parts such as barrier stacks (2-23). The arc chutes may also be removed from breaker if necessary, to replace parts not exposed when tilted by removing fastenings per Section 5.3.

5.2 PHASE BARRIERS (Fig. 1)

Full size barriers of high dielectric flame retardent material isolate each phase.

To remove phase barriers on 5 kv breakers - lift panel spring assembly (1-13) out of slots (1-14) to release panel (1-32). Lift and remove panel. Remove center phase screw (1-23). The phase barrier assemblies (1-5) and (1-7) can now be lifted and removed from the breaker. Note: On MA 250/350B breakers remove screw (1-2) and remove barrier (1-25) prior to above instructions.

To remove phase barriers on 15 kv breakers remove screws (i-13) and channels (1-9) on rear of breaker. Lower panel (1-32) and loosen three screws (1-23); remove three screws (1-24) and panel (1-22) on front of breaker. The phase barrier assemblies (1-5) can now be removed from the front of the breaker.

Replace the above parts in reverse order taking care that barriers are seated properly and that channels (1-9) are located inside of washers (1-8).

5.3 TILTING ARC CHUTES

Remove phase barriers (see Section 5.2).

On the 5 kv breakers remove screws (1-23) and (1-37) of each phase. Remove screws (1-39) and (1-17) to remove barriers (1-19) and (1-22).

On the 15 kv breakers remove screws (1-1 and 1-37) on each phase. Loosen screws (1-23) and remove screws (1-24) and(I-39) to remove panel (1-22).

With arc chute support in place. at the rear of the breaker, tilt back the arc chutes.

After tilting arc chutes upright, and replacing barriers, be sure all screws are tightened securely on all three phases.

5.4 BARRIER STACKS (Fig. 2)

The barrier stacks are fragile and should be handled carefully. The barrier stacks should be inspected for erosion of the plates in the areas of the slots. The stacks should be replaced when a milky glaze is observed on the full length of the edges of most of the slots. They should be likewise replaced if plates are broken or cracked. When cleaning the breaker and cubicle, inspect for pieces of barrier stack refractory material which would obviously indicate breakage.

To remove the barrier stacks tilt back the arc chutes (see Section 5.3).

On the 5 kv breakers remove four screws (2-2), (five screws on MA-250B), barrier (2-1), from each arc chute. Slide barrier stack (2-23) through top of arc chute.

On the 15 kv breakers remove four screws (1-26), two barriers (2-1) and if applicable, two screws (2-6) and two tubes (2-5) from each arc chute. Slide barrier stack (2-23) through top of arc chute.

When sliding a barrier stack into the arc chute, care should be taken to see that the end containing the Vee-shaped slots goes in first.

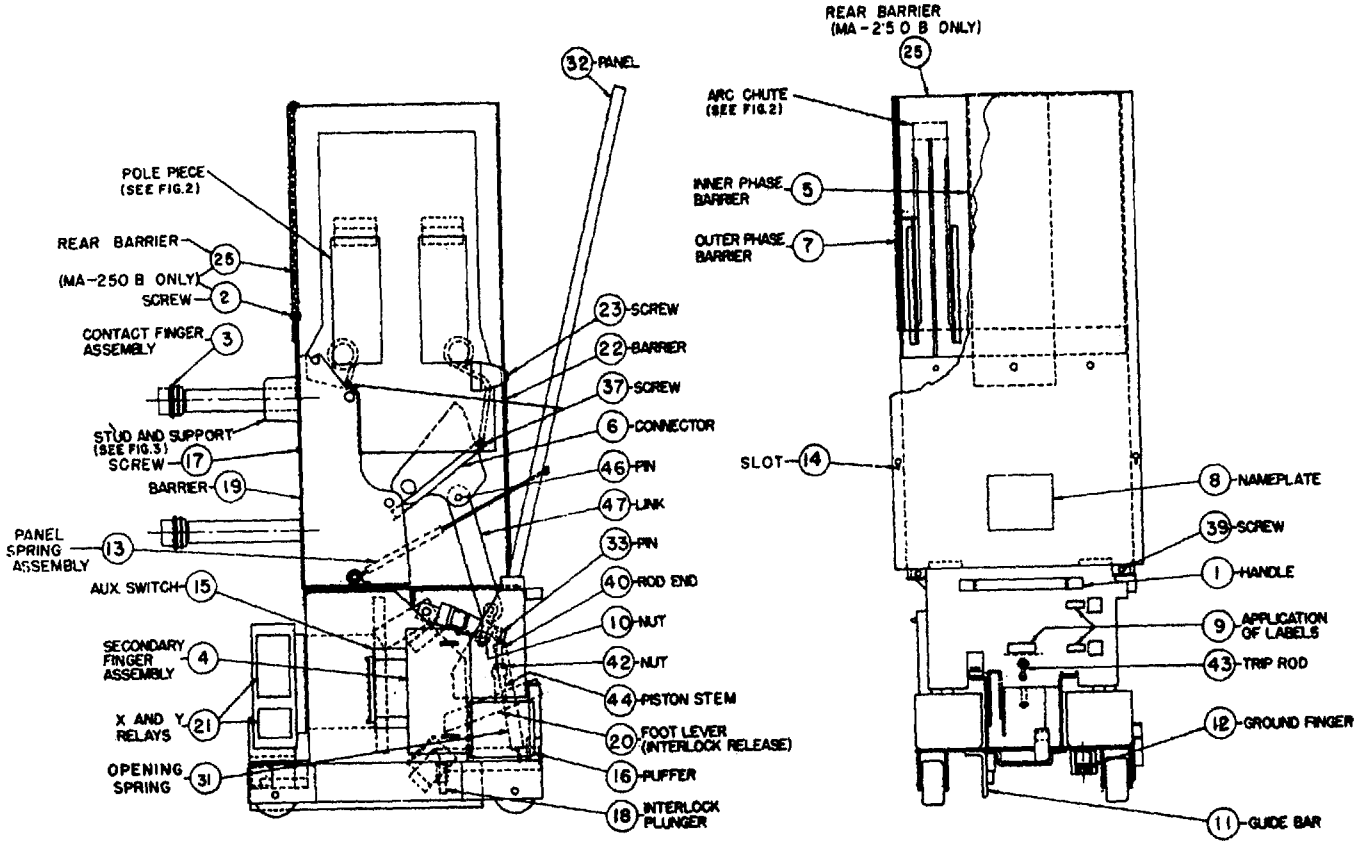


FIG. 1. TYPICAL MAGNETIC BREAKER

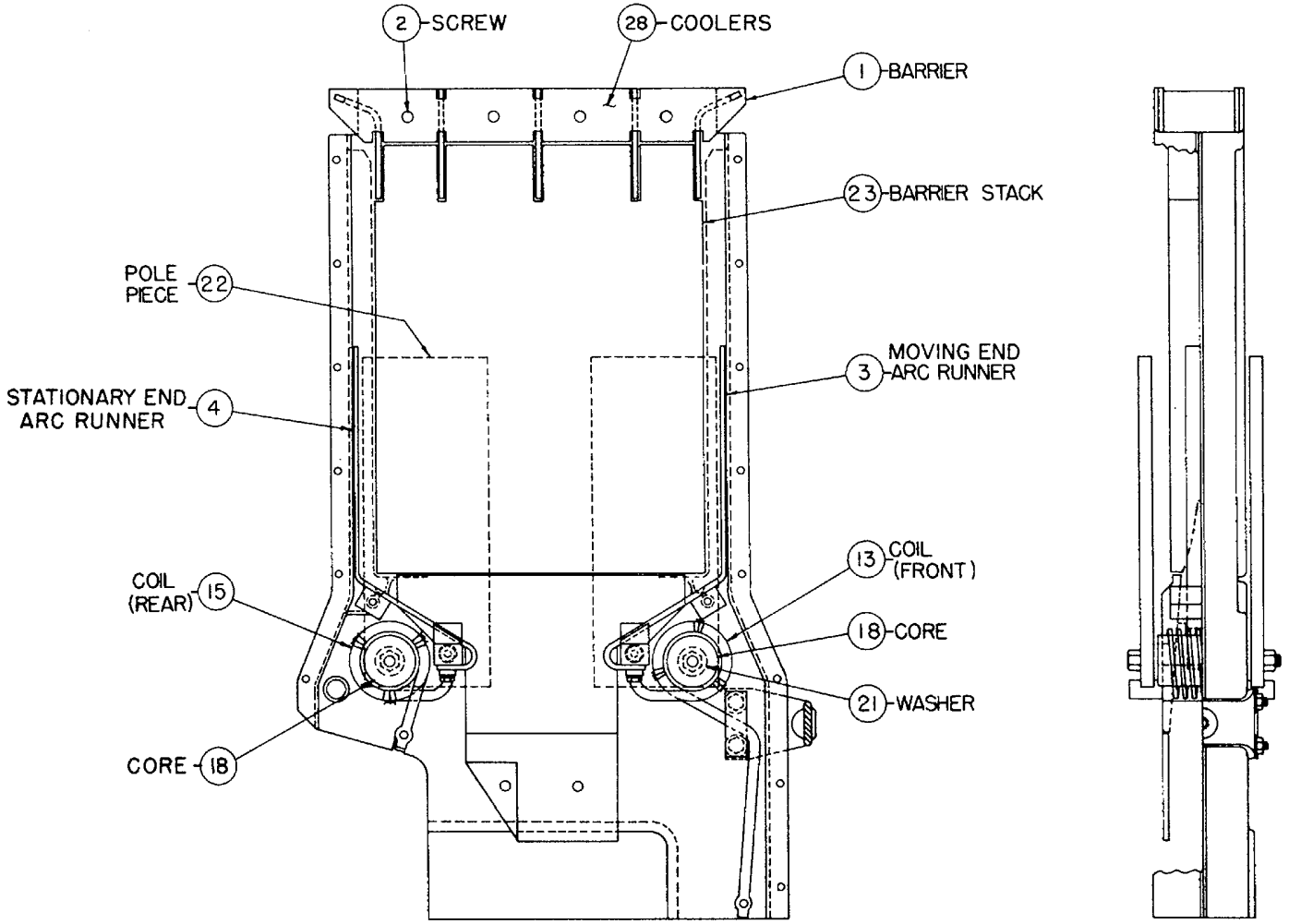


FIG. 2. TYPICAL ARC CHUTE

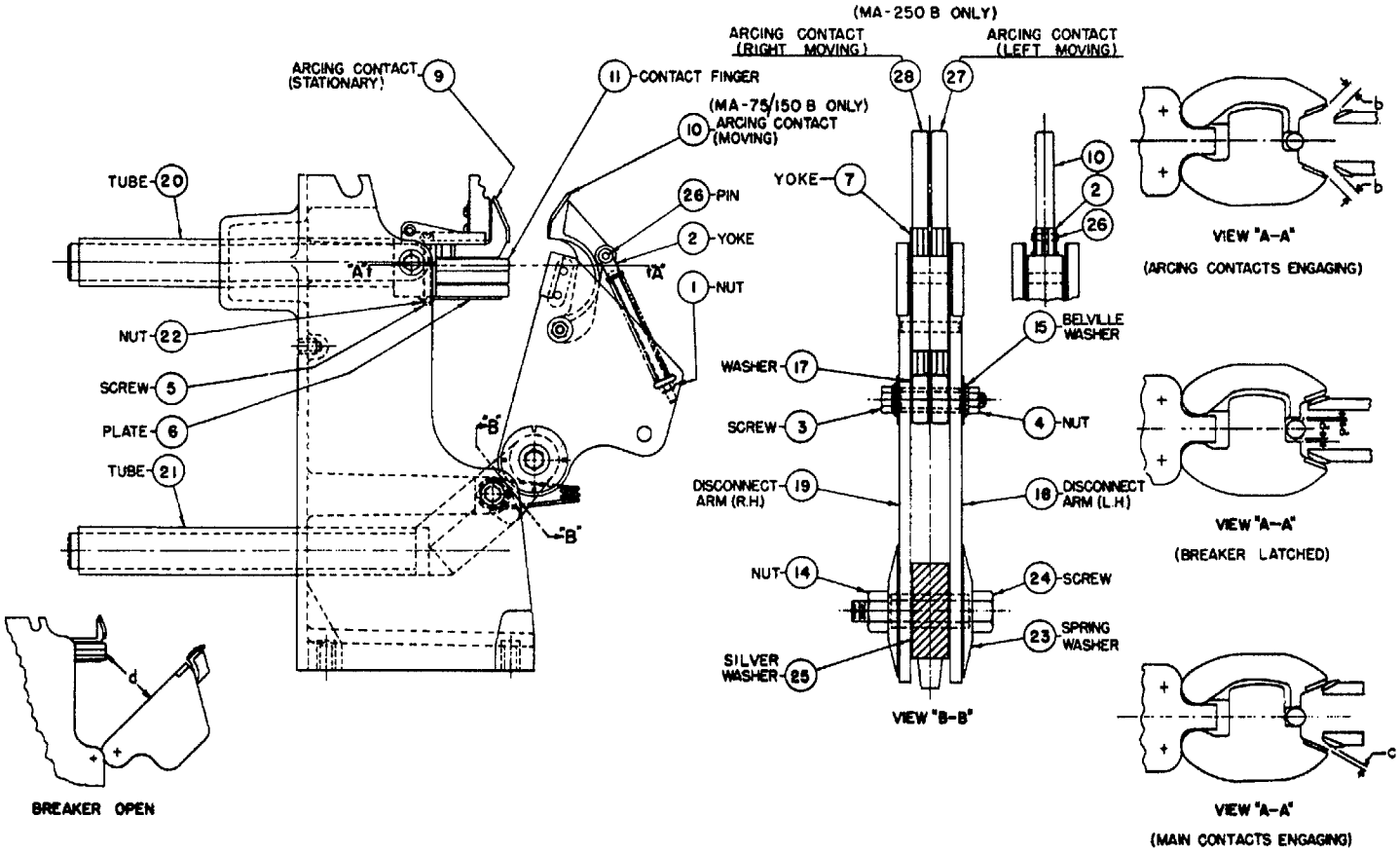


FIG. 3. TYPICAL STUD & SUPPORT

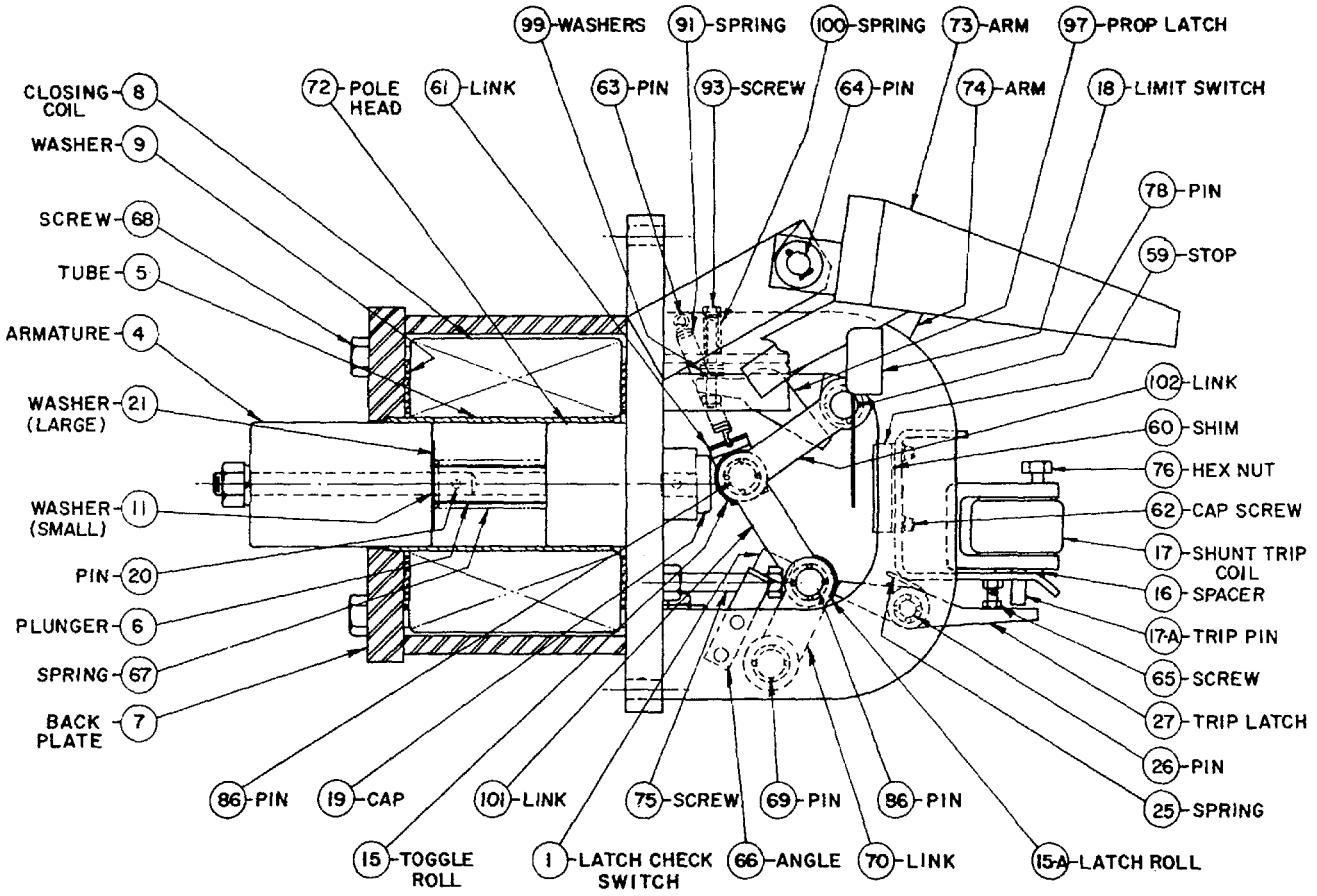


FIG.4. TYPICAL OPERATOR ASSEMBLY

FIGURES 5 THROUGH 10 NOT APPLICABLE

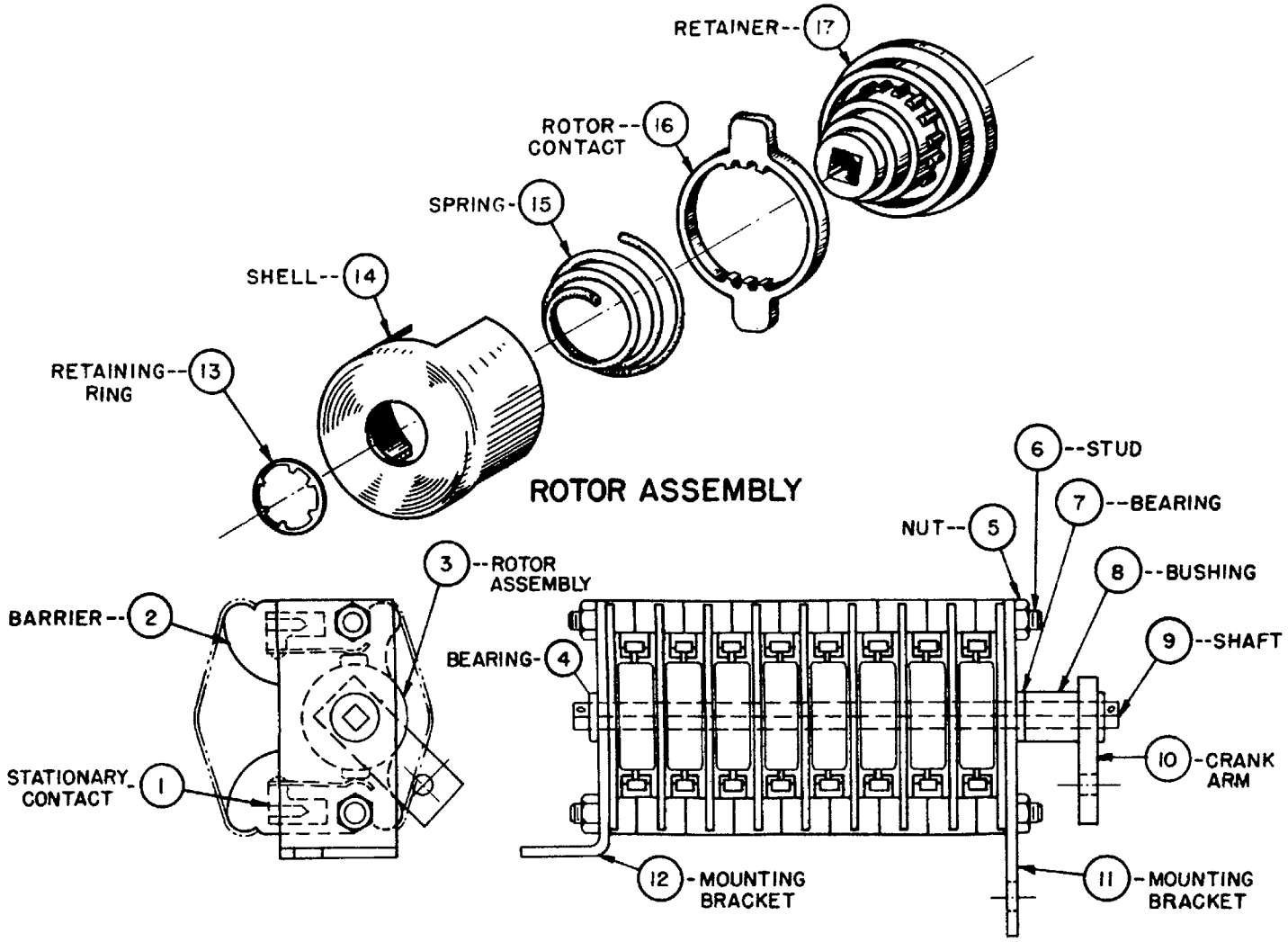
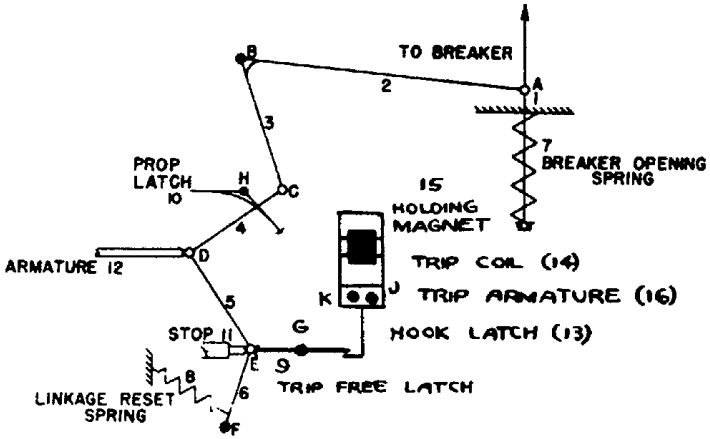
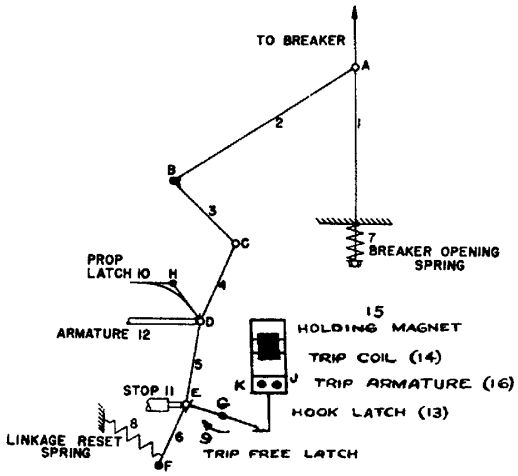


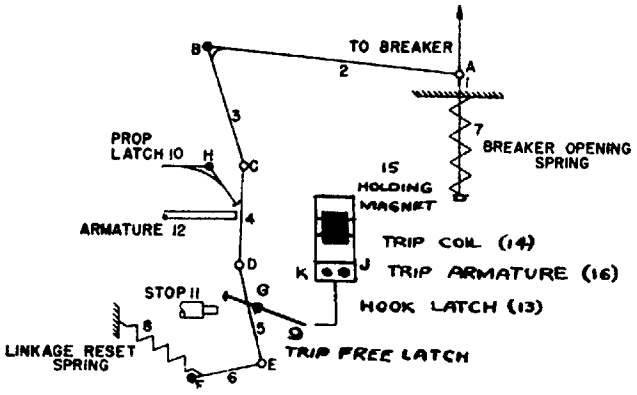
FIG. 11. TYPICAL AUXILIARY SWITCH



OPEN
FIG. 13



CLOSED
FIG. 14



TRIP FREE
FIG. 15
TYPICAL OPERATOR LINKAGE DIAGRAM

INSTRUCTIONS

for

the Installation, Care and Operation of Circuit Breakers and Accessories

SECTION 30.

DIRECT CURRENT

CONTROL RELAY

BOOK BWX-6540

3-339

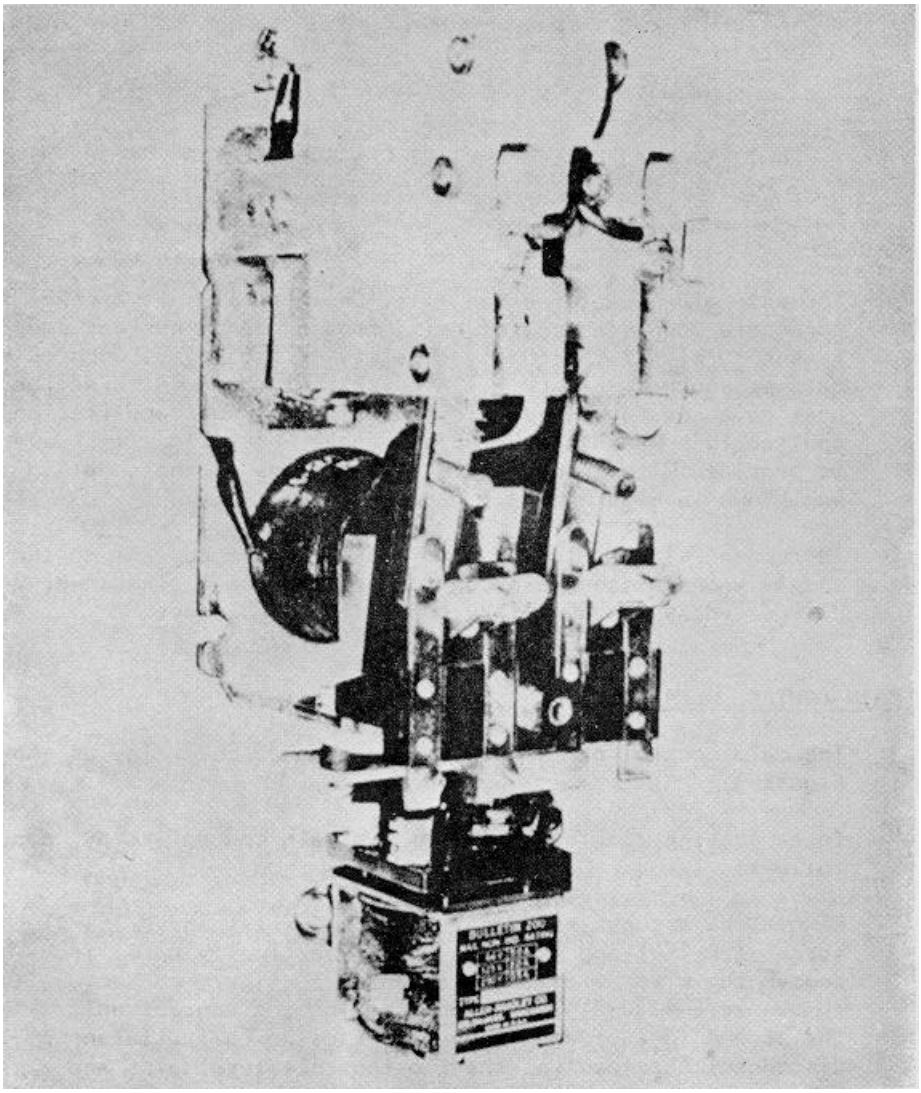


FIG.1. TYPICAL DIRECT CURRENT CONTROL RELAY

INSTRUCTIONS FOR
DIRECT CURRENT CONTROL RELAY

GENERAL

1. The solenoid operator of an Allis-Chalmers circuit breaker is designed for operation by a control relay from a direct current source only. This control relay actually consists of two relays mounted on a common base as shown in Figure 1. A cover, not shown in this figure; is available and furnished with the relay for most applications. For applications where shock due to breaker operations is heavy, the base is provided with shock mounts. Dimensions of the complete assembly are shown in Figure 2.

2. The upper relay in this assembly handles the current to the solenoid and Is known as the main control or "X" relay. The lower relay is designated as the auxiliary control or '"Y" relay.

MAIN CONTROL RELAY

3. The main control or "X" relay is a type JD-802 relay as shown in Figure 3.

4. To remove the closing coil from the main control relay, proceed as follows:

5. Remove the arc chutes (consisting of J-161-L and J-161-R) by removing screws (JD-254) and lift the chutes vertically until free. Next remove the wires from the stationary auxiliary contact unit(J-219) and remove screws (J-255), thereby freeing the contact unit. Next, remove the screws (J-256) and remove the closing coil retainer (J-218). Now disconnect the leads at the closing coil terminals, and remove the coil.

REPLACEMENT OF CONTACTS

6. To replace the stationary contacts (J-164), remove the arc chutes as described in paragraph 5 and disconnect the lower leads of the blow-out coils (J-192) and screws (J-258). The contacts can then be replaced.

7. When it is necessary to replace the movable contact and shunt, remove the screws (J-254), thereby releasing the shunt, then press back the contact pin (J-223) until contact pin retaining washer (J-225) protrudes at the rear of the moulded movable contact carrier (J-227). Remove the washer and pull out the pin and spring, thus permitting the removal of the movable contact arm.

8. When replacing the movable auxiliary contact (J-220) press auxiliary contact pin (J-221) until small wire pin is exposed on opposite side. Then remove wire pin, holding the auxiliary contact. Contact can then be replaced.

9. To replace stationary auxiliary contacts (J-219), remove all wires and screws (J-255). The contacts Can then be replaced as a unit.

REPLACING INSERTS

10. If It is found that the arc chute inserts (J-226) require replacement, remove the arc chutes, and screws (J-260), releasing the magnetic blowout plate (J-162). Insert will then slide free for replacement.

AUXILIARY CONTROL RELAY

11. the Auxiliary or "Y"' Relay is a Type G-110, as shown in Figure 4.

REMOVAL OF COIL

12. To remove the coil, remove the solenoid base, (Item I), which is held to frame by 4 screws. Coil Is now free to slip off solenoid core.

REMOVAL OF CONTACTS

13. To remove stationary contact assembly (Item 1), remove screws on top of relay and lift off.

14. To remove movable contact assembly (Item 2), remove one screw holding cross bar to plunger bar and lift off.

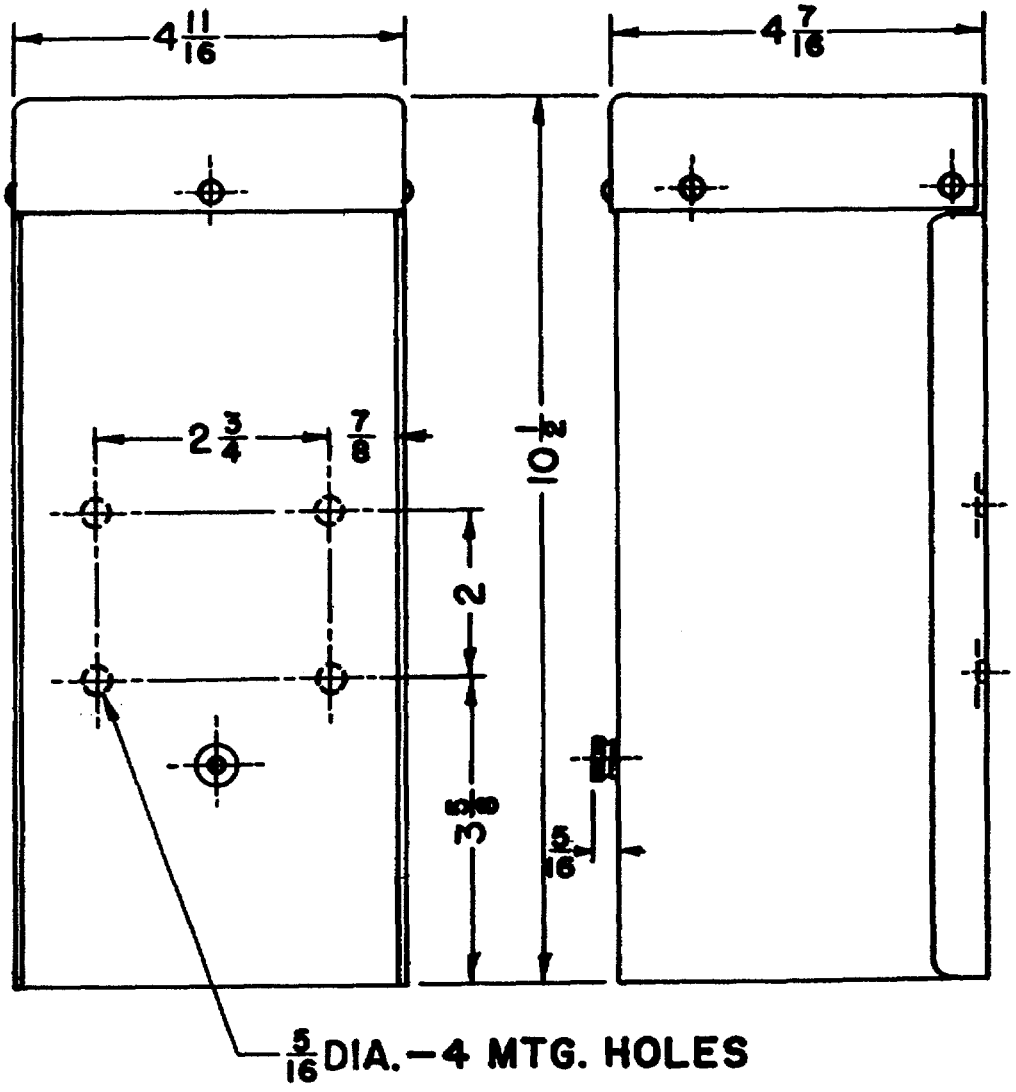


FIG. 2. RELAY COVER

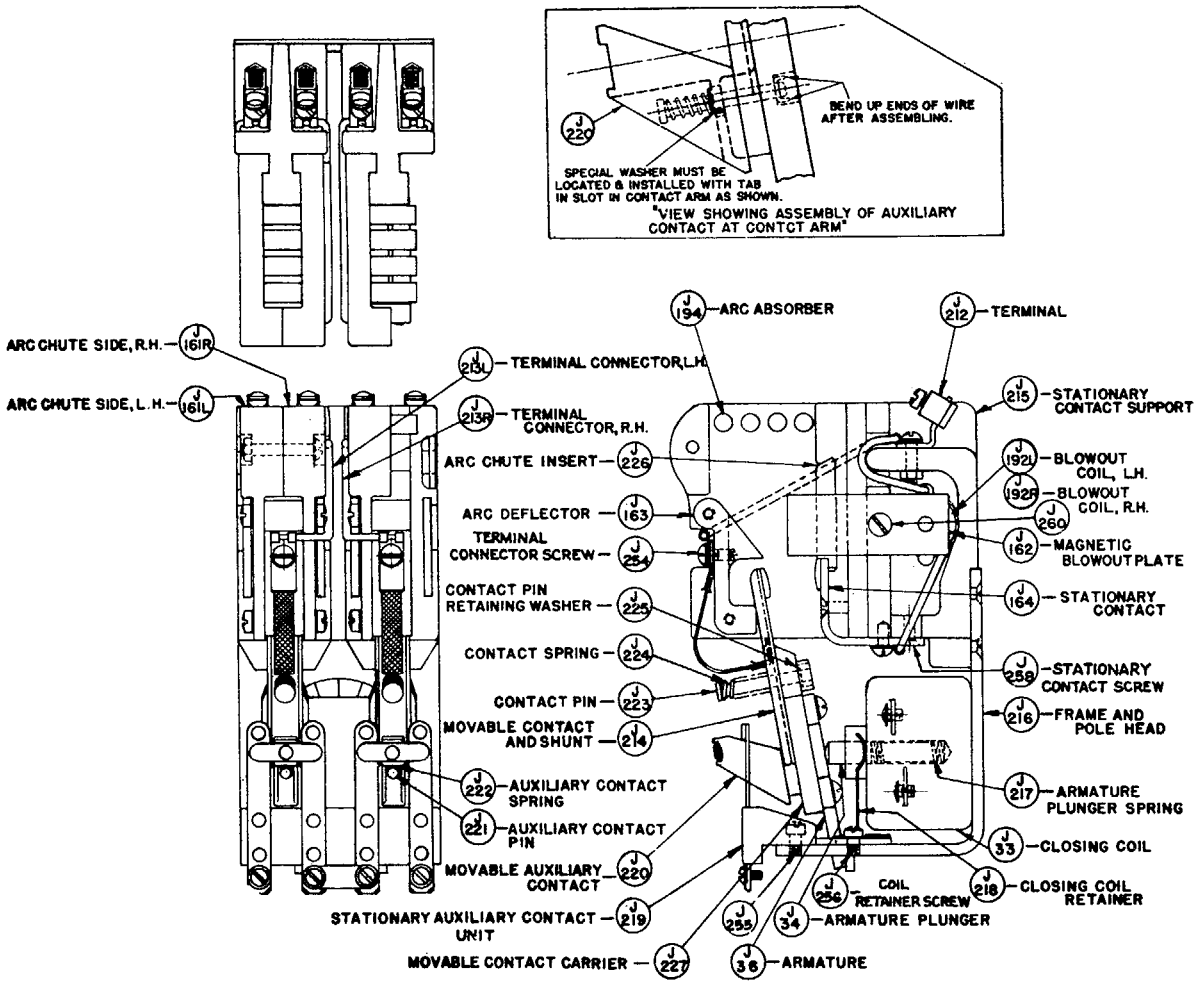
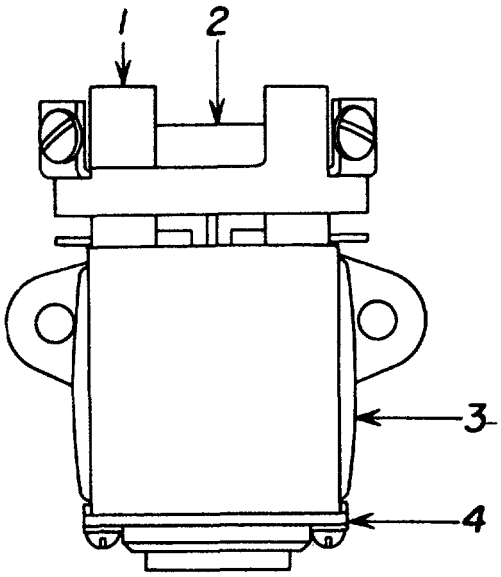


FIG. 3. TYPICAL TYPE JD-802 RELAY

D.C. CONTROL RELAYS
Type G



Renewal Parts List

Item		Description of Part	
1		Stationary Contact	
2		Cross Bar.....	
3		Operating Coil	
4		Solenoid Base(Less Coil)	

Type of Relay	Stationary Contacts Item 1	Cross Bars Item 2	Solenoid Base Item 4
G-100	X-159612	X-159625	X-165704
G-010	X-159613	X-159624	X-165704
G-200	X-159611	X-159621	X-165704
G-110	X-159615	X-159623	X-165704
G-020	X-159614	X-159622	X-165705

Operating Coils

Volts	6	12	24	32	64	115	230
Old Coil No.	RH-6714	RH-6716	RH-713	RH-6702	RH-6712	RH-6710	RH-6711
New Coil No.	00D0150	00D151	00D152	00D153	00D154	00D155	00D156

FIG. 4

SECTION 31. CONTROL DEVICE

Type 210 Instrument and Control Switches

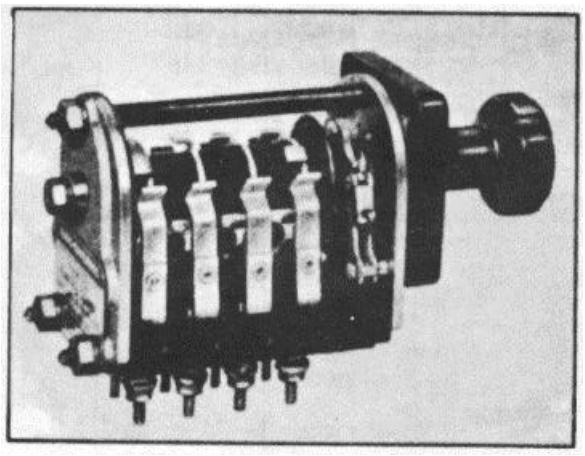


Fig. 1-Standard 210 instrument switch with four stages.

DESCRIPTION

Type 210 Instrument and Control switches are available as either maintained or spring return contact types. These switches are available with or without pullout feature and with fixed or removable handles. They are used in conjunction with such instruments as circuit breakers, transformer tap changers, motor-operated rheostats, and many other types of electrically controlled apparatus. Switches are designed for panel mounting.

Switches may be furnished with a magnetic release mechanism, in which an operating magnet is used to trip the switch (Fig. 4). *The switch must be reset manually.*

The Type 210 switch circuits are usually connected from a stud on one side of the terminal base through a segment of the shaft assembly to a stud on the other side. This constitutes a single contact or stage. A stage is a single-pole, double-break, single-throw con-tact. In other switches involving various sequences and connections to the same circuit, the entire switch may serve as a single-pole.

The operating shaft (14) is made of 3/8-inch square, cold-rolled steel and rotates on nickel-plated brass bearings. The end plates (1) and (2) provide ample sup-port for the shaft (14) and base block (5). They assure permanent alignment of the contacts. Movable contact segments (26) and (27) are made of silver-plated brass.

The stationary contacts (6) and (7) are made of heavy phosphor bronze and are silver-plated. This means low contact drop throughout the life of the switch even under conditions of oxidation or other corrosion. The rotating contacts (26) and (27) are separated by high resistance insulators (20). A square, linen-base phenolic insulation (15) covers the shaft. It is a strong, high grade insulation and is impervious to humidity. Spacers (25) and contacts (26) and (27) are held on the shaft by a screw and lockwasher. High compression springs give excellent contact pressure. The contact construction utilizes a self-aligning, wiping action. This assures clean, low resistance contact and means longer operating life. Copper shunts conduct the current from the contacts to the terminal studs. The studs are mounted on the base block and are designed so they cannot come loose.

Terminal base block (5) is made of molded, industry quality phenolic and has high mechanical and dielectric strength. Each terminal base is numbered for identifying the connection from the wiring diagram.

OPERATION

All Type 210 switches are made for partial or full 360degree rotation with 2 to 12 radial positions. Spring return switches are made for three positions but can be furnished for a maximum of seven positions, three from either side of center position. Maintained contact switches are available from 2 to 12 positions. Any in-crease in the number of positions decreases the travel between positions and reduces the interrupting capacity.

Circuit breaker control switches have a window in the position plate with a red and green flag indicator to show the last operation of the switch. In the trip position, the signal lamp circuit can be opened by pulling the handle into the latch position. When latched the lamp is not lighted up, indicating that the circuit con-trolled by the breaker is not in use. Voltage control, speed control, and motor control switches are not usually furnished with the flag indicator or pullout feature. The rotating contacts of the Type 210 switch are mounted on a square insulated shaft. Contacts may or may not be electrically insulated from each other, depending upon the desired circuit. In operation, circuits are completed across various members of stationary contacts or a continuous circuit is maintained across two or more stationary fingers for a number of switch positions by means of conductive spacers. The stationary contacts

TABLE I. TYPE 210 SWITCHES AVAILABLE

Description	2 Contacts Per Stage	3 Contacts Per Stage
With indicator flag; spring return and pull-out	Type210-1	Type 210-11
No indicator flag; no spring return; no pull-out	210-2	210-12
	210-52*	210-62*
No flag; no spring return; key handle	210-3	210-13
	210-53*	210-63*
No pull-out; no flag; with spring return	210-4	210-14
Coil operated release; manual reset	210-5	210-15
Pull-out with horizontal spring return; no spring return	210-6	210-16
Pull-out with lock at 100 from "off"; no spring return	210-7	210-17
Mechanically driven; no handle; no face plate; no positioning wheel	210-8	210-18
Pull-out with lock at 10° from "off"; with spring return	210-9	210-19
	210-59*	210-69*
Spring return; no flag; pull-out and lock-in 2 positions	210-10	210-20
Spring return; no flag; pull-out in center position	210-21	210-31
Spring return; with flag; no pull-out	210-22	210-32
2 key handles; each handle turns switch in one direction only	210-23	210-33
2 gang, switch	210-24	Can be either 2 or 3 contacts or both.
3 gang, switch	210-25	210-35
Coil-operated release, spring return, slip contacts; pushbutton type	210-26	210-36
Rotary and horizontal spring return; pull-out, no lock	210-27	210-37
Rotary and horizontal spring return with removable key handle	210-28	210-38
Special construction (not suitable in any of the above for classification)	210-SP	Either 2 or 3 contacts per stage.

* New Style - Positive Positioning

(6) and (7) and positioning fingers (8) are mounted on finger supports. These; in turn, are mounted on a base of insulating material. Contact pressure is provided by a spring. External connections are made to the stationary contact finger through terminal studs below the base.

A new positive positioning device features a star-shaped position wheel, two roller arm assemblies and two tension springs. The peaks around the outline of the position wheel virtually eliminate any hang-up area. This, combined with the push-pull effect of the roller, makes in-between positioning impossible.

A positioning wheel (22) and two stationary fingers hold the shaft assembly in each position on maintained contact switches. Mounted on the operating shaft (14), the notched positioning wheel corresponds to the number of switch positions. Spring action engages the positioning finger by the notches in the positioning wheel. This holds the switch in the desired position. The switch also is designed to provide a spring return.

Because interrupting capacity depends on the current, voltage and inductance of the circuit and the speed of contact opening, control relays should be used with control switches on heavy currents. These switches are made in standard construction for up to fourteen circuits. In many cases, additional circuits may be provided.

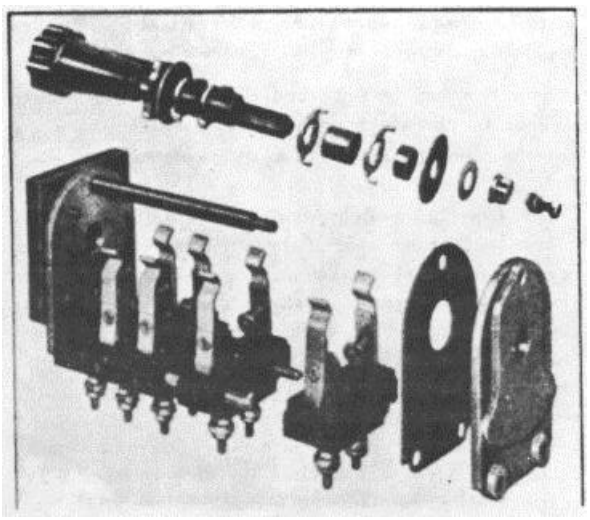


Fig. 2. Dismantling is easy and quick on oil 210 switches.

GENERAL DATA

Ratings . . . Type 210 switches are rated for 20 ampere continuous capacity with 600 volts insulation.

Circuit Voltage	*Momentary Interrupting* Amps	
	Inductive Circuit	Non-Inductive Circuit
125 ac	30	50
250 ac	15	25
600 ac	3	5
125 dc	4	8
250 dc	1	2
600 dc	0.2	0.5

The following data applies to the Type 210 switches when the contacts are new:

Normal Contact Lift - Min. 1/32-in.; Max. 1/16-in.

Required Contact Pressure - 10 to 12 ounces

Wear Allowance - 1/32-in. per contact

MAINTENANCE

The only maintenance required is to periodically examine the stationary contact fingers (6) and (7) and movable contact segments (26)and (27) for wear. Contacts should be replaced when the wear is approximately 1/32-in. Per contact.

Lubrication: A few drops of light machine oil on the bearings (16) and (18) every six months and a thin film of vaseline on the contact surfaces are the only lubrication requirements on the switches.

Replacing a Stationary Contact: To remove a stationary contact (6) and (7), first remove the cover (12) and then remove the hex nuts, lockwashers, washers and leads on the contact terminal. This frees the contact assembly from the switch base (5). Next remove the cotter pin, washer, contact spring and contact finger from the support. Replace with new contact finger and and new spring if necessary.

Replacing a Movable Segment: Should the movable segments (27) or slip contacts (26) have to be replaced, remove the switch from the panel. First remove all wiring to the switch, be sure each lead is coded, and then remove handle (13). Press the position plate (11) in on the side that has a dot, then slide under the face plate (10) and back out. Slip the position plate off the shaft (14). Unscrew the three flat head mounting screws and remove the switch from the panel.

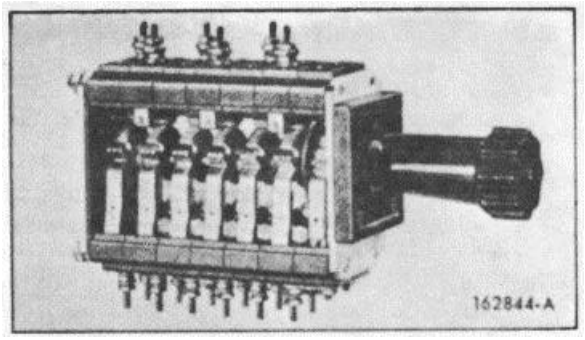


Fig. 3 - Type 210 switch with 3 contacts per stage construction.

All segments, excepting the slip contacts, are coded by a number stamped on each segment. It is best to make a sketch of the position of each segment on the shaft and show the location of the conductive and non-conductive spacers between segments. Notice that the actuator on the slip contact bushing is opposite the file mark, on the front end of the shaft or pointing down. In addition, note the position of the slip contact segment, as the contact surface is longer on the side of the slot which engages the bushing actuator of the slip contact(9).

The letters indicate the position of the shaft. The number indicates the position of the prick punch on the segment with respect to the file mark or cut-out portion at the front of the shaft.' Thus, each segment is coded such as A-1, B2, C-3, etc. (Fig. 8). Section "V-V" (Fig. 9) shows the position of the numbers with respect to the file mark. The positioning wheel also has an indicating punch mark.

To remove the shaft (14) from the switch, remove the three hex nuts and lockwashers holding the front end-plate (1) to the switch, a6d slip out the shaft from the switch. Remove the hex nut, lockwasher and washer from the end of the shaft. The bearing bushing (18), insulating washer (19), insulating bushing (20), movable

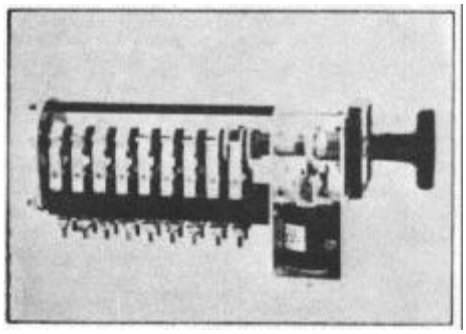


Fig. 4. Type 210-5 control switch.

contact segments (26) and (27), and spacers (25), may be slipped off the shaft. Notice the relative positions of the contact segments, conductive and non-conductive spacers so that they will be returned to their correct place and position.

Replacing a Rotary Return Spring: Follow the above procedure in removing the shaft from the switch and the spring (23) can be slipped .off of the front end of the shaft. When replacing the new spring, press the spring ends and insert the spring on the shaft with the spring ends surrounding the pin on the shaft stop plate. Insert the assembled shaft on the switch. Be sure the large washer (19) in front of the spring is in place. Slide the shaft assembly forward, inserting the bearing pin (17) on the front end plate (1) between the spring ends and over the bearing pin on the shaft stop plate (22).

Replacing a Horizontal Pull Out Spring: In applications where both return spring and horizontal spring return are used on a switch, the horizontal spring return is mounted in the front of the shaft and the return spring is mounted at the rear of the shaft. To replace a horizontal spring return (23), follow the procedure previously outlined for the removal of a shaft from the switch. The spring can then be slipped out. In reassembly, be sure the large washer in front of this spring is replaced.

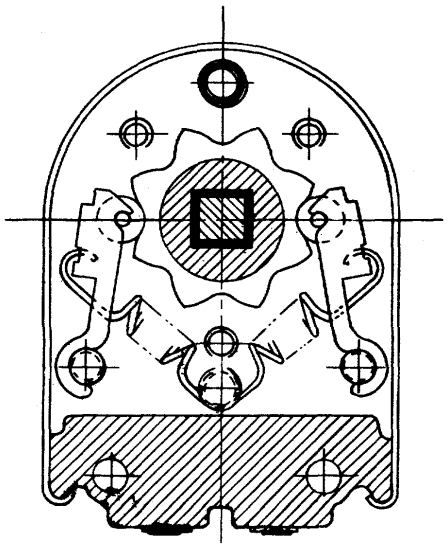


Fig. 5. Front end plate showing star-shaped positive positioning device.

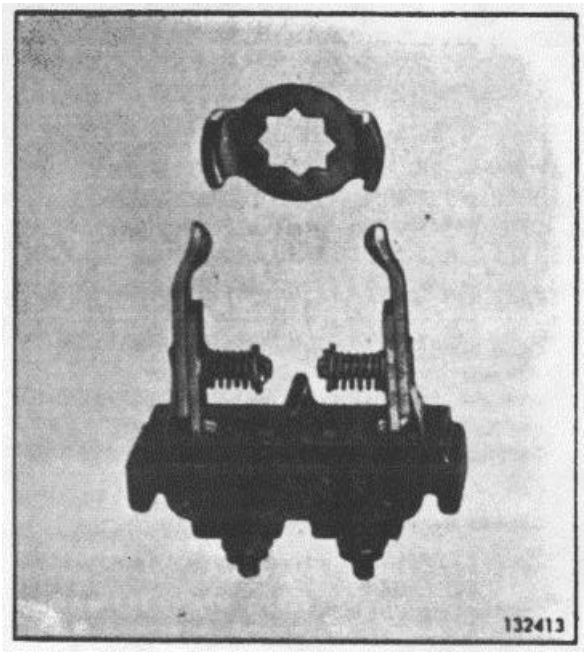
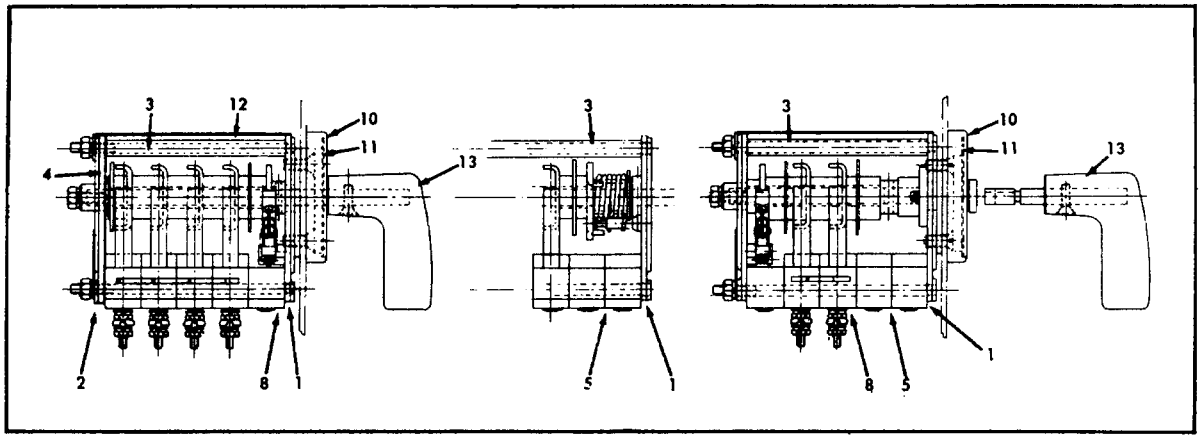
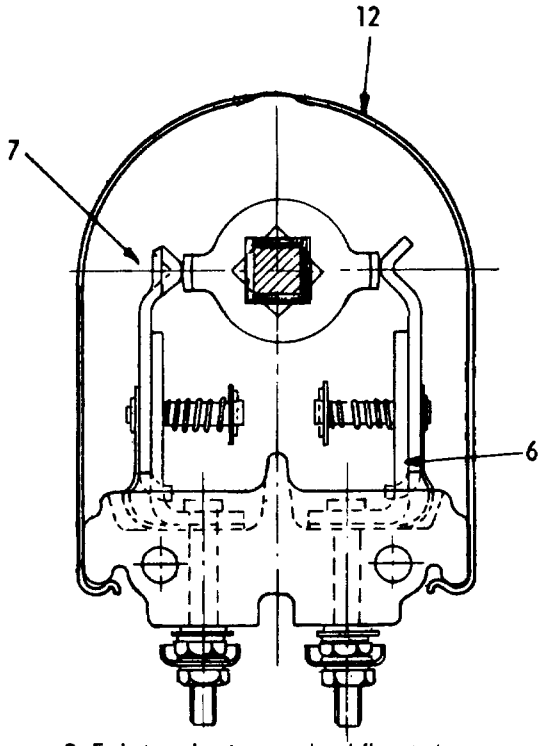


Fig. 6. Contact stage showing unitized construction.

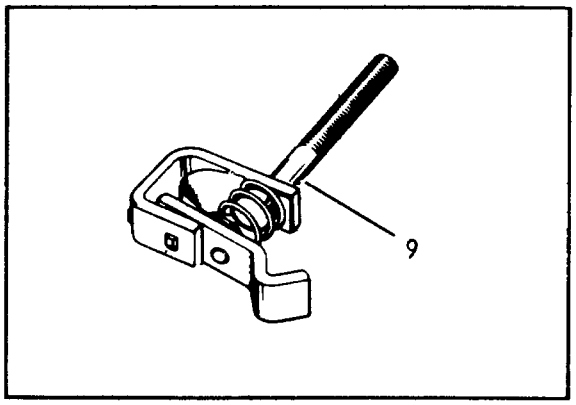
Magnetic Release Mechanism: (Fig. 10) Switches provided with this mechanism should be inspected frequently to check that the trip mechanism is mechanically free and that it will trip at the minimum voltage indicated for the magnet coil used.



A. Handle arrangements.



B. End view showing round and flat stationary contact fingers.



C. Standard flat upper contact used with 3 contacts per stage. For rotary switch only.

Item No.	Description of Part
1	Front end plate assembly
2	Rear end plate assembly
3	Insulating tube
4	Insulating plate
5	Base block
6	Stationary contact assembly (std.)
7	Stationary contact assembly (round)
8	Positioning finger assembly (complete)
9	Standard flat upper contact
9	Standard ball upper contact (not shown)
10	Face plate
11	Position plate
12	Cover
13	Operating handle (round)
13	Operating handle (pistol-grip)
13	Operating handle (oval)
13	Removable key handle

Fig. 7 - Control switch details.

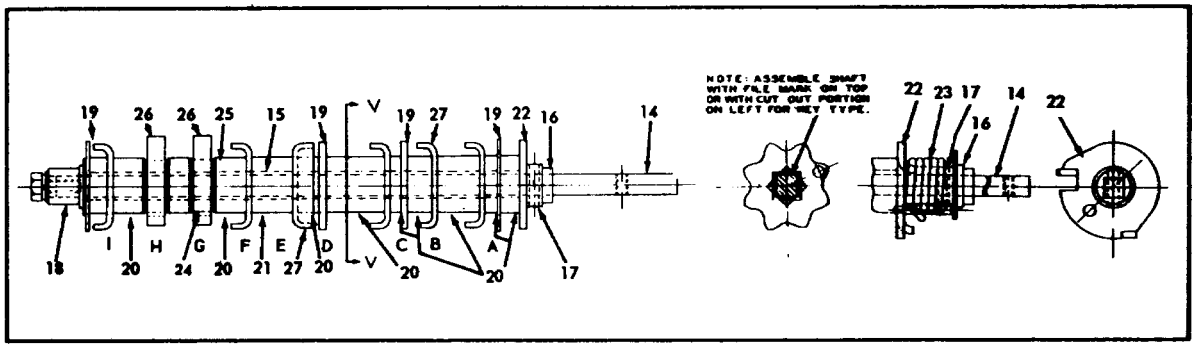
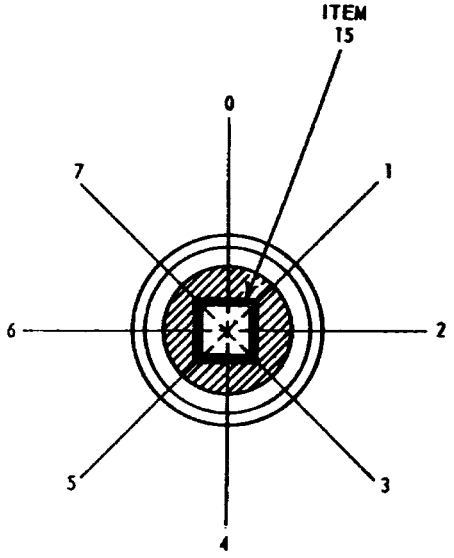


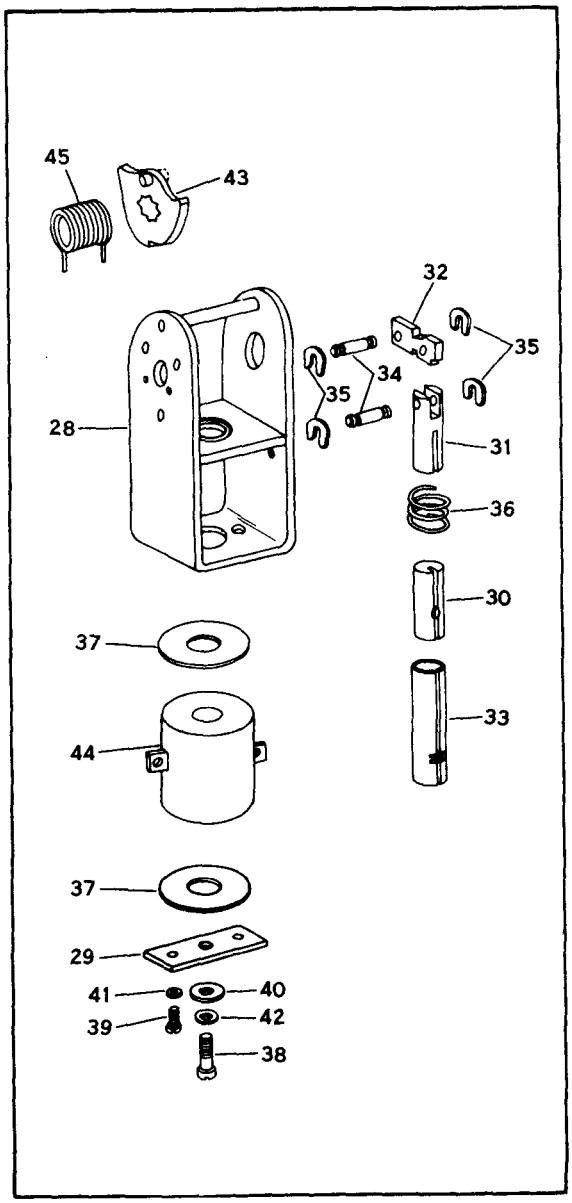
Fig. 8 – Shaft assembly.

Item No.	Description of Part
14	Shaft
15	Shaft insulation
16	Front bearing
16	Front bearing for spring return switch
17	Bearing pin
18	Rear bearing
19	Insulating washer (17/32-in. I.D. 1/8-in. thick)
19	Insulating washer (45/64-in. I.D. 1/8-in. thick)
19	Insulating washer (17/32-in. I.D. 1/16-in. thick)
19	Insulating washer (45/64-in. I.D. 1/16-in. thick)
20	Insulating bushing
21	Conductor bushing .442-in. long
21	Conductor bushing .723-in. long
22	Positioning wheel or stop plate
** 23	Return spring (for max. 45° turn)
** 23	Return spring (for max. 90° turn)
24	Bushing assembly
25	Spacer
26	Slip contact segment
27	Contact segment



SECTION V-V

Fig. 9 - Control switch positions (numbers 0 to 7).



Item No.	Description of Part
28	Coil support assembly for 2-contact type, left turn release
29	Core support plate
30	Magnet core
31	Plunger
32	Release bar
33	Core bushing
34	Bearing pin
35	"U" washer
36	Spring
37	Insulating washer
38	1/4-in. x 20 x 3/4-in. long filister head mach. screw, steel
39	10/32 x 3/8-in. long filister head mach. screw, steel
40	1/4-in. steel washer
41	No. 10 washer, steel
42	1/4-in. lockwasher
43	Stop plate assembly
44	Magnet coil
45	Torsion spring

Table 2. Trip Coils

Dc Volts	Dc Ohms	Minimum Trip Volts
125-250	59.2	50.
48-125	14.0	32.
24-48	2.3	12.
Ac Volts	**Dc Ohms**	
110	17.5	70.
220	105.0	105.

Fig. 10 - Magnetic release mechanism.

INSTALLATION • OPERATION • MAINTENANCE

INSTRUCTIONS

TYPE CO OVERCURRENT RELAY

CAUTION

Before putting relays into service, remove all blocking which may have been inserted for the purpose of securing the parts during shipment, make sure that all moving parts operate freely, inspect the contacts to see that they are clean and close properly, and operate the relay to check the settings and electrical connections.

APPLICATION

These induction overcurrent relays are used to disconnect circuits or apparatus when the current in them exceeds a given value. Where a station battery (48 volts or over) is available, the circuit closing type relays are normally used to trip the circuit breaker.

CONTENTS

This instruction leaflet applies to the following types of relays:

Type CO-2 Short Time Relay
CO-5 Long Time Relay
CO-6 Definite Minimum Time Relay
CO-7 Moderately Inverse Time Relay
CO-8 Inverse Time Relay
CO-9 Very Inverse Time Relay
CO- 11 Extremely Inverse Time Relay

CONSTRUCTION AND OPERATION

The type CO relays consist of an overcurrent unit (CO), an indicating contactor switch (ICS). and an indicating instantaneous trip unit (IIT) when required. The principal component parts of the relay and their location are shown in Figs. 1-5.

Electromagnet

The electromagnets for the types CO-5, CO-6, CO-7, CO-8 and CO-9 relays have a main tapped coil located on the center leg of an "E" type laminated structure that produces a flux which divides and returns through the outer legs. A shading coil causes the flux through the left leg to lag the main pole flux. The out-of-phase fluxes thus produced in the air gap cause a contact closing torque.

The electromagnets for the types CO-2 and CO-11 relays have a main coil consisting of a tapped primary winding and a secondary winding. Two identical coils on the outer legs of the lamination structure are connected to the main coil secondary in a manner so that the combination of all the fluxes produced by the electromagnet result in out-of-phase fluxes in the air gap. The out-of-phase air gap fluxes produced cause a contact closing torque.

Indicating Contactor Switch Unit (ICS)

The d-c indicating contactor switch is a small clapper type device. A magnetic armature, to which leaf-spring mounted contacts are attached, is attracted to the magnetic core upon energization of the switch. When the switch closes the moving contacts bridge two stationary contacts, completing the trip circuit. Also during this operation two fingers on the armature deflect a spring located on the front of the switch. Which allows the operation indicator target to drop.

The front spring. in addition to holding the target, provides restraint for the armature and thus controls the pickup value of the switch.

Indicating Instantaneous Trip Unit (lIT)

The instantaneous trip unit is a small a-c operated clapper type device. A magnetic armature, to which leaf-spring mounted contacts are ,attached, is attracted to the magnetic core upon energization of the switch. When the switch closes, the moving contacts bridge two stationary contacts completing the trip circuit. Also. during the operation. two fingers on the armature deflect a spring located on the front of the switch which allows the operation indicator target to drop.

A core screw accessible from the top of the switch provides the adjustable pickup range.

CHARACTERSTICS

The relays are generally available in the following current ranges:

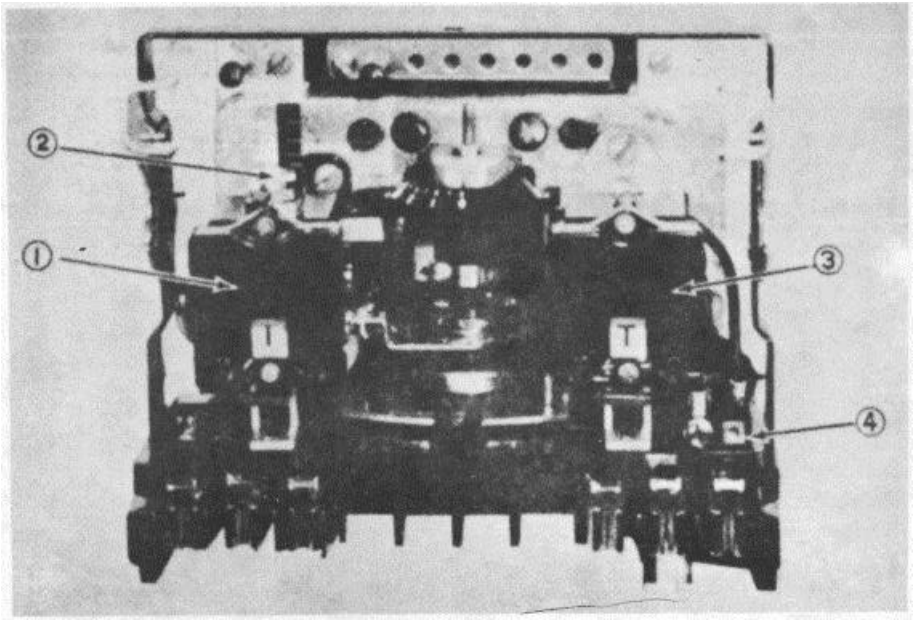


**Fig. 1. Type CO Relay Without Case. 1-Indicating Instantaneous trip (IIT). 2-IIT Adjusting Screw. 3-Indicating Contactor Switch (ICS). 4-Indicating Contactor Switch Tap Block.*

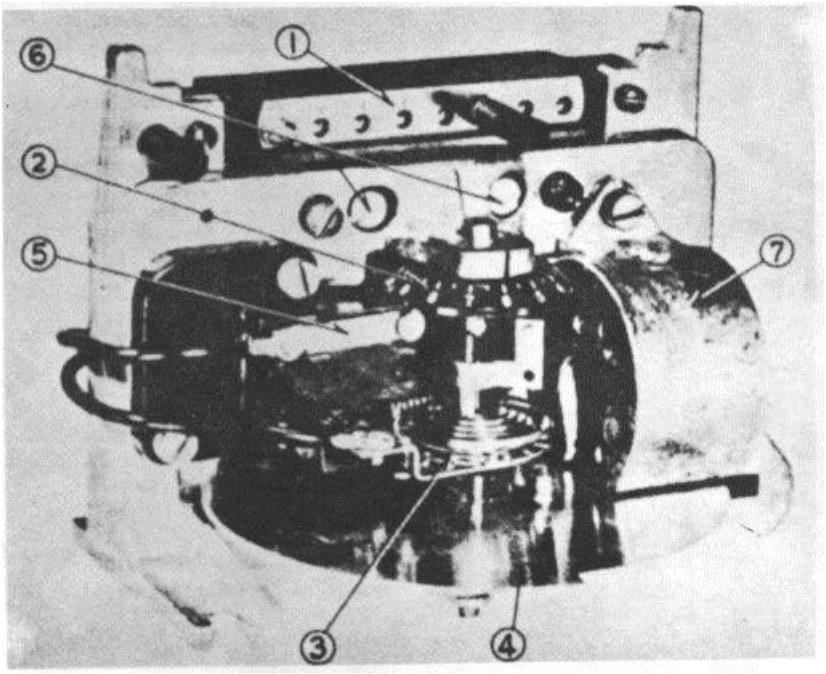


Fig. 2. Time Overcurrent Unit (Front View). 1-Top Block. 2-Time Dial. 3-Control Spring Assembly. 4-Disc. 5 -Stationary Contact Assembly. 6-Magnetic Plugs. 7-Permanent Magnet.

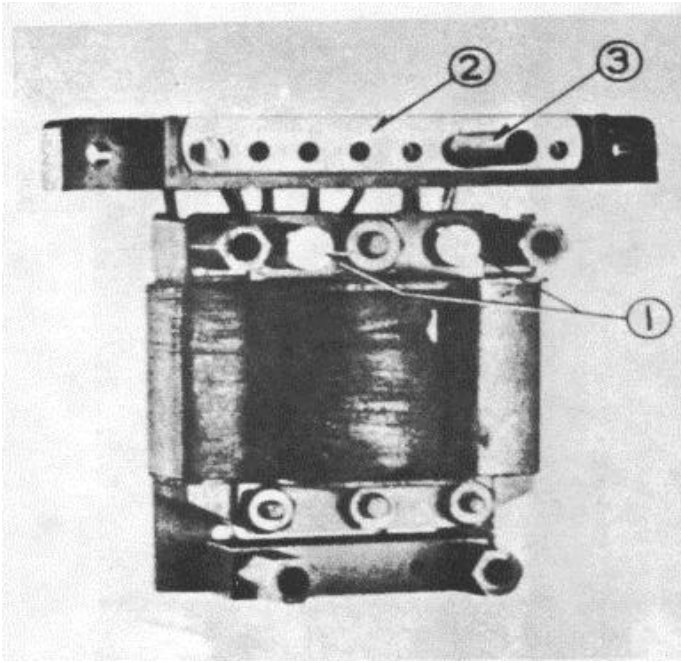


Fig. 3. "E" Type Electromagnet. 1- Magnetic Plugs. 2-Top Block. 3-Tap Screw.

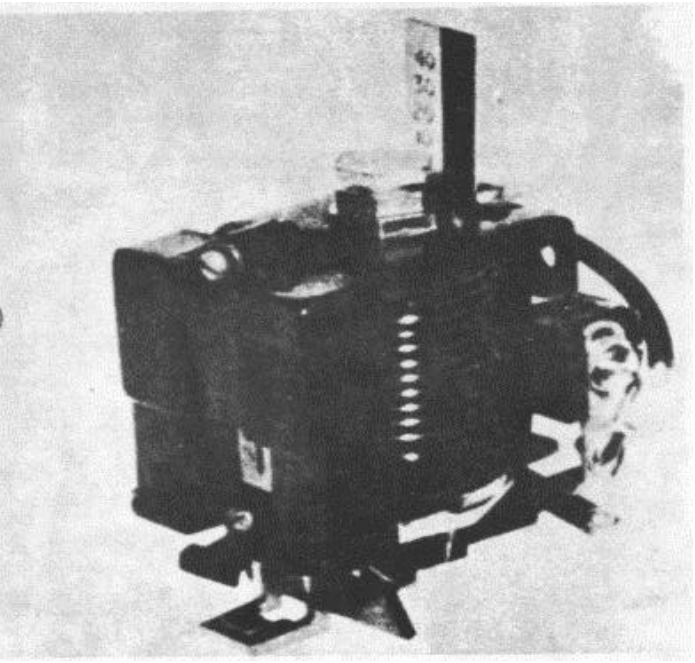


Fig. 4. Indicating Instantaneous Trip Unit (IIT).

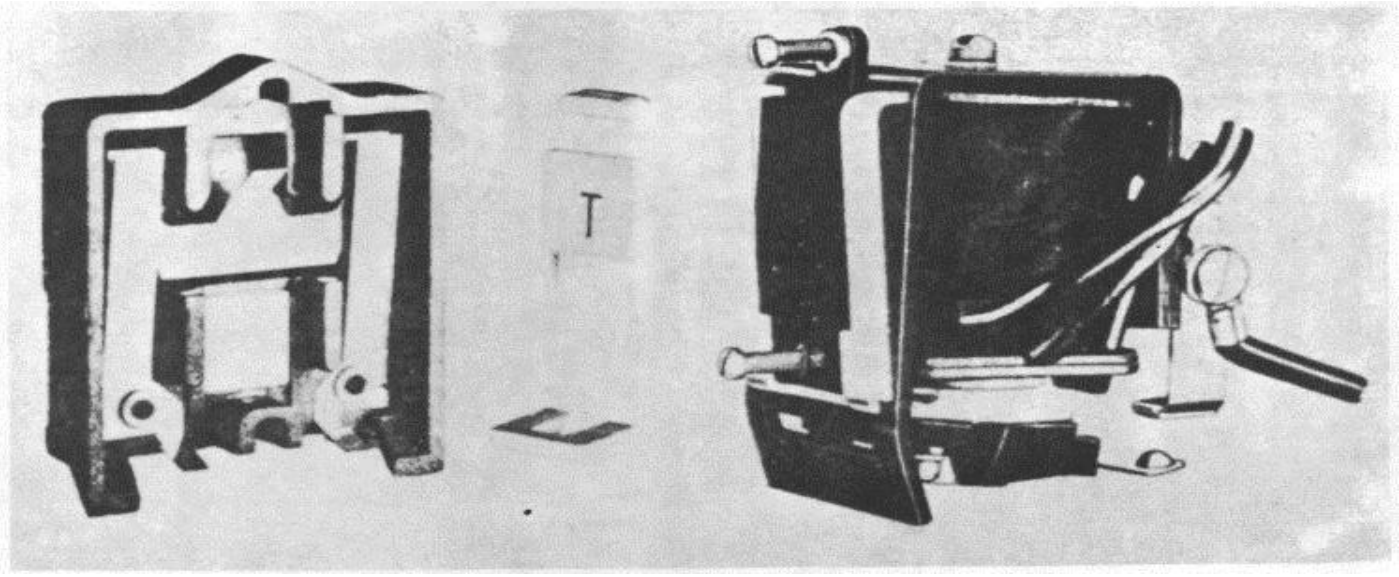


Fig. 5. Indicating Contactor Switch (ICS).

Range	Taps						
.5 - 2.5	0.5	0.6	0.8	1.0	1.5	2.0	2.5
2 - 62	2.5	3	3.5	4	5	6	
4 - 12	4	5	6	7	8	10	12

These relays may have either single or double circuit closing contacts for tripping either one or two circuit breakers.

The time vs. current characteristics are shown in Figs. 7 to 13. These characteristics give the contact closing time for the various time dial settings when the indicated multiples of tap value current are applied to the relay.

Trip Circuit

The main contacts will safely close 30 amperes at 250 volts d-c and the seal-in contacts of the indicating contactor switch will safely carry this current long enough to trip a circuit breaker.

The indicating instantaneous trip contacts will safely close 30 amperes at 250 volts d-c., and will carry this current long enough to trip a breaker.

The indicating contactor switch has two taps that provide a pickup setting of 0.2 or 2 amperes. To change taps requires connecting the lead located in front of the tap block to the desired setting by means of a screw connection.

Trip Circuit Constants

Contactor Switch -

0.2 ampere tap - 6.5 ohms d-c resistance

2.0 ampere tap - 0.15 ohms d-c resistance

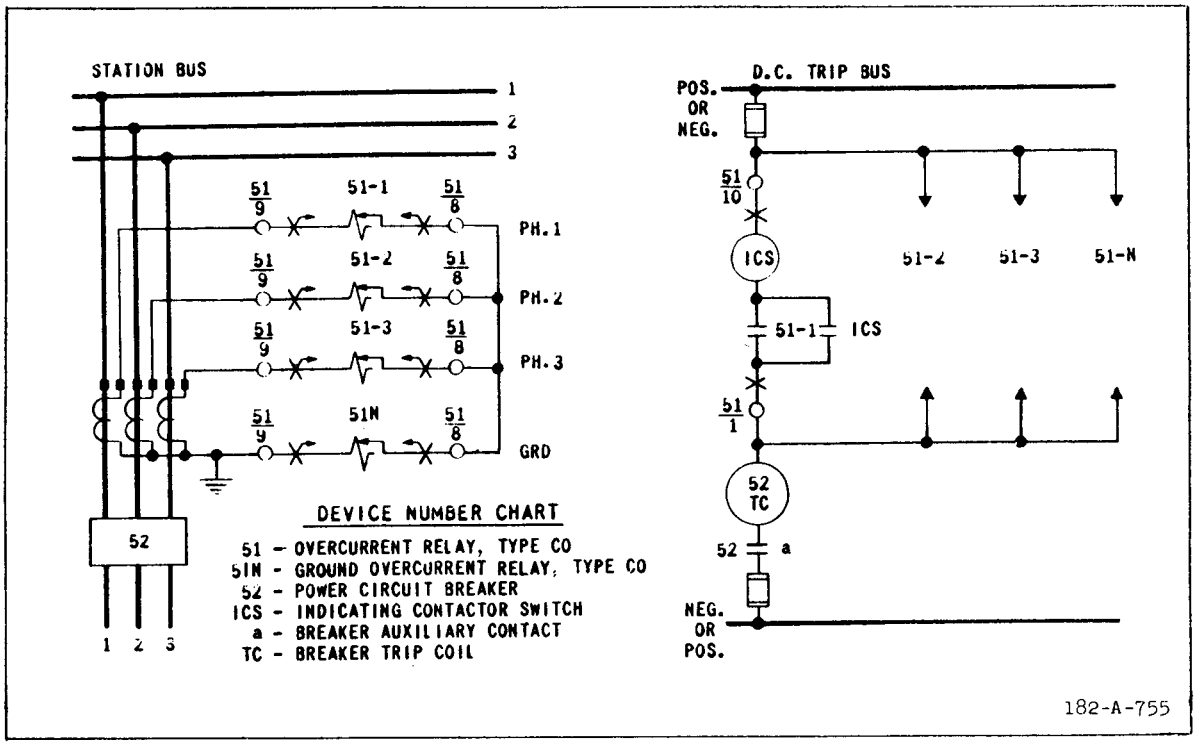


Fig. 6. External Schematic of the Circuit-Closing Type CO Relay for Phase and Ground Overcurrent Protection on a Three-Phase System.

ENERGY REQUIREMENTS

* Instantaneous Trip Unit (IIT)

RANGE IN AMPERES	BURDEN IN VOLT-AMPS. AT MINIMUM SETTING	BURDEN IN VOLT-AMPS. AT MAXIMUM SETTING
2 - 8	4.5	32
4 - 16	4.5	32
10 - 40	4.5	40
20 - 80	6.5	70
40 - 160	9.0	144

TYPE CO-2 RELAY

AMPERE RANGE	TAP	CONTINUOUS RATING (AMPERES)	ONE SECOND RATING* (AMPERES)	POWER FACTOR ANGLEØ	VOLT AMPERES** AT TAP VALUE CURRENT	AT 3 TIMES TAP VALUE CURRENT	AT 10 TIMES TAP VALUE CURRENT	AT 20 TMES TAP VALUE CURRENT
	0.5	0.91	28	58	4.8	39.6	256	790
	0.6	0.96	28	57	4.9	39.8	270	851
	0.8	1.18	28	53	5.0	42.7	308	1024
0.5/2.5	1.0	1.37	28	50	5.3	45.4	348	1220
	1.5	1.95	28	40	6.2	54.4	435	1740
	2.0	2.24	28	36	7.2	65.4	580	2280
	2.5	2.50	28	29	7.9	73.6	700	2850
	2.0	3.1	110	59	5.04	38.7	262	800
	2.5	4.0	110	55	5.13	39.8	280	920
	3.0	4.4	110	51	5.37	42.8	312	1008
2/6	3.5	4.8	110	47	5.53	42.8	329	1120
	4.0	5.2	110	45	5.72	46.0	360	1216
	5.0	5.6	110	41	5.90	50.3	420	1500
	6.0	6.0	110	37	6.54	54.9	474	1800
	4.0	7.3	230	65	4.92	39.1	268	848
	5.0	8.0	230	50	5.20	42.0	305	1020
	6.0	8.8	230	47	5.34	44.1	330	1128
4/12	7.0	9.6	230	46	5.53	45.8	364	1260
	8.0	10.4	230	43	5.86	49.9	400	1408
	10.0	11.2	230	37	6.6	55.5	470	1720
	12.0	12.0	230	34	7.00	62.3	528	2064

* *Thermal capacities for short times other* than *one second may be calculated on the basis of time being inversely proportional to the square of the current.*

Ø *Degrees current lags voltage oat tap value current.*

** *Yokes takes with Rectox type voltmeter.*

ENERGY REQUIREMENTS

CO-5 LONG TIME AND CO-6 DEFINITE MINIMUM TIME RELAYS

AMPERE RANGE	TAP	CONTINUOUS RATING (AMPERES)	ONE SECOND RATING* (AMPERES)	POWER FACTOR ANGLEØ	VOLT AMPERES** AT TAP VALUE CURRENT	AT 3 TIMES TAP VALUE CURRENT	AT 10 TIMES TAP VALUE CURRENT	AT 20 TMES TAP VALUE CURRENT
	(0.5	2.7	88	69	3.92	20.6	103	270
	(0.6	3.1	88	68	3.96	20.7	106	288
	(0.8	3.7	88	67	3.96	21	114	325
0.5/2.5	(1.0	4.1	88	66	4.07	21.4	122	360
	(1.5	5.7	88	62	4.19	23.2	147	462
	(2.0	6.8	88	60	4.30	24.9	168	548
	(2.5	7.7	88	58	4.37	26.2	180	630
	(2	8	230	67	3.88	21	110	308
	(2.5	8.8	230	66	3.90	21.6	118	342
	(3	9.7	230	64	3.93	22.1	126	381
2/6	(3.5	10.4	230	63	4.09	23.1	136	417
	(4	11.2	230	62	4.12	23.5	144	448
	(5	12.5	230	59	4.20	24.8	162	540
	(6	13.7	230	57	4.38	26.5	183	824
	(4	16	460	65	4.00	22.4	126	376
	(5	18.8	460	63	4.15	23.7	143	450
	(6	19.3	460	61	4.32	25.3	162	531
4/12	(7	20.8	460	59	4.35	26.4	183	611
	(8	22.5	460	56	4.40	27.8	204	699
	(10	25	460	53	4.60	30.1	247	880
	(12	28	460	47	4.92	35.6	288	1056

CO-7 MODERATELY INVERSE TIME RELAY

AMPERE RANGE	TAP	CONTINUOUS RATING (AMPERES)	ONE SECOND RATING* (AMPERES)	POWER FACTOR ANGLEØ	VOLT AMPERES** AT TAP VALUE CURRENT	AT 3 TIMES TAP VALUE CURRENT	AT 10 TIMES TAP VALUE CURRENT	AT 20 TMES TAP VALUE CURRENT
	(0.5	2.7	88	68	3.88	20.7	103	278
	(0.6	3.1	88	67	3.93	20.9	107	288
	(0.8	3.7	88	66	3.93	21.1	114	320
0.5/2.5	(1.0	4.1	88	64	4.00	21.6	122	356
	(1.5	5.7	88	61	4.08	22.9	148	459
	(2.0	6.8	88	58	4.24	24.8	174	552
	(2.5	7.7	88	56	4.38	25.9	185	640
	(2	8	230	66	4.06	21.3	111	300
	(2.5	8.8	230	63	4.07	21.8	120	342
	(3	9.7	230	63	4.14	22.5	129	366
2/8	(3.5	10.4	230	82	4.34	23.4	141	413
	(4	11.2	230	61	4.34	23.8	149	448
	(5	12.5	230	59	4.40	25.2	163	530
	(6	13.7	230	58	4.62	27	183	624
	(4	16	460	64	4.24	22.8	129	392
	(5	18.8	460	61	4.30	24.2	149	460
4/12	(6	19.3	460	60	4.62	25.9	168	540
	(7	20.8	460	58	4.69	27.3	187	626
	(8	22.5	460	55	4.80	29.8	211	688
	(10	25	460	51	5.20	33	260	860
	(12	28	460	46	5.40	37.5	308	1032

* *Thermal capacities for short times other than one second may be calculated* on the *basis of time being inversely proportional to the square of the current*

Ø *Degrees current lags voltage at tap value current.*

** *Voltages taken with Rectox type voltmeter.*

ENERGY REQUIREMENTS

CO-8 INVERSE TIME AND CO-9 VERY INVERSE TIME RELAYS

AMPERE RANGE	TAP	CONTINUOUS RATING (AMPERES)	ONE SECOND RATING* (AMPERES)	POWER FACTOR ANGLEØ	VOLT AMPERES** AT TAP VALUE CURRENT	AT 3 TIMES TAP VALUE CURRENT	AT 10 TIMES TAP VALUE CURRENT	AT 20 TIMES TAP VALUE CURRENT
	(0.5	2.7	88	72	2.38	21	132	350
	(0.6	2.1	88	71	2.38	21	134	365
	(0.8	3.7	88	69	2.40	21.1	142	400
0.5/2.5	(1.0	4.1	88	67	2.42	21.2	150	440
	(1.5	5.7	88	62	2.51	22	170	530
	(2.0	6.8	88	57	2.65	23.5	200	675
	(2.5	7.7	88	53	2.74	24.8	228	800
	(2	8	230	70	2.38	21	136	360
	(2.5	8.8	230	66	2.40	21.1	142	395
	(3	9.7	230	64	2.42	21.5	149	430
2/6	(3.5	10.4	230	62	2.48	22	157	470
	(4	11.2	230	60	2.53	22.7	164	500
	(5	12.5	230	58	2.64	24	180	580
	(6	13.7	230	56	2.75	25.2	198	660
	(4	16	460	68	2.38	21.3	146	420
	(5	18.8	460	63	2.46	21.8	158	480
	(6	19.3	460	60	2.54	22.6	172	550
4/12	(7	20.8	460	57	2.62	23.6	190	620
	(8	22.5	460	54	2.73	24.8	207	700
	(10	25	460	48	3.00	27.8	248	850
	(12	28	460	45	3.46	31.4	292	1020

TYPE CO-11 RELAY

AMPERE RANGE	TAP	CONTINUOUS RATING (AMPERES)	ONE SECOND RATING* (AMPERES)	POWER FACTOR ANGLEØ	VOLT AMPERES** AT TAP VALUE CURRENT	AT 3 TIMES TAP VALUE CURRENT	AT 10 TIMES TAP VALUE CURRENT	AT 20 TIMES TAP VALUE CURRENT
	0.5	1.7	56	36	0.72	6.54	71.8	250
	0.6	1.9	56	34	0.75	6.80	75.0	267
	0.8	2.2	56	30	0.81	7.46	84.0	298
0.5/2.5	1.0	2.5	56	27	0.89	8.30	93.1	330
	1.5	3.0	56	22	1.13	10.04	115.5	411
	2.0	3.5	56	17	1.30	11.95	136.3	502
	2.5	3.8	56	16	1.48	13.95	160.0	610
	2.0	7.0	230	32	0.73	6.30	74.0	264
	2.5	7.8	230	30	0.78	7.00	78.5	285
	3.0	8.3	230	27	0.83	7.74	84.0	309
2/6	3.5	9.0	230	24	0.88	8.20	89.0	340
	4.0	10.0	230	23	0.96	9.12	102.0	372
	5.0	11.0	230	20	1.07	9.80	109.0	430
	6.0	12.0	230	20	1.23	11.34	129.0	504
	4.0	14	460	29	0.79	7.08	78.4	296
	5.0	16	460	25	0.89	8.00	90.0	340
	6.0	17	460	22	1.02	9.18	101.4	378
4/12	7.0	18	460	20	1.10	10.00	110.0	454
	8.0	20	460	18	1.23	11.1	124.8	480
	10.0	22	460	17	1.32	14.9	131.6	600
	12.0	26	460	16	1.8	16.3	180.0	720

* *Thermal* capacities *for short times other than one second may be calculated on the basis of* time *being inversely proportional to the square of the current.*

Ø Degrees current lags voltage at tap value current.

** *Voltages* taken *with Rectox type voltmeter.*

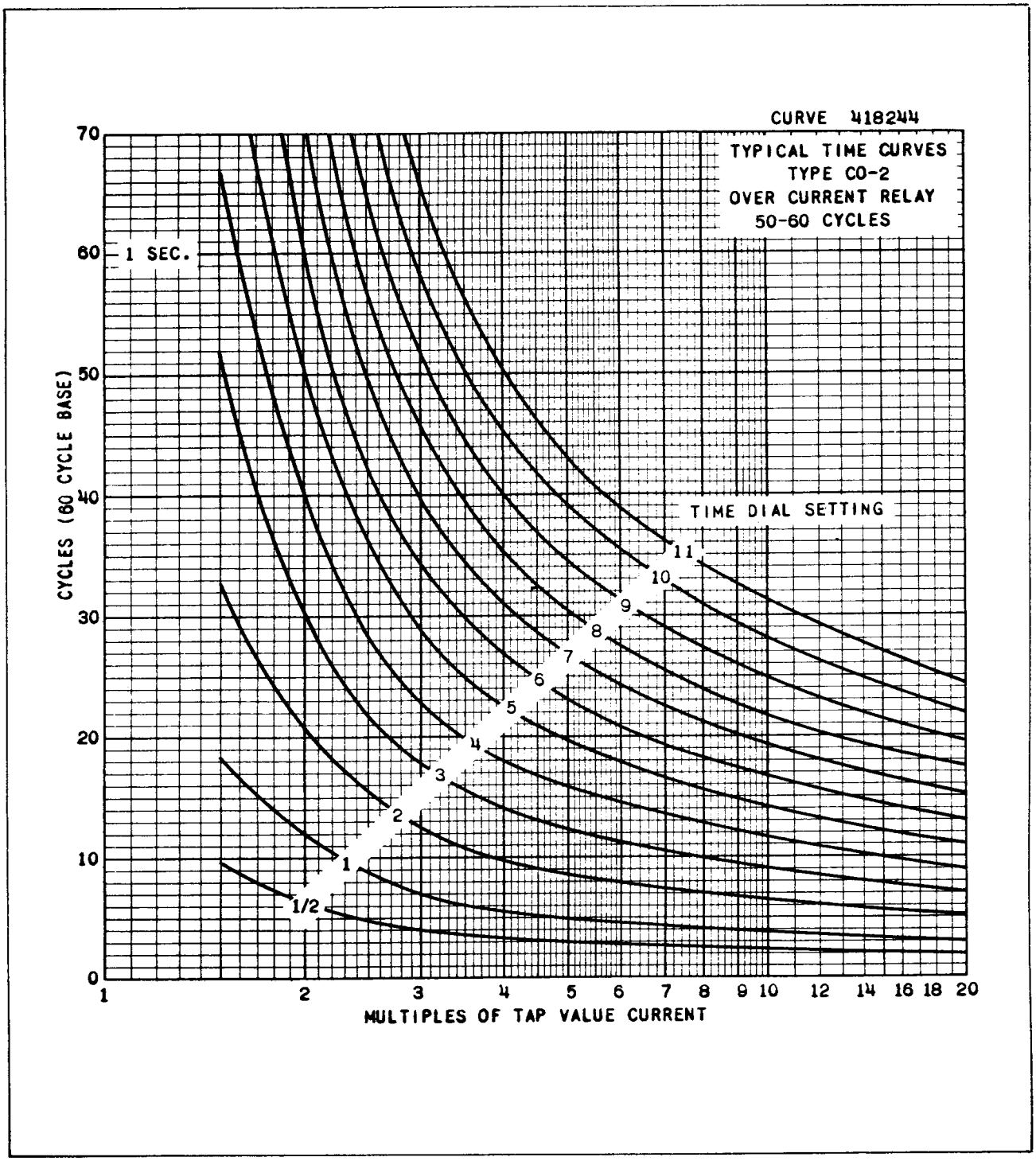


Fig. 7. Typical Time Curves of the Type CO-2 Relay.

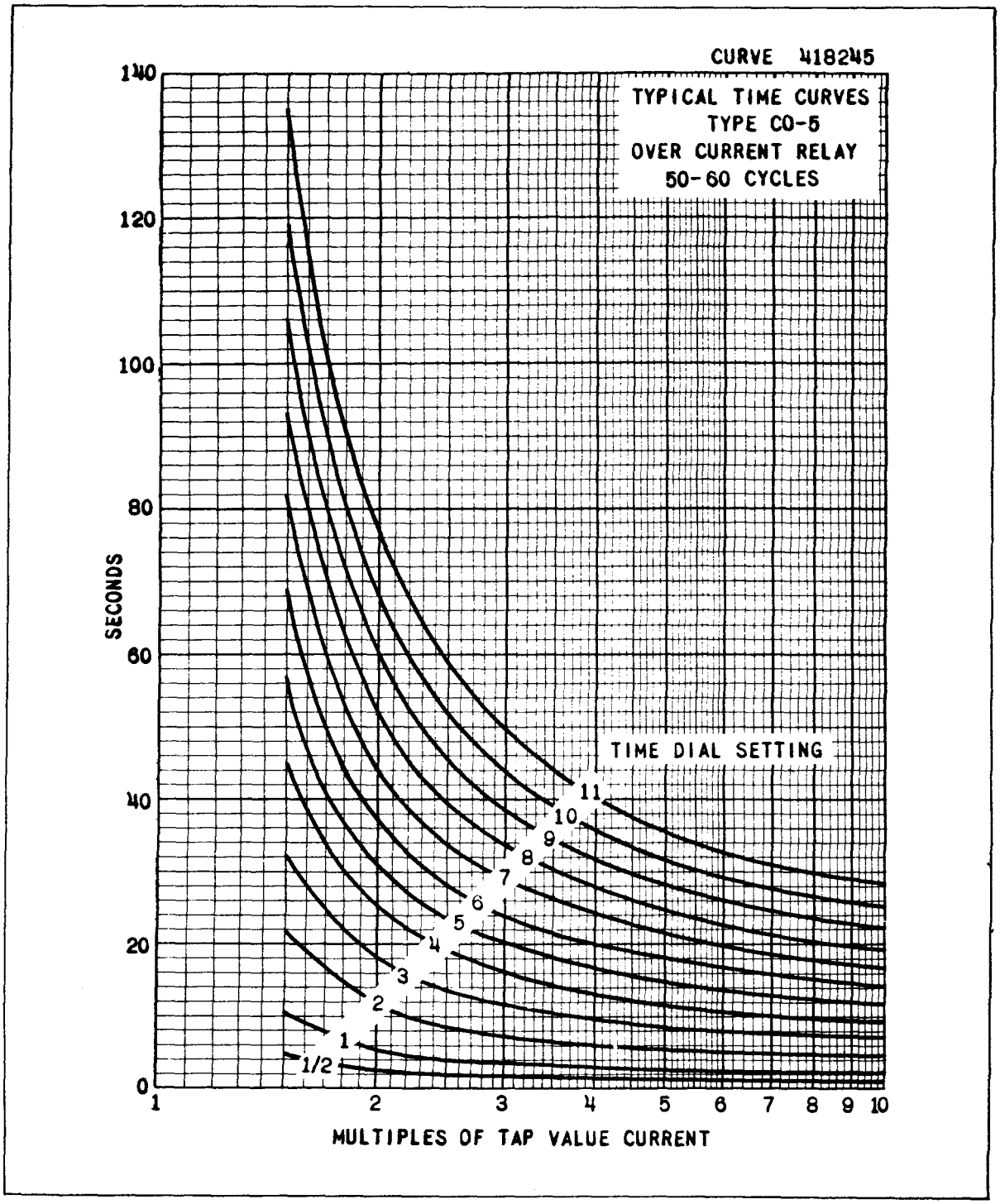


Fig. 8. Typical Time Curves of the Type CO-5 Relay.

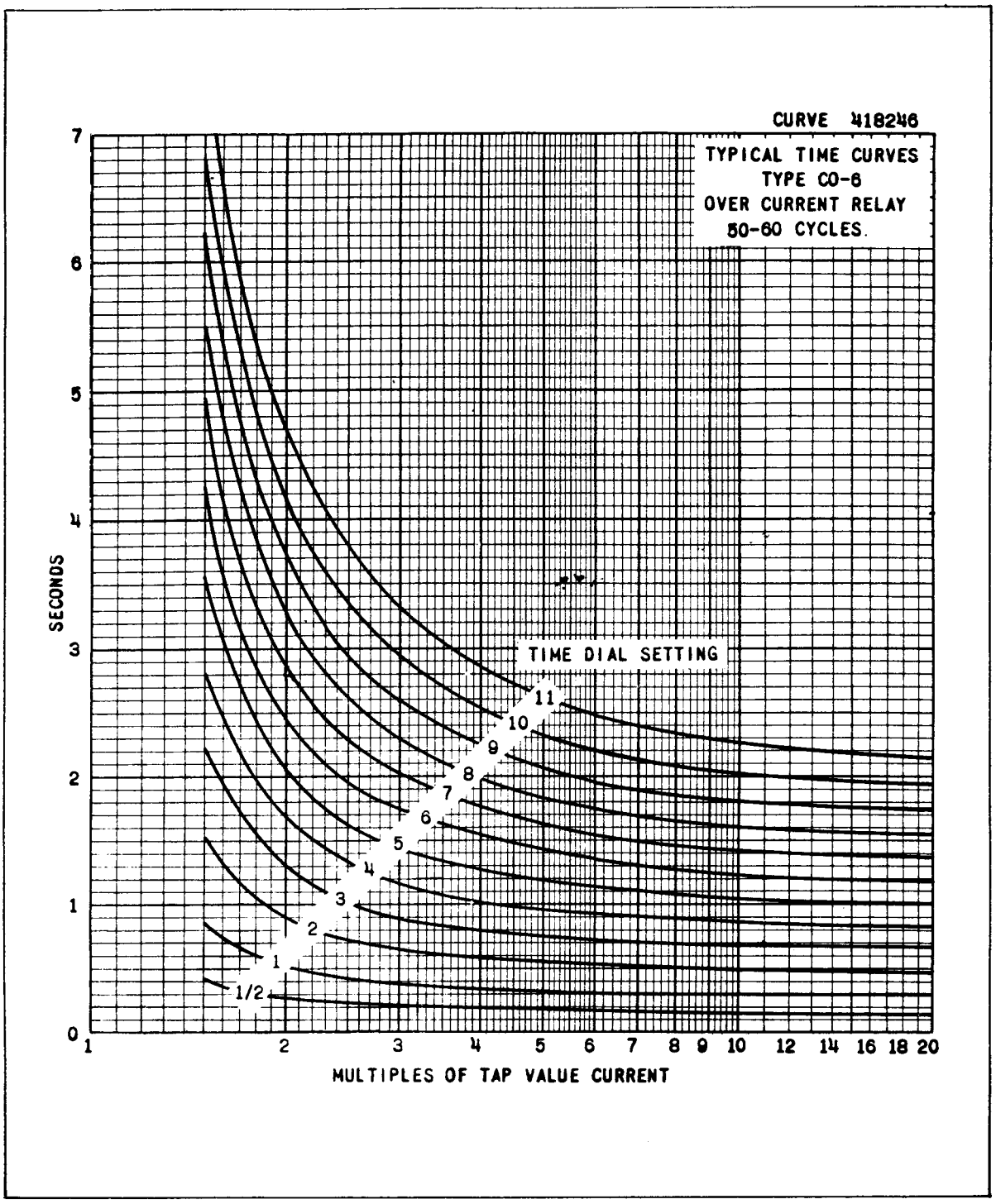


Fig. 9. Typical Time Curves of the Type CO-6 *Relay.*

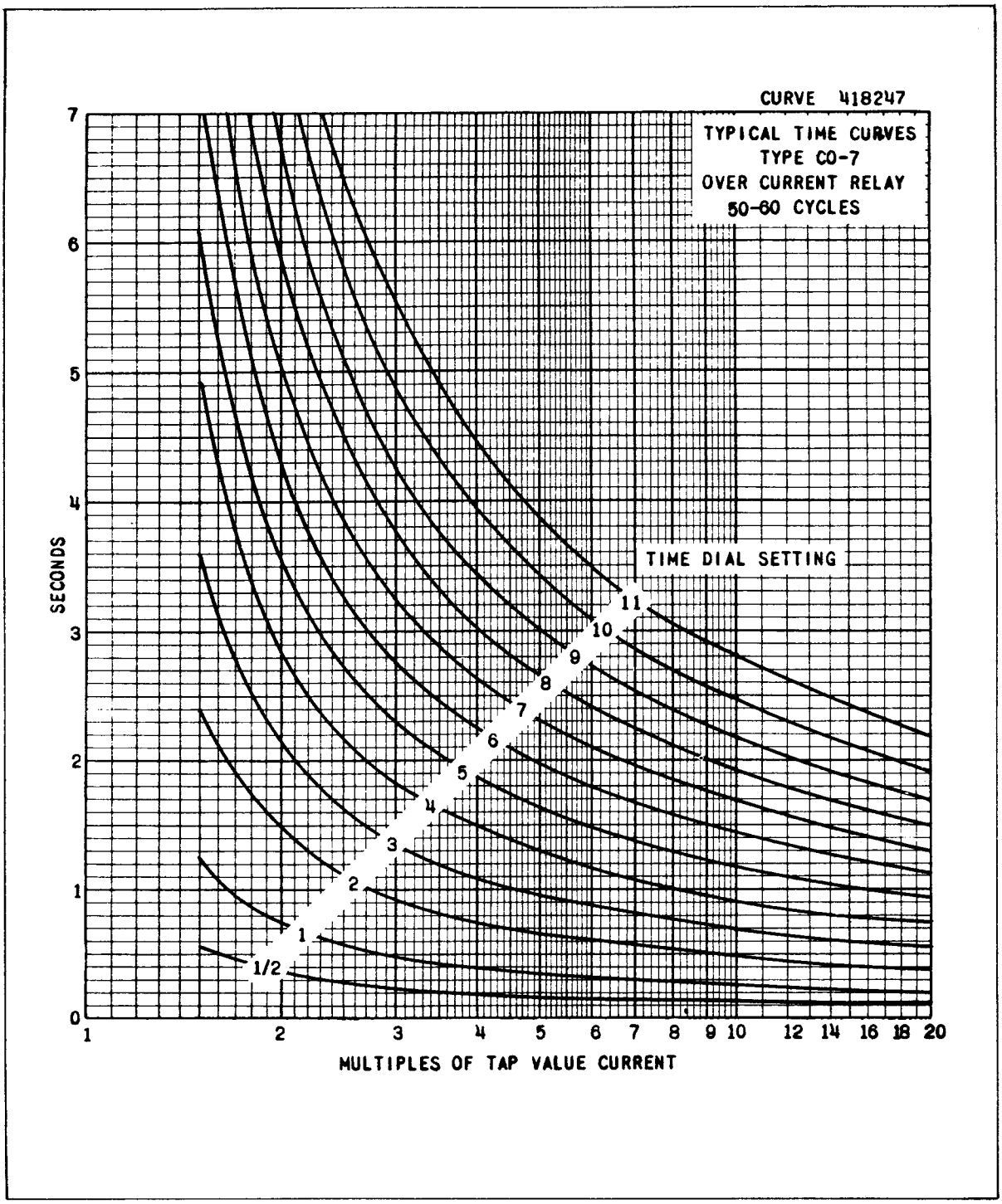


Fig. 10. Typical Time Curves of the Type CO-7 Relay.

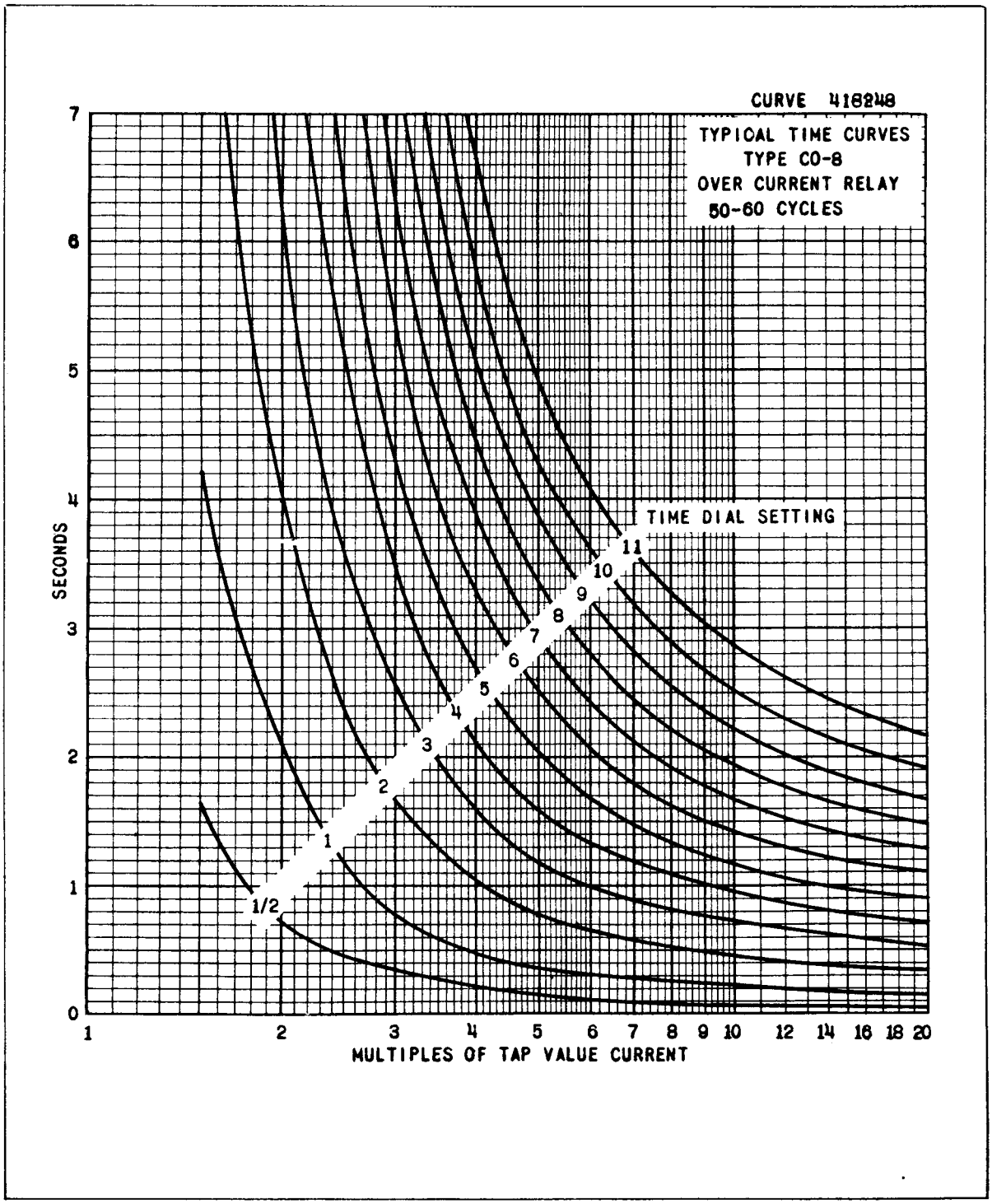


Fig. 11. Typical Time Curves of the Type CO-8 Relay.

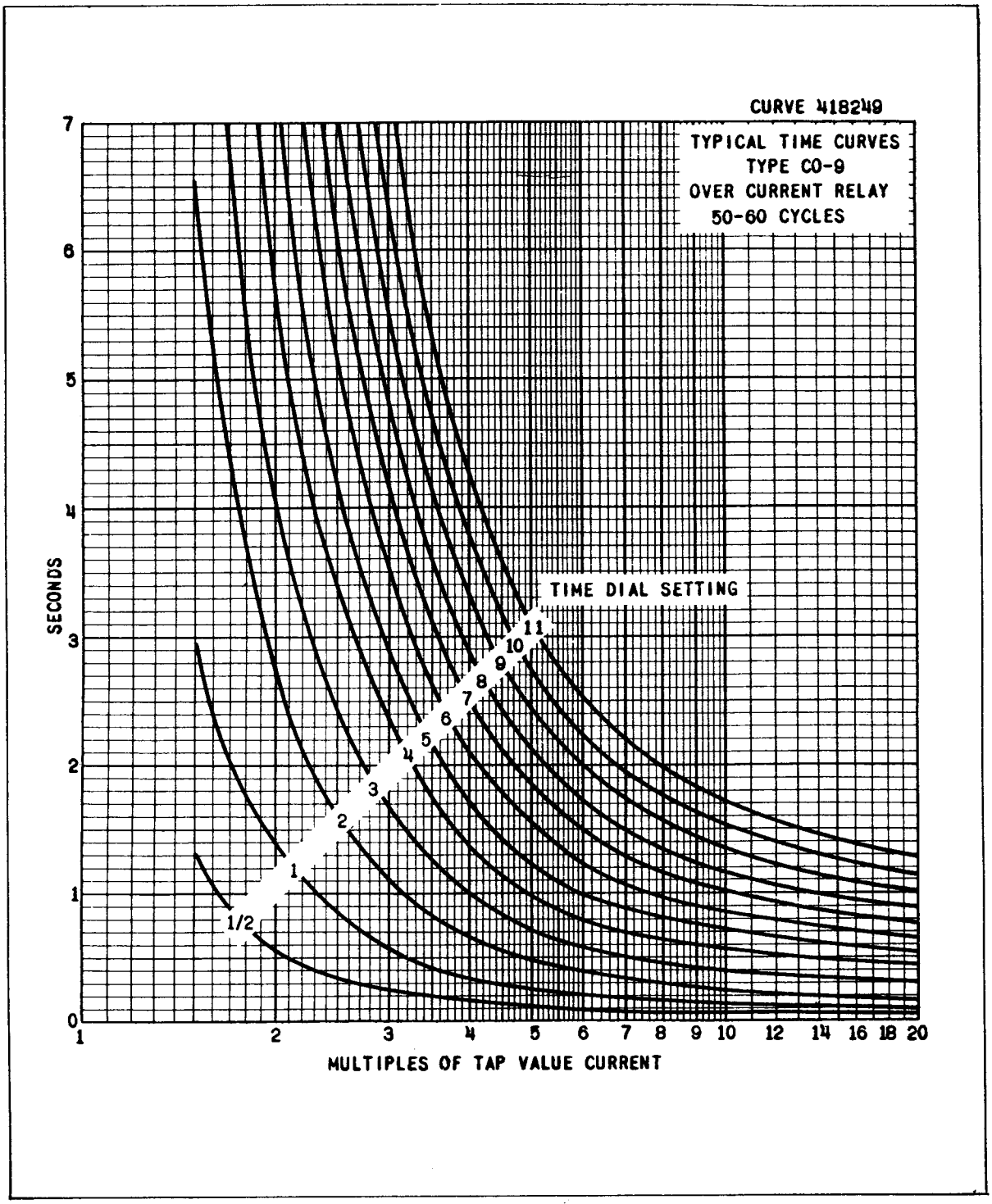


Fig. 12. Typical Time Curves of the Type CO-9 Relay.

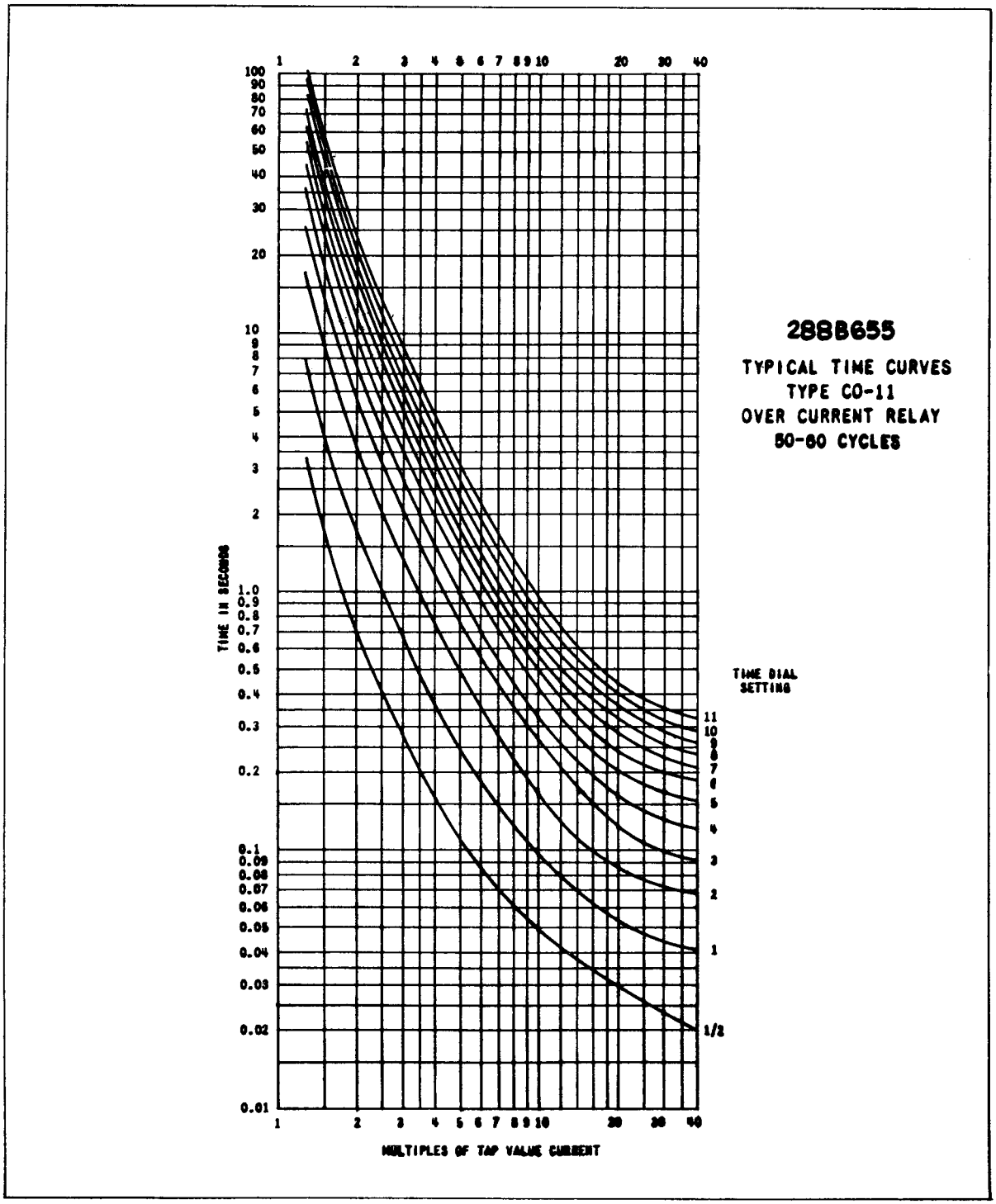


Fig. 13. Typical Time Curves of the Type CO-11 Relay.

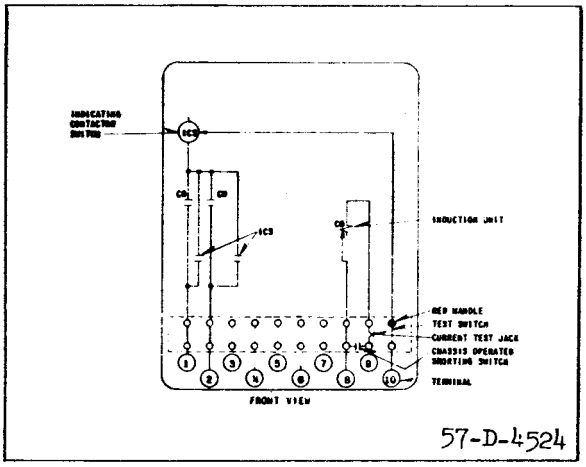


Fig. 14. Internal Schematic of the Double Trip Circuit Closing Relay. For the Single Trip Relay the Circuits Associated with Terminal 2 are Omitted.

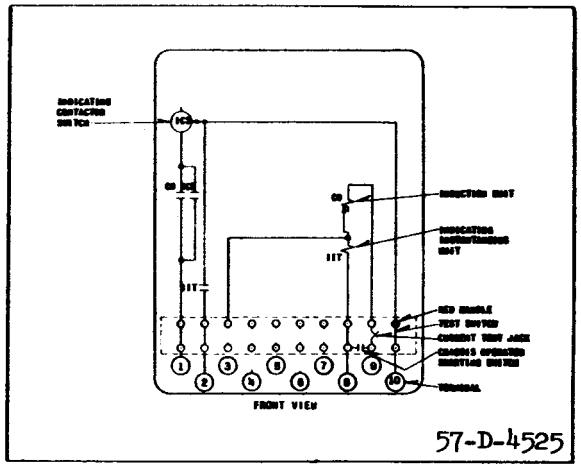


Fig. 15. Internal Schematic of the Single Trip Circuit-Closing Relay with Indicating Instantaneous Trip Unit.

SETTINGS

CO Unit

The overcurrent unit settings can be defined either by tap setting and time dial position or by tap setting and a specific time of operation at some cur-rent multiple of the tap setting (e.g. 4 tap setting, 2 time dial position or 4 tap setting, 0.6 seconds at 6 times tap value current).

To provide selective circuit breaker operation, a minimum coordinating time of 0.3 seconds plus circuit breaker time is recommended between the relay being set and the relays with which coordination is to be effected.

The connector screw on the terminal plate above the time dial makes connections to various turns on the operating coil. By placing this screw in the various terminal plate holes, the relay will respond to multiples of tap value currents in accordance with the various typical time-current curves.

Caution

Since the tap block connector screw carries operating current, be sure that the screw is turned tight. In order to avoid opening the current transformer circuits when changing taps under load, connect the spare connector screw in the desired tap position before removing the other tap screw from the original tap position.

Instantaneous Reclosing

The factory adjustment of the CO unit contacts provides a contact follow. Where circuit breaker re-closing will be initiated immediately after a trip by the CO contact, the time of the opening of the contacts should be a minimum. This condition is obtained by loosening the stationary contact mounting screw, removing the contact plate and then replacing the plate with the bent end resting against the contact spring.

For double trip relays, the upper stationary contact is adjusted such that the contact spring rests solidly against the back stop. The lower stationary contact is then adjusted such that both stationary contacts make contact simultaneously with their respective moving contact.

Indicating Contactor Switch (ICS)

The only setting required on the ICS unit, is the selection of the 0.2 or 2.0 ampere tap setting. This selection is made by connecting the lead located in front of the tap block to the desired. setting by means of the connecting screw.

Indicating Instantaneous Trip (IIT)

The core screw must be adjusted to the value of pick-up current desired.

The nameplate data will furnish the actual current range that may be obtained from the UT. Unit.

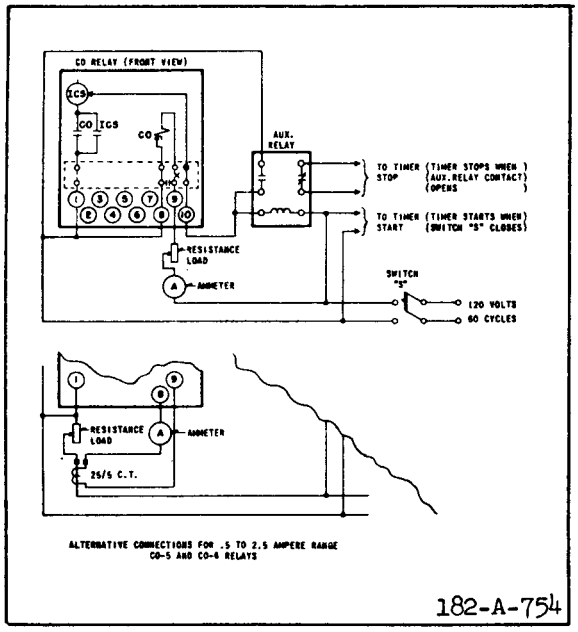


Fig. 16. Diagram of Test Connections for the *Circuit-Closing Type* CO *Relay.*

INSTALLATION

The relays should be mounted on switchboard panels or their equivalent in a location free from dirt, moisture, excessive vibration and heat. Mount the relay vertically by means of the mounting stud for projection mounting or by means of the four mounting holes on the flange for the semi-flush mounting. Either the stud or the mounting screws may be utilized for grounding the relay. The electrical connections may be made directly to the terminals by means of screws for steel panel mounting or to be terminal stud furnished with the relay for thick panel mounting. The terminal stud may be easily removed or inserted by locking two nuts on the stud and then turning the proper nut with a wrench.

ADJUSTMENTS AND MAINTENANCE

The proper adjustments to insure correct operation of this relay have been made at the factory. Upon receipt of the relay no customer adjustments, other than those covered under "SETTINGS" should be required.

For relays which include an indicating instantaneous trip unit (IIT), the junction of the induction and indicating instantaneous trip coils is brought out to switch jaw #3. With this arrangement the overcurrent units can be tested separately.

Acceptance Check

The following check is recommended to insure that the relay is in proper working order:

1. Contact

a) By turning the time dial, move the moving contacts until they deflect the stationary contact to a position where the stationary contact is resting against its backstop. The index mark located on the movement frame should coincide with the "O" mark on the time dial. For double trip relays, the follow on the stationary contacts should be approximately 1/64".'

b) For relays identified with a "T", located at lower left of stationary contact block, the index mark on the movement frame will coincide with the "O" mark on the time dial when the stationary contact has moved through approximately one-half of its normal deflection. Therefore, with the stationary contact resting against the backstop, the index mark is offset to the right of the "O" mark by approximately .020". The placement of the various time dial positions in line with the index mark will give operating times as shown on the respective time-current curves. For double trip relays, the follow on the stationary contacts should be approximately 1/32".

2. Minimum Trip Current - Set the time dial to position 6 using the lowest tap setting, alternately apply tap value current plus 3% and tap value' current minus 3%. The moving contact should leave the back-stop at tap value current plus 3% and should return to the backstop at tap value current minus 3%.

3. Time Curve - For type CO-11 relay only, the 1.30 times tap value operating time from the number 6 time dial position is 54.9 ± 5% seconds and should be checked first. It is important that the 1.30 times tap value current be maintained accurately. The maintaining of this current accurately is necessary because of the steepness of the slope of the time-current characteristic (Figure 13). A 1% variation in the 1.30 times tap value current (including measuring instrument deviation) will change the nominal operating time by approximately 4%.

Table I shows the time curve calibration points for the various types of relays. With the time

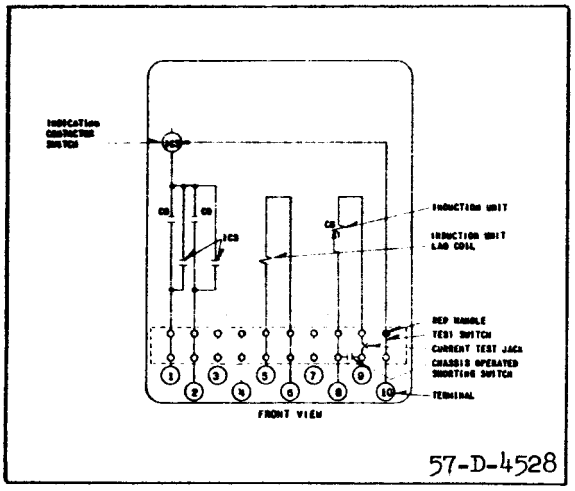


Fig. 17. *Internal* Schematic of *the Double Trip Circuit Closing* Relay *with Torque Control Terminals. For the Single Trip Relay, the Circuits Associated with Terminal 2 are Omitted.*

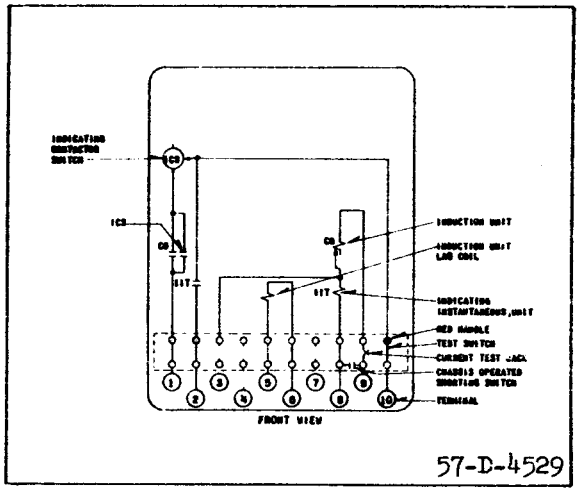


Fig. 18. Internal Schematic of the Single Trip Circuit Closing Relay with Torque Control Terminals and Indicating Instantaneous Trip Unit.

dial set to the indicated position and the relay set on the lowest-tap setting, apply the currents specified by Table I, (e.g. for the CO-2, 3 and 20 times tap value current) and measure the operating time of the relay. The operating times should equal those of Table I plus or minus 5%.

4. Indicating Instantaneous Trip Unit (IIT) - The core screw which is adjustable from the top of the trip unit determines the pickup value. The trip unit has a nominal ratio of adjustment of 1 to 4 and an accuracy within the limits of 10%.

The making of the contacts and target indication should occur at approximately the same instant. Position the stationary contact for a minimum of 1/32" wipe. The bridging moving contact should touch both stationary contacts simultaneously.

Apply sufficient current to operate the IIT. The operation indicator target should drop freely.

5. Indicating Contactor Switch (ICS) - Close the main relay contacts and pass sufficient d-c current through the trip circuit to close the contacts of the ICS. This value of current should be not greater than the particular ICS tap setting being used. The operation indicator target should drop freely.

The contact gap should be approximately .047" between the bridging moving contact and the adjustable stationary contacts. The bridging moving contact should touch both stationary contacts simultaneously,

Routine Maintenance

All relays should be inspected and checked periodically to assure proper operation. Generally a visual inspection should call attention to any noticeable changes. A minimum suggested check on the relay system is to close the contacts manually to assure that the breaker trips and the target drops. Then release the contacts and observe that the reset is smooth and positive.

If an additional time check is desired, pass secondary current through the relay and check the time of operation. It is preferable to make this at several times pick-up current at an expected operating point for the particular application. For the .5 to 2.5 ampere range CO-5 and CO-6 induction unit use the alternative test circuit in Fig. 16 as these relays are affected by a distorted wave form. With this connection the 25/5 ampere current transformers should be worked well below the knee of the saturation.

All contacts should be periodically cleaned. A contact burnisher #182A836H01 is recommended for this purpose. The use of abrasive material for cleaning contacts is not recommended, because of the danger of embedding small particles in the face of the soft silver and thus impairing the contact.

CALIBRATION

Use the following procedure for calibrating the relay if the relay has been taken apart for repairs or

the adjustments disturbed. This procedure should not be used until it is apparent that the relay is not in proper working order. (See 'Acceptance Check')

CO Unit

1. Contact

a) By turning the time dial, move the moving contacts until they deflect the stationary contact to a position where the stationary contact is resting against its backstop. The index mark located on the movement frame should coincide with the "O" mark on the time dial. For double trip relays, the follow on the stationary contacts should be approximately 1/64".

b) For relays identified with a "T", located at lower left of stationary contact block, the index mark on the movement frame will coincide with the "0" mark on the time dial when the stationary contact has moved through approximately one-half of its normal deflection. Therefore, with the stationary contact resting against the backstop, the index mark Is offset to the right of the "O" mark by approximately .020". The placement of the various time dial positions in line with the index mark will give operating times as shown on the respective time-current curves. For double trip relays, the follow on the stationary contacts should be approximately 1/32".

2) Minimum Trip Current - The adjustment of the spring tension in setting the minimum trip current value of the relay is most conveniently made with the damping magnet removed.

With the time dial set on "O", wind up the spiral spring by means of the spring adjuster until approximately 6-3/4 convolutions show.

Set the relay on the minimum tap setting, the time dial to position 6.

Adjust the control spring tension so that the moving contact will leave the backstop at tap value current +1.0% and will return to the backstop at tap value current -1.0%.

3. Time Curve Calibration - Install the permanent magnet.

Apply the indicated current per Table I for permanent magnet adjustment (e.g. CO-8, 2 times tap value) and measure the operating time. Adjust the permanent magnet keeper until the operating time corresponds to the value of Table I.

For type CO-11 relay only, the 1.30 times tap value operating time from the number 6 time dial position is 54.9 + 5% seconds. It Is important that the 1.30 times tap value current be maintained accurately. The maintaining of this current accurately is necessary because of the steepness of the slope of the time-current characteristic (Figure 13). A 1% variation in the 1.30 times tap value current(including measuring instrument deviation) will change the nominal operating time by approximately 4% If the operating time at 1.3 times tap value is not within these limits, a minor adjustment of the control spring will give the correct operating time without any undue effect on the minimum pick-up of the relay. This check is to be made after the 2 times tap value adjustment has has been completed.

Apply the indicated current per Table I for the electromagnet plug adjustment (e.g. CO-8, 20 times tap value) and measure the operating time. Adjust the proper plug until the operating time corresponds to the value in Table I. (Withdrawing the left hand plug, front view, increases the operating time and withdrawing the right hand plug, front view, decreases the time.) In adjusting the plugs, one plug should be screwed in completely and the other plug run in or out until the proper operating time has been obtained.

Recheck the permanent magnet adjustment. If the operating time for this calibration point has changed, readjust the permanent magnet and then recheck the electromagnet plug adjustment.

4. Indicating Contactor Switch (ICS) - Close the main relay contacts and pass sufficient d-c current through the trip circuit to close the contacts of the ICS. This value of current should be not greater than the particular ICS tap setting being used. The operation indicator target should drop freely.

5. Indicating Instantaneous Trip Unit (IIT) The core screw must be adjusted to the value of pick-up current desired.

The nameplate data will furnish the actual current range that may be obtained from the IIT unit.

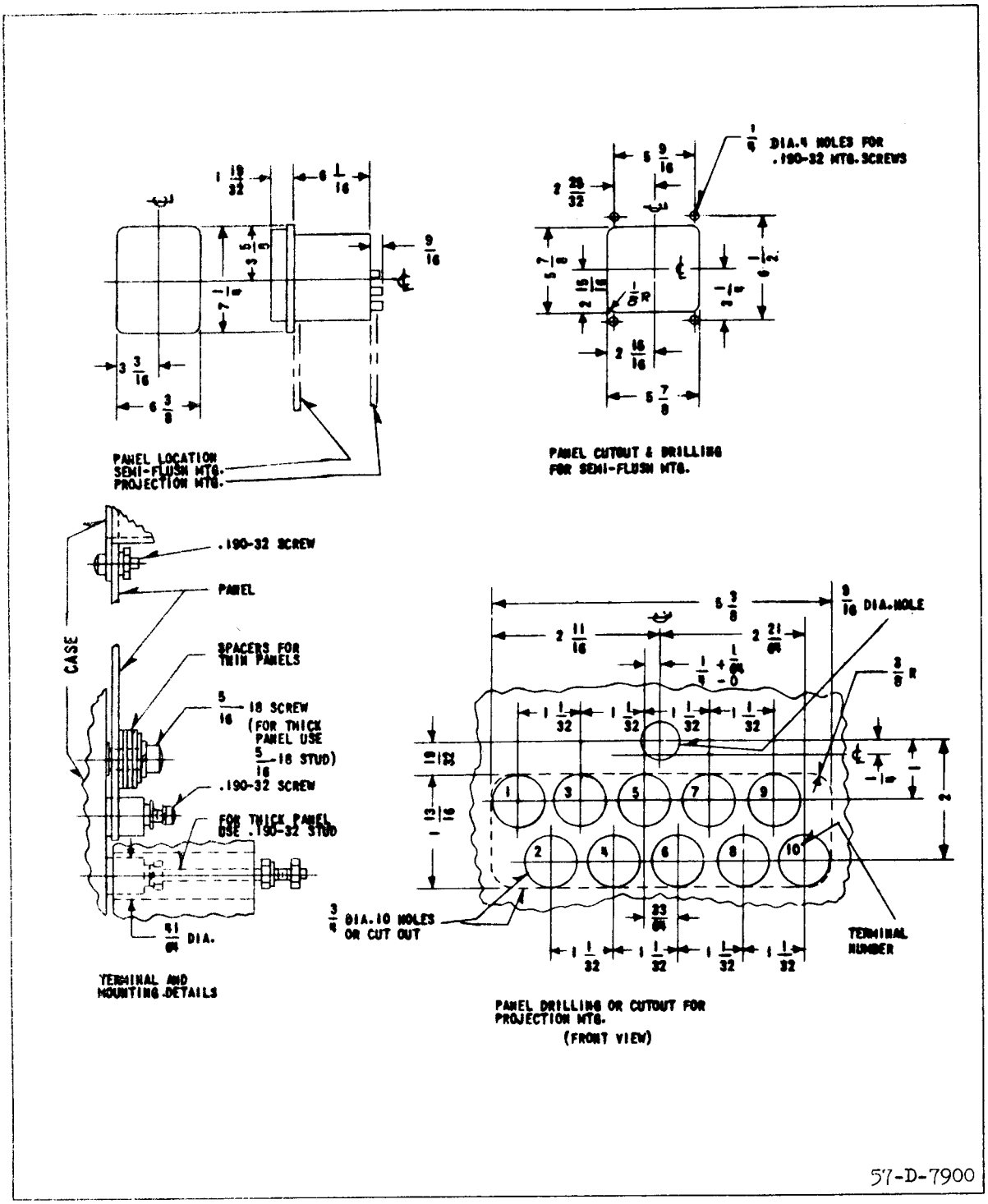


Fig. 19. Outline and Drilling Plan for the Type CO Relay.

TABLE I

TIME CURVE CALIBRATION DATA - 50 & 60 CYCLES

	PERMANENT MAGNET ADJUSTMENT		ELECTROMAGNET PLUGS		
RELAY TYPE	TIME DIAL POSITION	CURRENT (MULTIPLES OF TAP VALUE)	OPERATING TIME SECONDS	CURRENT (MULTIPLES OF TAP VALUE)	OPERATING TIME SECONDS
CO-2	6	3	0.57	20	0.22
CO-5	6	2	37.8 0	10	14.30
CO-6	6	2	2.46	20	1.19
CO-7	6	2	4.27	20	1.11
CO-8	6	2	13.35	20	1.11
CO-9	6	2	8.87	20	0.65
CO-11	6	2	11.27	20	0.24 Δ

Δ For 50 cycle CO-11 relay 20 times operating time limits are 0.24 + 10%, -5%.

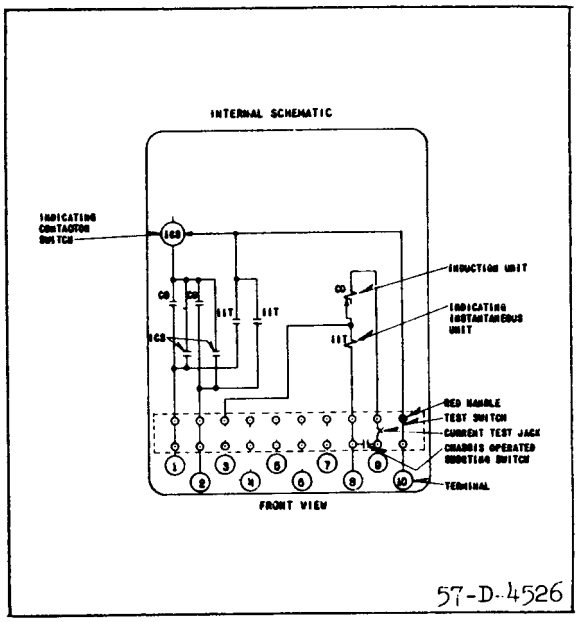


Fig. 20. Internal Schematic of the Double *Trip Circuit Closing Relay with Indicating Instantaneous Trip Unit.*

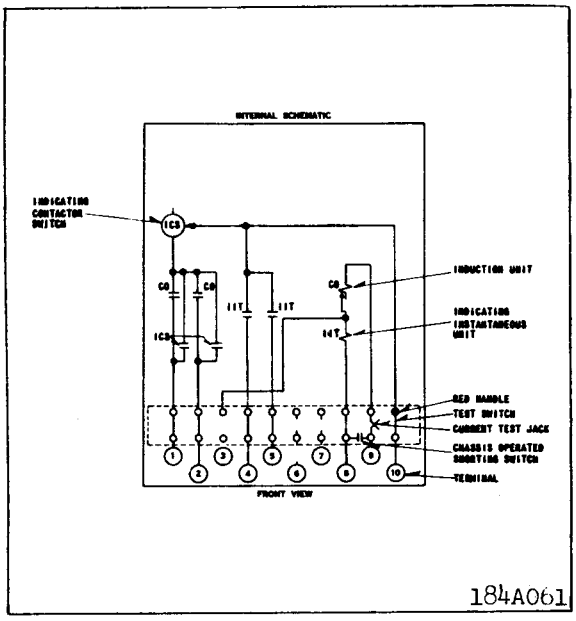


Fig. 21. Internal Schematic of the Double Trip Circuit Closing Realy with Indicating Instantaneous Trip Unit to Separate Terminals.

INSTALLATION • OPERATION • MAINTENANCE

INSTRUCTIONS

TYPE CV OVERCURRENT RELAY

CAUTION Before putting relays into service, remove all blocking which may have been inserted for the purpose of securing the parts during shipment, make sure that all moving parts operate freely, inspect the contacts to see that they are clean and close properly, and operate the relay to check the settings and electrical connections.

APPLICATION

The type CV relays are single-phase induction-disc type relays operating either on under or over voltage or both. These relays are applied as a volt-age fault detector operating in conjunction with other protective relays. The relays are also used as timing devices for various automatic operations.

CONTENTS

This instruction leaflet applies to the following types of relays:

CV-1 Long Time Undervoltage Relay
CV-2 Short Time Undervoltage Relay
CV-4 Long Time Overvoltage Relay
CV-5 Short Time Overvoltage Relay
CV-6 Long Time Over or Undervoltage Relay
CV-7 Short Time Over or Under voltage Relay
CV-8 Low Voltage Pickup Overvoltage Relay

CONSTRUCTION AND OPERATION

The types CV-1,. CV-2, CV-4, CV-5, CV-6, and CV-7relays consist of a voltage unit and an indicating contactor switch (ICS). The principal component parts of the relay and their location are shown in figures 1, 2, and 3.

The type CV-8 relay in addition to the above components also has a capacitor which is series tuned with the main coil of the electromagnet. This tuned circuit offers a low impedance to fundamental current and a high impedance to third harmonic currents. Hence, the relay has a low pick up value for fundamental voltage and a much higher value of pickup for third harmonic voltage. At rated voltage the electromagnet is saturated causing the circuit to be detuned. The impedance of the circuit is increased and limits the fundamental current to a safe value.

A. Voltage Unit (CV)

The overvoltage unit operates on the induction-disc principle. A main tapped coil located on the center leg of an "E" type laminated structure produces a flux which divides and returns through the outer legs. A shading coil causes the flux through the left leg (front view) to lag the main pole flux. The out-of-phase fluxes thus produced in the air gap causes a contact closing torque.

The undervoltage unit operates on the same principle as the overvoltage unit except the shading coil is on the right leg (front view). This causes the out-of-phase fluxes to produce a contact opening torque.

B. Indicating Contactor Switch (ICS)

The indicating contactor switch is a small d-c operated clapper type device. A magnetic armature, to which leaf-spring mounted contacts are attached, is attracted to the magnetic core upon energization of the switch. When the switch closes, the moving contacts bridge two stationary contacts, completing the trip circuit. Also, during this operation two fingers on the armature deflect a spring located on the front of the switch, which allows the operation indicator target to drop. The target is reset from the outside of the case by a push rod located at the bottom of the case.

The front spring, in addition to holding the target, provides restraint for the armature and thus controls the pickup value of the switch.

CHARACTERISTICS

The low pickup CV-8 Overvoltage Relay is available with the following continuous voltages.

67 volts
199 volts

The minimum voltage required to just close the CV-8 contacts is 8% of the continuous voltage. Typical operating times of the type CV-8 relay are shown on figure 8.

The CV-1 and CV-2 Undervoltage Relays, CV-4 and CV-5 Overvoltage Relays, and CV-6 and CV-7

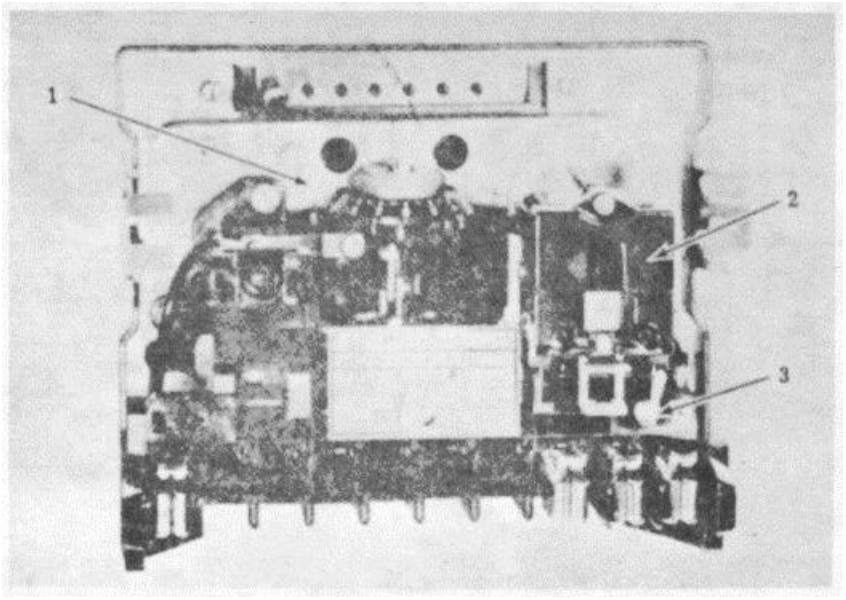


Fig. 1. Type CV-2 Relay Without Case. I-Voltage Unit (CV). 2-Indicating Contactor Switch (ICS). 3-indicating Contactor Switch Top Block.

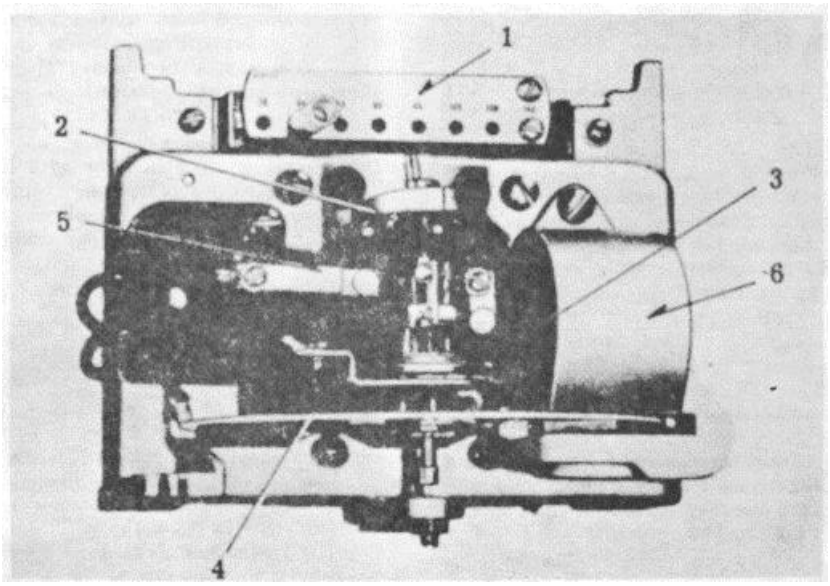


Fig 2. Voltage Unit (CV). 1-Tap Block. 2-Time Dial. 3-Control Spring Assembly. 4-Disc. S-Stationary Contact Assembly. 6-Permanent Magnet.

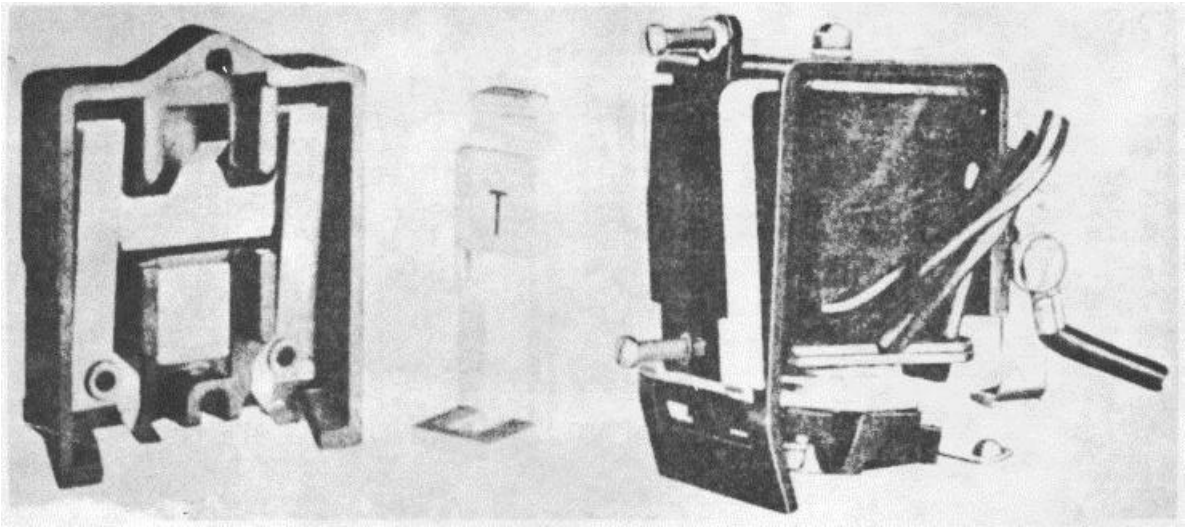


Fig. 3. Indicating Contactor Switch (ICS).

Over or Undervoltage Relays are available in the following voltage ranges:

Range	Taps							
55-140	55	64	70	82	93	105	120	140
110-280	110	128	140	164	186	210	240	280

A. CV-1 and CV-2 Undervoltage Relays -- CV-4 and CV-5 Overvoltage Relays

Tap value voltage is the minimum voltage required to just close the relay contacts. At this value of voltage, the moving contacts will leave the back-stop of the time dial and move to close the front contacts. Normal operation of the two relays is such that the CV-1 and CV-2 undervoltage relays will open its contacts with application of voltages greater than tap value voltage, while the CV-4 and CV-5 overvolt-age relay closes its contacts with voltages greater than tap value voltage. Thus, the operating curves of figures 9 and 10 of the undervoltage relays apply when the voltage is originally higher than tap value voltage and is suddenly reduced to a value shown on the curves. The operating curves of figures 11 and 12 of the overvoltage relays apply when the voltage -is initially below tap value voltage and is suddenly raised to a value shown on the curves.

B. CV-6 and CV-7 Over or Undervoltage Relays

Tap value voltage is the value of voltage at which the stationary front contact closes. The stationary back contact will close within 5% of this value.

When the relay is used as an overvoltage relay, the moving contact is made with the stationary back contact for values of applied voltage less than tap value voltage. With application of voltages greater than tap value voltage, the moving contact moves to close the front contact in a time as shown by the right-hand curves of either figures 13 or 14.

When the relay is used as an undervoltage relay, the moving contact is made with the stationary front contact for values of applied voltage greater than tap value voltage. With the application of voltages less than tap value voltage, the moving contact moves to close the back contact in a time as shown on the left-hand curves of either figures 13 or 14.

Trip Circuit

The main contacts will safely close 30 amperes at 250 volts d-c and the seal-in contacts of the indicating contactor switch will safely carry this current long enough to trip a circuit breaker.

The indicating contactor switch has two taps that provide a pickup setting of 0.2 or 2 amperes. To change taps requires connecting the lead located in front of the tap block to the desired setting by means of a screw connection.

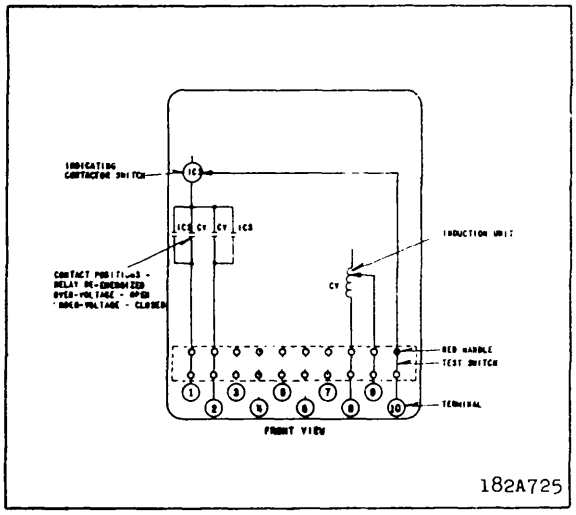


Fig. 4. Internal Schematic of the Double Trip Type CV Under or Overvoltage Relays In Type FTIT Case. For those Single Trip Relays the Circuits Associated with Terminal 2 are Omitted.

Trip Circuit Constants

Indicating contactor - switch	0.2 amp. tap 6.5 ohms d-c resistance 2.0 amp. tap 0.15 ohms d-c resistance

ENERGY REQUIREMENTS

The burdens of the CV-1, CV-2, CV-4, CV-5, CV-6, CV-7 relays at rated voltage are as follows:

Rated∆ Voltage	Taps 120 Volt Relay	Taps 240 Volt Relay	Volt-Amps.	Power Factor	Watts
	55	110	10.l0	.38	3.8
	64	128	7.0	.35	2.5
	70	140	5.8	.34	2.0
120 or	82	164	4.0	.33	1.3
240 Volts	l93	186	3.1	.31	1.0
	105	210	2.4	.29	.7
	120	240	1.8	.28	.5
	140	280	1.3	.26	.3

∆These relays will continuously stand either 110% of rated voltage or tap value voltage, whichever is higher.

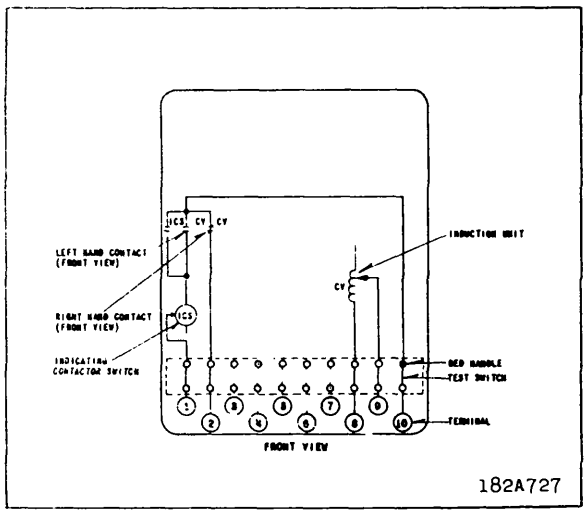


Fig. 5. Internal Schematic of the type CV Over or Undervoltage Relay In Type FTI1 case.

The burdens of the CV-8 relays at continuous voltage are as follows:

Continuous Voltage	Volt Amps.	Power Factor	Watts
199	30	.342	10
67	30	.342	10

SETTINGS

A. CV Unit

The setting of the CV unit can be defined either by tap setting and time dial position or by tap setting and a specific time of operation at some percentage of tap value voltage (e.g. on CV-4 120 tap setting, 2 time dial position or 120 tap setting, 12 seconds at 140 percent of tap value voltage).

To provide selective circuit breaker operation, a minimum coordinating time of 0.3 seconds plus circuit breaker time is recommended between the relay being set and the relays with which coordination is to be effected.

The connector screw on the terminal plate above the time dial connects various turns of the operating coil. By placing this screw in the various terminal plate holes, the relay will just close its contacts at the corresponding voltage of 55-64-70-82-93-105-120-*140 volts or as marked on the terminal plate.

The nylon screw on the terminal plate holds the tap plate in position when taps are being changed. To

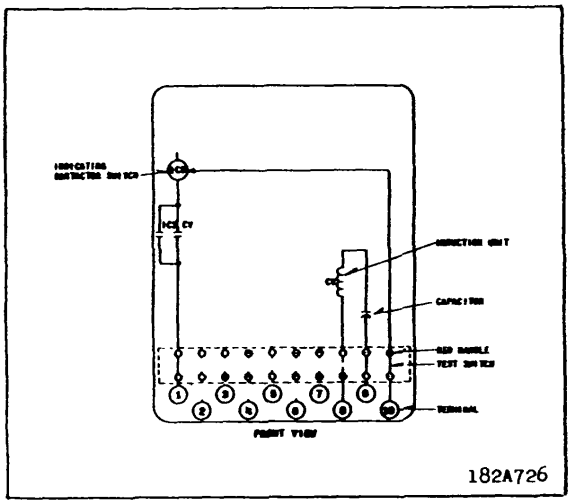


Fig. 6. Internal Schematic of the typeCV8 1, 9 volt relay in type FT11 case.

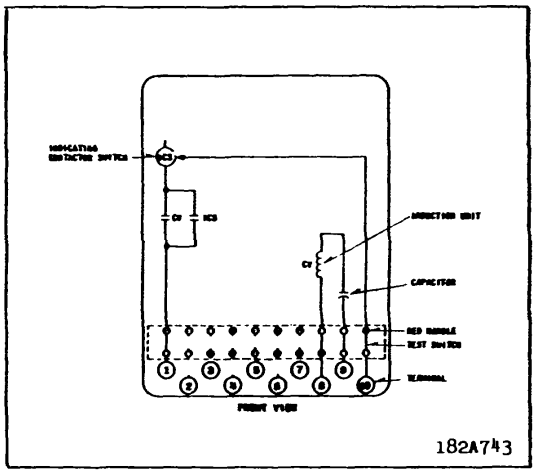


Fig. 7. Internal Schematic of the typo CV. 67 volt relay in type FT21 case.

use the position on the terminal plate in which the nylon screw is used, remove the nylon screw and place it in one of the unused holes. Then remove the tap screw and insert it in the terminal plate hole.

Instantaneous Reclosing

The factory adjustment of the voltage unit contacts provides a contact follow. Where circuit breaker reclosing will be initiated immediately after a trip by the over voltage contact, the time of the opening of the contacts should be a minimum. This condition is obtained by loosening the stationary contact mounting screw, removing the contact plate and then replacing the plate with the bent end resting against the contact spring.

For double trip relays, the upper stationary contact is adjusted such that the contact rests solidly against the back stop. The lower stationary contact is then adjusted such that both stationary contacts make contact simultaneously with their respective moving contact.

B. Indicating Contactor Switch (ICS)

No setting is required on the ICS unit except the selection of the 0.2 to 2.0 ampere tap setting. This selection is made by connecting the lead located in front of the tap block to the desired setting by means of the connecting screw.

INSTALLATION

The relays should be mounted on switchboard panels or their equivalent in a location free from dirt, moisture, excessive vibration, and heat. Mount the relay vertically by means of the four mounting holes on the flange for semi-flush mounting or by means of the rear mounting stud or studs for projection mounting. Either a mounting stud or the mounting screws may be utilized for grounding the relay. The electrical connections may be made directly to the terminals by means of screws for steel panel mounting or to the terminal studs furnished with the relay for thick panel mounting. The terminal studs may be easily removed or inserted by locking two nuts on the stud and then turning the proper nut with a wrench.

ADJUSTMENTS AND MAINTENANCE

The proper adjustments to insure correct operation of this relay have been made at the factory. Upon receipt of the relay, no adjustments, other than those covered under “Settings”, should be required.

Acceptance Check

The following check is recommended to insure that the relay is in proper working order:

A. CV Unit

1. Contact

a) By turning the time dial. move the moving contacts until they deflect the stationary contact to a position where the stationary contact is resting against its backstop. The index mark located on the movement frame should coincide with the "'O" mark on

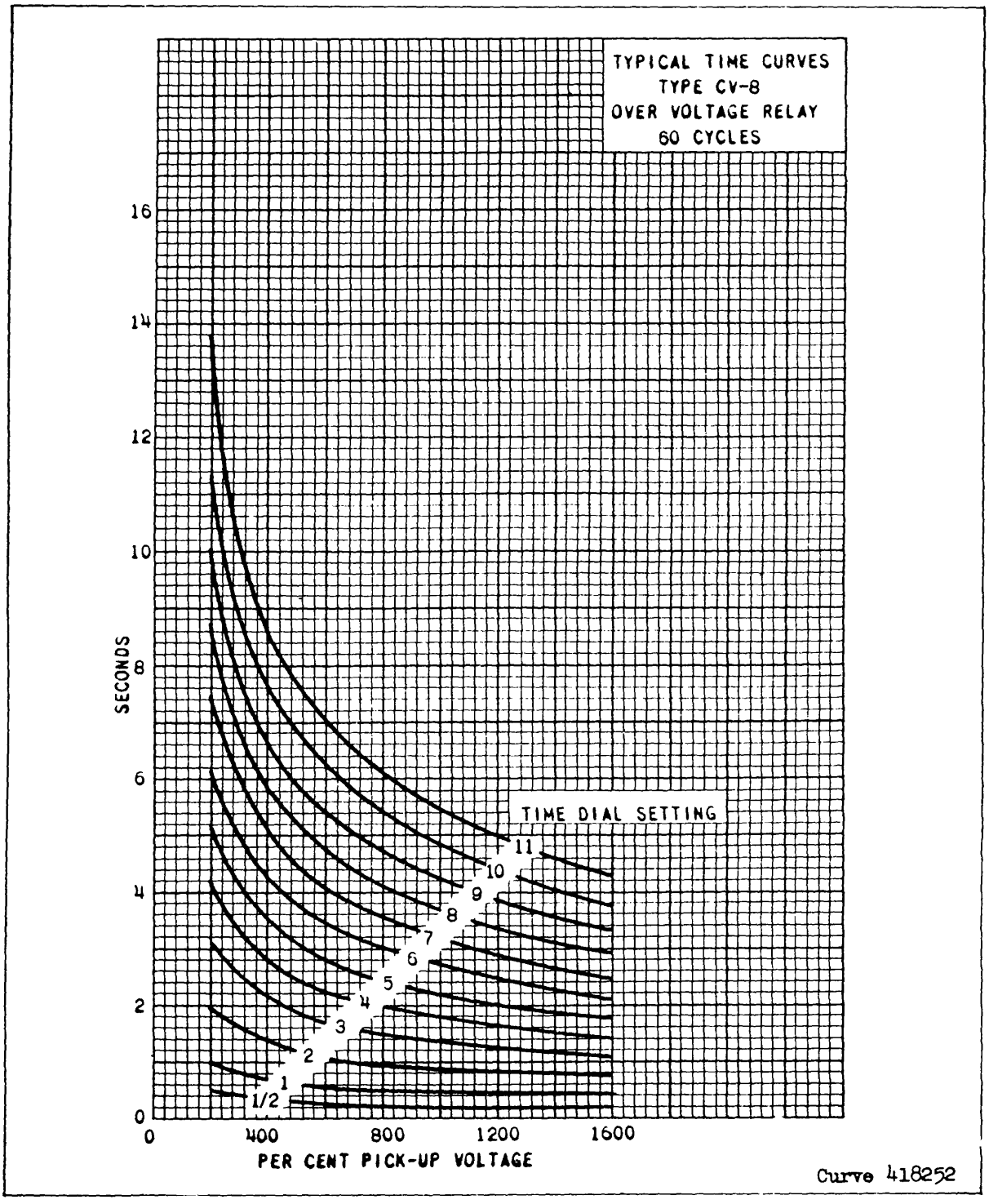


Fig. 8. Typical 60-cycle time curves of the type CV8 Low Pickup Overvoltage Relay.

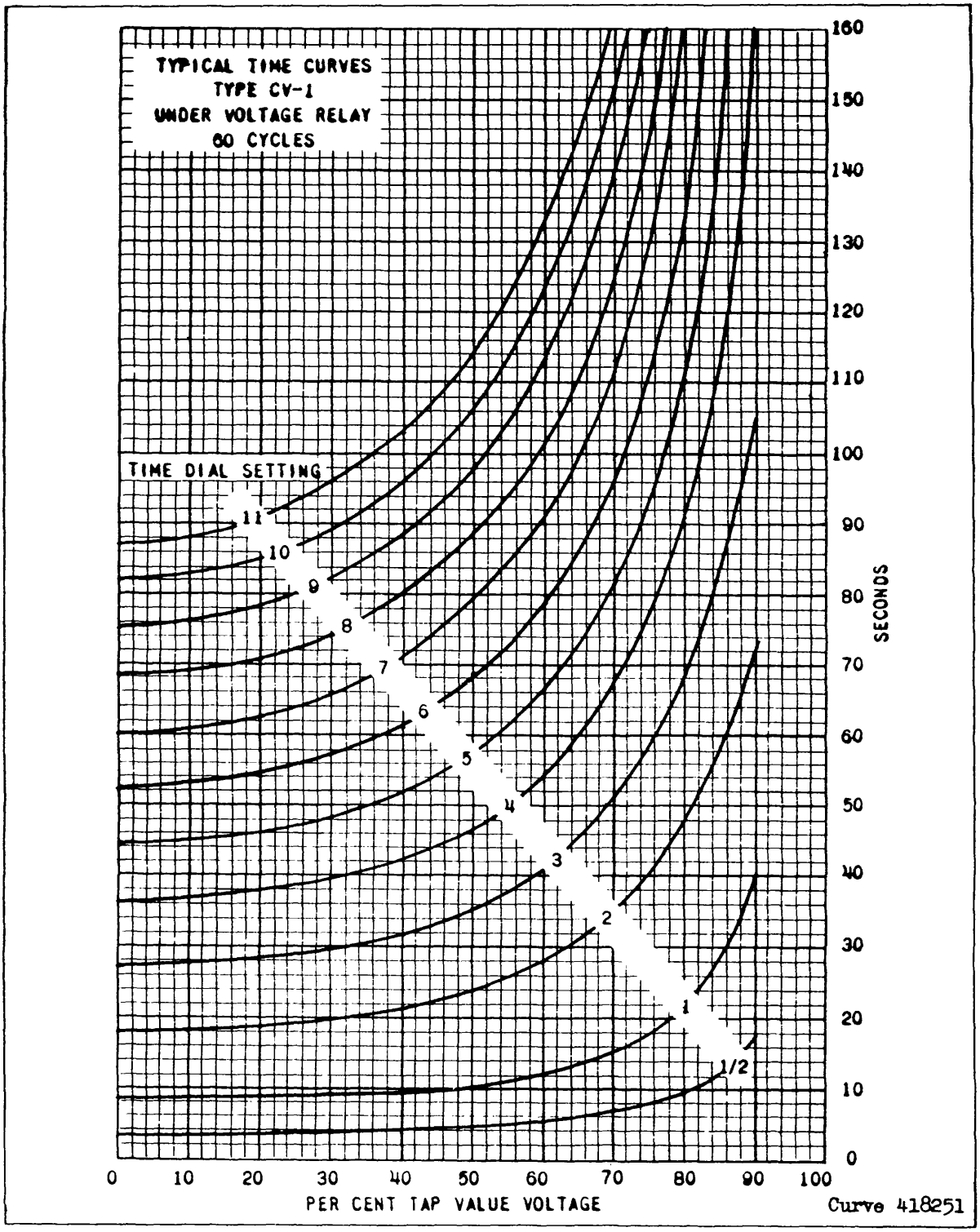


Fig. 9. Typical 60-cycle time curves or the type CVI Long Time Undervoltoge Relay.

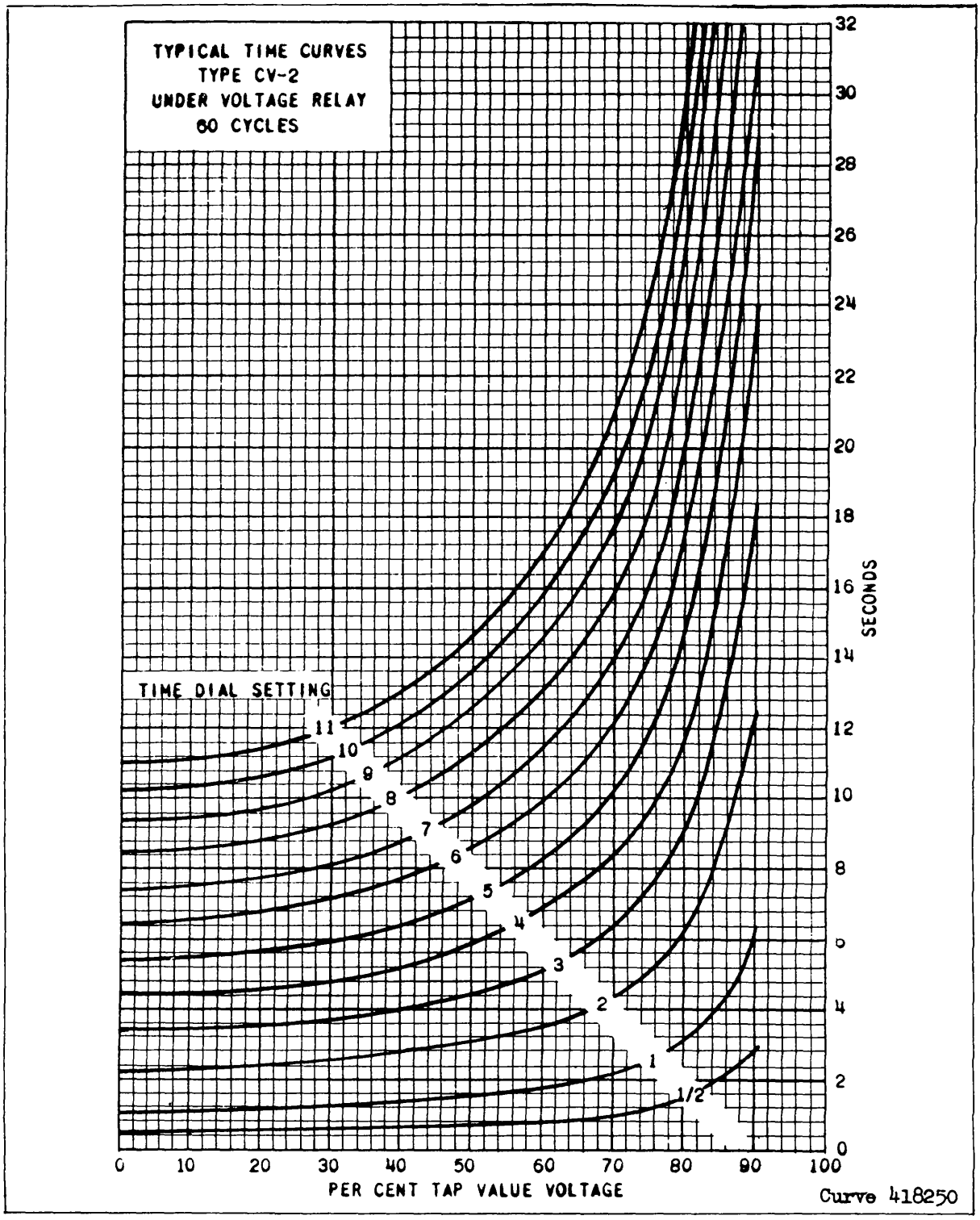


Fig. 10. Typical 60-cycle Time curves of the type CV2 Short Time Undervoltoge Relay.

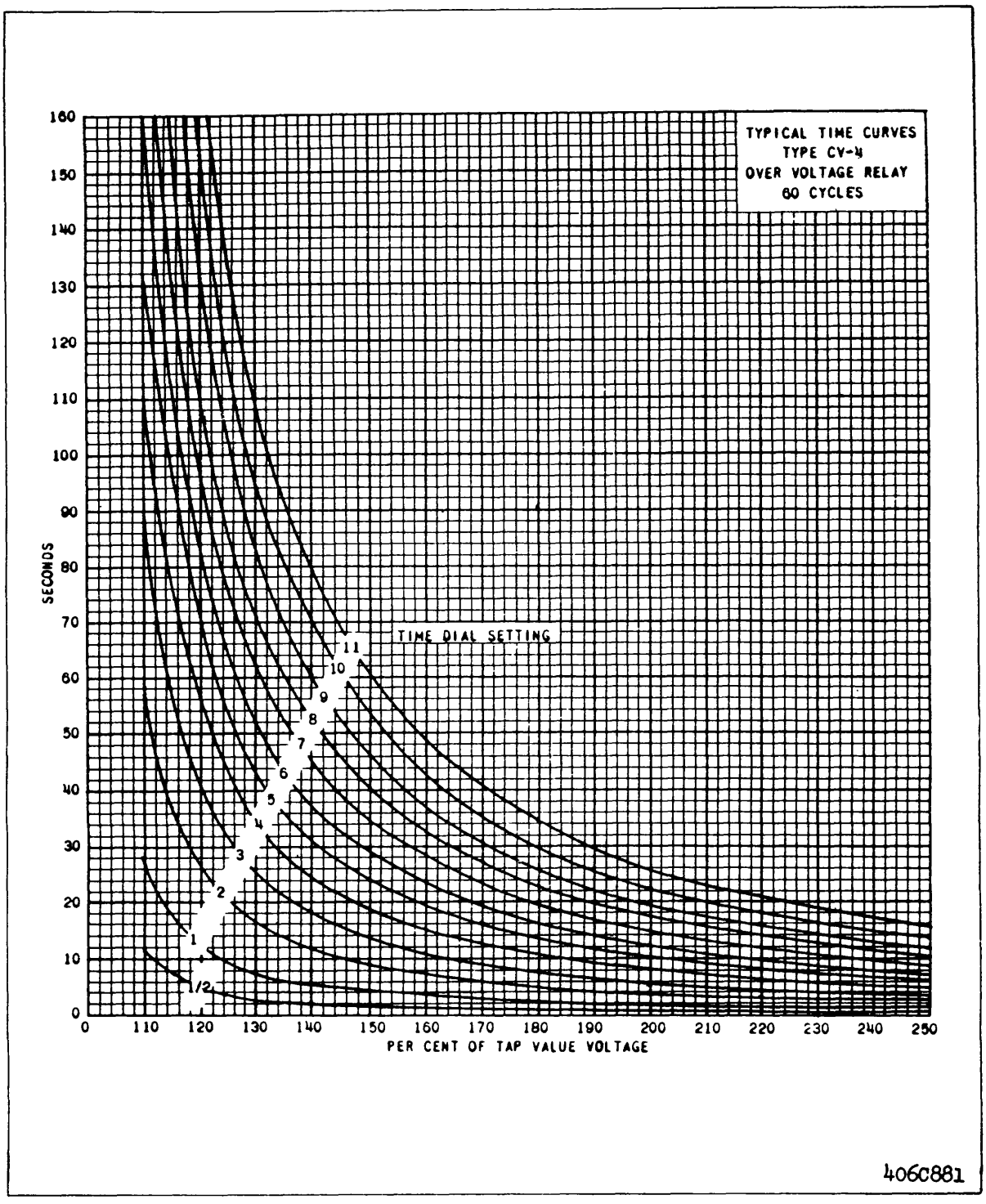


Fig. 11. Typical 60-cycle time curves of the type CV4 Long Time Overvoltage Relay.

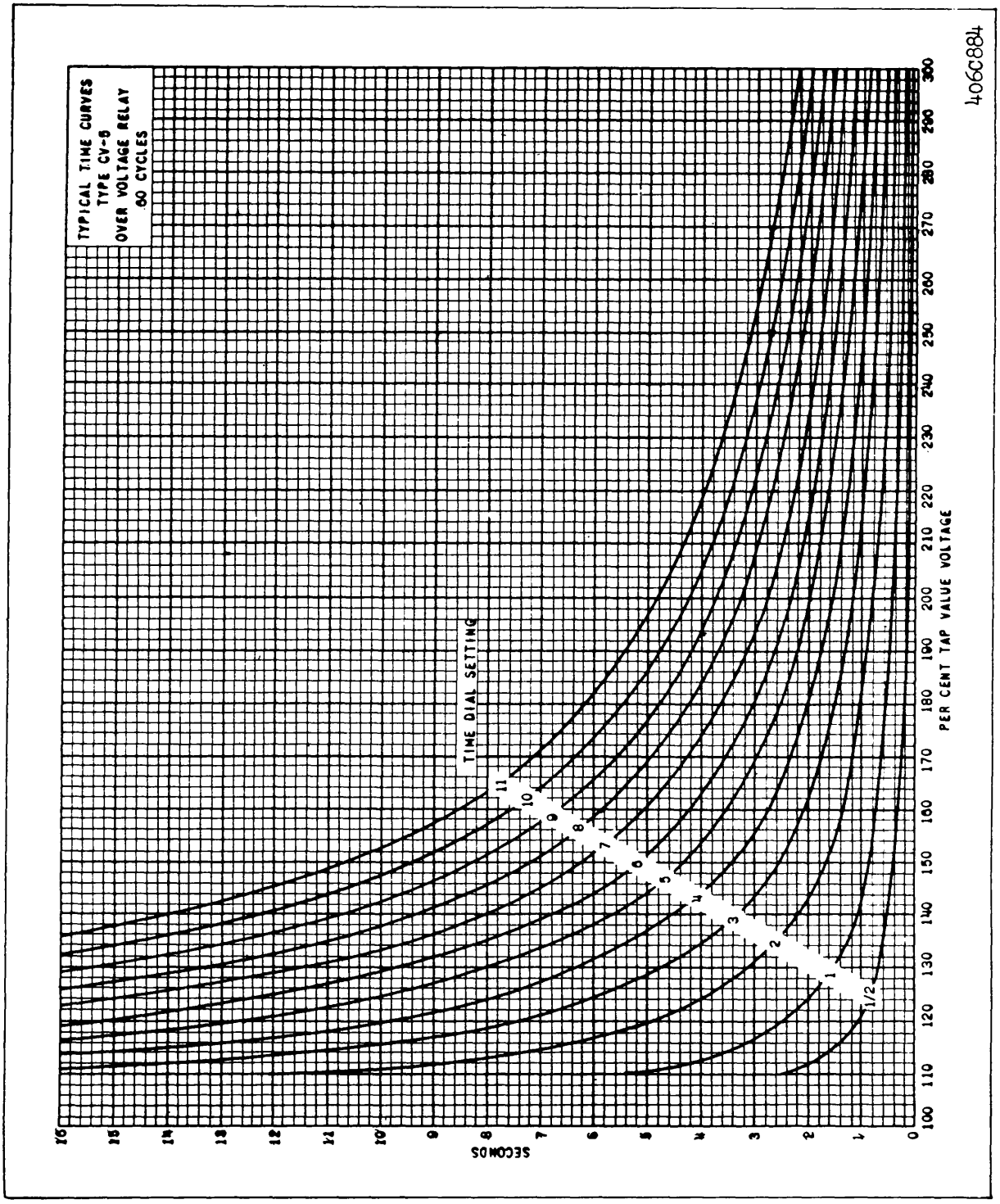


Fig. 12. Typical 60-cycle time curves of the type CV5 Short Time Overvoltage Relay.

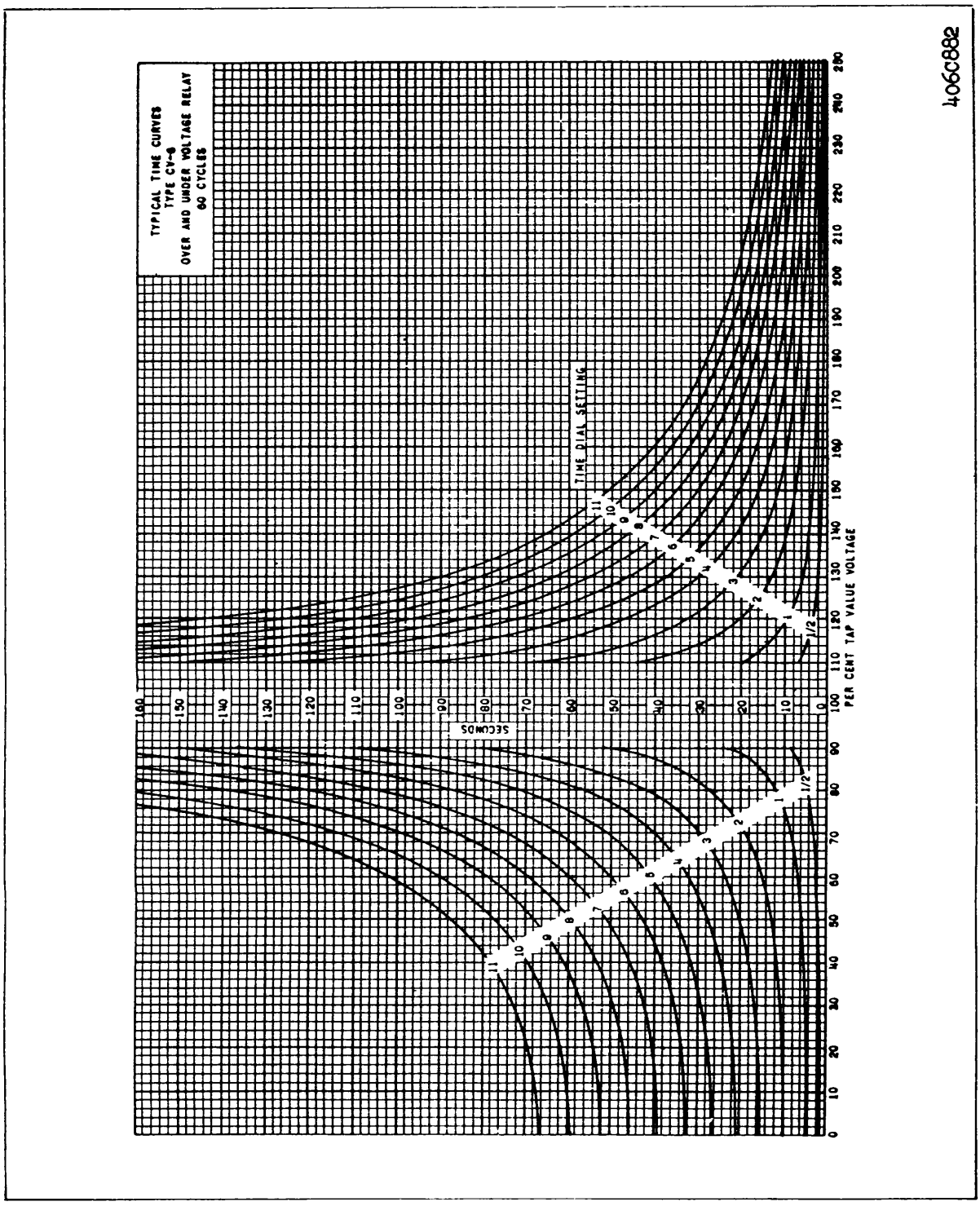


Fig. 13. Typical 60-cycle time curves of the type CV6 Long Time Over and Undervoltoge Relay.

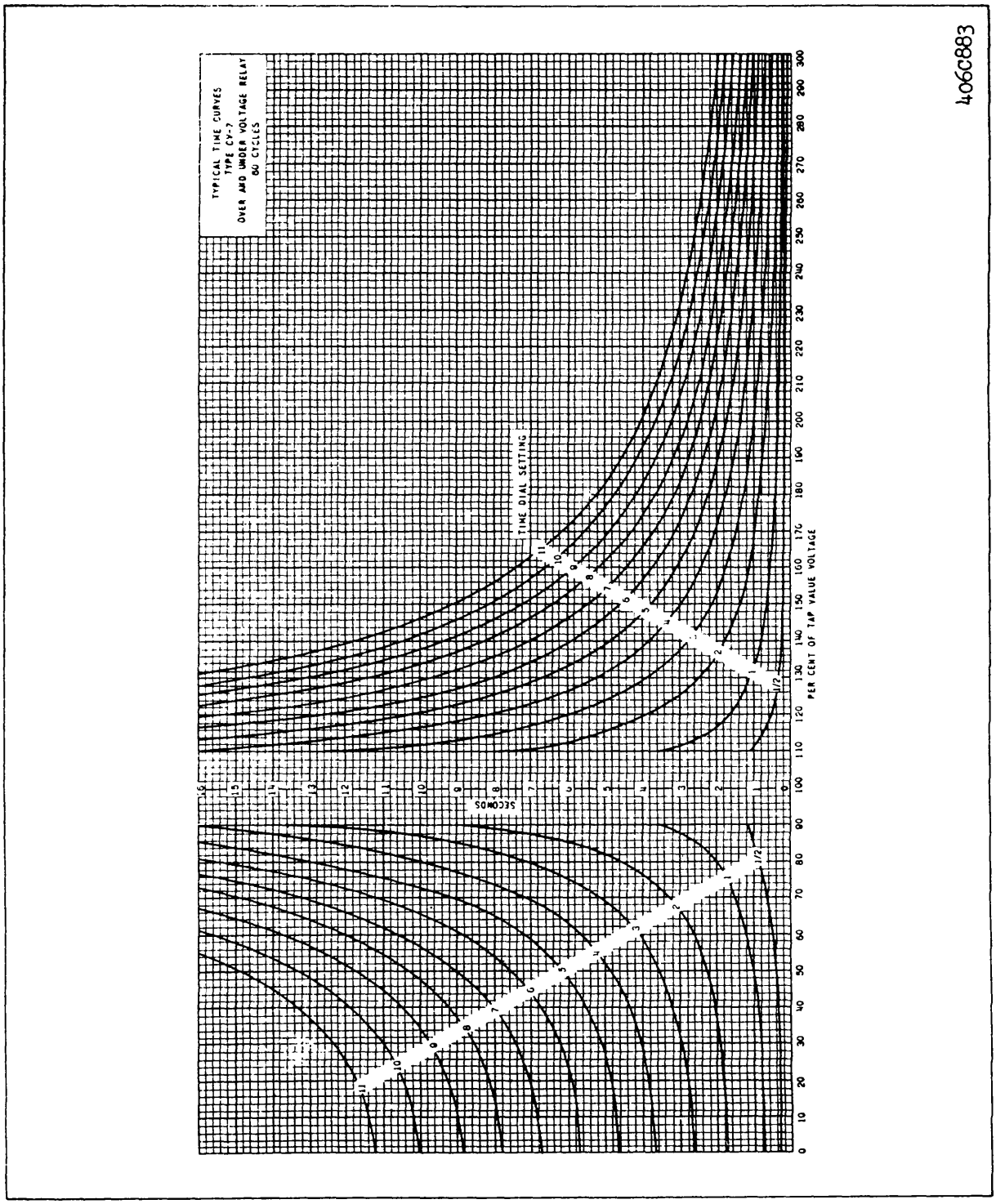


Fig. 14. Typical 60-cycle time curves of the type CV7 Short Time Over and Undervoltoge Relay.

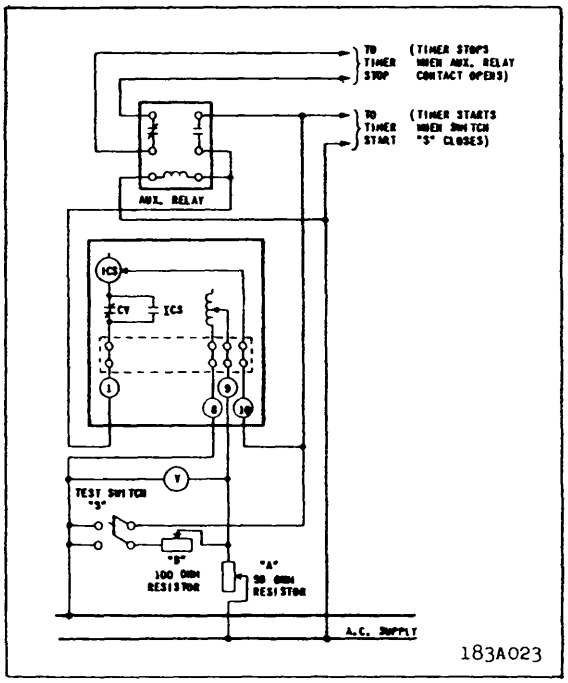


Fig. 15. Diagram of Test Connections of the type CV Undervoltage Relay.

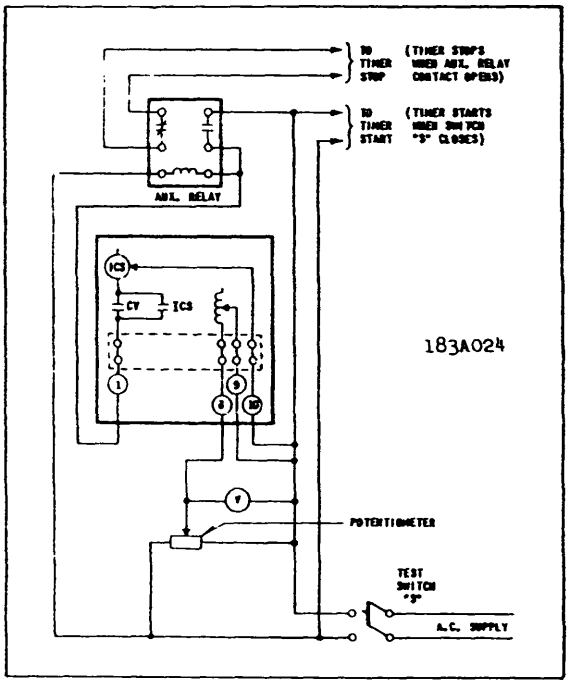


Fig. 16. Diagram of Test Connections of the type CV Overvoltage Relay.

the time dial. For double trip relays, the follow on the stationary contacts should be approximately 1/64".

b) For relays identified with a "T" , located at lower left of stationary contact block, the index mark on the movement frame will coincide with the "0" mark on the time dial when the stationary contact has moved through approximately one half of its normal deflection. Therefore, with the stationary contact resting against the backstop, the index mark is offset to the right of the "O" mark by approximately .020". (For the type CV-6 and CV-7 relays the back contact has no follow when the front contact is through one-half of its follow). The placement of the various time dial positions in line with the index mark will give operating times as shown on the respective time-current curves. For double trip relays, the follow on the stationary contacts should be approximately 1/32".

2. Minimum Trip Voltage- Set the time dial to position 6. Alternately apply tap value voltage plus 3% and tap value voltage minus 3%.

a. CV-4 and CV-5 Overvoltage Relays. CV-6 and CV-7 Over or Undervoltage Relays - The moving contact should leave the backstop at tap value volt- age plus 3% and should return to the backstop at tap value voltage minus 3%.

b. CV-1 and CV-2 Undervoltage Relays - The moving contact should leave the backstop at tap value voltage minus 3c% and should return to the backstop at tap value voltage plus 3%.

c. CV-8 Overvoltage Relays - The moving contact should leave the backstop at 8.5% of continuous voltage.

3. Time Curve - Table 1 shows the time curve calibration points for the various types of relays. With the time dial set to the indicated position, apply the voltages specified in table 1 (e.g. for the CV-4, 140 percent of tap value voltage) and measure the operating time of the relay. The operating time should equal those of table 1 plus or minus 5%.

B. Indicating Contactor Switch (ICS)- Close the main relay contacts and pass sufficient d-c current through the trip circuit to close the contacts of the ICS. This value of current should not be greater than the particular ICS setting being used. The indicator target should drop freely.

The contact gap should be approximately .047" between the bridging moving contact and the adjust-

able stationary contacts. The bridging moving contact should touch both stationary contacts simultaneously.

Routine Maintenance

All relays should be inspected periodically and the time of operation should be checked at least once every year or at such other time intervals as may be dictated by experience to be suitable to the particular application. Phantom loads should not be used in testing induction-type relays because of the resulting distorted current wave form which produces an error in timing.

All contacts should be periodically cleaned. A contact burnisher S#182A836H01 is recommended for this purpose. The use of abrasive material for cleaning contacts is not recommended, because of the danger of embedding small particles in the face of the soft silver contact and thus impairing the contact.

Calibration

Use the following procedure for calibrating the relay if the relay has been taken apart for repairs, or the adjustments have been disturbed. This procedure should not be used until it is apparent that the relay is not in proper working order (See "Acceptance check").

A. CV Unit

1. Contact

a) By turning the time dial, move the moving contacts until they deflect the stationary contact to a position where the stationary contact is resting against its backstop. The index mark located on the movement frame should coincide with the "0" mark on the time dial. For double trip relays, the follow on the stationary contacts should be approximately 1/64".

b) For relays identified with a "T", located at lower left of stationary contact block, the index mark on the movement frame will coincide with the "O" mark on the time dial when the stationary contact has moved through approximately one half of its normal deflection. Therefore, with the stationary contact resting against the backstop, the index mark is offset to the right of the "0" mark by approximately .020". (For the type CV-6 and CV-7 relays the back contact has no follow when the front contact is through one-half of its follow). The placement of the various time dial positions in line with the index mark will give operating times as shown on the respective time-current curves. For double trip relays, the follow on the stationary contacts should be approximately 1/32".

2. Minimum Trip-Voltage - The adjustment of the spring tension in setting the minimum trip voltage value of the relay is most conveniently made with the damping magnet removed.

With the time dial set on "0", wind up the spiral spring by means of the spring adjuster until approximately 6-3/4 convolutions show. Set the relay on the minimum tap setting and the time dial to position 6.

a. CV-4 and CV-5 Overvoltage, CV-6 and CV-7 Over or Undervoltage - Adjust the control spring tension so that the moving contact will leave the backstop of the time dial at tap value voltage +1.0% and will return to the backstop at tap value voltage -1.0%.

b. CV-1 and CV-2 Undervoltage Relays - Adjust the control spring tension so that the moving contact will leave the backstop of the time dial at tap value voltage -1.0%o and will return to the backstop at tap value voltage +1.0%.

c. Low Pickup Overvoltage Relay - Adjust the control spring so that the moving contact will leave the backstop of the time dial at 8.1% of continuous voltage and return at 7.9% of continuous voltage.

3. Time Curve Calibration - Install the permanent magnet.

a. CV-1 and CV-2 Undervoltage Relay - Use test circuit of figure 15. With switch "S" opened, adjust resistor "A" until voltmeter reads tap value voltage or higher. Close switch "S" and adjust resistor "B" until the voltmeter reads 50 percent of tap value voltage. Open switch "S" and allow the moving contact to move to the backstop of the time dial. Close switch "S" and measure operating time.

Adjust the permanent magnet gap until the operating time corresponds to the value given in table 1.

b. CV-4 and CV-5 Overvoltage Relay, CV-8 Low Pickup Overvoltage Relay - Apply the indicated voltage of table 1 and measure the operating time.

Adjust the permanent magnet keeper until the operating time corresponds to the value given in table 1.

c. CV-6 and CV-7 Over or Undervoltage Relay - Apply the indicated voltage of table 1 and measure the operating time. Adjust the permanent magnet keeper until the operating time corresponds to the value given in table 1.

Measure the reset time of the disc from the stationary front contact to the stationary back contact. This time should be as shown in table 1.

TABLE 1

Type Relay	Percent Top Value Voltage Or Pickup Voltage	Time Dial Setting	Operating Time in Sec.	Reset Time in Sec.
CV1	50	6	68	
CV2	50	6	8.6	
CV4	140	6	37.5	
CV5	140	6	6.8	
CV6	140	6	33	32.5
CV7	140	6	5.9	5.7
CV8	800	6	3.0	

B. Indicating Contactor Switch Unit (ICS) Close the main relay contacts and pass sufficient d-c current through the trip circuit to close the contacts of the ICS. This value of current should not be greater than the particular ICS setting being used. The indicator target should drop freely.

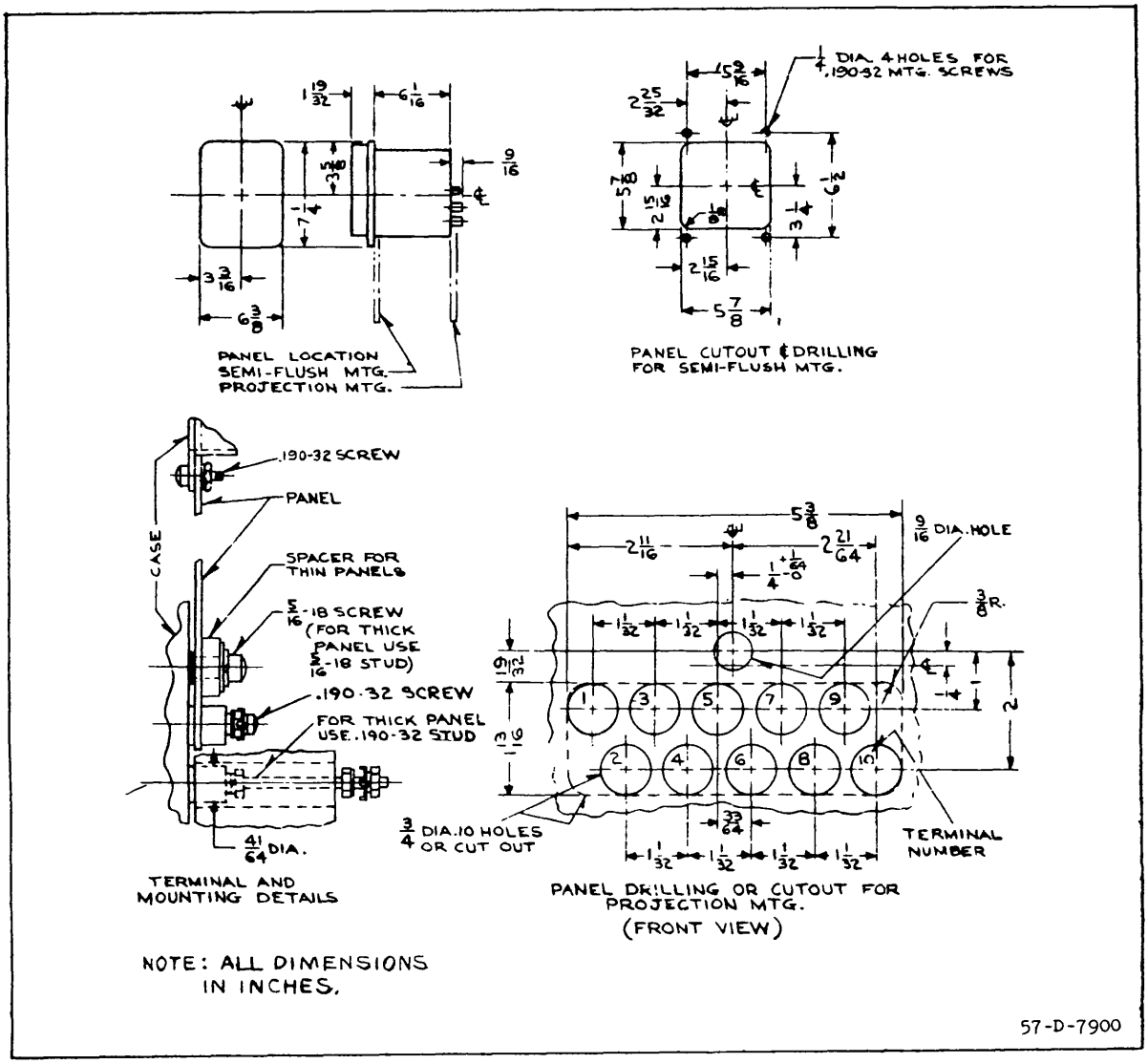


Fig. 17. Outline and drilling for FT11 case used for projection and/or semi-flush case.

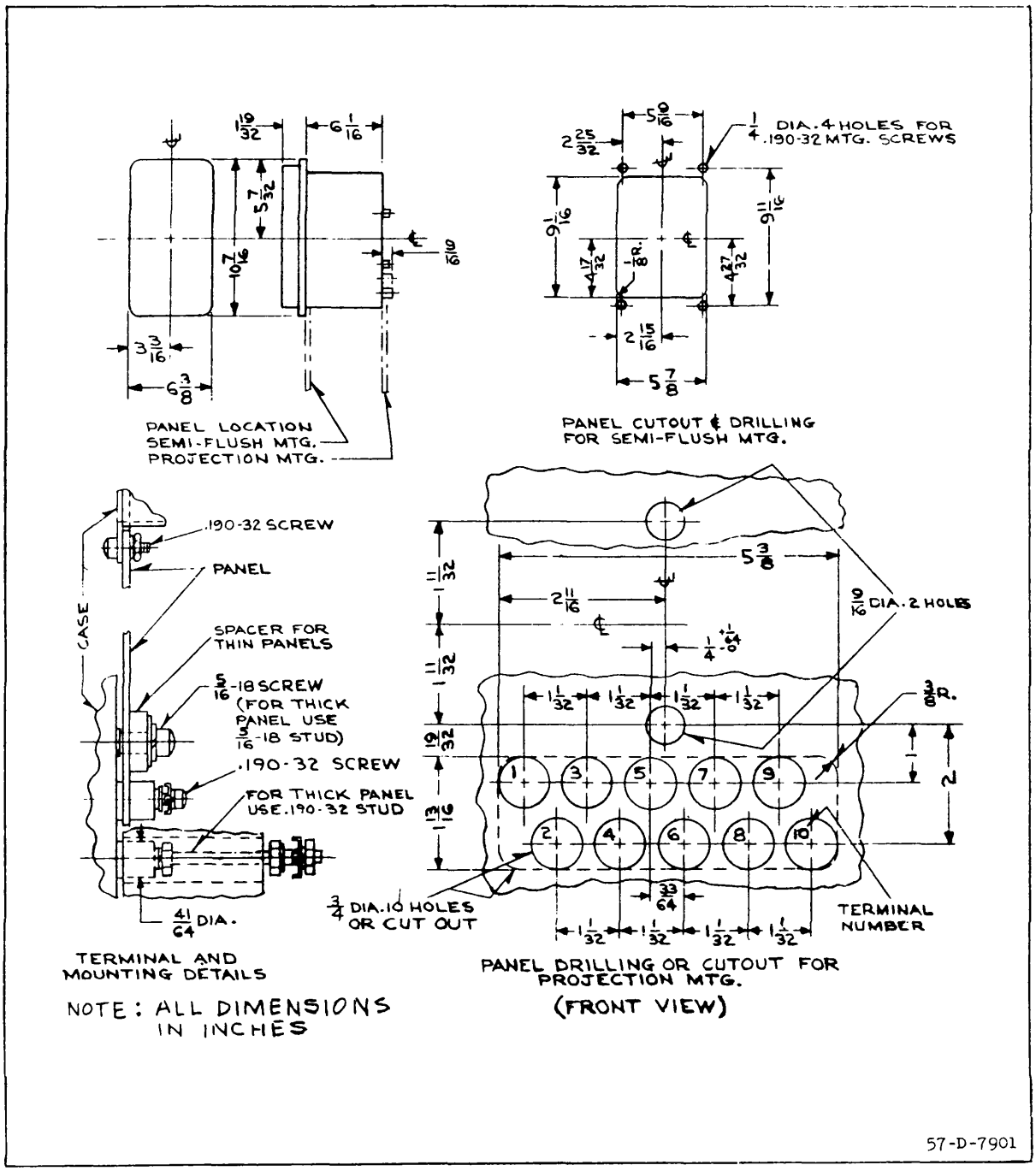


Fig. 18. Outline and drilling for FT21 case used for projection and/or semi-flush case. (For 67 volt CV-8 relay only)

TYPE CW POWER RELAY SINGLE PHASE APPLICATION

CAUTION Before putting relays into service, remove all blocking which may have been inserted for the purpose of securing the parts during shipment, make sure that all moving parts operate freely, inspect the contacts to see that they are clean and close properly and operate the relay to check the settings and electrical connections.

APPLICATION

The type CW relay is a single phase induction type relay providing over power or reverse power protection for electrical equipment or circuits. It is not intended for use as a fault protective relay.

CONSTRUCTION

The relay consists of a product operated unit, a phase shifter and an indicating contactor switch (ICS).

Product Type Unit

The electromagnet for the main element has a tapped current. coil located on the center leg of an "E" type laminated structure and two potential coils on the outer legs. Operating torque is obtained by energizing the tapped coil with line current and the two outer coils with line potential from the line potential transformers. Out of phase air gap fluxes necessary for operating torques are produced by a phase shifting network in conjunction with the potential coils. Maximum torque occurs when the current and voltage are in phase. The voltage is independent of the direction of power flow. This provides a reference so that the disc can rotate in either direction depending upon direction of the line current. The combination of voltage and current produces an operating torque proportional to power.

Phase Shifter The phase shifter network consists of a capacitor in parallel with the potential coils and a reactor in series with the above combination.

Indicating Contractor Switch Unit (ICS)

The d-c indicating contactor switch is a small clapper type device. A magnetic armature, to which leaf-spring mounted contacts are attached, is attracted to the magnetic core upon energization of the switch When the switch closes, the moving contacts bridge two stationary contacts, completing the trip circuit. Also during this operation two fingers on the armature deflect a spring located on the front of the switch, which allows the operation indicator target to drop. The target is reset from the outside of the case by a push rod located at the bottom of the cover.

The front spring, in addition to holding the target, provides restraint for the armature and thus controls the pickup value of the switch.

CHARACTERISTICS

The type CW relays are available in the following ranges and taps:

SINGLE PHASE WATT RANGE	POTENTIAL COIL	TAPS
20 - 120	120	20-3040-60-80-100-120
100 - 600	120	100-150-200-300-400-500-600

Typical 60 cycle Time-Power Curves are shown in Figs. 3 & 4. The curves are taken at maximum torque which occurs with the current and voltage in phase (within ±4°).

Trip Circuit

The main contacts will safely close 30 amperes at 250 volts d-c and the seal-in contacts of the indicating contactor switch will safely carry this current long enough to trip a circuit breaker.

The indicating contactor switch has two taps that provide pickup setting of 0.2 or 2 amperes. To change taps requires connecting the lead located in front of the tap block to the desired setting by means of a screw connection.

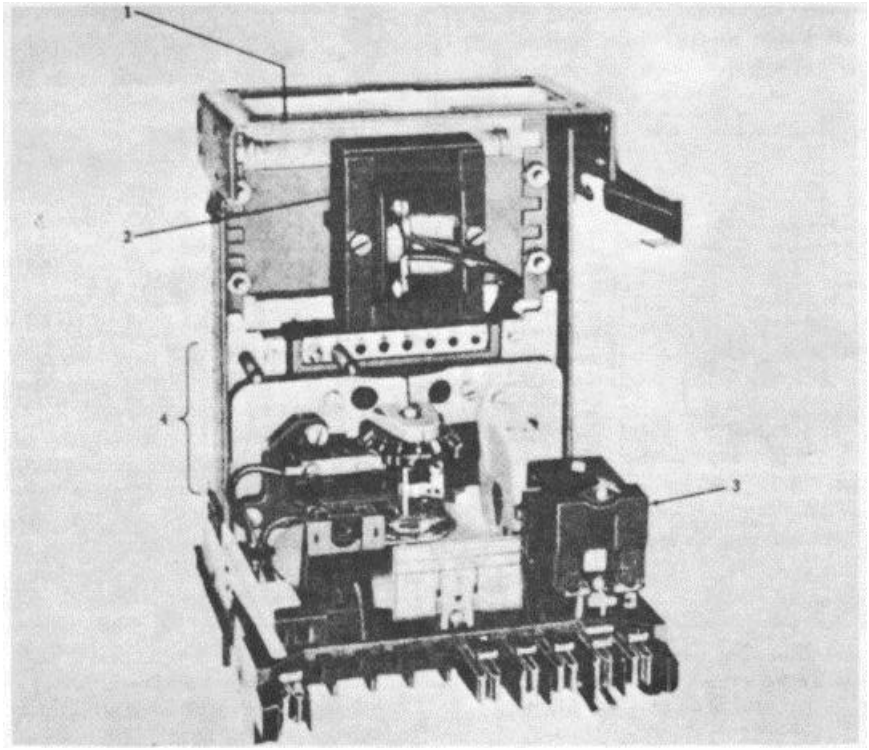


Fig. 1. Type CW Relay Without Case.1I - Capacitor. 2 - Reactor. 3 - Indicating Contactor Switch (ICS). 4 - Time-Power Unit.

Trip Circuit Constant

Indicating Contactor Switch (ICS)

0.2 ampere tap 6.5 ohms d-c resistance

2.0 ampere tap 0.15 ohms d-c resistance

INSTALLATION

The relays should be mounted on switchboard panels or their equivalent in a location free from dirt, moisture, excessive vibration and heat. Mount the relay vertically by means of the four mounting holes on the flange for semi-flush mounting or by means of the rear mounting stud or studs for projection mounting. Either a mounting stud or the mounting screws may be utilized for grounding the relay. The electrical connections may be made directly to the terminals by means of screws for steel panel mounting or to the terminal studs furnished with the relay for thick panel mounting. The terminal studs may be easily removed or inserted by locking two nuts on the stud and then turning the proper nut with a wrench.

SETTINGS

Product Unit

There are two settings to be made. One is the current tap setting, and the second, the time dial setting.

The power to operate the relay equals the primary power divided by the current and potential transformer ratios. This relay power expressed as multiples of the chosen tap locates a value on the abscissa of the Time-Power Curves of Fig. 3 and 4. The relay operating time for various time dial settings then is observed on the ordinate. By changing taps or time dial, the required operating time can be selected for a specific power value.

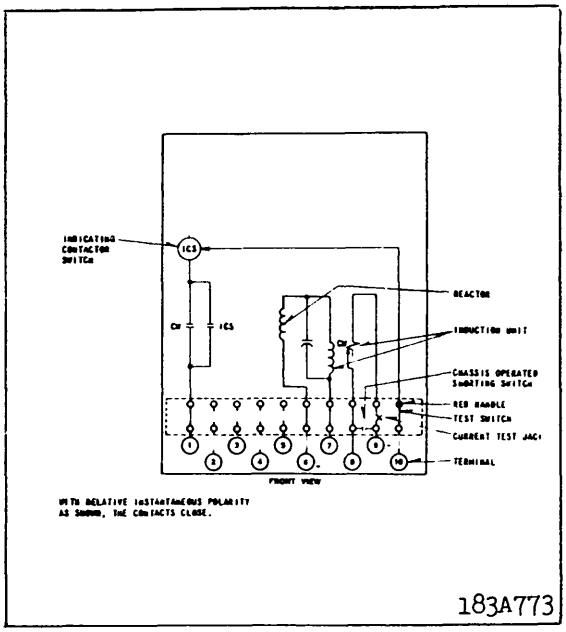


Fig. 2. Internal Schematic of the Type CW Relay in the Type FT 21 Case.

CAUTION

When changing taps with the relay in service, screw the extra tap screw in the new tap hole before removing the old tap screw. This prevents open circuiting the current transformers.

Indicating Contactor Switch (ICS)

No setting is required on the ICS unit except the selection of the 0.2 or 2.0 ampere tap setting. This selection is made by connecting the lead located in front of the tap block to the desired setting by means of the connecting screw.

ADJUSTMENT AND MAINTENANCE

The proper adjustments to insure correct operating of this relay have been made at the factory and should not be disturbed after receipt. If the adjustments have been changed, the relay taken apart for repairs, or if it is desired to check the adjustments at regular maintenance periods, the instructions below should be followed.

All contacts should be cleaned periodically. A contact burnisher S#182A836H01 is recommended for this purpose. The use of abrasive material for cleaning contacts is not recommended, because of the danger of embedding small particles in the face of the soft silver and thus Impairing the contact.

Product Unit

Contacts - The index mark on the movement frame will coincide with the "0" mark on the time dial when the stationary contact has moved through approximately one-half of its normal deflection. Therefore, with the stationary contact resting against the backstop, the index mark is offset to the right of the "O" mark by approximately .020". The placement of the various time dial positions in line with the index mark will give operating times as shown on the respective time-current curves.

Minimum Trip Watts - Set the time dial to position 6. Using the lowest tap setting, alternately apply tap value watts plus 3% and tap value watts minus 3% with the current and the voltage in phase. The moving contact should leave the backstop at tap watts plus 3% and should return to the backstop at tap value watts minus 3%. The relay should be calibrated with 10 times tap value watts at the number six time dial position. Check several points on the typical time curves. Time curve calibration is effected by adjusting the position of the permanent magnet keeper.

Indicating Contactor Switch (ICS)

Close the main relay contacts and pass sufficient d-c current through the trip circuit to close the contacts of the ICS. This value of current should not be greater than the particular ICS tap setting being used. The indicator target should drop freely.

ENERGY REQUIREMENTS

The 60 cycle burdens of the type CW Relay Single Phase Application are as follows:

1. The 20-120 Watt, 120 Volt Relay

   A. Potential Circuit Burden at Rated Voltage

Current Lags By	Volt Amperes
26.5°	5.4

   B. Current Coil at 5 Amperes

TAP	CURRENT LAGS BY	VOLT AMPERES
20	78°	16.2

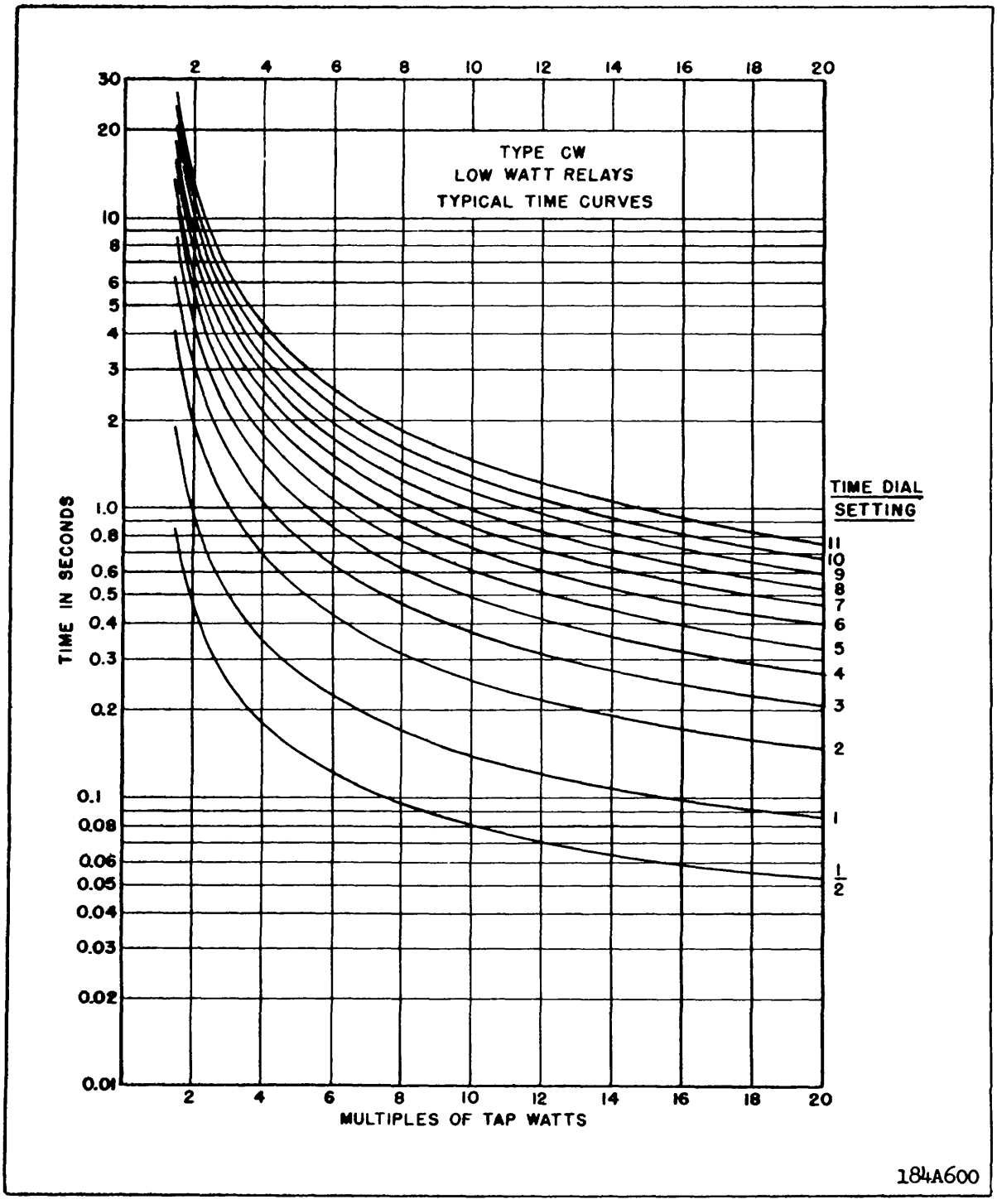


Fig. 3. Typical 60 cycle Time Curves of the 20-120 watt Type CW Relay.

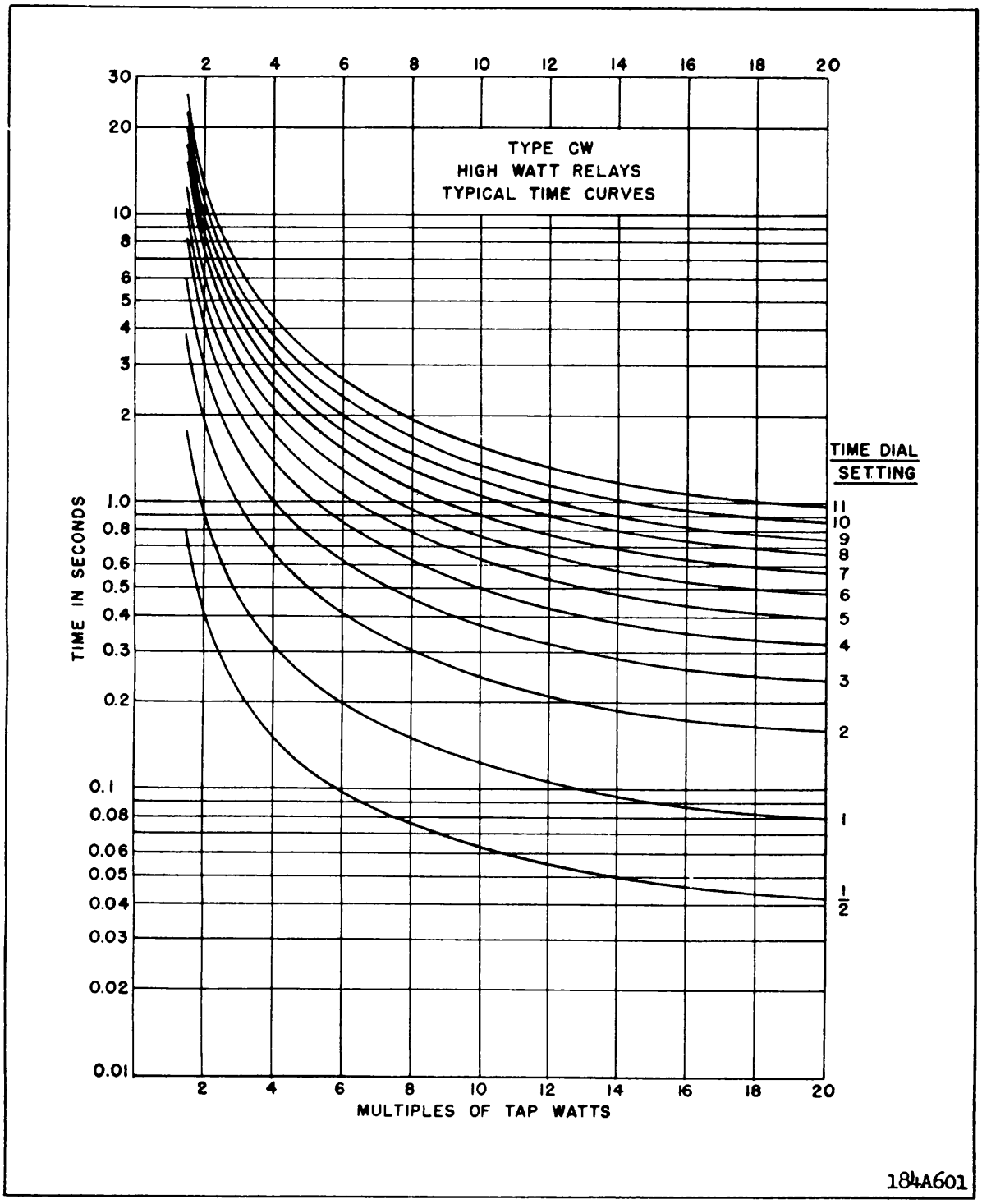


Fig. 4. Typical 60 cycle Time Curves of the 100-600 watt Type CW Relay.

2. The 100-600 Watt, 120 Volt Relay

   A. Potential Circuit Burden at Rated Voltage

Current Lags by	Volt Amperes
20°	5.9

   B. Current Coil Burden at 5 Amperes

TAP	CURRENT LAGS BY	VOLT AMPERES
100	67°	5.4

Current Coil Ratings

	Continuous	1 Sec.
A. 20-120 Watt Range	5 Amperes	230 Amperes
B. 100-600 Watt Range	8 Amperes	370 Amperes

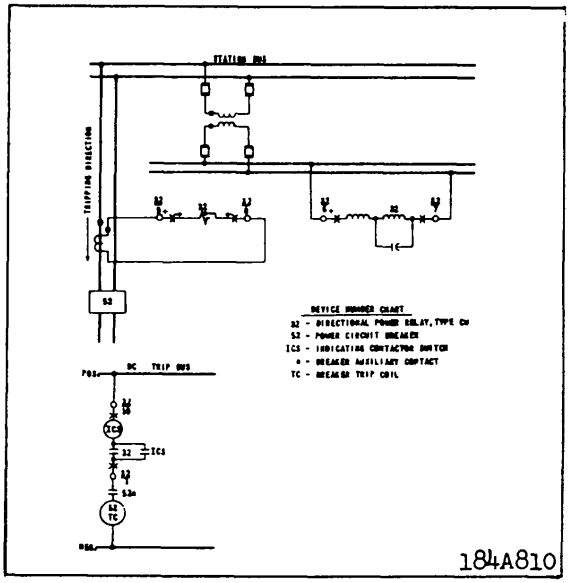


Fig. 5. External Schematic of One Type CW Relay on a Single Phase System.

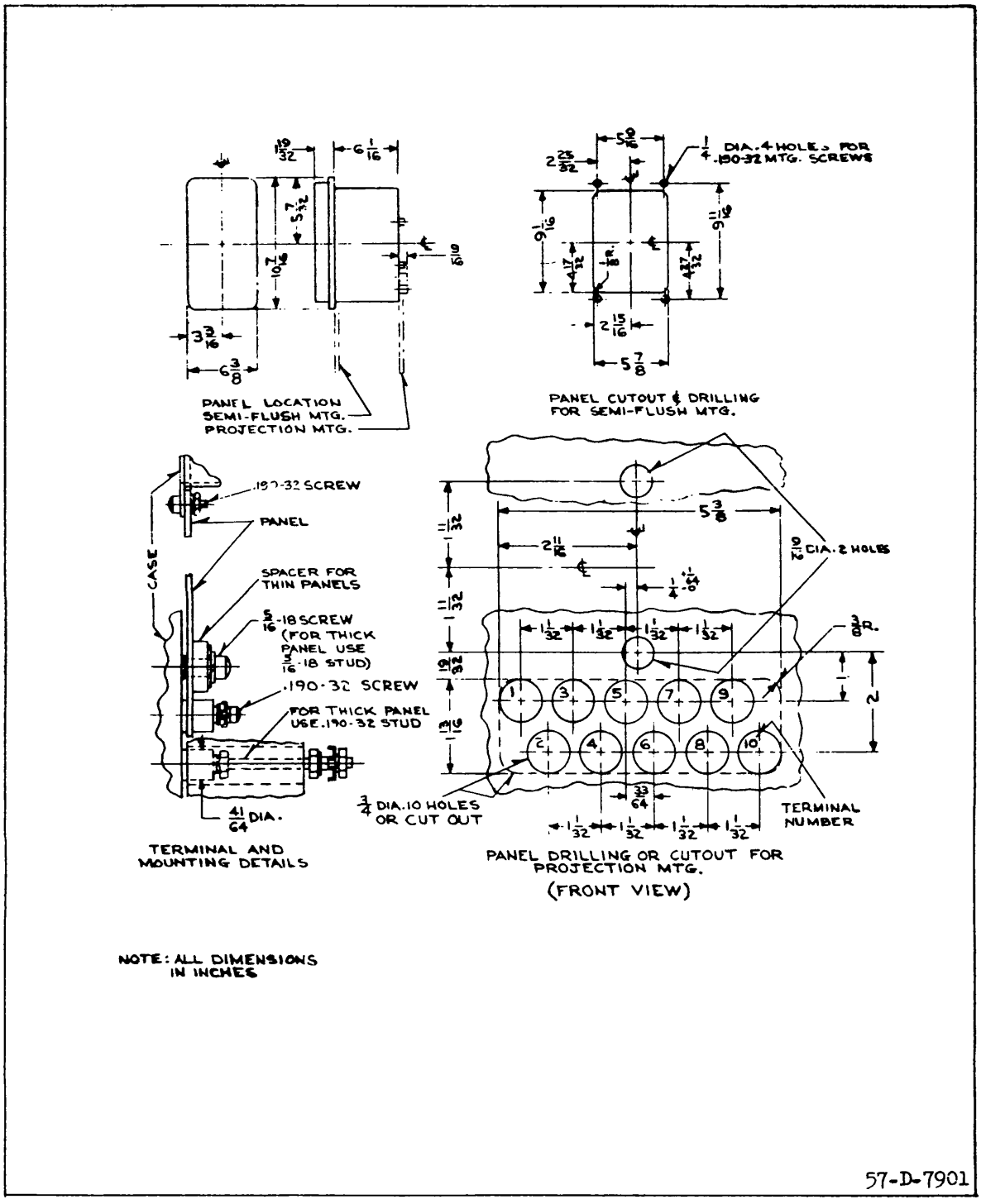


Fig. 6. Outline and Drilling Plan for the Type CW Relay In the Type FT 21 Case.

TYPE CW POWER RELAY 30° CHARACTERISTIC

CAUTION Before putting relays into service, remove all blocking which may have been inserted for the purpose of securing the parts during shipment, make sure that all moving parts operate freely, inspect the contacts to see that they are clean and close properly, and operate the relay to check the settings and electrical connections.

APPLICATION

The type CW relay for three-phase application is a single phase induction type relay providing over power or reverse power protection for electrical equipment or circuits. It is not intended for use as a fault protective relay.

The CW relay for three-phase application uses phase-to-phase voltage and line current, with maximum torque occurring when the relay current leads the relay voltage by 30° at system unity power factor. The relay operates on single phase watts multiplied by $\sqrt{3}$. One CW relay is required for balanced three phase system and three relays are required for unbalanced conditions.

CONSTRUCTION

The relay consists of a product operated unit, a phase shifter and an indicating contactor switch (ICS).

Product Type Unit

The electromagnet for the main element has a tapped current coil located on the center leg of an "E" type laminated structure and two potential coils on the outer legs. Operating torque is obtained by energizing the tapped coil with line current and the two outer coils with line potential from the line potential transformers. Out of phase air gap fluxes necessary for operating torques are produced by a phase shifting network in conjunction with the potential coils. Maximum torque occurs when the current leads the voltage by 30 degrees. The voltage is independent of the direction of power flow. This provides a reference so that the disc can rotate in either direction depending upon direction of the line current. The combination of voltage and current produces an operating torque proportional to power.

Phase Shifter - The phase shifter network consist of a resistor in series with the potential coils.

Indicating Contactor Switch Unit (ICS)

The d-c indicating contactor switch is a small clapper type device. A magnetic armature, to which leaf-spring mounted contacts are attached, is attracted to the magnetic core upon energization of the switch. When the switch closes, the moving contacts bridge two stationary contacts, completing the trip circuit. Also during this operation two fingers on the armature deflect a spring located on the front of the switch, which allows the operation indicator target to drop. The target is reset from the outside of the case by a push rod located at the bottom of the cover.

The front spring, in addition to holding the target, provides restraint for the armature and thus controls the pickup value of the switch.

CHARACTERISTICS

The type CW relays are available in the following ranges and taps:

Volts Line- to Line	$(I_L V_{LL})$ $\sqrt{3}$ single phase watts	
	Range	Taps
120	20-120	20-30-40-60-80-100-120
	100-600	100-150-200-300-400-500-600
208	35-200	35-50-70-100-140-175-200
	175-1000	175-250-350-500-700-875-1000

Typical 60 cycle Time-Power Curves are shown in Figs. 3 & 4. The curves are taken at maximum torque which occurs with the current leading the voltage by 30 degrees. (within ±4°)

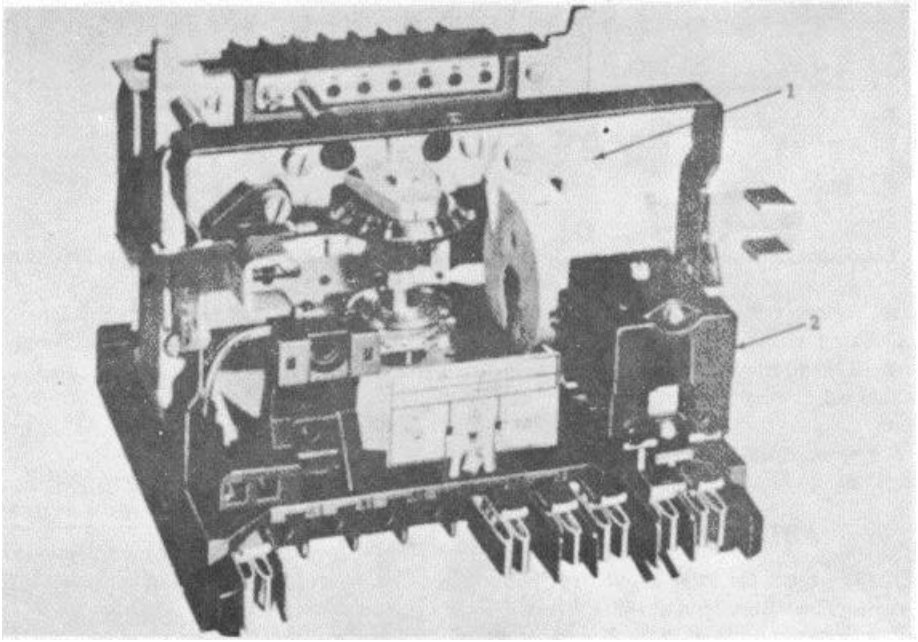


Fig. 1. 1. Time-power unit. 2. Indicating Connector Switch (ICS). Note: Phase shifting resistor is mounted in rear.

Trip Circuit

The main contacts will safely close 30 amperes at 250 volts d-c and the seal-in contacts of the indicating contactor switch will safely carry this current long enough to trip a circuit breaker.

The indicating contactor switch has two taps that provide pickup setting of 0.2 or 2 amperes. To change taps requires connecting the lead located in front of the tap block to the desired setting by means of a screw connection.

Trip Circuit Constant

Indicating Contactor Switch (ICS)

0.2 ampere tap 6.5 ohms d-c resistance

2.0 ampere tap 0.15 ohms d-c resistance

INSTALLATION

The relays should be mounted on switchboard panels or their equivalent in a location free from dirt, moisture, excessive vibration and heat. Mount the relay vertically by means of the four mounting holes on the flange for semi-flush mounting or by means of the rear mounting stud or studs for projection mounting. Either a mounting stud or the mounting screws may be utilized for grounding the relay. The electrical connections may be made directly to the terminals by means of screws for steel panel mounting or to the terminal studs furnished with the relay for thick panel mounting. The terminal studs may be easily removed or inserted by locking two nuts on the stud and then turning the proper nut with a wrench.

SETTINGS

Product Unit

There are two settings to be made. One is the current tap setting, and the second, the time dial setting.

The CW relay for three-phase application has taps which represents single phase watts multiplied by $\sqrt{3}$. The power to operate the relay equals the three phase primary power divided by the quantity $\sqrt{3}$ times the current and potential transformer ratios.

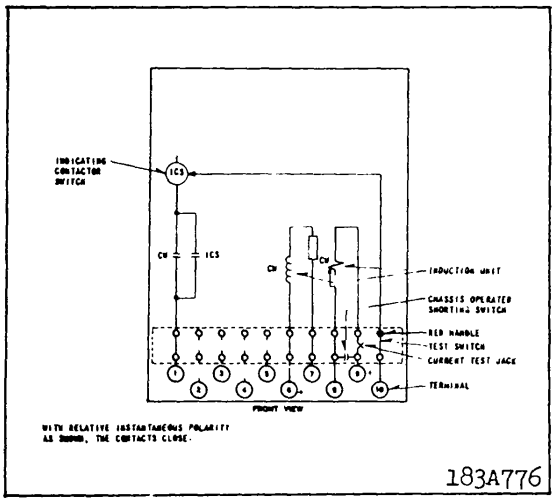


Fig. 2. Internal Schematic of the Type .CW Relay in the Type FT17 Case.

This relay power expressed as multiples of the chosen tap locates a value on the abscissa of the Time-Power Curves of Fig. 3 and 4. The relay operating time for various time dial settings then is observed on the ordinate. By changing taps or time dial, the required operating time can be selected for specific power value.

CAUTION

When changing taps with the relay in service, screw the extra tap screw in the new tap hole before removing the old tap screw. This prevents open circuiting the current transformers.

Indicating Contactor switch (ICS)

No setting is required on the ICS unit except the selection of the 0.2 or 2.0 ampere tap setting. This selection is made by connecting the lead located in front of the tap block to the desired setting by means of the connecting screw.

ADJUSTMENT AND MAINTENANCE

The proper adjustments to insure correct operating of this relay have been made at the factory and should not be disturbed after receipt. If the adjustments have been changed, the relay taken apart for repairs, or if it is desired to check the adjustments at regular maintenance periods, the instructions below should be followed.

All contacts should be cleaned periodically. A contact burnisher S#182A836H01 is recommended for this purpose. The use of abrasive material for cleaning contacts is not recommended, because of the danger of embedding small particles in the face of the soft silver and thus impairing the contact.

Product Unit

Contacts - The index mark on the movement frame will coincide with the "O'.' mark on the time dial when the stationary contact has moved through approximately one-half of its normal deflection. Therefore, with the stationary contact resting against the backstop, the index mark is offset to the right of the "O" mark by approximately .020". The placement of the various time dial positions in line with the index mark will give operating times as shown on the respective time-current curves.

Minimum Trip Watts - Set the time dial to position 6. Using the lowest tap setting, alternately apply tap value watts plus 3% and tap value watts minus 3% with the current leading the voltage by 300. The moving contact should leave the backstop at tap value watts plus 3% and should return to the backstop at tap value watts minus 3%. The relay should be calibrated with 10 times tap value watts at the number six time dial position. Check several points on the typical time curves. Time curve calibration is affected by adjusting the position of the permanent magnet keeper.

Indicating Contactor Switch (ICS)

Close the main relay contacts and pass sufficient d-c current through the trip circuit to close the contacts of the ICS. This value of current should not be greater than the particular ICS tap setting being used. The indicator target should drop freely.

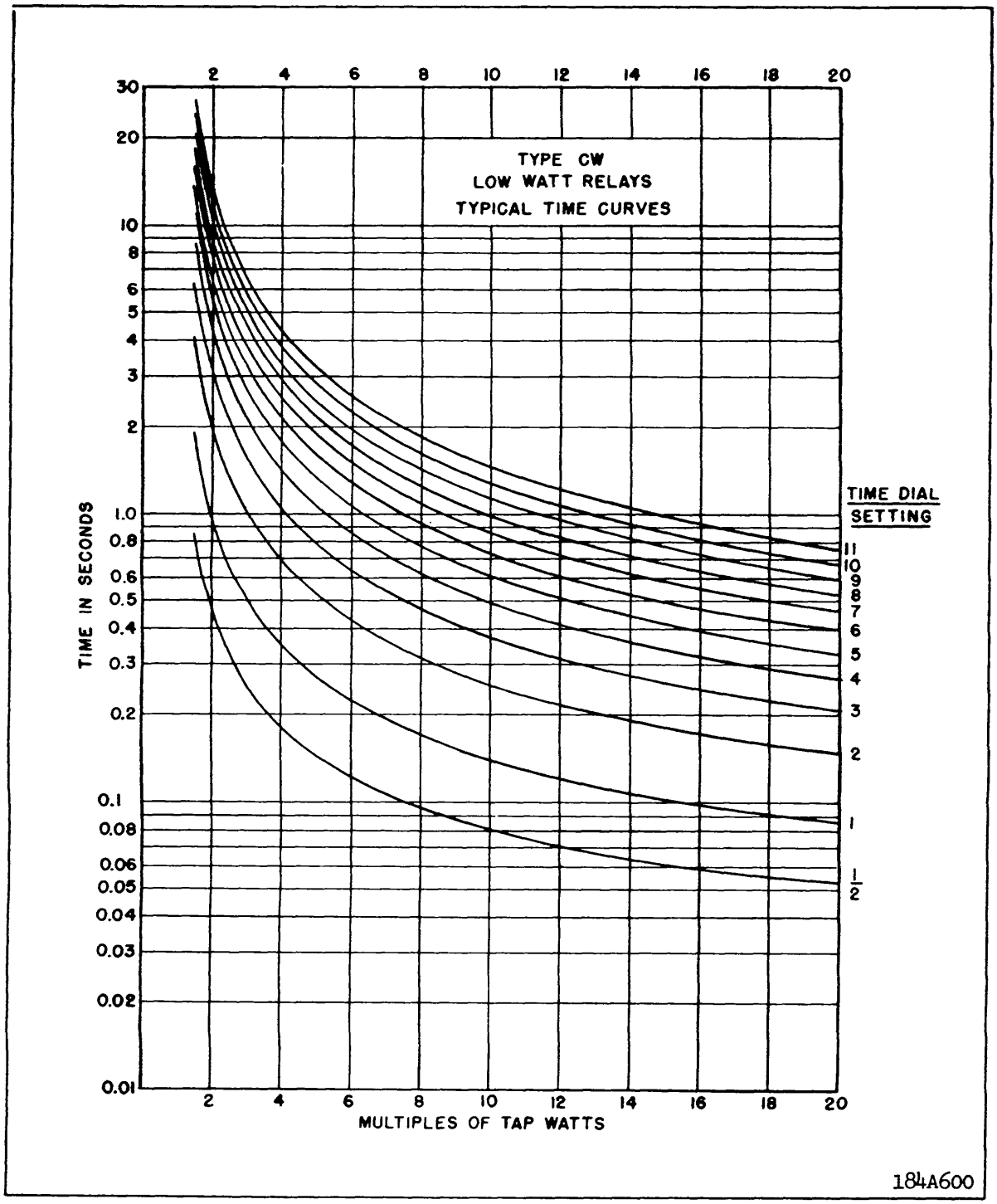


Fig. 3. Typical 60 cycle Time Curves of the 20-120 and 35-200 watt Type CW Relay.

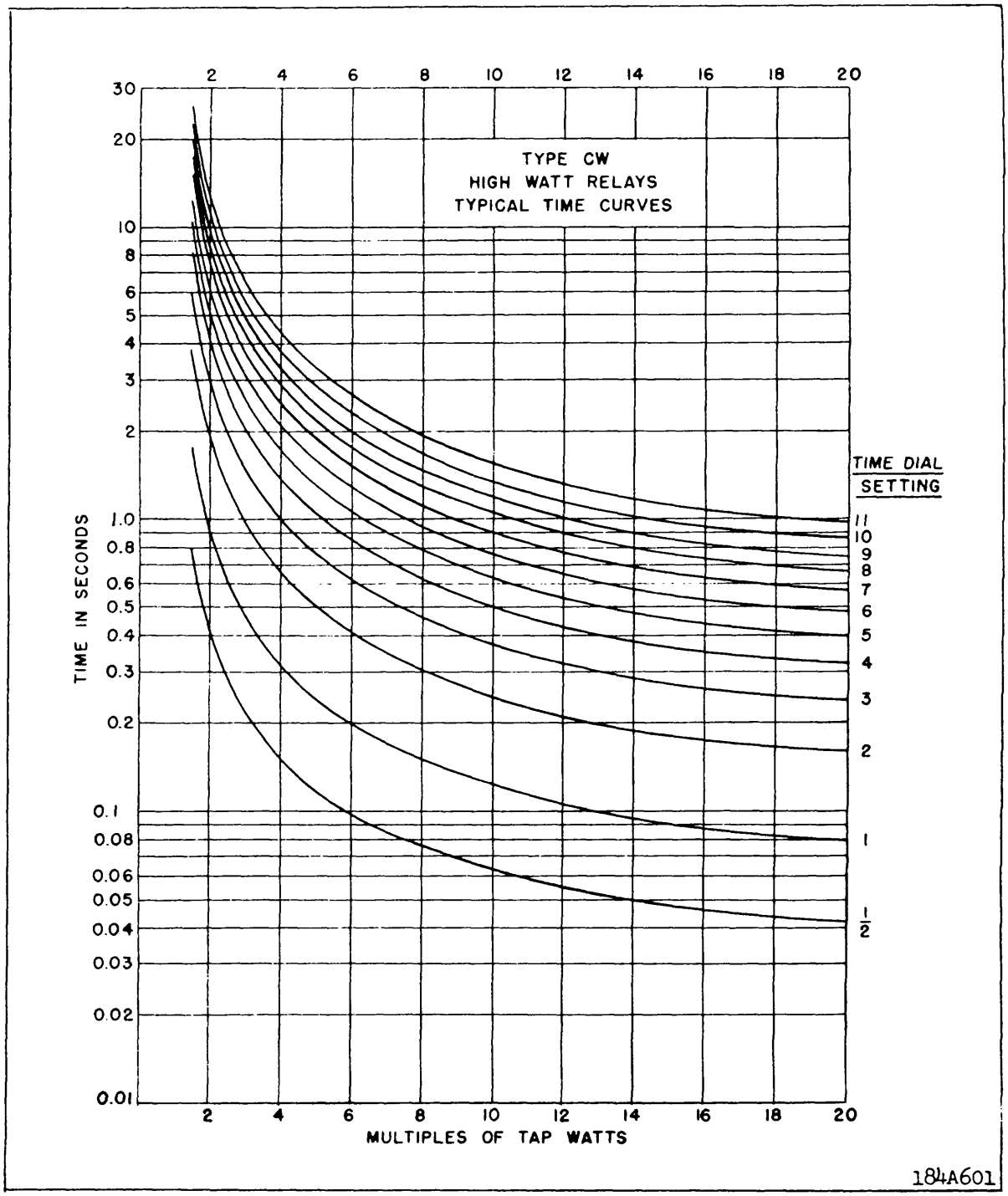


Fig. 4. Typical 60 cycle Time Curves of the 100-600 and 175-1000 watt Type CW Relay.

ENERGY REQUIREMENTS

The 60 cycle burdens of the type CW Relay
Three-Phase Application are as follows:

Relay Range	Potential Circuit			Current Circuit			
Watts	Voltage	Voltamperes	Current lags by	Current	Relay Tap	Voltamperes	Current lags by
20-120	120	20.5	68°	5 amp.	20	16.2	78°
100-600	120	20.5	68°	5 amp.	100	5.4	67°
35-200	206	18.8	59°	5 amp.	35	16.2	78°
175-1000	208	18.8	59°	5 amp.	175	5.4	67°

Current Coil Ratings:

		Continuous	1 Sec.
A.	20-120 Watt Range 35-200 Watt Range	5 Amperes	230 Amperes
B.	100-600 Watt Range 175-1000 Watt Range	8 Amperes	370 Amperes

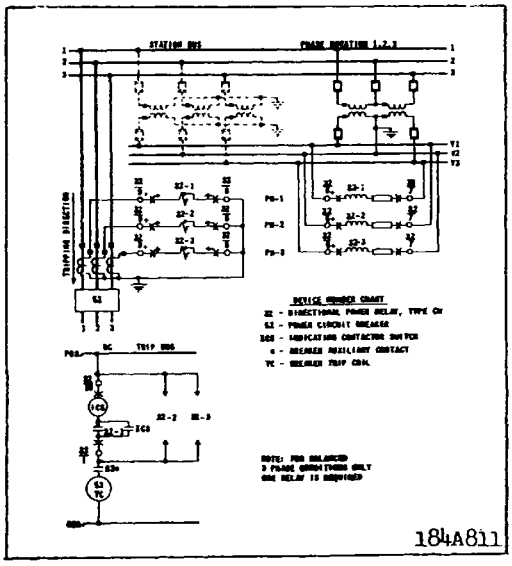


Fig. 5. External Schematic of Three Type CW Relays on a Three-Phase System. Note: For Balanced Three Phase Conditions only One CW Relay is required.

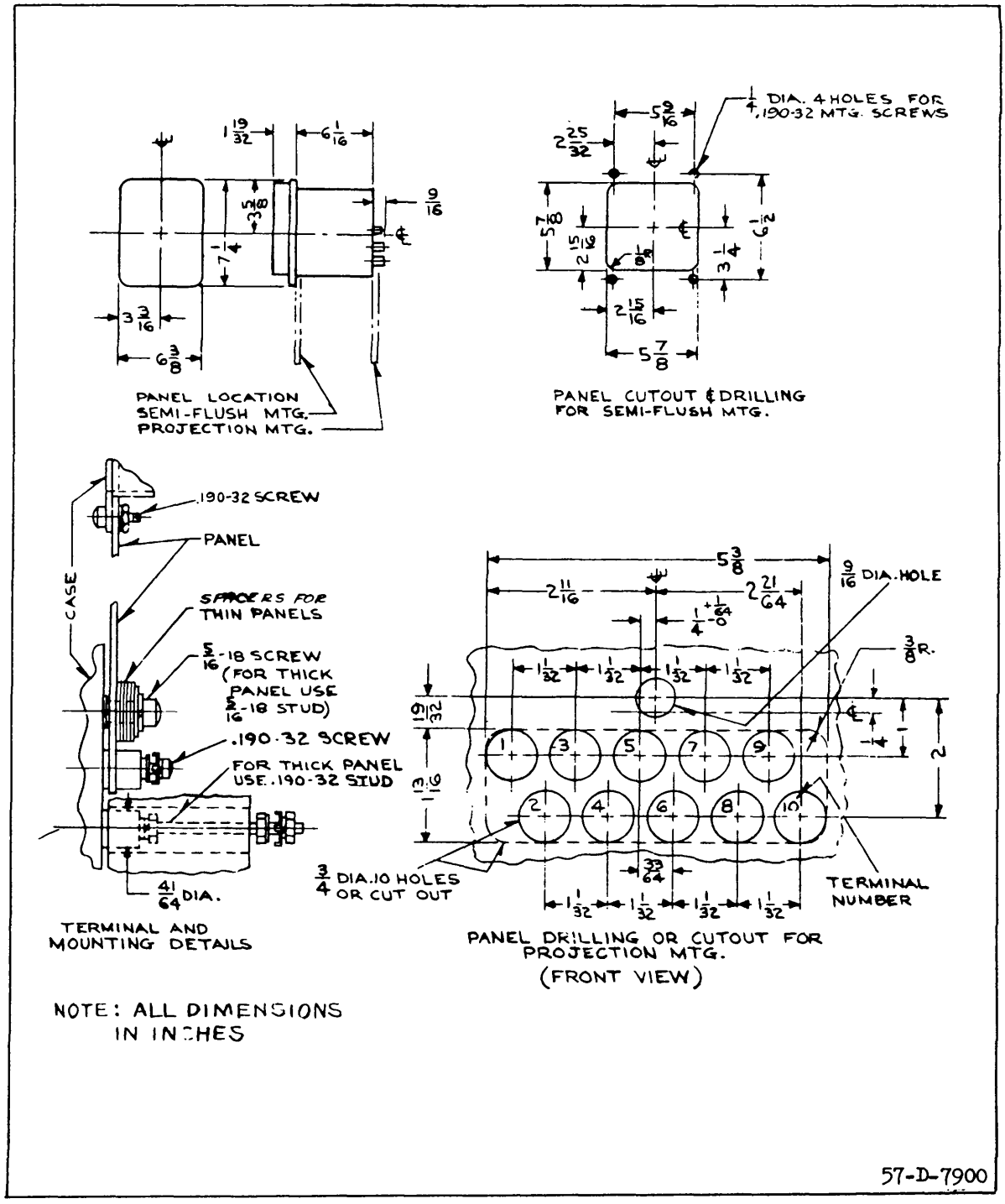


Fig. 6. Outline and Drilling Plan for the Type CW Relay in the Type FT11 Case.

TYPE HU AND HU-1 TRANSFORMER DIFFERENTIAL RELAYS

CAUTION Before putting relays into service, remove all blocking which may have been inserted for the purpose of securing the parts during shipment, make sure that all moving parts operate freely, inspect the contacts to see that they are clean and close properly, and operate the relay to check the settings and electrical connections.

APPLICATION

The types HU and HU-1 relays are high-speed relays used in the differential protection of transformers. These relays can be applied where the magnetizing inrush current to the transformers is severe.

Current transformer ratio error should not exceed 10% with maximum external fault current flowing, or with eight times relay tap current flowing.

The HU-1 relay has three restraint transformers and associated rows of taps; whereas, the HU relay has one less restraint transformer and two rows of taps. Otherwise the two relays are identical. Three winding banks normally require the HU-1 relay, although the auto transformer application uses the HU if the tertiary is not loaded.

Both the HU or the HU-1 are available with a sensitivity of either 0.30 or 0.35 times tap. The 30%-sensitivity relay satisfactorily handles up to 15% mismatch (e.g. ± 10% transformer tap changing plus 5% CT mismatch). The 35%-sensitivity relay handles as much as 20% mismatch. See Fig. 7 for a comparison of the characteristics of the two sensitivities. Any of the relays may be recalibrated in the field to obtain either characteristic.

Ordinarily the 30%-sensitivity relay will suffice; however, where CT mismatch is abnormally high or where the transformer tap-changing range exceeds ± 10%, this calibration may be too sensitive.

CONSTRUCTION

The types HU and HU-1 relays consist of a differential unit (DU), a harmonic-restraint unit (HRU), and an indicating contactor switch (ICS). The principal parts of the relay and their locations are shown in Figs. 1 to 4.

Differential Unit (DU)

The differential unit of the HU relay consists of two air-gap restraint transformers, three full-wave rectifiers, saturating operating-transformer, and a d-c polar unit.

The HU-1 relay, in addition to the above components, has a third air-gap restraint transformer, and a fourth full-wave rectifier.

Each of the restraint transformers and the operating transformer are provided with taps to compensate for mismatch of line current transformers. These taps are incorporated in the relay in such a manner that changing a tap on a restraint transformer automatically changes the same tap on the operating transformer.

Harmonic-Restraint Unit (HRU)

The harmonic-restraint unit of the HU and HU-1 relays consists of an air-gap operating transformer, a second harmonic block filter, a fundamental block-second harmonic pass filter, two full-wave rectifiers, indicating instantaneous trip unit, varistor, and a d-c polar unit.

Taps are also incorporated in this unit to compensate for mismatch of the line current transformers. Changing a tap on the restraint transformer of the differential unit also changes the tap of this unit.

Polar Unit

The polar unit consists of a rectangular shaped

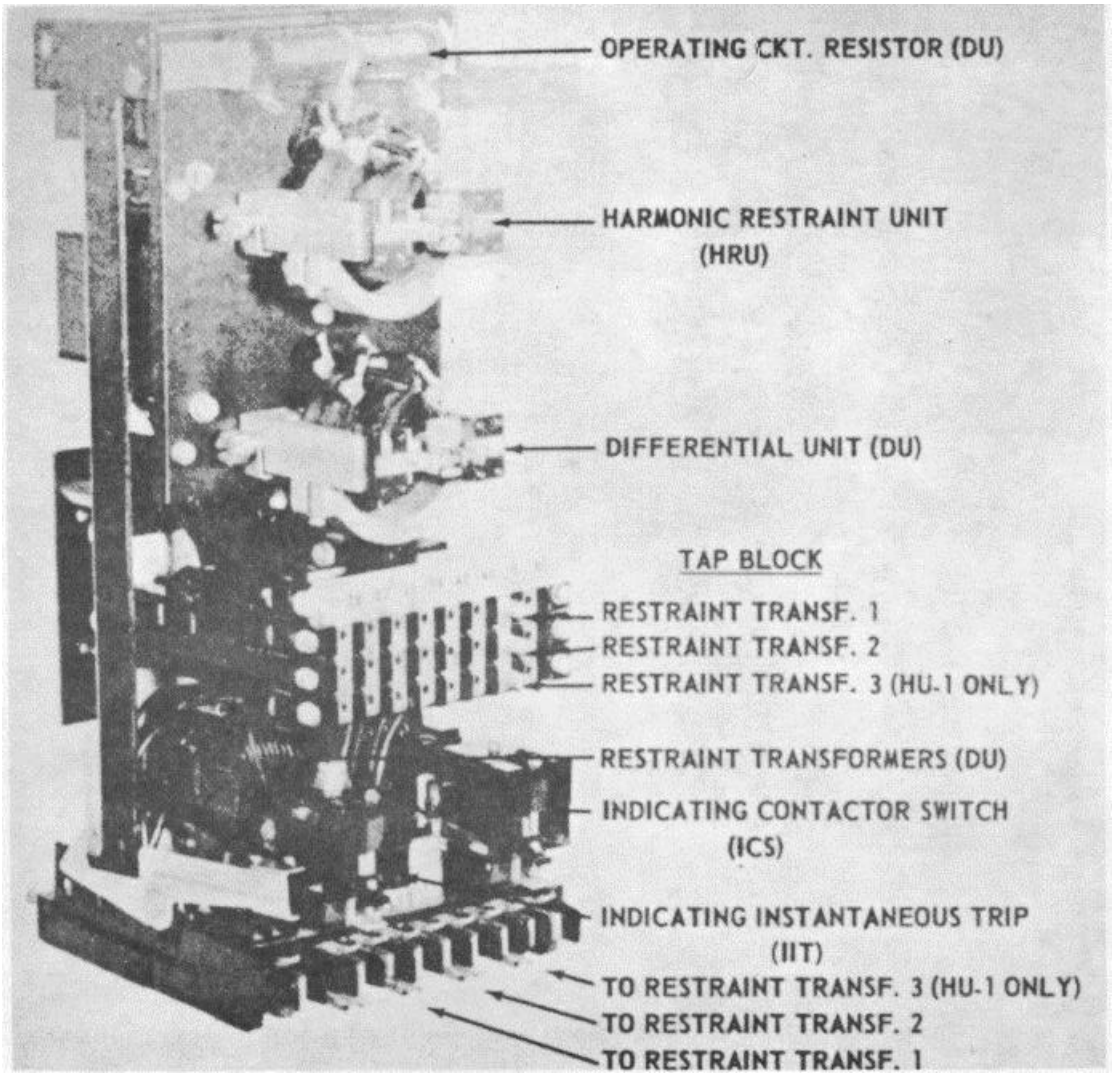


Fig. 1. Type HU-1 Relay - Front View.

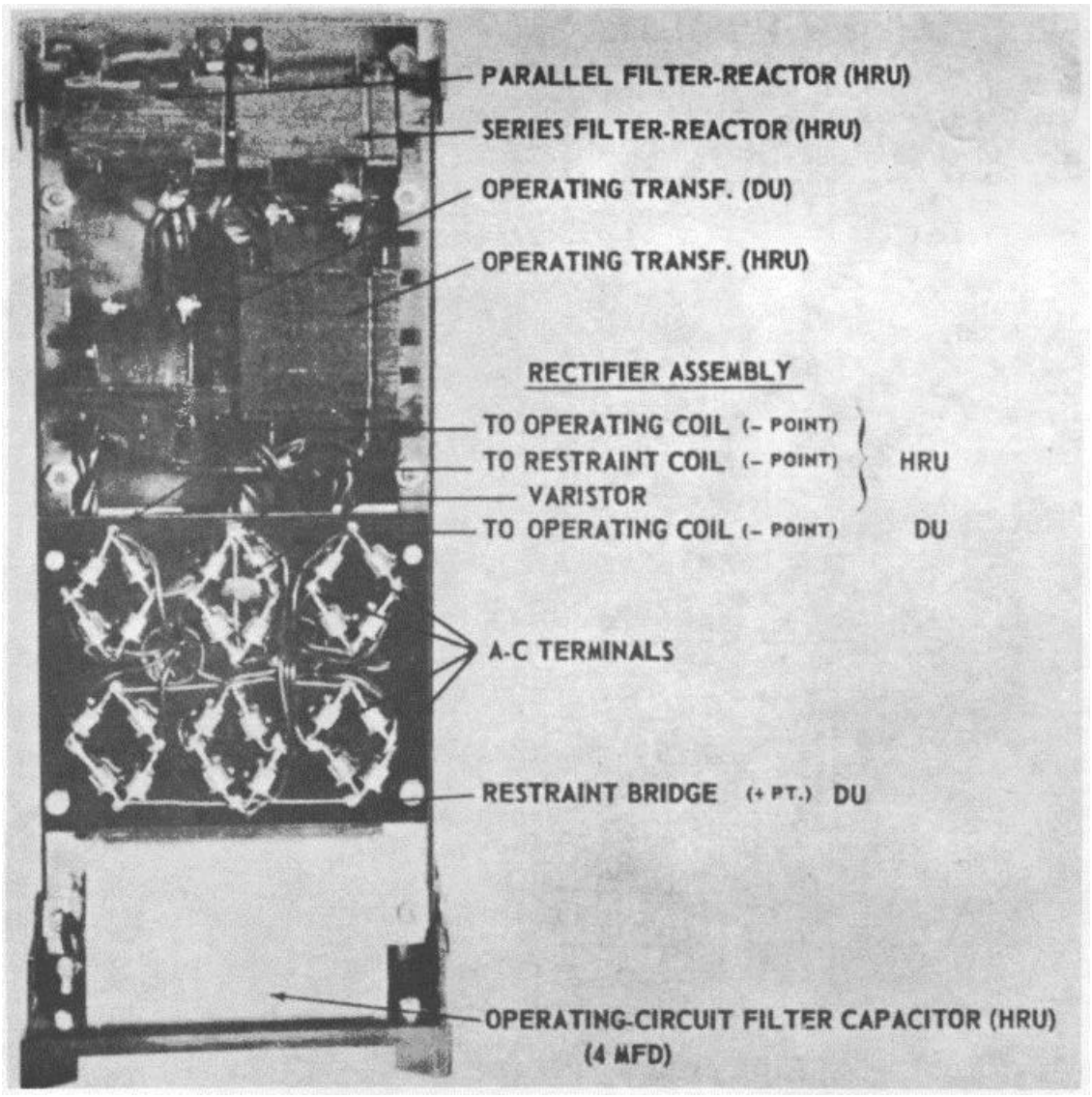


Fig. 2. Type HU-1 Relay - Rear View.

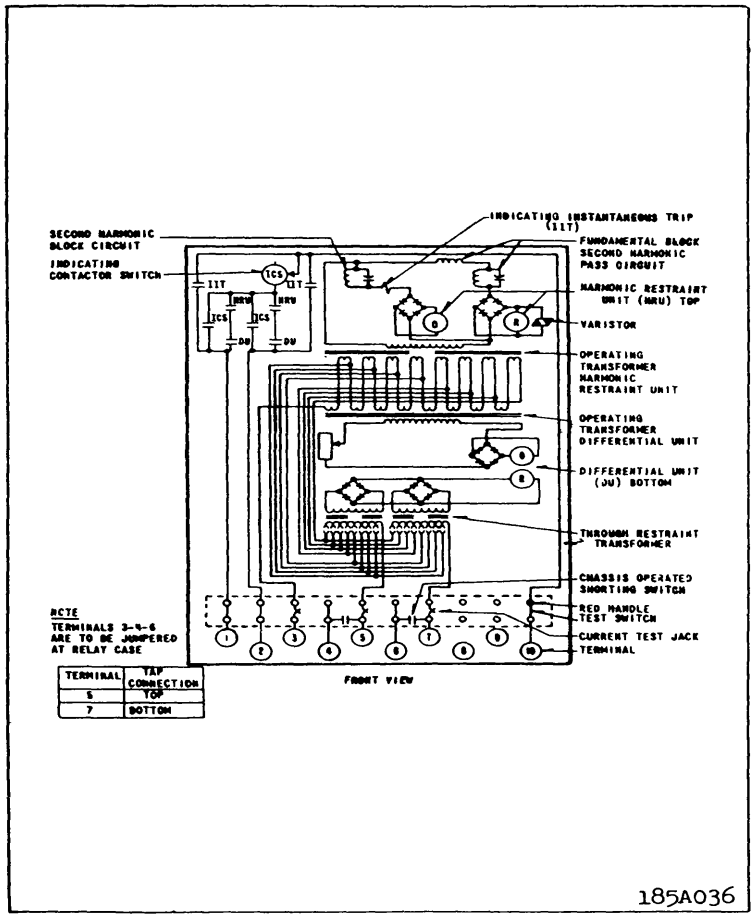


Fig 3. Internal Schematic of the Type HU Relay in FT31 Case. For Single Trip Relays the Circuit Associated with Terminal 2 Ls Omitted, 184A762.

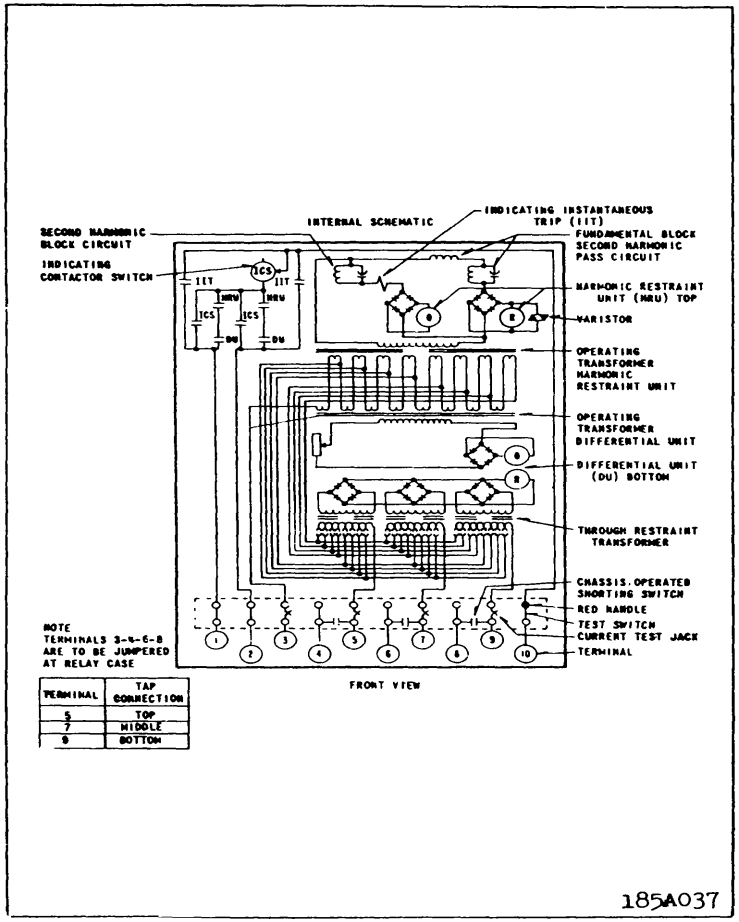


Fig. 4. Internal Schematic of the Type HU.1 Relay in FT31 Case. For Single Trip Relays the Circuit Associated with Terminal 2 is Omitted 184A736.

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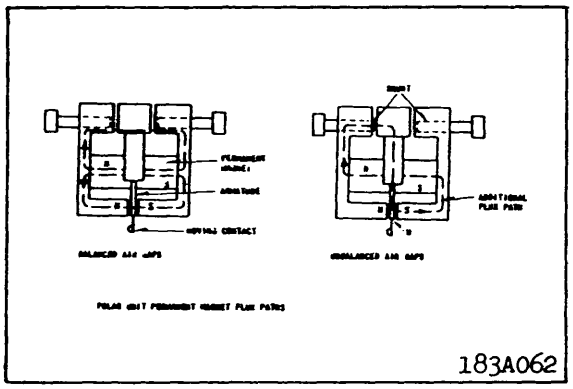


Fig 5. Polar Unit Permanent Magnet Flux Paints

magnetic fame, an electromagnet, a permanent magnet. and an armature. The poles of the crescent shaped permanent magnet bridge the magnet frame. The magnetic frame consists of three pieces joined in the rear with two brass rods and silver solder. These non-magnetic joints represent air gaps, which are bridged by two adjustable magnetic shunts. The windings are wound around a magnetic core. The armature is fastened to this core and is free to move in the front air gap. The moving contact is connected to the free end of a leaf spring, which, in turn, is fastened to the armature.

Indicating Contactor Switch Unit (ICS)

The d-c indicating contactor switch is a small clapper-type device. A magnetic armature, to which leaf-spring mounted contacts are attached, is attracted to the magnetic core upon energization of the switch. When the switch closes, the moving contacts bridge two stationary contacts, completing the trip circuit. Also, during this operation, two fingers on the armature deflect a spring located on the front of the switch, which allows the operation indicator target to drop.

The front spring, in addition to holding the target, provides restraint for the armature and thus controls the pick-up value of the switch.

OPERATION

The types HU and IIU-1 relays are connected to the protected transformer as shown in Fig. 6. In such a connection, the relays operate to protect the transformer for faults internal to the differential zone of the transformer, but not for faults external to the zone. Neither do the relays operate on magnetizing
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inrush currents associated with energization of the transformer, even though these currents may appear as an internal fault. To avoid these false operations, each unit of the relay performs a separate function. The differential unit (DU) prevents operation on external faults, while the harmonic-restraint unit (HRU) prevent operations on magnetizing inrush currents. Hence, the operation of the relay can best be described under the headings of external fault current, internal fault currents, and magnetizing inrush currents.

External Fault Currents

The types HU and tIU-1 relays have a variable percentage characteristic. This means that the operating current required to close the contact of the differential unit expressed in percent of restraint current varies with the magnitude of the larger restraint current. Fig. 7 and Fig. 8 illustrate this characteristic. To use these curves, divide each restraint current by the appropriate tap and enter the horizontal axis using the larger or largest restraint multiple. Then enter the vertical axis, using the difference of the restraint multiples.

With the relay connected as shown in the schematic diagram of Fig. 9a, an external fault causes currents to flow in the air-gap restraint transformers of the differential unit. If the line current transformers do not saturate and the correct ratio matching taps applied, no effective current flows in the operating transformer of the relay. Hence, only a contact opening torque is produced on the differential unit.

On heavy external faults where a main current transformer saturates, current flows in the operating circuit of the relay. With such a condition, the harmonic-restraint unit may or may not close its contacts, depending upon the harmonics present in the false operating current. However, operation of, the relay is prevented by the variable percentage' characteristic of the differential unit, since a large differential current is required to close its contacts during heavy external faults,

Internal Faults

In the case of an internal fault as shown in Fig. 9b, the restraint of the differential unit is proportional to the largest restraint current flowing. The sum of the two restraint currents flows into the operating transformer and produces an excess of operating torque, and the differential unit operates.

In the case of an internal fault fed from one source only, the fault current flows in one restraint

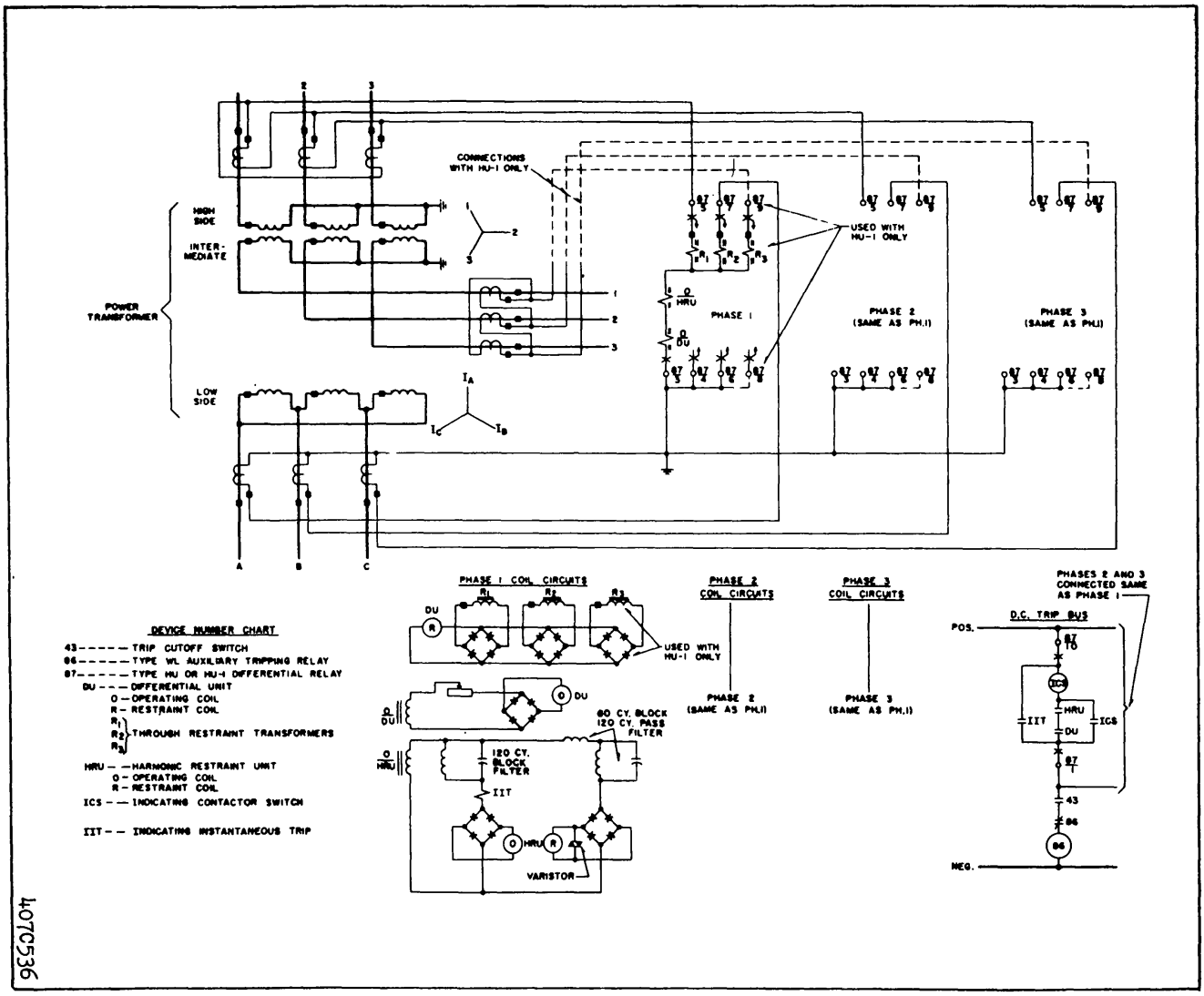


Fig. 6. External Schematic of the Type HU and HU-1 Relays.

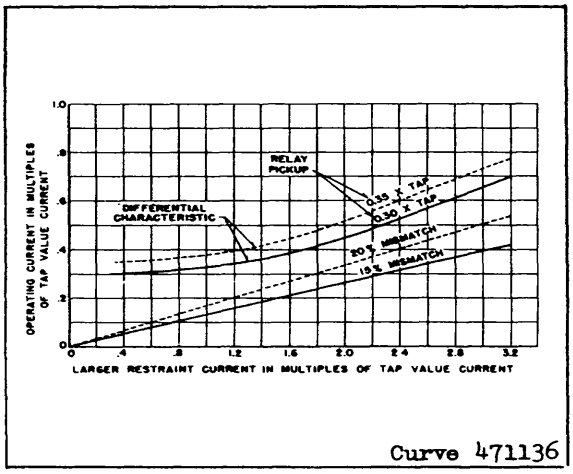


Fig. 7. Differential Characteristic of the DU Unit of the HU and HU-1 Relays at Smaller Values of Current Actual Operating Current Shown for 15 and 20% Mismatch.

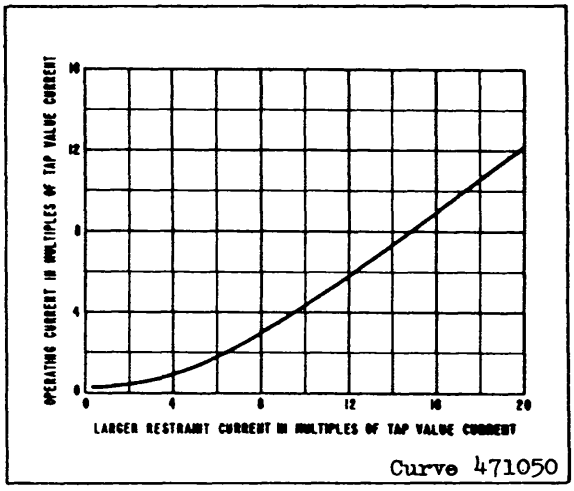


Fig. 8. Differential Characteristic of the Differential Unit (DU) of the HU and HU-1 Relays at Larger Values of Current.

transformer and the operating transformer. An excess of operating torque is produced on the differential unit and it operates.

Faults normally appear as an offset sine wave with a decaying d-c component, and contain very few harmonics. As a result, the harmonic-restraint unit will operate during internal faults to permit tripping of the relay.

For heavy internal faults, the indicating instantaneous trip unit (IIT) will operate before the main unit. Since this unit is connected to an air gap transformer, essentially only the sine wave component of an internal fault is applied to the UT unit. The d. c. component of the fault is bypassed by the transformer primary. For example, an internal fault with a first peak of 28 times tap value (includes fifty percent d. c.) is reduced to a first peak of approximately 14 times tap value (d. c. component absent) on the secondary of the transformer. The UT unit will just operate on this wave since it is set to pick up at a peak current of 14.1 times tap (r m. s. pick-up value = 10 times tap).

The varistor connected across the d. c. side of the restraint rectifier of the harmonic restraint unit prevents excessive voltage peaks from appearing across the rectifiers. These peaks arise through transformer action of the harmonic-restraint polar-unit coils during heavy internal faults. The varisor has a large value of resistance for low voltages, while presenting a low value of resistance for high voltages. This characteristic effectively reduces the voltage spikes on heavy internal faults while not hampering performance during inrush, where the voltage is considerably lower.

Magnetizing Inrush Currents

Magnetizing inrush current waves have various wave shapes. A typical wave appears as a rectified half wave with decaying peaks. In any case, the various wave shapes are rich in harmonics with the second harmonic predominant. Since the second harmonic is always present in inrush waves and not in internal fault waves, this harmonic is used to restrain the harmonic-restraint unit during inrushes. The differential unit may or may not close its contact, depending on the magnitude of the inrush.

When a magnetizing inrush wave is applied to the relay, the d-c component of the wave is by-passed by the air-gap operating transformer. The other components are fed into the filter circuits. The impedance characteristics of these filters are such that the second harmonic component flows into the restraint coil of the polar unit, while the other harmonics flow into the operating coil. The polar unit will not close

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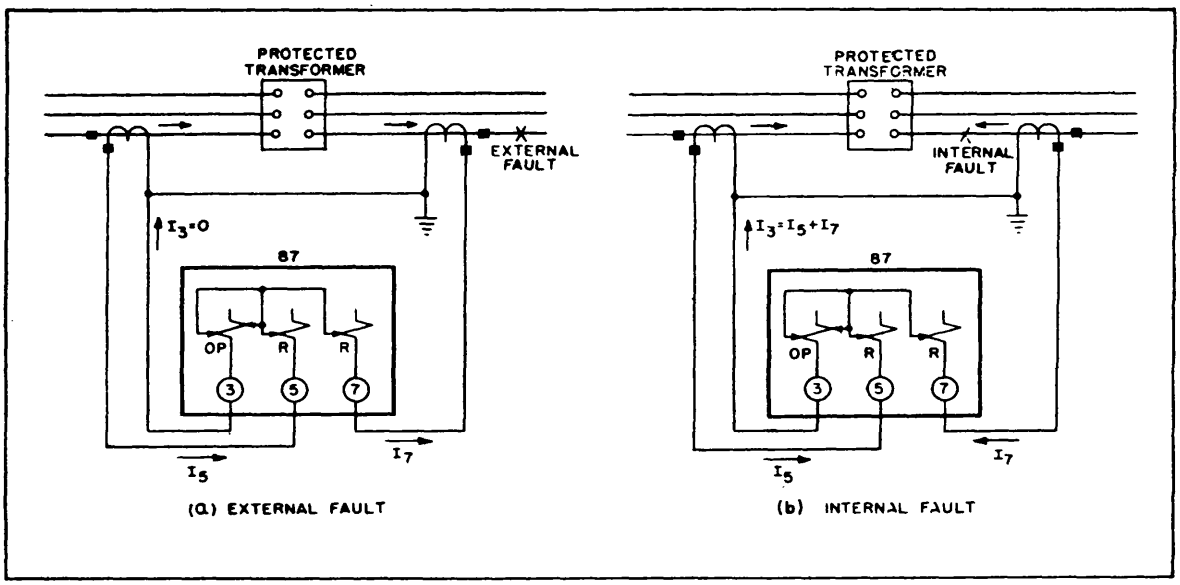


Fig. 9. Simplified Schematic of the Type HU Relay with Current t Distribution or (a) External Fault (b) Internal Fault.

its contacts unless the second harmonic content is less than 15 percent of the fundamental component.

The indicating instantaneous trip unit (IIT) will not operate on inrush. The air-gap transformer will bypass the d. c. component of the inrush thereby reducing the magnitude of the wave applied to the IIT unit. IU the inrush has an initial peak of 16 times tap-value current, the air-gap transformer will reduce this peak to approximately 8 times tap value on the secondary of the transformer. Since the UT unit is set for a peak value of 14.1 times tap (r. m. s. pick-up value = 10 times tap), it will not operate on this Inrush.

Breaker Maintenance

Before some of the CT's are bypassed for breaker maintenance the trip circuit should be opened, as shown in Fig. 6. Otherwise the false-unbalanced current will cause the relay to trip. It is not necessary to short-circuit the relay operating circuit since it has an adequate continuous-current rating. (See "Energy Requirements").

CHARACTERISTICS

Taps are incorporated in the HU and HU-i relays to compensate for main current transformer mismatch.

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These taps are as follows: 2.9, 3.2, 3.5, 3.8, 4.2, 4.6, 5.0, 8.7.

To measure the effective unbalance, a sensitive low-reading voltmeter (5000 ohms per volts) can temporarily be connected across the operating coil resistor (at top of case). With a perfect balance the voltmeter reading will be zero. The reading should not exceed the values indicated by the 15% mismatch curve in Fig. 10 when the relay pickup is 0.30 times tap. If the amount of mismatch is measured or calculated, the measured voltage can be checked against the interpolated value from the curve. For example, assume that the larger restraint current is measured as 1.5 tap multiple and the calculated mismatch is 7%. Then, from Fig. 10 the measured voltage should be approximately 1.0 volts. Use Fig. 11 if the pickup is 0.35 times tap.

Pickup of the harmonic-restraint unit and the differential unit is either 30 or 35% of tap value current. Pickup of the indicating instantaneous trip unit is ten times tap value current.

Components of the harmonic-restraint unit are selected such that 15% second harmonic will prevent operation of the unit. This factor is adequate to prevent false operation on Inrushes

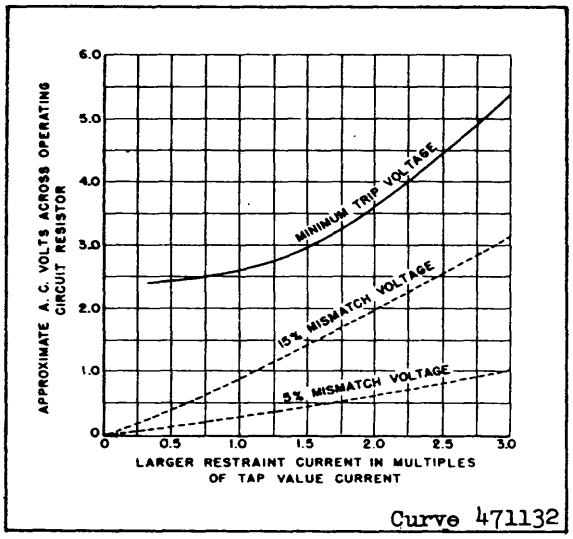


Fig. 10. Differential Voltage Characteristic of the DU Unit of the HU and HU-7 Relays with a Pickup of 0.30 Times Tap.

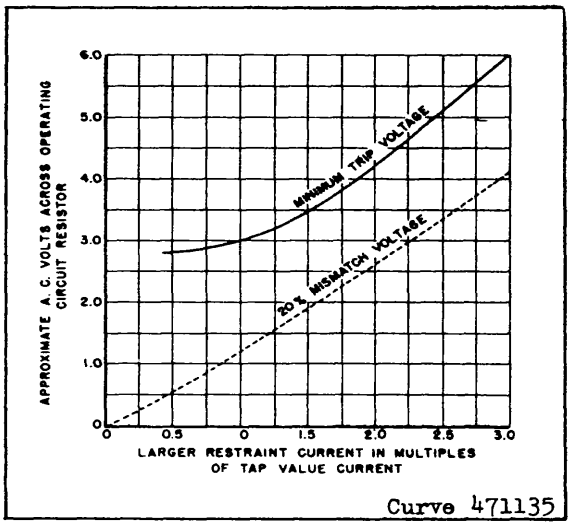


Fig. 11. Differential Voltage Characteristic of the DU Unit of the HU and HU-1 Relays with a Pickup of 0.35 Times Top.

The frequency response of the HU and HU-1 relays is shown in Fig. 13.

Trip Circuit

The main contacts will safely close 30 amperes at 250 volts d-c, and the seal-in contacts of the indicating contactor switch will safely carry this current long enough to trip a circuit breaker.

The indicating contactor switch has two taps that provide a pick-up setting of 0.2 or 2 amperes. To change taps requires connecting the lead located in font of the tap block to the desired setting by means of a screw connection.

SETTING

To set the relay, calculations must be performed as shown under "Setting Calculations". After the correct tap is determined, connections can be made to the relay transformers by placing the connector screws in the various terminal-plate holes in front of the relay. Only one tap screw should be inserted in any horizontal row of taps.

Indicating Contactor Switch (ICS)

No setting is required on the ICS unit except the selection of the 0.2 or 2.0 ampere tap setting. This selection is made by connecting the lead located in front of the tap block to the desired setting by means of the connecting screw. When the relay energizes a 125or 250-volt d-c type WL relay switch, or equivalent, use the 0.2-ampere tap; for 48 volt DC applications set relay in 2 tap and use Type WL Relay coil S#304C209G01 or equivalent.

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Indicating Instantaneous Trip (IIT)

No setting is required on the indicating instantaneous trip unit. This unit is set at the factory to pickup at 10 times tap value current.

SETTING CALCULATIONS

Select the ratio matching taps. There are no other settings. In order to calculate the required tap settings and check current transformer performance the following information is required.

Required Information

1. Maximum transformer power rating (KVA)M

2 Maximum external fault currents

3.Voltage ratings of power transformer (VH, VI, VL)

4 Current transformer ratios, full tap (NT)

5. Current transformer "10L" accuracy class

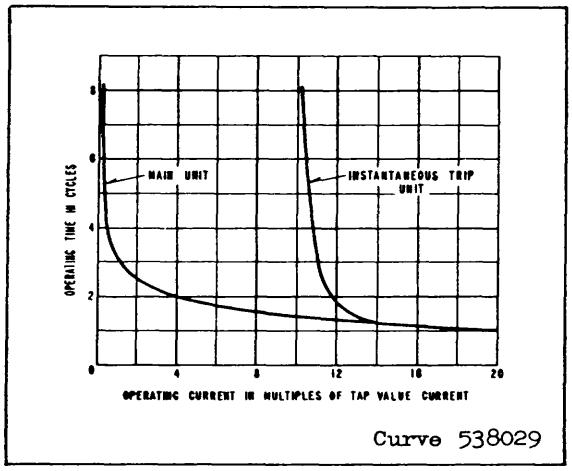


Fig. 12. Typical Tripping Time Characteristic (60 Cycle Currents).

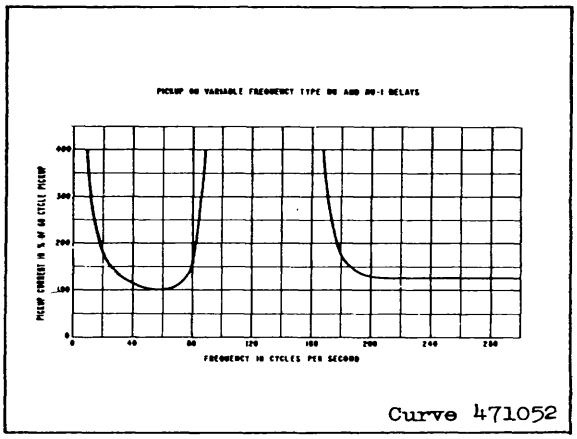


Fig. 13. Typical Frequency Response of the HU and HU-1 Relays.

voltage, (or excitation or ratio-overcurrent curve)

6. One way current transformer lead resistance at 250C (RL) (when using excitation curve. include CT winding resistance)
7. Current transformer connections(wye or delta)

Definitions of Terms

IP = Primary current at (KVA)M

IR Relay input current at (KVA)M

IRH, IRL, IRI are same as IR except for high, low and intermediate voltage sides respectively.

IS= CT secondary current at (KVA)M

TH, TL, T1 = Relay tap settings for high, low and intermediate voltage windings, respectively.

N = Number of current transformer turns that are In use.

Np = N/NT (Proportion of total turns in use)

NT = Current transformer ratio, full top

VCL - 10L accuracy class voltage

ZA = Burden impedance of any devices other than the HU or IHU1 relays, with maximum phase to-phase or 3-phase current flowing.

ZT = Total secondary burden in ohms (excluding current transformer winding resistance, except when using excitation curve)

.

Calculation Procedure

1. *Select current transformer taps*, where multiratio types are used.

   IR should be more than 2.9 amperes for high sensitivity and should not exceed the relay continuous rating (see "Energy Requirements"). For determining the required continuous rating of He relay, use the expected two-hour maximum load, since the relay reaches final temperature in this time.

2. *Select relay taps in proportion to the relay* currents, IR.

   IR should not exceed relay continuous rating. Also the maximum external fault current should not exceed 20 times relay tap.

3. Determine Mismatch (Not to exceed 15%) For 2 winding banks:

$$\% \text{ mismatch} = 100 \frac{(IRL/IRH)-(TL/TH)}{S} \quad (1)$$

where S is the smaller of the two terms, (IRL/IRH) or (TL/TH)

For 3 winding banks:

$$\% \text{ mismatch I- } 100 \frac{(IRH/IRI)-(TH/TI)}{S} \quad (2)$$

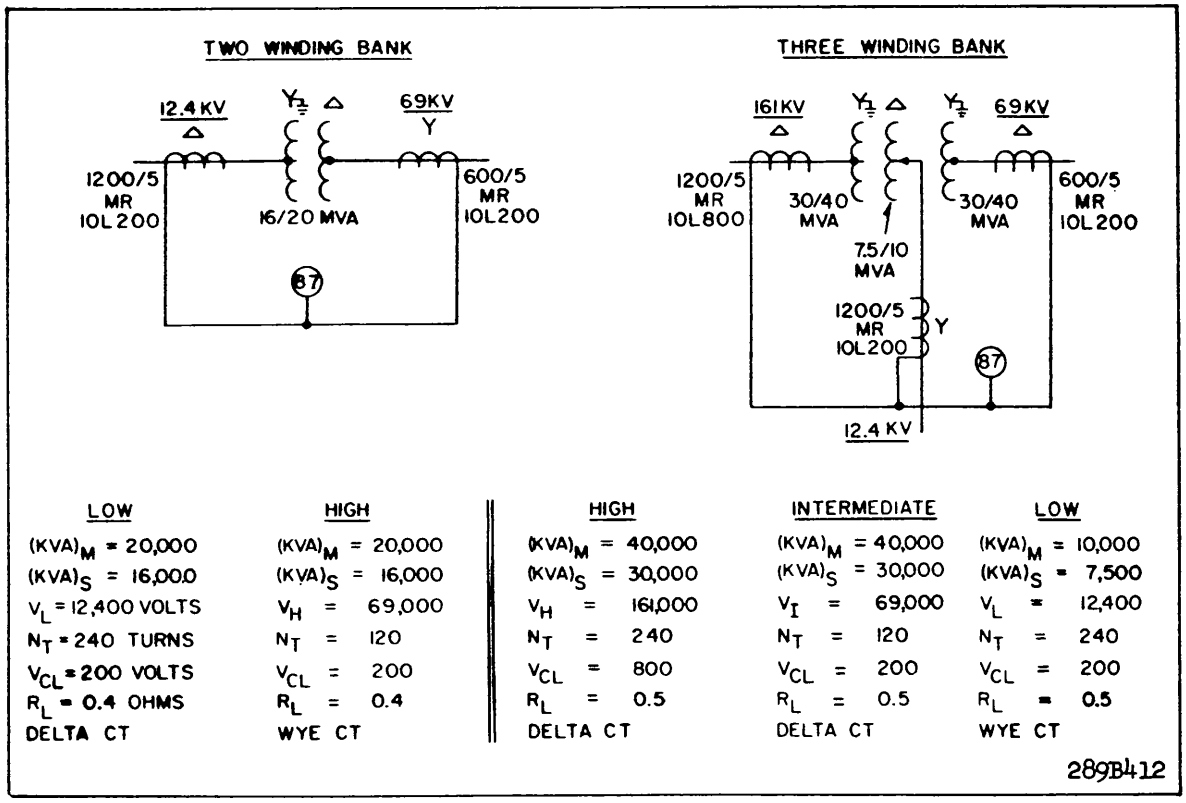


Fig. 14. Example for Setting Calculations.

where "S" is the smaller of the two terms, (IRH /IRI) or (TH/TI).

Equations similar to eq. (2) apply for mismatch from the high to low and from the intermediate to low voltage windings.

Where tap changing under load is performed the relays should be set on the basis of the middle or neutral tap position. The total mismatch, including the automatic tap change should not exceed 15% with a 30% sensitivity relay, and 20% with a 35% sensitivity relay. Note from Fig. ' that an ample safety margin exists at these levels of mismatch.

4. Check current transformer performance. Ratio error should not exceed 10% with maximum symmetrical external fault current flowing or with 8 times relay tap current flowing. An accurate method of determining ratio error is to use ratio-correction-factor curves (RCF)

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A less accurate, but satisfactory method is to utilize the ASA relaying accuracy classification. If the 10L accuracy is used, performance will be adequate if:

$$\frac{NpV_{CL}}{100} \text{ is greater than } ZT \qquad (3)$$

For wye-connected CT:

ZT = lead resistance + relay burden + ZA

$$= 1.13\ RL + \frac{0.15}{T} + ZA \text{ ohms} \qquad (4)$$

(RL multiplier, 1.13, is used to account for temperature rise during faults $\frac{0.15}{T}$ is an approximation, where T - relay tap.

ZA is any additional burden, when maximum external 3-phase fault current is flowing).

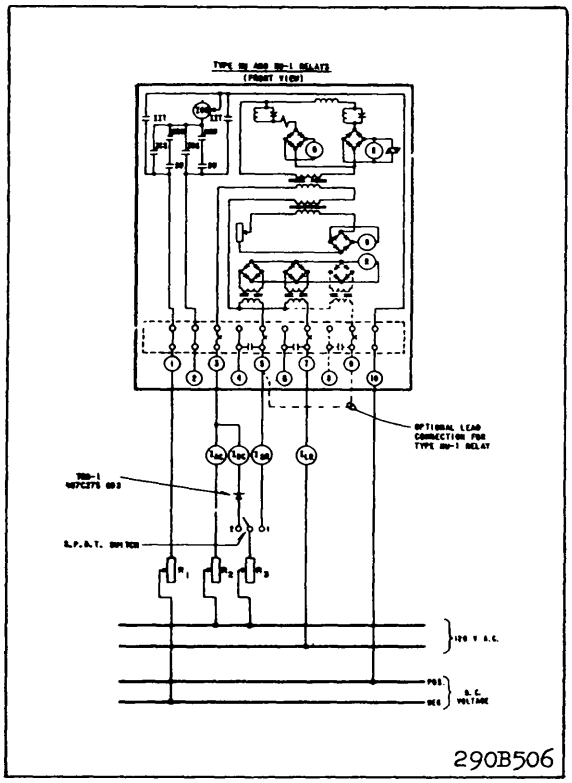


Fig. 15. Test Circuit of the HU and HU-I Relays.

For delta-connected CT:

$$ZT = 3(1.13RL + \frac{0.15}{T} + ZA)\text{ohms}$$

$$= 3.4\ RL + \frac{0,45}{T} + 3ZA \qquad (5)$$

(The factor of 3 accounts for conditions existing during a phase-to-phase fault. ZA is any additional burden, when maximum external phase to phase fault current is flowing)

5. ***Examples***

Refer to pages 13 and 14 and figure 14 for setting examples Note in both examples that the 8.7 tap was selected as the first step in selecting relay taps. If a lower tap such as tap 5 had been the first selection, a proper

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balance would have been impossible. On page 12 for the two winding bank,

IRL=8.05 -= 1.92. With tap 5 for the low side
IRH 4.18
the maximum current ratio that can be matched

$$\frac{5}{2.9} = 1.73$$

by the taps is . With tap 8.7 selected for the low side, a 3 to 1 current ratio can be matched. On page 13 for the three winding bank,

$$\frac{IRL}{IRH} = 3.02$$

This current ratio can be accommodated by the 8.7 & 2.9 taps without excessive mismatch.

INSTALLATION

The relays should be mounted on switchboard panels or their equivalent in a location free from dirt, moisture, excessive vibration, and heat. Mount the relay vertically by means of the four mounting holes on the flange for semi-flush mounting, or by means of the rear mounting stud or studs for projection mounting. Either a mounting stud or the mounting screws may be utilized for grounding the relay. The electrical connections may be made directly to the terminals by means of screws for steel panel mounting or to the terminal studs furnished with the relay for thick-panel mounting. The terminal studs may be easily removed or inserted by locking two nuts on the stud and then turning the proper nut with a wrench.

ADJUSTMENTS AND MAINTENANCE

The proper adjustments to insure correct operation of this relay have been made at the factory and should not be disturbed after receipt.

Acceptance Tests

The following check is recommended to insure that the relay is in proper working order. All checks can best be performed by connecting the relay per the test circuit of Fig. 15. Relay to be tested in case.

1. Minimum Trip Current. With switch open and relay set on 5ampere tap, apply 1.35 to 1.65 amperes for the 30%-sensitivity relay and 1.6 to 1.9

TWO-WINDING TRANSFORMER CALCULATIONS
(See Figure 14)

	LOW	HIGH
1. Select CT Ratio:		
$I_P = \frac{(KVA)}{\frac{V\sqrt{3}}{1000}}$	$\frac{20{,}000}{12.4\sqrt{3}}$ = 930 Amp.	$\frac{20{,}000}{69\ V\sqrt{3}}$ = 167 Amp.
Select Ratio	1000/5 (N = 200)	200/5 (N = 40)
2. Select Relay Taps:		
$I_S = \frac{I_P}{N}$ =	$\frac{930}{200}$ = 4.65 Amp.	$\frac{167}{47}$ = 4.18 Amp.
I_R =	I_{RL} = 4.65 $\sqrt{3}$ = 8.05 Amp.	I_{RH} = 4.18 Amp.
Select Tap	T_L = 8.7	
		$T_H = \frac{4.18}{8.05} \times 8.7 = 4.64$
Desired Tap		T_H = 4.6
3. Determine Mismatch:		
% Mismatch =		
$100\ \frac{(I_{RL}/I_{RH}) - (T_L/T_H)}{T_L/T_H}$ =	$100\ \frac{(8.05/4.18) - (8.7/4.6)}{8.7/4.6}$	
	$100\ \frac{1.92 - 1.89}{1.89}$	
	1.6%	
4.Check CT Performance		015
Z_T =	$3.4\ R_L + \frac{0.45}{T}$ =	$1.13\ R_L + \frac{0.15}{T}$ =
	$3.4 \times 0.4 + \frac{0.45}{8.7} = 1.36 + 0.05$ =	$1.13 \times 0.4 + \frac{0.15}{4.6} = 0.45 + 0.03$ =
	1.41 ohms	0.48 ohms
$Np = \frac{N}{N_T}$	$\frac{200}{240}$ = 0.833	$\frac{40}{120}$ = 0.333
$\frac{Np\ V_{CL}}{100}$	$\frac{0.833 \times 200}{100}$ = 1.67	$\frac{0.333 \times 200}{100}$ = 0.67
$(Np\ V_{CL}/100) > Z_T$	Yes	Yes

THREE-WINDING TRANSFORMER CALCULATIONS
(See Figure 14)

	HIGH	INTERMEDIATE	LOW
1. Select CT Ratio: $\frac{I_P(KVA)_{M=}}{V\sqrt{3}}$ / 1000	$\frac{40{,}000}{161\sqrt{3}}$=143 Amp.	$\frac{40{,}000}{69\sqrt{3}}$=334 Amp.	$\frac{10{,}000}{12.4\sqrt{3}}$=465 Amp.
Select Rato	400/5 (N 80)	600/5 (N = 120)	1000/5 (N = 200)
2. Select Relay Taps: $I_{S=}\ \frac{Ip}{N}$ =	$\frac{143}{80}$=1.78 Amp.	$\frac{334}{120}$=2.78 Amp.	$\frac{465}{200}$= 2.32 Amp (AT 10 MVA
IR (At 40 MVA) =	$I_{RH=}$1.78 $\sqrt{3}$ = 3.08 Amp.	I_{RI} = 2.78 $\sqrt{3}$. = 4.82 Amp.	I_{RL}=40.X $\frac{2432}{10}$ = 9.3 Amp.
Select Tap			T_L = 8.7
Desired Tap	T_H = 8.7 $\frac{3.08}{9.30}$ = 2.88	T_I = 8.7 $\frac{4.82}{9.30}$ = 4.52	
Select Tap	T_H = 2.9.	T_I = 4.6	
3. Determine Mismatch			
% Mismatch	$\frac{100\ (I_{RH}/I_{RI}(T_H/T_I)=}{T_H/T_I}$	$\frac{100\ (I_{RI}/I_{RL}(T_I/T_L)=}{(I_{RI}/I_{RL})}$	$\frac{100\ (I_{RL}/I_{HT}/T_L/T_H)=}{T_L/T_H}$
	100 $\frac{(3.08/4.82)-(2.9/4.6)}{2.9/4.6\ 4}$	100 $\frac{(4.82/9.30)-(4.6/8.7)}{82/9.30}$	100 $\frac{(9.3/3.08)-(8.7/2.9)}{8.7/2.9}$
	100 $\frac{640\text{-}0.630}{0.630}$=	100 $\frac{0.5180.528}{0.518}$=	100 $\frac{3.02\text{-}3.00}{3.00}$=
	1 6%	1.9%	0.67%
4. Check CT Performance			
Z_T =	$\frac{3.4\ R_L + 0.45}{T}$=	$\frac{3.4\ R_L + 0.45}{T}$=	$\frac{1.13R_L + 0.15}{T}$ =
	3.4 X 0.5 + $\frac{0.45}{2.9}$=	3.4 X 0.5 + $\frac{0.45}{4.6}$=	1.13 X 0.5 + $\frac{0.15}{8.7}$=
	1.70 + 0.16 =	1.70 + 0.10=	0.585 + 0.02=
	1.86 ohms	1.80 ohms	0.58 ohms
$N_{P=}N=\frac{}{N_T}$	$\frac{80}{240}$ =0.333	$\frac{120}{120}$ =1.0	$\frac{200}{240}$=0.833
(Np V_{CL})	$\frac{800\ X\ 0.333}{100}$=2.67	$\frac{200\ X\ 1.0}{100}$=2.0	$\frac{200\ X\ 0.833}{100\ 100}$=1.67
($N_P\ V_{CL}/100)>Z_T$	Yes	Yes	Yes

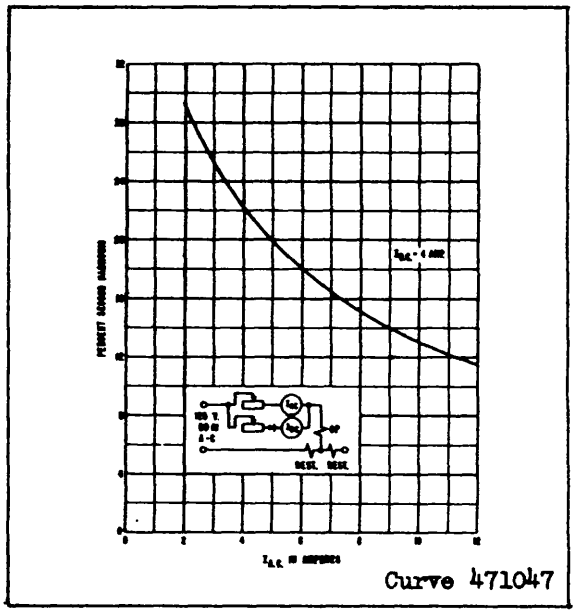


Fig. 16 Variation of Second Hormonic Content of Text Current.

amperes for the 35% sensitivity relay. Relay should operate. The upper polar unit may operate for lower currents, but not below 1.0 ampere. This low pickup will not impair its operation on magnetizing inrush currents and should not be disturbed if it is found to be less than the lower polar unit. If a higher pickup is desired, it is suggested that 20 times tap value current be applied to relay terminals 3 & 7. This will cause the upper polar unit to pick up at a current of approximately 1.65 amperes.

2. Indicating instantaneous Trip Pickup. With switch open and relay set on 5 ampere tap, apply 50 amperes to relay. Indicating instantaneous trip should pick up and its target should drop freely.

The contact gap should be approximately 0.094 inch between the bridging moving contact and the adjustable stationary contacts. The bridging moving contact should touch both stationary contacts simultaneously.

3. Indicating Contactor Switch. Block Polar unit contacts closed. Pass sufficient direct current through the trip circuit to close the contacts of the ICS. This value of current should not be greater than the particular ICS tap setting being used. The operation indicator target should drop freely

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The contact gap of the ICS should be approximately 0.047 inch between the bridging moving con tact and the adjustable stationary contacts. The bridging moving contact should touch both stationery contacts simultaneously.

4. Differential Characteristic.

a. 30% Sensitivity relay

Close switch to position 1. Set Iac to zero and adjust ILR to 10 amperes. Increase Iac to 2.8 amperes. If the lower polar unit does not operate with Iac= 2.8 amperes and ILR = 12.8 amperes, lower ILR current. The lower polar unit should operate between the following limits:

Iac = 2.8 to 2.95 amperes
ILR = 11.8 to 12.8 amperes

b. 35% Sensitivity relay

Close switch to position 1. Set Iac to zero and adjust ILR to 9 amperes. Increase I ac to 2.8 amperes. If the lower polar unit does not operate with Iac = 2.8 amperes and ILR = 11.8 amperes, lower I_{LR} current.

The lower polar unit should operate between the following limits:

Iac = 2.8 amperes
ILR = 10.8 to 11.8 amperes

5. Harmonic Restraint Characteristic. Close switch to position 2. Short out ILR ammeter. Set Idc to 4 amperes and adjust Iac until upper polar unit operates. Iac should read between 6.5 and 9 amperes. As shown in Fig. 16, these values of alternating current correspond to 17 percent and 14 percent second harmonic.

In Service Test

Table 1 is to be used as an in-service check of the HU or HU-1 relay using any tap combination.

The relay should be connected as shown in fig. 15 with the S.P.O.T. switch in position 1. The ammeter ISR measures the smaller restraint current and should be connected to the terminal associated with the tap block of the smaller setting. The ammeter ILR measures the larger restraint current, and should be connected to the terminal associated with the larger tap block setting. Terminal 5 supplies the upper tap block; terminal 7 supplies the second tap block; and terminal 9 (HU-1 only) supplies the lower tap block (refer to figs. 1 and 4).

Table 1 gives the values of IAC necessary to

operate the relay when using a value of ISR equal to 3 times tap value for all taps except the 8.7 tap. A value of ISR equal to 2 times tap value was chosen for the 8.7 tap setting in order to keep the current at a convenient value for testing.

Example (HU Relay)

Upper Tap Block Tap 3.5
Lower Tap Block Tap 5.0

Since the upper tap block has the smaller tap setting ISR should be connected to the upper tap block (Term. 5), and ILR should be connected to Terminal 7. From Table 1 under "Restraint Transformer tap: Larger" = 5.0 "Smaller" = 3.5, set ISR = 10.5 amps. The value of IAC to operate the relay should be between 8.3 and 9.2 amps.

To check the third restraint winding on the HU-1 repeat the above procedure using terminal 9 and either terminal 5 or 7.

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TABLE 1

Restraint Transformer Tap	Larger	2.9	3.2	3.5	3.8	4.2	4.6	5.0	8.7
Smaller	CURRENT IN AMPERES								
2.9	ISR	8.7	8.7	8.7	8.7	8.7	8.7	8.7	5.8
	IAC (Min.)	2.6	3.7	5.0	5.8	7.8	9.0	10.4	16.2
	IAC (Max.)	2.8	4.0	5.5	6.4	8.6	10.0	11.6	17.9
3.2	ISR		9.6	9.6	9.6	9.6	9.6	9.6	6.4
	IAC (Min)		2.7	4.0	4.9	6.9	8.1	9.6	15.7
	IAC (Max)		3.1	4.4	5.4	7.6	9.0	10.6	17.3
3.5	ISR			10.5	10.5	10.5	10.5	10.5	7.0
	IAC (Min)			3.0	3.8	5.7	6.9	8.3	14.5
	IAC (Max)			3.3	4.2	6.3	7.7	9.2	16.1
3.8	ISR				11.4	11.4	11.4	11.4	7.6
	IAC (Min)				3.2	5.2	6.5	7.9	14.1
	IAC (Max)				3.6	5.7	7.2	8.7	16.0
4.2	ISR					12.6	12.6	12.6	8.4
	IAC (Min)					3.5	4.7	6.2	12.9
	IAC (Max)					3.9	5.2	6.9	14.2
4.6	ISR						13.8	13.8	9.2
	IAC (Min)						3.9	5.3	12.4
	IAC (Max)						4.3	5.9	13.7
5.0	ISR							15.0	10.0
	IAC (Min)							4.3	11.6
	IAC (Max)							4.8	12.9
8.7	ISR								17.4
	IAC (Min)								5.0
	IAC (Max)								5.5

Routine Maintenance

All relays should be checked at least once every year or at such other time intervals as may be dictated by experience to be suitable to the particular application.

All contacts should be periodically cleaned. A contact burnisher style #182A836H01 is recommended for this purpose. The use of abrasive material for cleaning contacts is not recommended, because of the danger of embedding small particles in the face of the soft silver and thus impairing the contact.

Calibration (All Relays)

Use the following procedure for calibrating the relay if the relay has been taken apart for repairs or the adjustments disturbed. This procedure should not be used until it is apparent that the relay is not in proper working order. All adjustments to be done with relay inside its case. (See "Acceptance Check")

Polar Units

1. Contacts. Place a .060 to .070 inch feeler gage between the right hand pole face and the armature. gap should be measured near the front of the right hand pole face. Bring up the backstop screw until it just makes with the moving contact. Place gage between moving contact and the stationary contact on the left-hand side of the polar unit. On the upper unit, the gap should be .046 inch and on the lower unit the gap should be .065 to .070 inch. Bring up the stationary contact until it just makes with the gage and lock in place.

2. Minimum Trip Current

a Harmonic Restraint Unit (HRU)

Connect the relay per test circuit of Fig. 15. With the switch open, pass Iac = 20 times tap value current into the relay. This current should be applied for a very short period of time and it should be suddenly interrupted. Adjust right hand shunt on upper polar unit until it trips with Iac = 33% of tap value amperes. Lower Iac gradually to 15% of tap value current and adjust left-hand shunt until unit resets. Repeat these steps, if necessary, until the unit operates at 33% or slightly lower of tap value current immediately following the application of 20 times tap value current and until the unit resets at a value of current 15% of tap value or greater. After the dropout has been measured, the unit should pick up at 25%or higher of tap value current.

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On the application of the high current, the upper polar unit will be biased in the restraining direction and pickup will be greater than the nominal value of 30% of tap value current on the first application of pickup current. If the circuit is deenergized and pickup is measured again, the pickup current will be less than before. However, pickup will be stable after the second application of pickup current. If 20 times tap value current is applied again, the pickup immediately after applying this current will be high. However, measuring the pickup the second time will show that the pickup is again reduced. The variation between these pickups should be between 25% and 33% of tap value current.

The filter circuits are charged by the application of this heavy current and upon the removal of the current, these circuits will discharge their energy. The element will be biased in the restraining direction because the restraint coil has approximately 7 times the number of turns as the operating coil. Upon the application of pickup current, the operating ampere turns will be greater than the restraint ampere turns and the bias will be removed.

If a lower biasing current is used instead of 20 times tap value current, the pickup of the upper unit will be less than before for the first application of pickup current. Pickup will be further reduced with the second application of pickup current, but the current will be stable after this energization. However, this value of pickup will be lower than the limits of 25% and 33% of tap value current. This is in the direction of making the sensitivity of the polar unit lower than 30%7c, but does not impair the performance of the unit on inrush currents.

b. Differential Unit (DU)

Set the adjustable resistor at top of the relay in the approximate center of its range. Open the switch and pass Iac = 20 times tap value current. This current should be applied for a very short period of time and it should be suddenly interrupted. Adjust right hand shunt of lower polar unit until it trips with Iac = 30% of tap value amperes. Lower Iac gradually to 15% of tap value current and adjust left-hand shunt until unit resets. If polar unit resets before 15% of tap value current, no adjustments are necessary to the left-hand shunt. Repeat these steps until the lower polar unit will pickup at 30% of tap value current and reset for values of tap value current greater than 15%

Indicating Instantaneous Trip Unit (IIT)

With switch open, pass Iac = 10 times tap value current. Adjust core of the instantaneous trip unit until it picks up. Its target should drop freely.

The contact gap should be approximately 0.094 inch between the bridging moving contact and the adjustable stationary contacts. The bridging contact should touch both stationary contacts simultaneously.

Harmonic-Restraint Unit (HRU)

Close switch to position 2. Short out ILR ammeter. Adjust direct current until Idc reads 0.8 times tap setting. Gradually increase alternating current until upper polar unit operates with Iac reading between 1.3 and 1.8 times tap setting. The percent second harmonic in the wave may be derived by the use of the formula:

$$\% \text{ second harmonic} = \frac{47\ I_{dc}}{I_{ac} + 1.11\ I_{dc}}$$

This formula is plotted in curve form in Fig. 16 for Idc = 4 amperes.

Percentage Slope Characteristic (DU)

Close switch to position 1. Set Iac to zero and ILR to 5.5 times tap value current. Then adjust Iac to 4 times tap value current.

Adjust resistor at top of relay until lower polar unit operates. Interchange lead positions to terminals 5 and 7 and repeat the above test. The lower polar unit should operate between the limits of:

Iac = 4 times tap value current
I_{LR} 9 to 10 times tap value current

Trip condition can best be determined by holding Iac at 4 times tap value current and varying ILR. If ILR is too low the contacts will be closed when the currents are first applied. Hence, I LR should be increased until the contacts open and then decreased until contacts close.

The adjustment of the resistor will have some on the pickup of the unit. Hence, recheck the pickup. If necessary readjust shunts to obtain a pickup of 30% of tap value current and dropout of 15% or greater of tap value current. If shunts are changed,
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check to see that above readings are obtained on the higher restraint currents. If necessary readjust resistor and repeat procedure until the unit operates within the specified limits.

Apply Iac = .56 times tap value and vary ILR until lower polar unit operates. The lower polar unit should operate between following limits.

I_{LR}= 2.36 to 2.56 times tap value current.

Indicating Contactor Switch (ICS)

Block polar unit contacts closed. Pass sufficient direct current through the trip circuit to close the contacts of the ICS. This value of current should be not greater than the particular tap setting being used. The operation-indicator target should drop freely.

The contact gap should be approximately 0.047 inch between the bridging moving contact and the adjustable stationary contacts. The bridging moving contact should touch both stationary contacts simultaneously.

Calibration (35%-Sensitivity Relays)

The differential unit (DU) should first be calibrated as outlined under "Calibration (All Relays)". Next the right hand shunt of the lower polar unit should be turned out until the relay operates at

Iac = .45 times tap value current
I_{LR} = 1.64 times tap value current

This changes the percentage slope curve of the relay to that shown by the 35 percent sensitivity curve of figure 7. Pickup of the relay is increased from 300 to approximately 35% of tap value current and the curve is changed at low Values of restraint current to that shown in figure 7. At large values of restraint current the percentage slope characteristic is essentially the same as shown in figure 8.

As shown in figure 7, the margin of safety between the relay calibrated for a 35% sensitivity and the 20% mismatch curve is the same as that of the relay calibrated for a 30%0 sensitivity and the 15% mismatch curve. This margin of safety is also shown in the voltage differential characteristic of figure 11 for the 35 percent sensitivity relay.

Electrical Checkpoints

Differential Unit

a. Restraint Circuit

Apply two times tap-value current successively to each restraint transformer. This is done by connecting leads to a tap screw and to terminals 5, 7 and 9 in turn (Terminal 9 on HU-1 only). Now measure the a-c voltage across the restraint rectifier bridges (See Fig. 2) using a high-resistance voltmeter (5000 ohms per volt). The voltage should be measured from the left-to the right-hand corners of the bottom set of bridges. A voltage of 2.17 to 2.27 volts should appear only across the appropriate bridge as specified in the following table:

Current in Term.	Associated Rectifier Bridge (Rear View)	
	HU	HU-1
5	Center	Center
7	Right Hand	Left Hand
9 -	Right Hand	

b. Operating Circuit

Apply 30 per cent tap-value current to terminal 3 and a tap screw. Using a high-resistance a-c voltmeter measure the voltage on the operating coil bridge across the left-to right-hand corners (See Fig. 2). The voltage should be approximately 2.4 volts. Now, measure the voltage output of the operating transformer (top two coil terminals). The voltage should be about 5.3 volts.

Harmonic Restraint Unit (HRU)

Apply 30 per cent tap-value current to terminal 3 and a tap screw. The following are the approximate voltages that should be obtained using a high resistance a-c voltmeter (See Fig. 2 for location):

1.	Output of operating transformer (top coil terminals)	4.0 volts
2.	4 mfd. capacitor	2.5 volts
3.	0.45 mfd. capacitor	3.9 volts
4.	Operating-rectifier bridge (left-to right-hand corners)	2.5 volts
5.	Restraint-rectifier bridge (left-to right-hand corners)	0.6 volts
6.	Series Filter-Reactor	0.2 volts

APPROXIMATE RESISTANCE VALUES OF COMPONENTS IN HU RELAY

Unit	Circuit	Description
Harmonic Restraint	Operating	Transformer (Primary taps 8.7, 5, 4.6, 4.2, 3.8, 3.5, 3.2, 2.9) Secondary d.c. Resistance 50 to 70 ohms. Reactor d.c. Resistance 8 to 10 ohms. 4 MFD Capacitor. Rectifier 700 Volts, 600 Milliampere Silicon Diodes Indicating Instantaneous Trip Unit 14 to 16 ohms. Polar Unit Coil d.c. Resistance 80 to 100 ohms.
	Restraint	Series Reactor d.c. Resistance 110 to 130 ohms. Parallel Reactor d.c. Resistance 300 to 360 ohms. .45 MFD Capacitor. Rectifier 200 Volts, 600 Milliampere Silicon Diodes Polar Unit Coil d c. Resistance 650 to 800 ohms. Varistor 100,000 t-10% at 10 V.D.C. 4000 + 25% at 30 V.D.C.
Differential	Operating	Transformer (Primary taps 8.7, 5, 4.6, 4.2, 3.8, 3.5, 3.2, 2.9) Secondary d.c. Resistance 20 to 30 ohms. Adjustable 3' inch 280 ohm Resistor Rectifier 700 Volts, 600 Milliampere Silicon Diodes Polar Unit Coil d.c. Resistance 75 to 100 ohms.
	Restraint	Transformer (Primary taps 8.7, 5, 4.6, 4.2, 3.8, 3.5. 3.2, 2.9) Rectifier 200 Volts, 600 Milliampere Silicon Diodes Polar Unit Coil d. c. Resistance 60 to 110 ohms.
Indicating Contactor Switch	Trip	0. 2 Amp.. tap 6.5 ohms d. c. 2.0 Amp. tap 0. 15 ohms. d.c.

ENERGY REQUIREMENTS

Burden of Each Restraint Circuit

Top	Continuous Rating	Power Factor Angle q	at top value current	volt amperes t at 8 times top value current	at 20 times top value current
2.9	10	71	88	50	191
3.2	12	70	.89	51	211
3.5	13	66	.90	51	203
3.8	14	65	.91	53	220
4.2	15	58	.91	53	235
4.6	16	57.5	.91	55	248
5.0	18	52.5	.92	59.	280
8.7	22	30	1.28	94.	340

Burden of Operating Circuit

Top	Continuous Rating	Power Factor Angle q	at top value current	volt amperes t at 8 times top value current	at 20 times tap value current
2.9	10	35	2.26	76	487
3.2	12	34	2.30	78	499
3.5	13	33	2.30	81	504
3.8	14	33	2.30	83	547
4.2	15	31	2.30	84.	554
4.6	16	30	2.40	88.	598
5.0	18	29	2.50	92.	640
8.7	22	23	3.18	132.	850

q Degrees current lags voltage at tap value current

† Voltages taken with Rectox type voltmeter

* Thermal Rating

One Second - 300 amperes

Thermal capacities for short times other than one second may be calculated on the basis of time being inversely proportional to the square of the current.

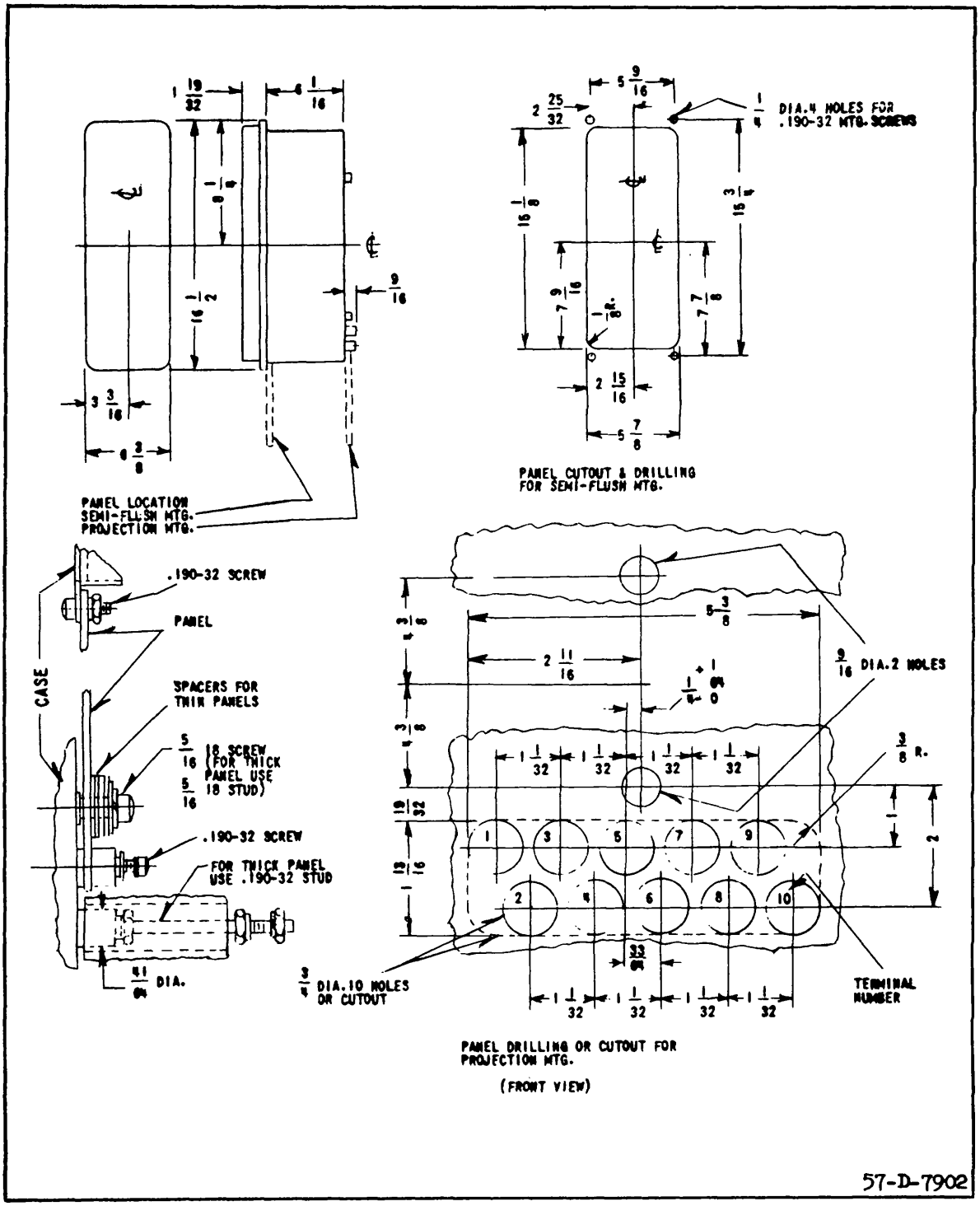


Fig. 17. Outline and Drilling Plan of the Type HU and HU-1 Relays in the FT31 Case.

NSTALLATION • OPERATION •· MAINTENANCE INSTRUCTIONS

TYPE MG-6 MULTI-CONTACT AUXILIARY RELAY

CAUTION Before putting relays into service, remove all blocking which may have been inserted for the purpose of securing the parts during shipment, make sure that all moving parts operate freely, inspect the contacts to see that they are clean and close properly, and operate the relay to check the settings and electrical connections.

APPLICATION

The type MG-6 relay is designed for applications where several independent circuits must be energized or de-energized upon the operation of a single primary relay contact, or where the capacity of the primary relay contact is inadequate for the energy required in a control circuit. In certain applications these relays may be used directly as primary relays. Since the stationary contacts can readily be reversed so as to be suitable for either circuit opening or circuit closing service (although a slight increase in spring tension may be required on the D-C MG-6 relay see 'ADJUSTMENTS AND MAINTENANCE") it is unnecessary to predetermine the arrangements of the circuits for which the relay is to be used.

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An operating coil cutoff contact can be supplied with the electric-reset type, where an intermittent duty coil is required for faster than normal operation, but where the operating coil circuit must be energized continuously. An operating coil, rated at 190% of supply rating may be applied, with a maximum duty of 10,000 operations. (e.g. 24 volt coil on 125 volt dc circuit.

CONSTRUCTION AND OPERATION

The operating electromagnet is at the lower end of the relay, as shown in Fig. 1. The stationary iron circuit is built up of U-shaped punchings. These are slotted at the outer end of the lower leg to receive the copper lag loops used to obtain quiet operation on A-C, The operating coil is mounted on this leg of the punchings. In order to improve the performance of the relay on D-C, the pole face area is increased by means of an iron plate. This plate is assembled at the end of the coil and the corners of the lamination side plates are bent outward, serving to hold the plate in place. The inner end of the upper leg of the punching assembly is shaped so that the lower end of the armature restraining spring can be hooked over it.

The armature is made of high-silicon steel. Projecting sections on the sides, near the center, act as knife-edge bearings and rest on suitably shaped supports which are a part of the moulded base. A stud attached to the lower leg of the electromagnet extends through a hole in the lower end of the armature, and a stop-nut on the outer end of this stud is used to limit and adjust the travel of the armature in the de-energized direction. The special stop nut used will remain at any position in which it is placed without additional locking means.

The upper end of the armature carries an adjusting screw to which one end of the armature restraining spring is attached. In the hand or electrically reset relays, a latch screw is mounted at the extreme end of the armature. In the self-reset relays this screw is replaced by a set screw which serves to separate the locking plate (see Fig. 1) slightly from the armature. Between the spring adjusting screw and the latch screw (or set screw), there is a third screw which when tightened applies pressure to the threads of the former screws and effectively locks them against turning.

The moving contact fingers are mounted on moulded insulation which is fastened to the armature

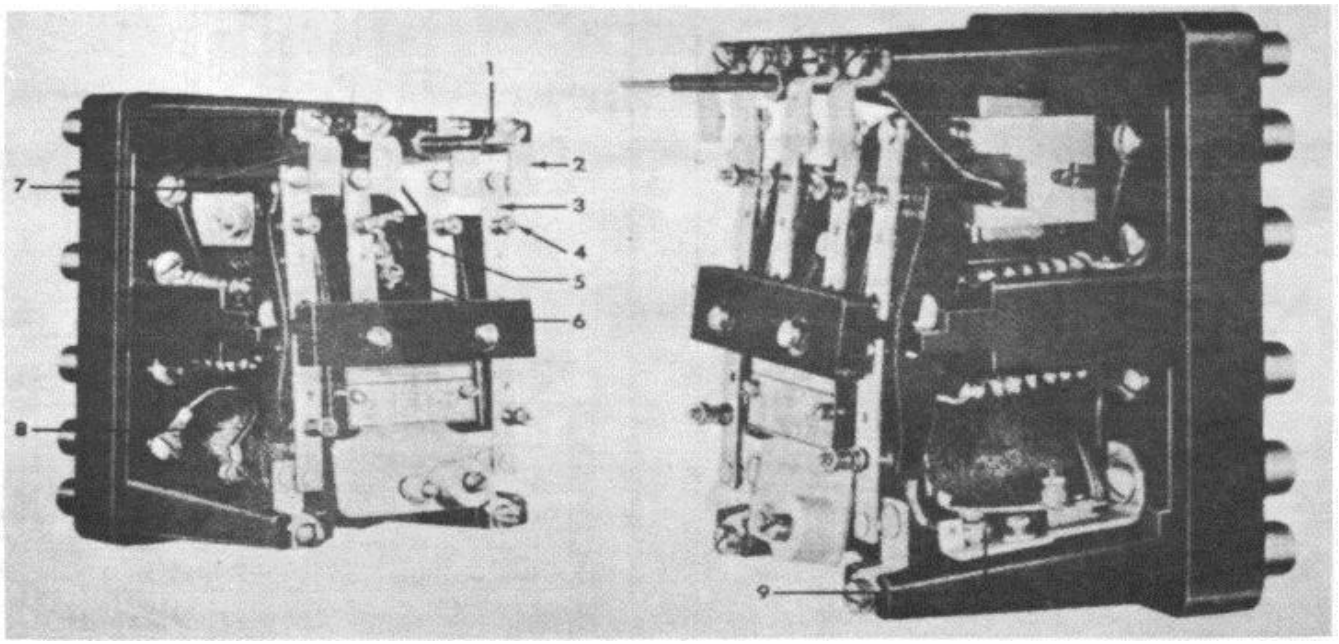


Fig. 1. Front View (Cover Omitted) and Side View of the MG-6 Electric d Hand Reset Relay in Molded Case. I Reset push rod, 2 stationary contact, 3 --moving contact, 4 moving contact spring assembly, 5 latch adjustment screw, 6 adjusting screw for armature spring tension, 7 reset coil, 8 operating col, 9 optional operating coil cut. off contact.

by two screws. Silver contact buttons are on both sides of these fingers so that they can be used for either a circuit-opening or a circuit-closing contact. The fingers are assembled on guide pins, between two springs in such a way that definite spring compression and contact wipe is assured for either contact-closing or contact-opening service. Flexible leads assemblies are welded to the contact fingers. Since the armature assembly has contact fingers both above and below the bearing points, the armature weight is partially balanced about the bearings and there is less tendency for severe shocks to move the armature.

The stationary contacts consist of large silver buttons welded to brackets which can be assembled so that they close with the moving contacts when the armature is in either the energized or de-energized position. The stationary contact brackets are connected directly to the terminal inserts by means of long screws which pass through brass tubes. These tubes are of such length that the moulded material of the base is not under direct compression when the screws are tightened. Therefore, there is always a tight connection from contact to terminal regardless of possible shrinkage or other variation in the moulded base material. The contact bracket is held against its seat by means of a spring ring which is compressed between shoulders in the base and on the hexagonal terminal insert.

The construction of the latch and electrical reset is shown in Fig. 2, in which the lower portion is a partial front view of the relay In the moulded case, and the upper portion a top view. In the latter view, the latch screw (in the main armature) is In the energized position, and the reset armature is free to be moved to the right by the tension spring until the hardened latch plate on the reset armature rests against the tip of the latch screw. When the operating coil is de-energized, the latch screw will move slightly so that its shoulder rests on the edge of the latch plate. When the reset coil is energized its armature moves to the left, thus permitting the main armature to return to its open position. Pressing the reset push rod, which extends through the cover stud, will also release the latch through the medium of the reset lever shown in the figure.

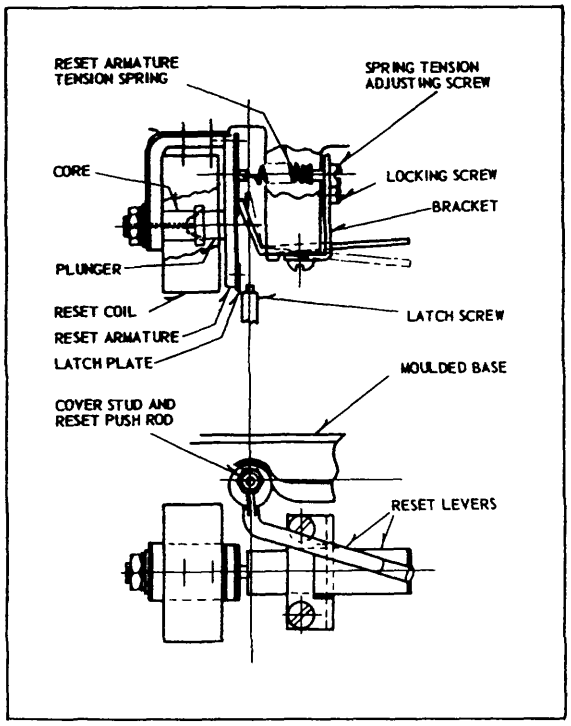


Fig. 2. Detail Views of the Latch and Electrical Reset of the Type MG-6 Relay.

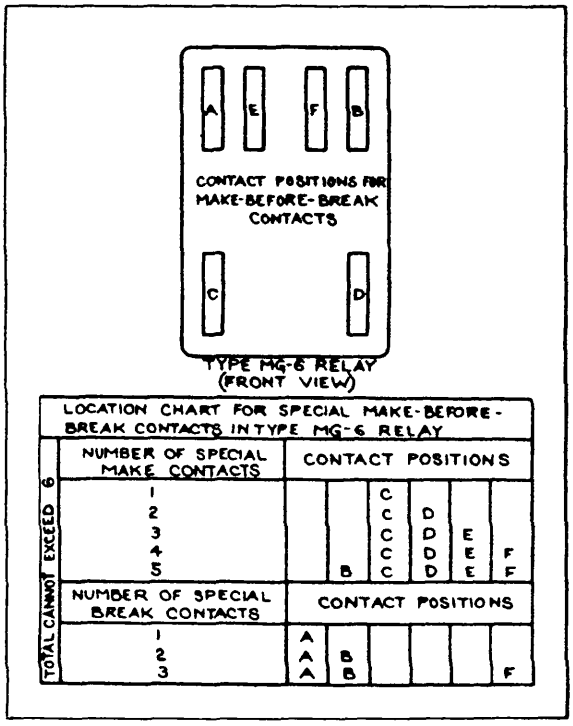


Fig. 3. Contact Positions for Combinations of Make Before-Break Contacts.

In some applications of the relay with latch and electrical reset, it may be desirable to have the operating and reset coils deenergized automatically as soon as they have performed their functions. In the case of the reset coil this can be accomplished by connecting the coil through one of the relay 'make' contacts. An auxiliary contact is required to open the operating coil circuit. This contact, when provided, is assembled on the lower right-hand side of the relay, and is held in position by the terminal screw to which the right-hand coil lead ordinarily connects. The coil lead is connected to the moving contact of the auxiliary contact, and the end of the stationary contact bracket is in contact with the head of the terminal screw. The auxiliary contact is closed when the main armature is open. When the armature approaches the closed position, the spring on the molded insulation block snaps off the roller and causes the contacts to open and interrupt the operating coil current. When this auxiliary contact is used, a weight is screwed to the lower end of the armature to increase its mass and stabilize contact action. This contact will interrupt the coil current

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at up to five times rated coil voltage.

In certain applications of the type MG6 relay, it may be desirable to have one or more of the contacts close before other contacts on the same relay open. A special armature assembly is required to obtain such operation, and the number of special make and break contacts desired must be known when the relay is built. The special moving contacts have longer follow than the standard contacts and greater armature spring tension is required for full deflection of the break contacts. Consequently, it is preferable to limit the number of special break contacts to two. A maximum of three may be used, although the increased armature spring tension needed may raise the minimum pick-up voltage above the standard value. As many as five contacts may be special make contacts, with the total of special make and break contacts limited to six, of course. The locations of the make and break contacts for any combination of these special contacts are shown in Fig. 3. This figure indicates the physical location of the contacts in the relay, and can be used in conjunction with the inte-

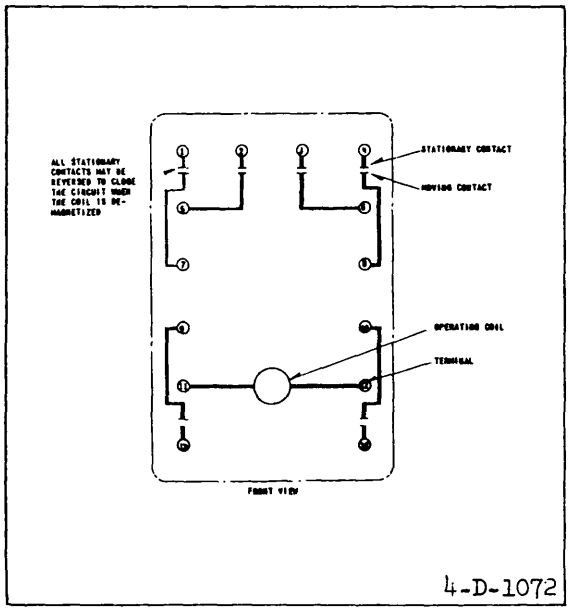


Fig. 4. Internal Schematic of the Type MG-6 Relay, With- out Electrical Reset, In Molded Case.

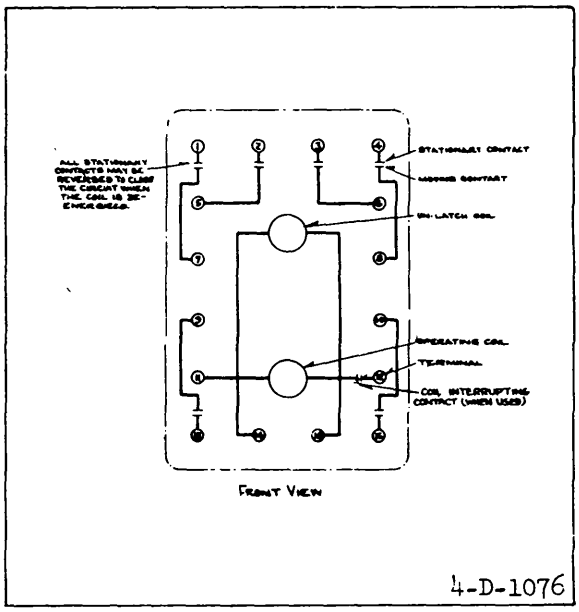


Fig. 5. Internal Schematic of the Type MG-6 Relay, With Electrical Reset, In Molded Case.

nal schematic diagram for the type of case involved to determine the corresponding terminal locations.

The type MG-6 relay may be provided without cover, for front connection, or in a variety of completely closed cases, for rear connection. The moulded base for rear connection is shown in Fig. 1. The base for front connection is similar except that there are no terminals projecting in the rear. This same base is also used as a sub-base when the relays are supplied in the F'T22 case.

CHARACTERISTICS

The type MG-6 relay has an operating time of approximately 2 cycles on a-c and 5 cycles on d-c (on a 60 cycle basis) when energized at the rated voltage.

If faster operation is desired and if the application requires only intermittent energization of the relay, the operating coils may be energized at higher than rated voltage. (1) Twice rated voltage will give an operating time of approximately 1 cycle on a-c, and the coil will stand this voltage safely for over two minutes if 60 cycles o0 4 minutes if 25 cycles. (2) The time of the d-c relay can be reduced to slightly

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over 1 cycle if the coil is energized at five times rated voltage. The coil will stand this voltage for one minute. If faster time is desired on a d-c relay which must be energized continuously, the use of a low voltage coil with a series resistor will reduce the time. With 100% of the line voltage across the relay coil and the balance across a series resistor, the reduced inductance of the circuit results in an operating time of approximately 2 cycles. The time of operation may be reduced to approximately one cycle by applying 4 or 5 times rated d-c voltage to the coils through the coil interrupting contact.

Reset coils are for intermittent duty only and should not be energized longer than one-half minute.

The relay contacts will close circuits carrying 30 amperes. They will carry this current for 1 minute, and will carry 12 amperes continuously.

The contacts will interrupt the following currents, in non-inductive circuits, at the voltages listed.

Current	Volts A-C
30	115
20	230
15	460
10	575

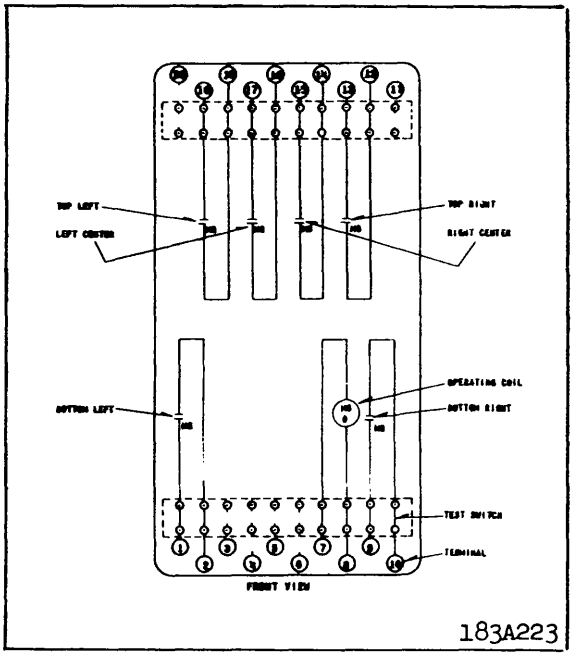


Fig. 6. Internal Schematic of the Type MG-6 Relay, With. out Electrical Reset, In FT22 Case.

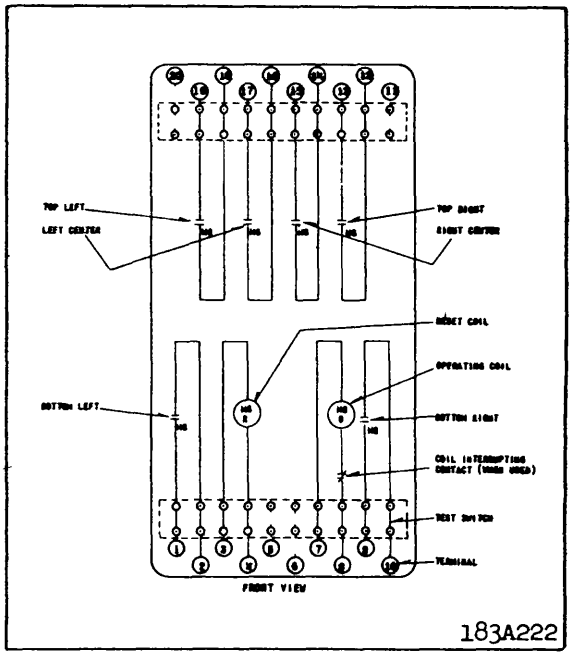


Fig. 7. Internal Schematic of the Type MGI6 Relay, With Electrical Reset, In FT22 Case.

Current	Volts D-C
30	12
15	24
10	32
8	48
3	125
1	250

The type MG6 relay for a-c can be used with any combination of contacts, but the d-c relay can have up to four circuit-opening contacts with the normal operating spring adjustment. With more than four the operating spring should be adjusted to give the correct back contact follow.

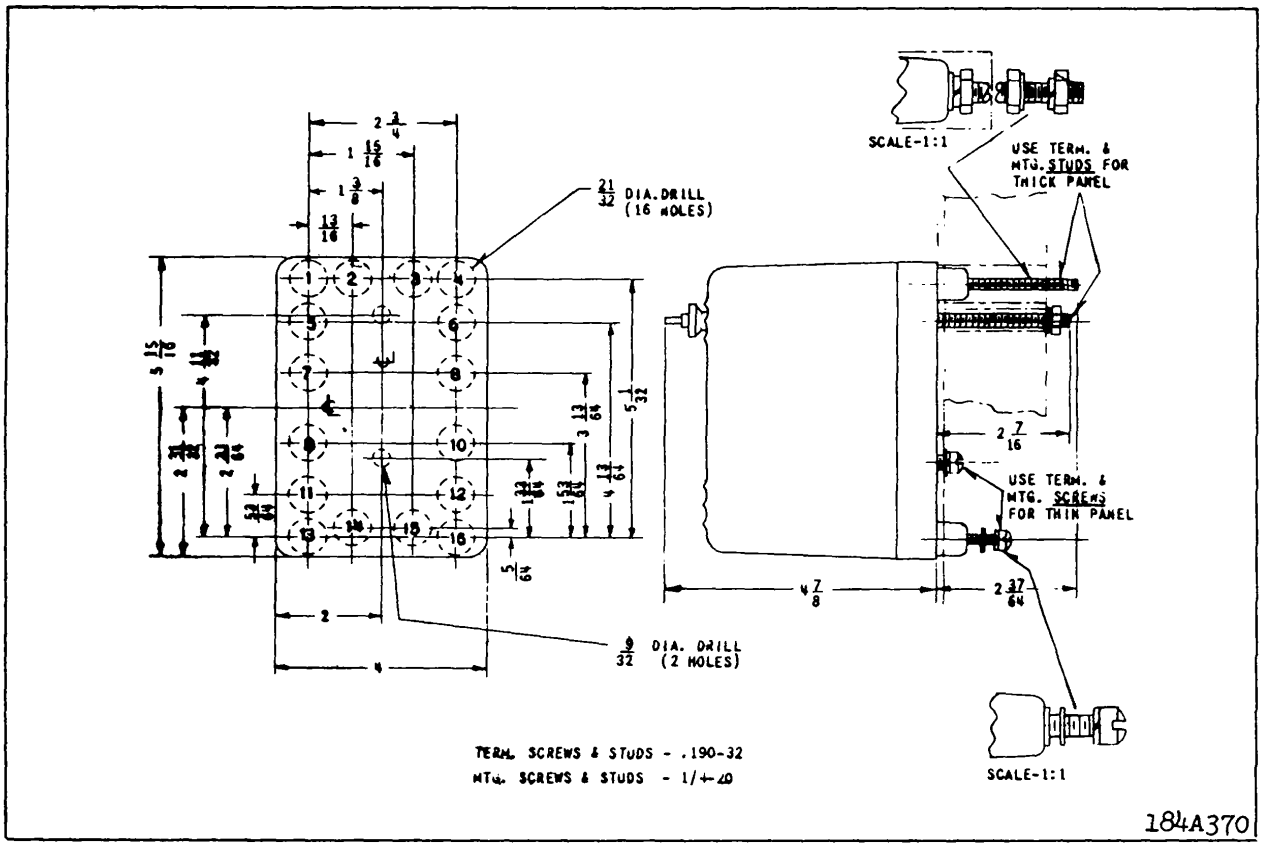
INSTALLATION

The relays should be mounted on switchboard panels or their equivalent in a location free from dirt, moisture, excessive vibration. and heat. Mount the relay vertically by means of the four mounting holes on the flange for semi-flush mounting or by means of the rear mounting stud or studs for projection mounting. Either a mounting stud or the mounting screws may be utilized for grounding the relay. .The electrical

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connections may be made directly to the terminals by means of screws for steel panel mounting or to the terminal studs furnished with the relay for thick panel mounting. The terminal studs may be easily removed or inserted by locking two nuts on the stud and then turning the proper nut with a wrench.

Relays in the rear-connected moulded cases should be mounted and electrically connected similar to the other projection cases. The lower mounting stud may be used to ground the electromagnet iron. The hexagon-shaped terminal inserts are slightly loose in the base but this does not affect the electrical connections. Only the two mounting studs should be used to secure the relay to the panel. Removal of terminal insert end-play (in the case of thick-panel mounting) by turning a nut on the terminal stud tightly against a large diameter washer (not supplied) at the rear of the panel should not be attempted as this may distort the relay base and affect the adjustments, or possibly damage the relay. Relays in the font-connected moulded cases should be



** Fig. 8. Outline and Drilling Plan for the Type MG-6 Relay In the Rear Connected Molded Case. For Reference Only.*

mounted by four screws through the sides of the base as indicated in the drilling plan.

ADJUSTMENTS AND MAINTENANCE

The relays are shipped tom the factory correctly adjusted for armature travel and for contact, follow and pressure, and it should not be necessary to disturb these adjustments. The relays normally are shipped with all contacts assembled for circuit-closing operation. To convert them for circuit-opening operation, it is necessary merely to loosen the mounting screw for the stationary contact bracket, turn this bracket over, and tighten the screw. After reversing the position of the contact brackets, it may be necessary to bend them slightly to obtain contact follows approximately as stated in the fourth paragraph of this section. On a d-c relay not more than four contacts can be assembled in the circuit-opening position if normal contact pressure and travel are

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maintained. With more than four the operating spring should be adjusted to give the correct back contact follow.

If a relay has been dismantled and is being reassembled, the following adjustments should be made or checked. Reference should be made to Figs. I and 2 for identification of the parts mentioned in these instructions.

The armature stop nut should be adjusted so that when the armature is in contact with it the lower edge of the armature is 7/16" above the position which it assumes when the relay is energized. When adjusting the armature spring tension, the locking screw for the spring adjusting screw is loosened, and this adjusting screw is turned (inward, to reduce the spring tension) until the spring barely holds the armature against the stop nut. The relay must be in its normal vertical position when this adjustment is made, with

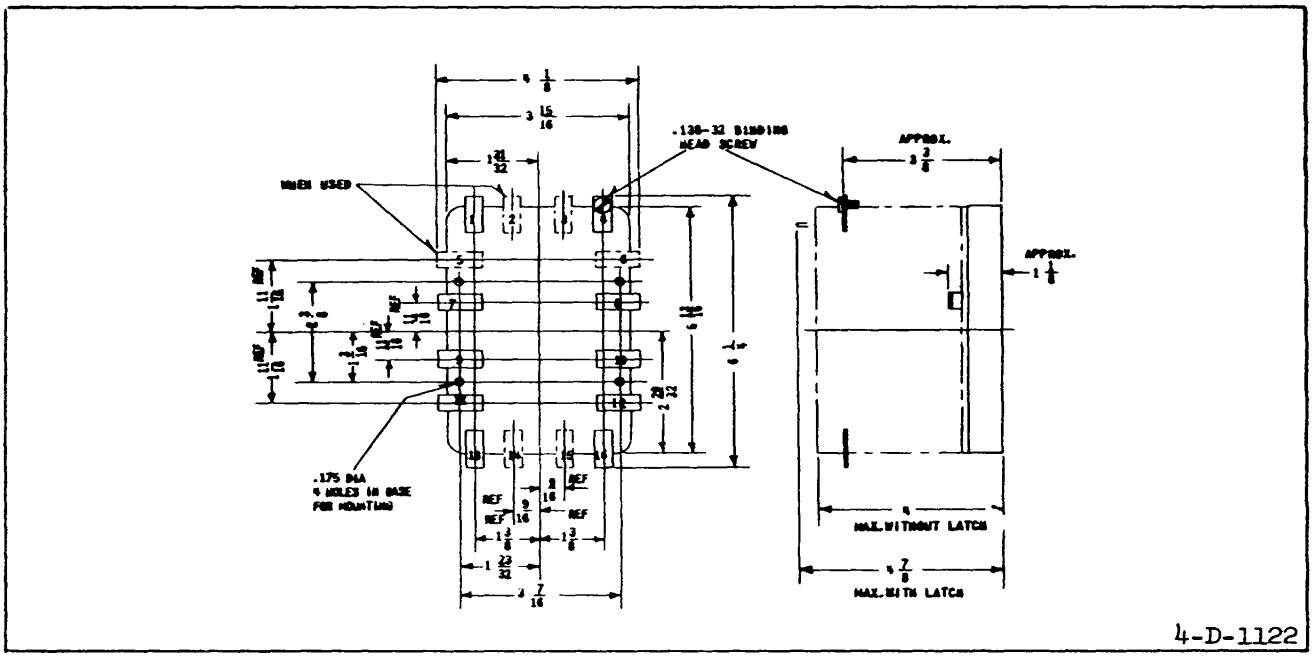


Fig. 9. Outline and Drilling Plan for the Type MG-6 Relay In the Front Connected Molded Case. See Internal Schematic for Terminals Supplied. For Reference Only.

all contacts assembled as circuit-closing. The armature spring should then be tightened by turning the adjusting screw 4 turns counter-clockwise for a-c relays or 2 turns for d-c relays, and the locking screws should be tightened. If the relay is being used with a number of break contacts, it may be necessary to increase the spring tension to obtain full follow on the break contacts. The adjusting screw should be turned just enough farther to obtain full follow with the armature against the stop nut.

The follow of the moving contact fingers should be 3/32" for the make contacts and 1/16" for the break contacts, measured at the contacts. This can be checked more conveniently by measuring the travel of the lower edge of the armature after the contacts touch. This should be approximately 1/8" for the make 'contacts and 3/32" for the break contacts. In case moving contact fingers have been removed from their guide pins, it is important that the coil springs on the two sides of the fingers be replaced correctly.

The springs which are compressed by circuit-closing contacts are approximately three times as strong as the ones compressed by circuit-opening contacts and thus they can be readily distinguished. The positions of the two springs are reversed at the two ends of the relay.

When special contacts are supplied for make before-break operation, the stationary members of the special contacts are bent equally toward their respective moving contacts to obtain“make” at the point where the 'break' moving contact has approximately 1/16" follow before parting from its stationary contact.

If an a-c relay is to be used with a series resistor so that the relay can be dropped out by shorting the coil, either the resistance value must be such that the watt consumption with the coil shorted will be quite high or the relay armature spring tension must be reduced to about 1-1/2 turns and the follow of the stationary make contacts must be reduced (by bending) to about 1/16". With the reduced armature spring tension, not more than two of the contacts can be used as break contacts. Because of the low relay impedance with armature open as compared to the impedance with armature closed, it is not advantageous to use a resistor in series with a coil rated at less than line voltage, as in the case of d-c applications. For the contact and spring adjustments

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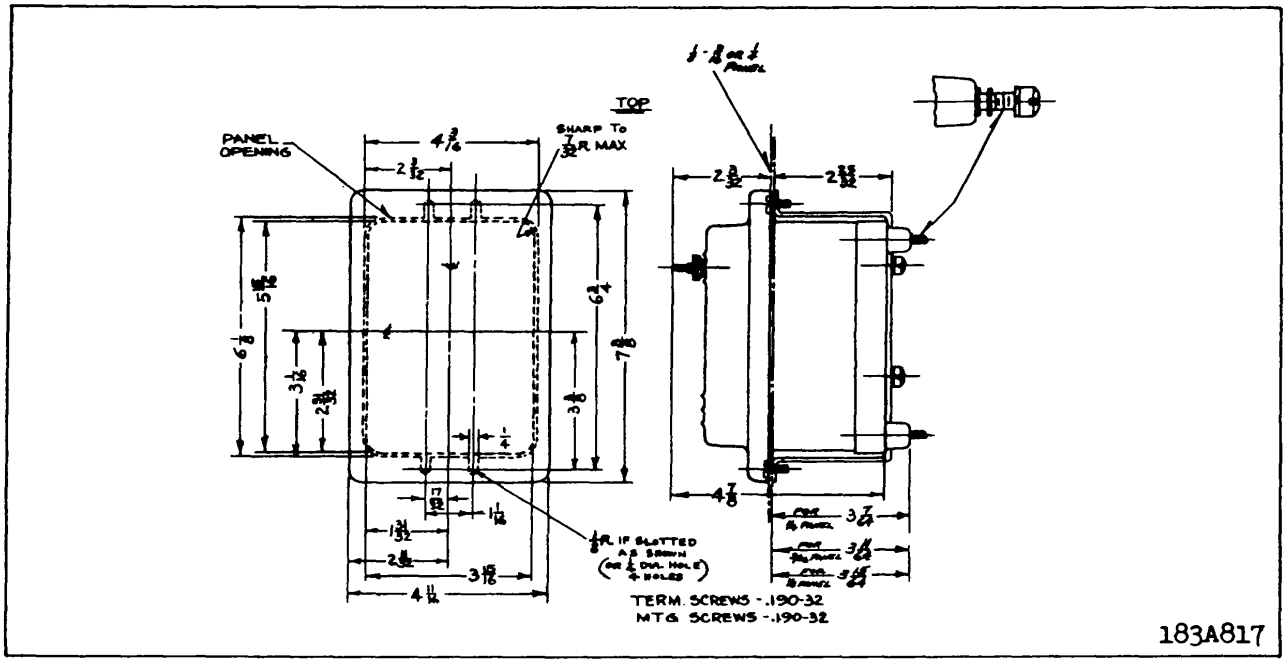


Fig. 10. Outline and Drilling Plan for the Molded Semi-Flush Case. For Reference Only.

specified above, a 60 cycle MG relay with voltage rating equal to the line voltage can be used with a series resistor which will take about 90 watts when directly across the line. Of course, if the coil will be shorted only momentarily or if a higher watt consumption is not objectionable, it may be unnecessary to reduce the spring--tension or contact follow.

If the complete armature assembly is to be removed from the relay, the screws which fasten the lower ends of the moving contact leads to the terminals should be removed, the armature spring tension adjusting screw should be turned in as far as possible, and the armature stop nut should be removed. The upper end of the armature spring should then be slipped off of the grooved member at the lower end of the adjusting screw, and the armature should be lifted off of its bearing carefully so as to avoid distortion of the coiled leads. The leads to the upper center moving contacts are not coiled but the coiling of the four other moving contact leads should be such that when the relay base is horizontal and the armature is on its bearings and approximately at its mid-position, the lead terminals will just touch the base terminal inserts or be within about 1/8" of that position.

On latch-type relays the latch screw is adjusted so that with the armature latched and the operating coil de-energized, there will be a gap of between .005 and .010 inch between the electromagnet pole face and the raised section of the armature which strikes the pole face. The locking screw should be tightened securely after making this adjustment. There is a small amount of clearance between the armature and its supporting posts, and in order to insure proper operation allowance must be made for this in the following manner. With the armature held against its left-hand support and nearly closed, the latch spring or reset armature should be moved to the left as far as it will go by means of the hand reset. To assure that the latch will always release the armature the resulting space between the latch and the latch screw should be at least .005 inch, and should not be more than about 1/64". This should also be checked electrically if electrical reset is provided. Some change of this gap can be made by loosening the mounting screws in the relay base and moving the latch support in the desired direction. The gap also can be changed by loosening the two screws which hold the moving contact insulation block to the armature and shifting the armature in the desired direction.

On electrical reset relays, the tension of the spring which draws the reset armature toward the

.

latch screw must be adjusted if these parts are being reassembled. The locking screw (Fig. 2) is screwed out until its head clears the head of the adjusting screw. The main armature is then held completely closed and against its right hand support, and the latch spring tension adjusting screw is turned until the latch barely touches the stop projecting from the center of the latch screw. Then the latch spring tension should be increased by turning the screw clockwise 9 turns, and the locking screw should be tightened.

If either the core nut of the electrical reset assembly or the screws which mount its armature have been loosened, the relative positions of the core and plunger may shift sufficiently to cause the plunger to strike on the side of the conical core opening. To assure correct alignment of these parts, .042 diameter holes are provided through the center of the core and about 1/16" deep in the center of the plunger. After tightening the core nut, a close fitting pin should be inserted through the core and into the plunger. With the pin in place, and plunger pressed firmly against the core, and the mounting end of the armature centrally located with respect to the electromagnet, the two armature mounting screws should be tightened. The pin then should be removed.

A slight amount of medium viscosity slushing oil is supplied at the factory to the polished and hardened surfaces of the latch screw and the latch plate to minimize wear and as protection against corrosion. Oil should be reapplied after any cleaning and reassembling of these parts, and it is desirable also to renew this at the regular maintenance periods.

If the relay is provided with a coil interrupting contact, the following points must be observed to assure satisfactory operation. With the relay in its normal operating position and the armature shifted to the extreme right, align the armature 'snap" spring so that it is at least 1/64 inch in from the right hand edge of the moving contact spring. With an .020 inch gap between the armature and the lower pole face of the electromagnet, adjust the bracket by means of the adjusting screw, until the snap spring just passes the roller. The latch screw should be adjusted so that with the armature in the latched position and the operating coil deenergized, the gap between the armature and the lower pole face of the electromagnet is .010 inch. With the armature in this position the coil interrupting contact should be open at least 3/64 inch.

All contacts should be periodically cleaned. A contact burnisher S#182A836H01 is recommended for this purpose. The use of abrasive material for cleaning contacts is not recommended, because of the danger of embedding small particles in the face of the soft silver and this impairing the contact.

ENERGY REQUIREMENTS

Operating Coil Burdens at rated Voltage

Frequency	Closed Gap		Open Gap	
(cycles)	Watts	Volt-Amps	Watts	Volt-Amps
25	6.8	23	19.6	53
50	9.8	31	17.4	78
Δ60	12	37	17.6	92
D-C	7.8 cold--		7.8 cold--	
D-C	6.5 hot--		6.5 hot--	

ΔRated voltage is 115 volts or its multiples.

Reset Coil Burdens at Rated Voltage (Multiples)

Frequency	Closed Gap		Open Gap	
(cycles)	Watts	Volt-Amps	Watts	Volt-Amps
25	48	51.6	52	54
50	46	58.2	57	63.8
60	84	104.5	96	112.8
D-C	66 cold-		68 cold-	

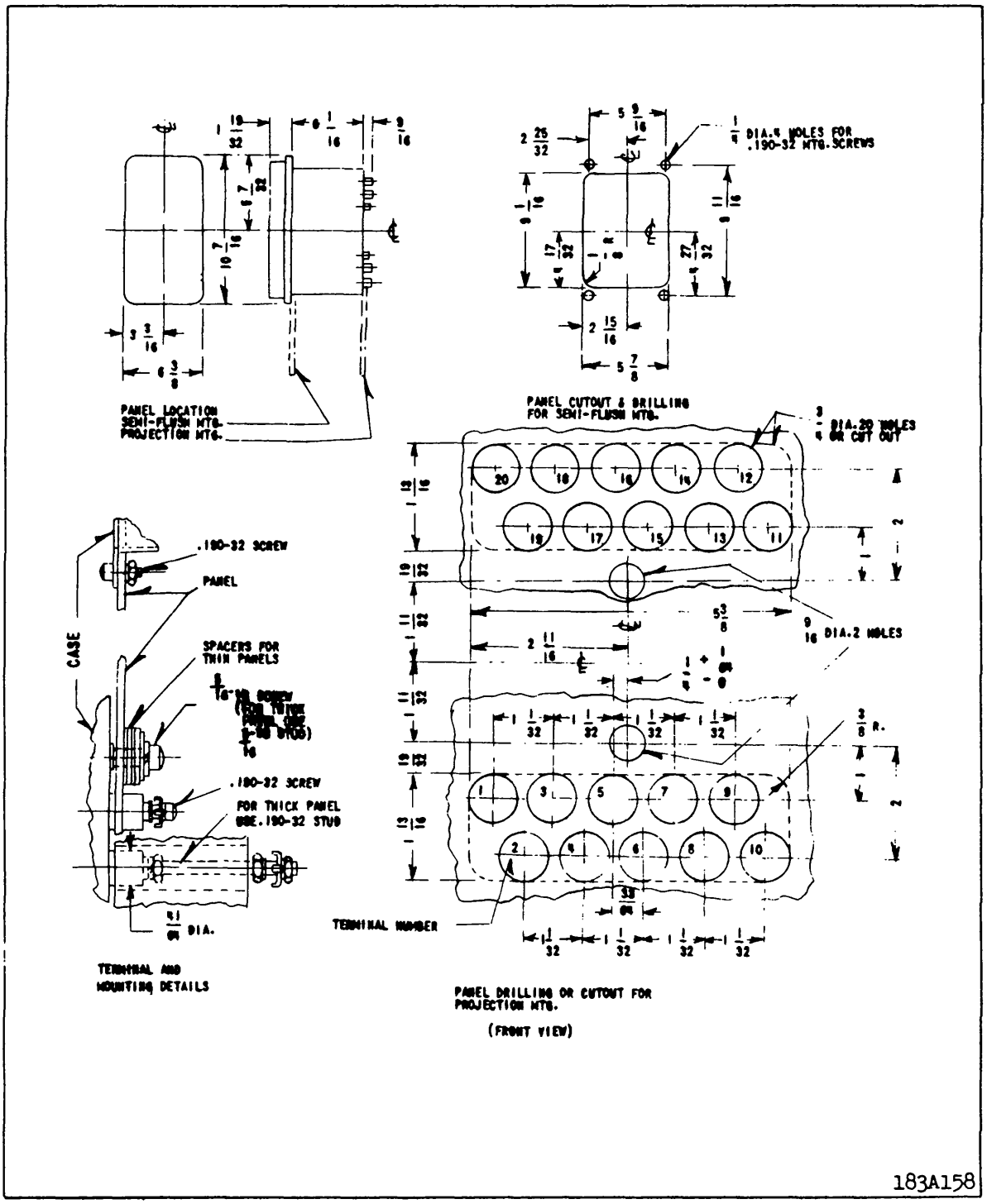


Fig. 11. Outline and Drilling Plan for the Type MG-6 Relay In Type FT22 Case.

INSTALLATION •· OPERATION • MAINTENANCE
I N S T R U C T I O N

SWITCHBOARD WATTHOUR METERS TYPES D2B-2F; D2B-7F AND D2B-8F IN FT-21 FLEXITEST CASE

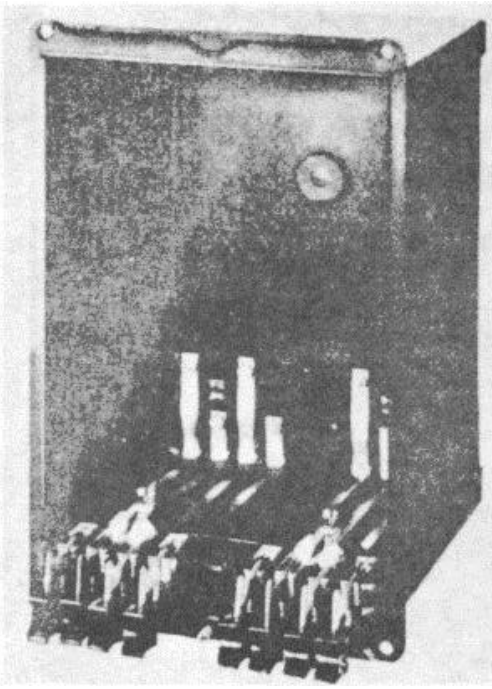


Fig 1. FT-21 Case.

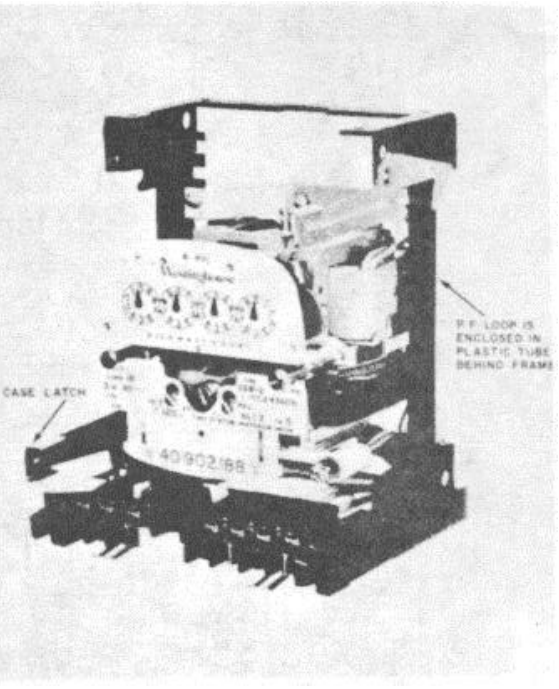


Fig. 2. D2B Chassis.

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APPLICATION CHART		
METER TYPE	NUMBER OF STATORS	CIRCUIT APPLICATION
D2B-2F	2	2, or 3-phase, 3 wire 3-phase, 4 wire Delta 3-phase, 4 wire Wye
D2B-7F	2	3-phase, 4 wire Delta
D2B-F	2	3-phase, 4 wire Wye

GENERAL

The meter elements are mounted on a removable chassis, which is held in the case by two latches. All connections between the case and the chassis are made through the test switches. Automatic shorting switches are provided on all current circuits to prevent opening current transformers when testing or removing the chassis. For testing, leads can be clipped to the test lugs above the chassis jaws and on the switch blades.

Two test plugs are available to facilitate calibration of these meters. The 10-circuit plug is inserted into the chassis jaws and is provided with binding post terminals for connections to the test circuit. Current measurements are made by connecting ammeters to a current circuit test plug, which is then inserted into the current switch assembly, between the chassis and the case.

The hardware supplied with the meter permits mounting either projection or semi-flush on panels up to 3/16" thick. For projection mounting on panels thicker than 3/16" special hardware is furnished on request.

Provisions have been made on all FT-21 cases for convenient field installation of either 2 or 3 wire contact devices. Three knockouts located on the back of the case (close to the top) when removed, allow a molded insulation block, with two or three terminals and male plugs, to be fastened to the case. A bracket, with the proper number of female sockets, can be attached to the rear of the meter-frame & latch assembly in the proper position to allow the male and female parts to mate when the meter is inserted in the case. The parts are available in kit form for this application.

CALIBRATION

All meters are calibrated on single phase. The basic watthour constant (K_h) for these meters is .6 per nominal 600 watt rating. The single-phase test speed 16-2/3 rpm except for the D2B-8 for which it is 22-2/9 rpm. Both of these are given on a 120 volt basis.

The following is a guide to watthour stator calibration. Detailed calibration procedure is available in IL-42-102.3.

ADJUSTMENTS

Full Load, Light Load and Balance.

All of these adjustments are made at the front of the meter. The full load adjuster knob is in the center; the light load knob at the left and the balance knob at the right. Direction of adjustment is indicated by the arrow on the nameplate ("F" indicates fast).

Power Factor

Power factor adjustment is made by changing the resistance of the soldered loop located at the back of each electromagnet. Increasing the resistance (lengthening the loop) increases the speed on lagging power factors.

GENERAL DATA		
COMBINED STATORS OF 5. AMP. - 120. VOLT - 60 CYCLE METERS		
TYPE	D2B-2F	D2.8F
STARTING WATTS	6.	6.
WATTHOUR CONSTANT (K_h)	1.2	1.8
FULL LOAD R.P.M. ON SINGLE PHASE TEST	16-2/3	22-2/9

FOR TRANSFORMER BURDENS SEE THE TABLE ON PAGE 3.

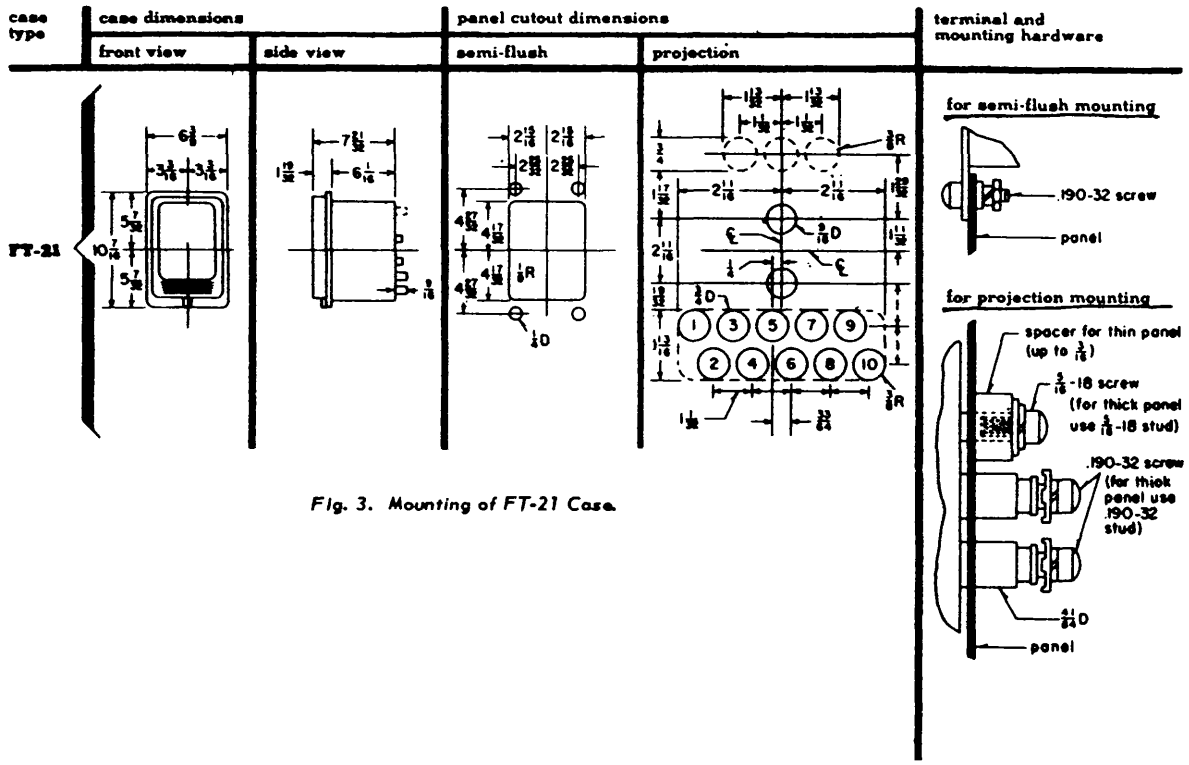


Fig. 3. Mounting of FT-21 Case.

Fig. 3 Mounting of FT-21 Case.

TRANSFORMER BURDENS FOR 60 CYCLE METERS			
VOLTAGE COIL CIRCUITS, INCLUDING P.I. LAMP.			EACH STATOR
FOR RATED MULTIPLES OF 120. V.	VOLT-AMPS.		8.65
	WATTS		1.35
	POWER FACTOR		.156
CURRENT COIL CIRCUITS			
EACH STATOR	FULL COIL	HALF COIL	Z CIRC.
5. AMPS. ON 5. AMP. COIL.			
VOLT-AMPS.	.39	.25	.39
WATTS	.29	.21	.29
POWER FACTOR	.75	.84	.75
5. AMPS. ON 2.5 AMP. COIL.			
VOLT-AMPS.	1.2	.65	1.2
WATTS	.64	.39	.64
POWER FACTOR	.533	.600	.533

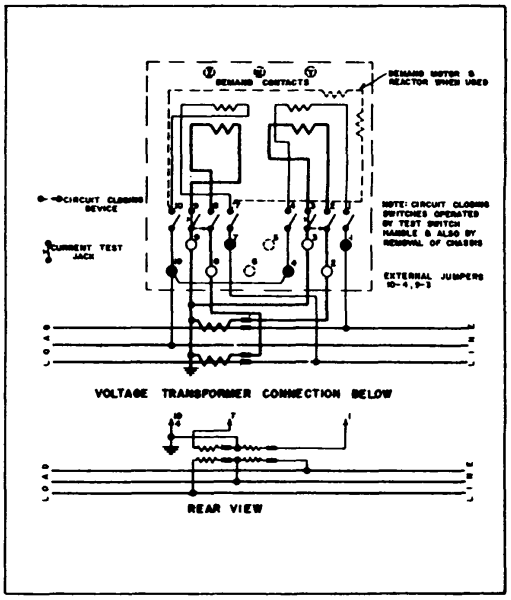


Fig. 4. Type D2B-2F, 3-Phase, 3 Wire.

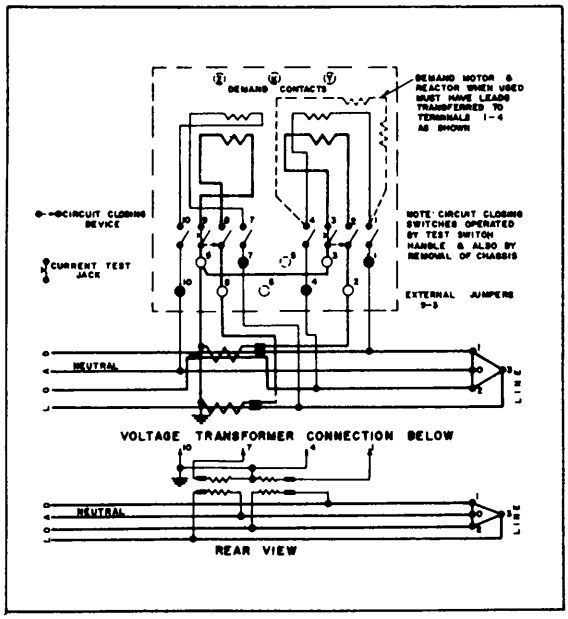


Fig. 5 Type D2B-2F, 3-Phase, 4-Wire, Delta

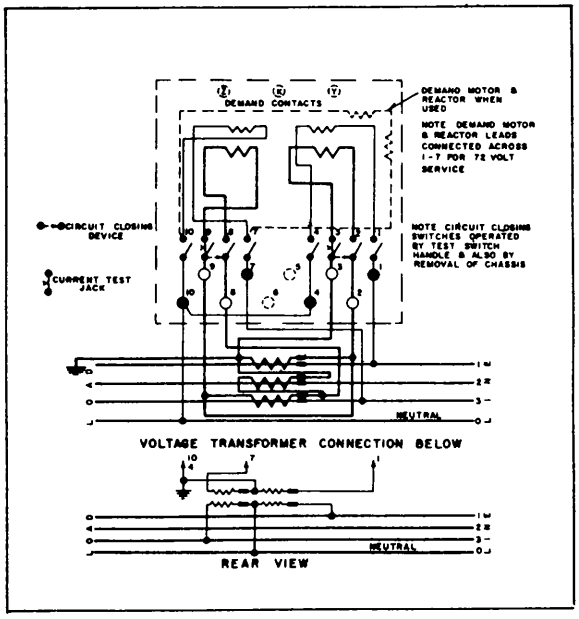


Fig. 6 Type D2B-2F, 3-Phase, 4-Wire, Wye.

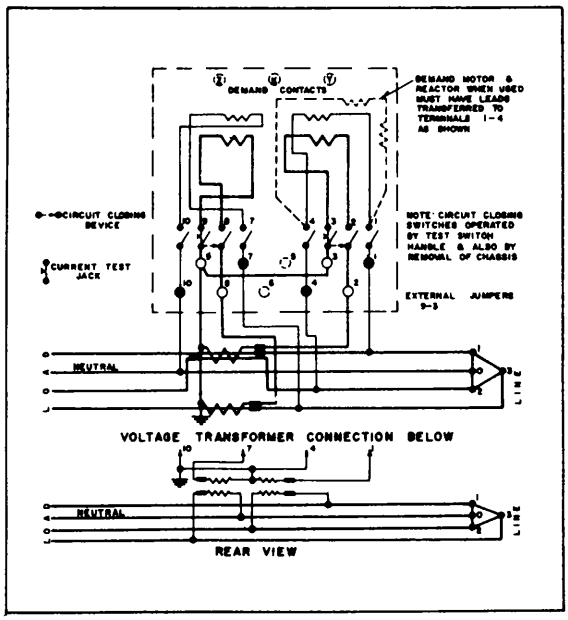


Fig. 7 Type D2B-7F, 3-Phase, 4-Wire, Delta

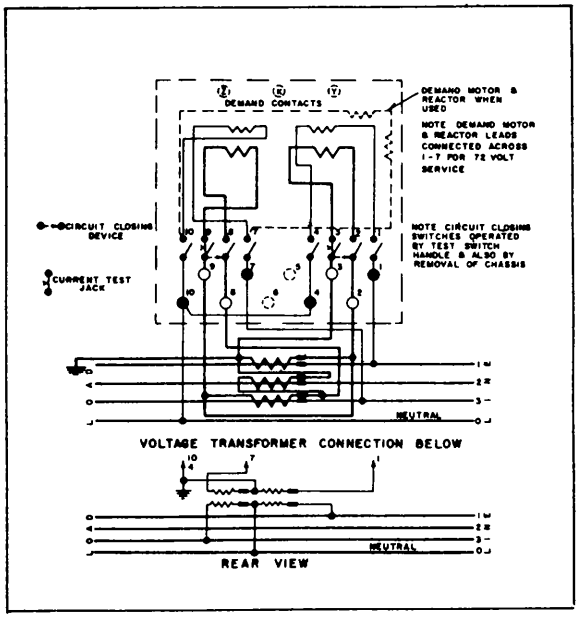


Fig. 8 Type D2B-8F, 3-Phase, 4-Wire, Wye

K-241 LINE
SWITCHBOARD INSTRUMENTS
FOUR AND ONE-HALF INCH CLASSIFICATION
FULL-VIEW CIRCULAR SCALE TYPE

GENERAL

Type K-241 instruments are designed and built to meet or exceed the requirements of American Standard C39.1 for electrical indicating switchboard instruments. The rated accuracy class is one per cent.

CASES

The first letter in the Type designation indicates the form of case used. K = Rectangular Flush Case, Flange mounted.

MECHANISMS

The second letter in the type designation indicates the principle of operation.

X = Permanent magnet moving coil
A = Repulsion-Attraction, moving iron
P = Watt transducer plus X
I = Rotating iron vane
C = Rectifier plus X
F = Iron core electromagnetic

All of the above mechanisms employ the taut band suspension bearing system except the I and F types.

CAUTION: When the instrument mechanism is exposed, avoid contact with the tension springs. These springs are precisely made and positioned, and any pressures inadvertently applied to them may cause misalignment of the moving element.

DIAL NOTES

References to type style number, use of external components if required, coil ratings, calibration data etc., are made on the dial mask.

INSTALLATION

Unpack instruments carefully. Terminal and mounting hardware, and any external components may be in separate packages.

Drill panels and connect instruments according to the diagrams in this leaflet, or according to switchboard drawings if instruments are supplied as part of a switchboard.

Before energizing the instrument, adjust the pointer to zero by means of the zero adjuster at the front of the instrument.

CIRCUIT PRECAUTIONS

HIGH VOLTAGE OPERATION

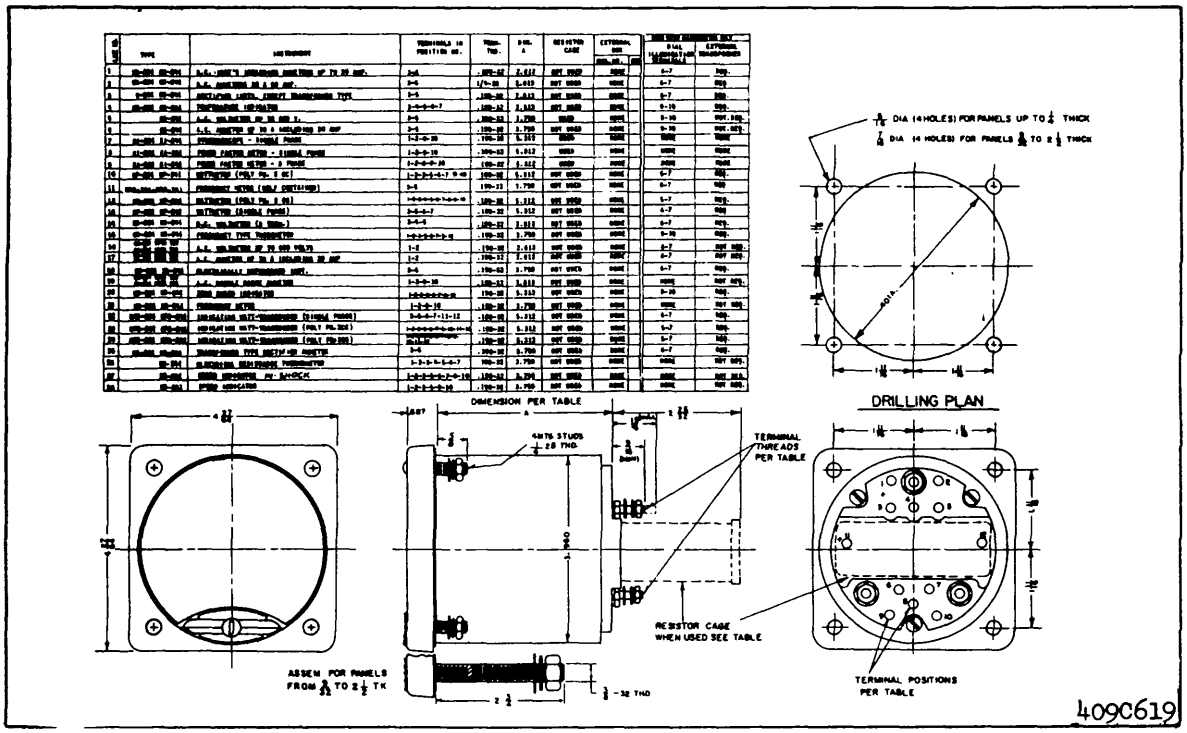
All instruments are insulated for 800 volt maximum service.

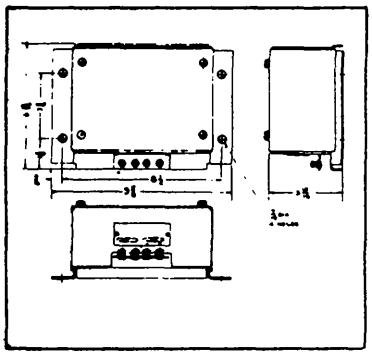
When voltmeters are used with external resistors on voltages higher than the insulation rating of the instrument, one terminal of the instrument should be grounded.

Arnmeters with external shunts must be used with leads having the resistance specified in the dial notes. If the circuit voltage exceeds the insulation rating of the instrument, the shunt should be in the grounded side of the line.

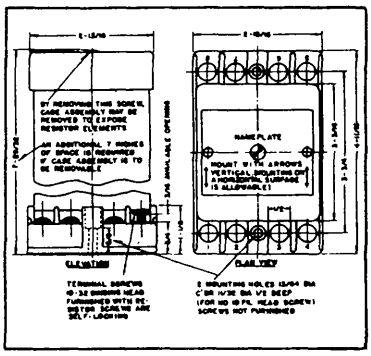
GROUNDING OF CASES

Instruments, when mounted on grounded metal structures, are considered adequately grounded when secured to the structures by metal hardware. For mounting on insulated structures any one of the three case to base mounting screws may be used as a grounding terminal.

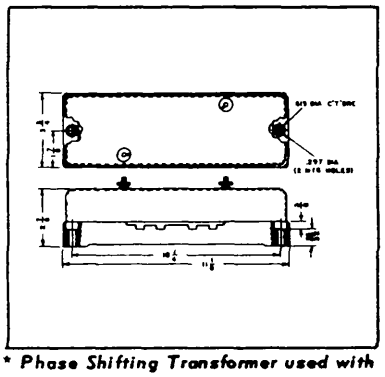




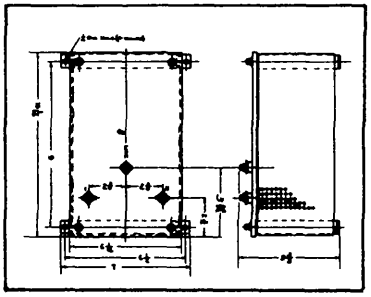
Transducer used with Frequency Meter.



VR-825 External Resistor.



** Phase Shifting Transformer used with 3-phase, 3-wire and 3-phase 4-wire Varmeter.*



Reaction Compensation used with Single Phase Varmeter.

Fig. 1 Outline Dimensions and Drilling Plan for Type K-241 Instruments and Accessories.

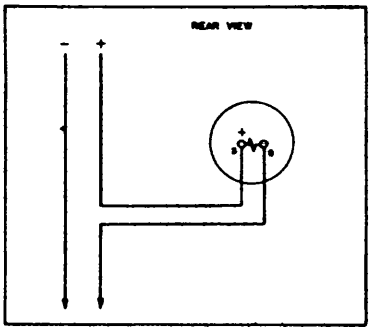


Fig. 2. Type X-241 Ammeter and Millimeter (self contained

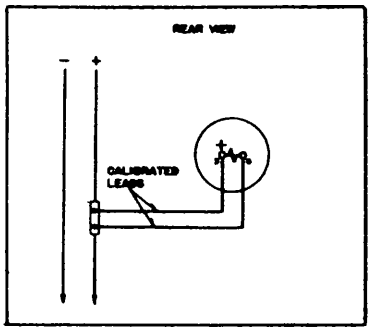


Fig. 3 Type X-241 Ammeter External Shunt

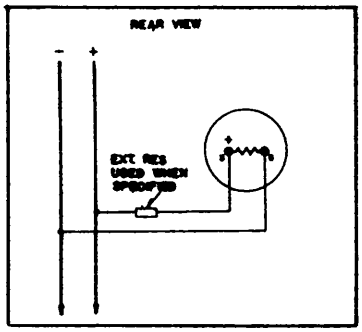


Fig 4. Type X-241 Voltmeter

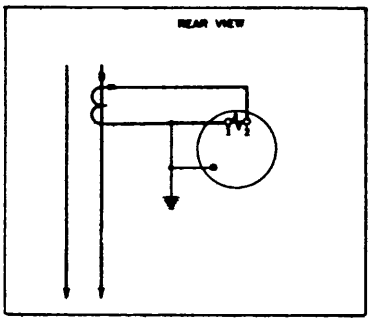


Fig. 5. Type A-241 and C-241 Ammeter.

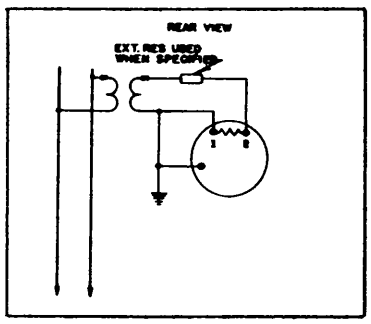


Fig. 6. Type A-241 and C-241 Voltmeter

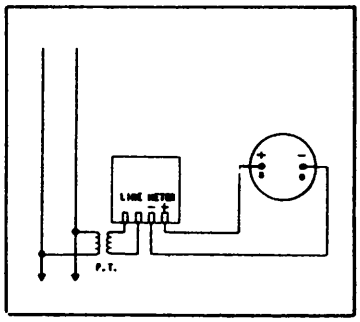


Fig. 7. Type X-241 Frequency Meter with External Transducer

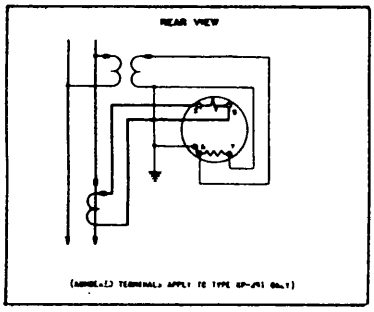


Fig. 8. Type F-241 and P-241 Single Phase Wattmeter.

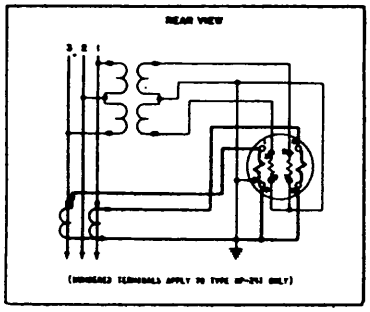


Fig. 9. Types F-241 and P-241 Polyphase 2 current coil Wattmeter.

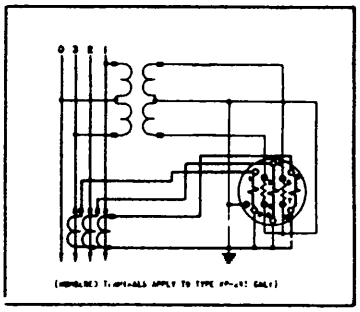


Fig. 10. Types F-241 and P-241 Polyphase 3 current coil wattmeter.

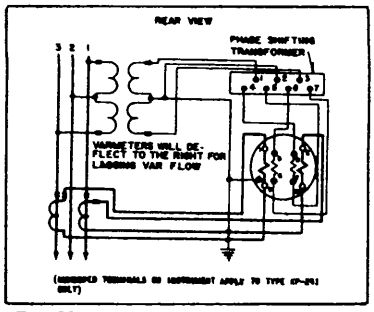


Fig. 11. Types F-241 and P-241 Polyphase 2 Current Coil Varmeter

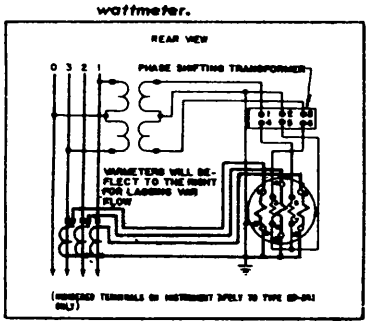


Fig. 12. Types F-241 and P-241 Polyphase 3 Current Coil Varmeter.

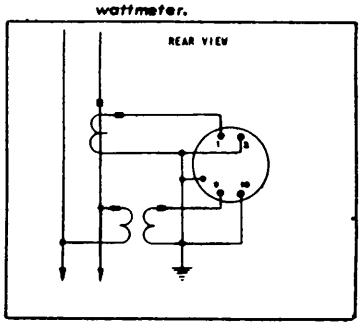


Fig. 13. Type i-241 Single Phase Power Factor Meter.

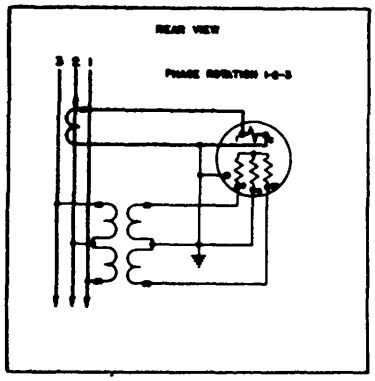


Fig. 14. Type I-241 Polyphase Power Factor Meter.

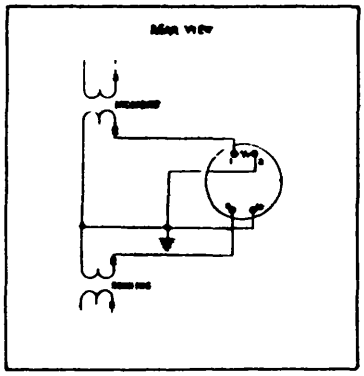


Fig. 15. Type I-241 Synchroscope

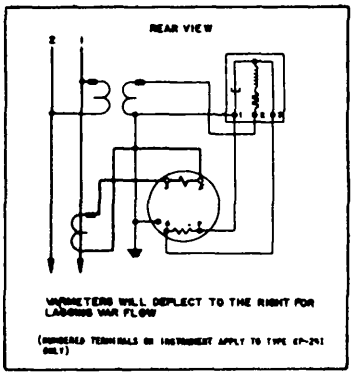


Fig. 16. Types F-241 and P-241 Single Phase Varmeter.

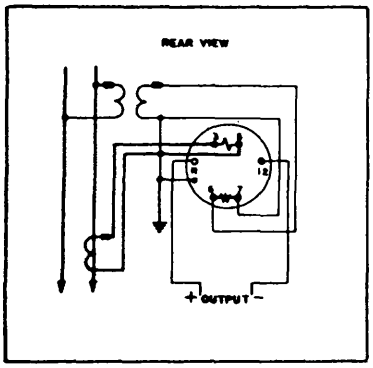


Fig. 17. Type KP2-241 Watt Transducer Single Phase

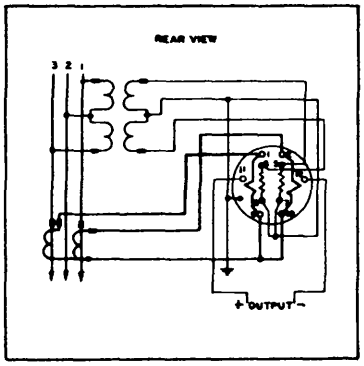


Fig. 18 Type KP2-241 Indicating Watt Transducer 2 Current Coil

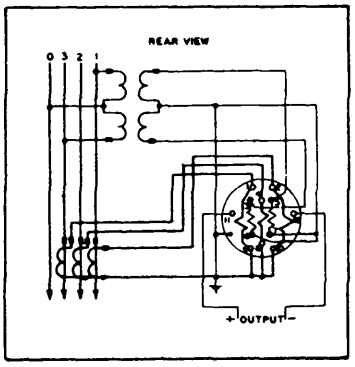


Fig. 19. Type KP2-241 Indicating Watt Transducer 3 Current Coil

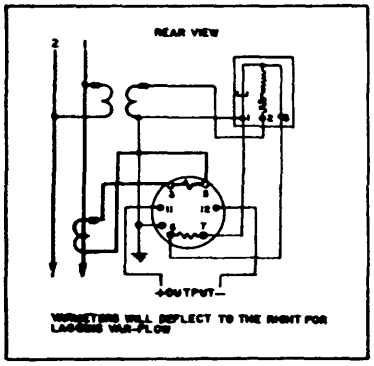


Fig. 20 Type KP2-241 Indicating VAR Transducer Single Phase.

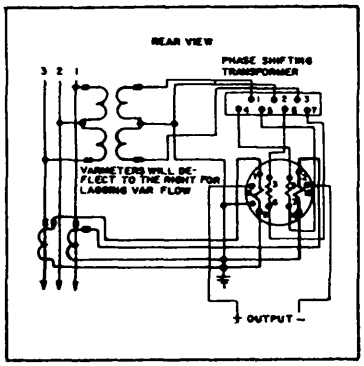


Fig. 21. Type KP2-241 Indicating VAR Transducer 2 t Current Coil.

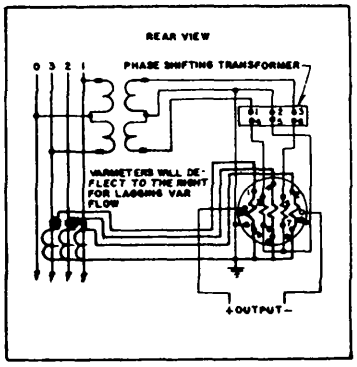


Fig. 22 Type KP2-241 Indicating VAR Transducer 3 Current Coil.

APPENDIX A

BASIC ISSUE ITEMS LIST

Section I. INTRODUCTION

A-1. Scope

This appendix lists items which accompany the Power Plants or are required for installation, operation, or operator's maintenance.

A-2. General

This Basic Issue Items List is divided into the following sections:

a. Basic Issue Items -- Section II. A list of items which accompany the Power Plants or are required for the installation, operation, or operator's maintenance.

b. Maintenance and Operating Supplies -- Section III. A listing of maintenance and operating supplies required for initial operation.

A-3. Explanation of Columns

The following provides an explanation of columns in the tabular list of Basic Issue Items, Section II.

a. Source, Maintenance, and Recoverability Codes (SMR).

NOTE: Common hardware items known to be readily available in Army supply will be assigned Maintenance Codes only. Source Codes, Recoverability Codes, and quantity Authorized will not be assigned to this category of items.

Column 1:

(1) Source Code, indicates the selection status and source for the listed item. Source codes are:

Code	Explanation
P	Applied to repair parts which are stocked in or supplied from GSA/DSA or Army supply system, and authorized for use at indicated maintenance categories.

(2) Maintenance Code, indicates the lowest category of maintenance authorized to install the listed item The maintenance level code is:

Code	Explanation
C	Operator/crew
0	Organizational maintenance

(3) Recoverability Code, indicates whether unserviceable items should be returned for recovery or salvage. Items not coded are expendable.

b. Federal Stock Number, Column 2. This column indicates the Federal stock number for the item.

c. Description, Column 3. This column indicates the Federal item name and any additional description of the item required. A part number or other reference number is followed by the applicable five-digit Federal supply code for manufacturers in parentheses. Repair parts quantities included in kits, sets, and assemblies are

shown in front of the repair part name.

d. Unit of Issue, Column 4. This column indicates the unit used as a basis for issue, e.g., ea, pr, ft, yd, etc.

e. Quantity Incorporated in Unit Pack, Column 5. This column indicates the actual quantity contained in the unit pack.

f. Quantity Incorporated in Unit, Column 6. This column indicates the quantity of the item used in the functional group.

g. Quantity Furnished With Equipment, Column 7. This column indicates the quantity of an item furnished with the equipment.

h. Quantity Authorized, Column 8. This column indicates the quantity of an item authorized the operator/crew to have on hand or to obtain as required. As required items are indicated with an asterisk.

i. Illustration, Column 9. This column is divided as follows:

(1) Figure Number, column 9a. Indicates the figure number of the illustration in which the item is shown.

(2) Item Number, column 9b. Indicates the callout number used to reference the item in the illustration.

A-4. Explanation of Columns in the Tabular List of Maintenance and Operating Supplies -- Section III.

a. Component Application, Column 1. This column identifies the component application of each maintenance or operating supply item.

b. Federal Stock Number, Column 2. This column indicates the Federal stock number for the item and will be used for

requisitioning purposes.

c. Description, Column 3. This column indicates the item and brief description.

d. Quantity Required for Initial Operation, Column 4. This column indicates the quantity of each maintenance or operating supply item required for initial operation of the equipment.

e. Quantity Required for 8 Hours Operation, Column 5. This column indicates the estimated quantities required for an average eight hours of operation.

f. Notes, Column 6. This column indicates informative notes keyed to data appearing in a preceding column.

A-5. Abbreviations

Abbreviations	Explanation
dia	diameter
dim	dimensions
ea	each
h	high
in	inch(es)
lg	long/length
lbs	pounds
o/a	overall
sect	section
thd	thread
w/	with

Section II. BASIC ISSUE ITEMS

(1) SMR CODE	(2) FEDERAL STOCK NUMBER	(3) DESCRIPTION Ref no. & mfr Code / Usable on code	(4) UNIT OF ISSUE	(5) QTY INC IN UNIT PACK	(6) QTY INC IN UNIT	(7) QTY FURN WITH EQUIP	(8) QTY AUTH	(9) ILLUSTRATION (a) FIG NO.	(9) ILLUSTRATION (b) ITEM NO.
		GROUP 31 - BASIC ISSUE ITEMS MANUFACTURER INSTALLED 3100 - BASIC ISSUE ITEMS MANUFACTURER OR DEPOT INSTALLED							
P C	7510-889-3494	BINDER, LOOSELEAF: 3 ring type fasteners, blind embossed printed, U.S. Army Equipment Log Book: For replacement envelope see FSN 7510-763-5996	EA			1	1		
P C	7520-559-9618	CASE, MAINTENANCE AND OPERATIONAL MANUAL: W/1 pocket 16 in. h, 1 1/d in. deep, 9 3/4 in. lg. and 1 pocket 16 in. h, 1 3/8 in. deep, 9 in. lg: O/A dim. 22 in. h, 12 3/4 in. lg. MIL-B-11743 DEPARTMENT OF THE ARMY: Operator, Organizational, Direct Support, General Support and Depot Maintenance Manual TM 5-6115-456-15	EA			1	1		

Section II. BASIC ISSUE ITEMS

(1) SMR CODE	(2) FEDERAL STOCK NUMBER	(3) DESCRIPTION Ref no. & mfr Code / Usable on code	(4) UNIT OF ISSUE	(5) QTY INC IN UNIT PACK	(6) QTY INC IN UNIT	(7) QTY FURN WITH EQUIP	(8) QTY AUTH	(9) ILLUSTRATION (a) FIG NO.	(9) ILLUSTRATION (b) ITEM NO.
		3100 - BASIC ISSUE ITEMS MANUFACTURER OR DEPOT INSTALLED (cont)							
P C	4210-555-8837	EXTINGUISHER, FIRE: Monobromotriflouromethane, charged hand type, penetrating seal valve, W/bracket 2 3/4 lbs MIL-SPEC-E-52031				2	2		
P C	5975-878-3791	ROD, GROUND: 3 sect; steel; 9 ft lg; 5/8 in dia; copper coated finish, cone point; male thd end; separable clamp for attaching ground wire; furnished W/6 ft grounding cable and ground terminal; MIL-R-11461, Type II, Style 2				2	2		

Section III. MAINTENANCE AND OPERATING SUPPLIES

(1) Component application	(2) Federal stock number	(3) Description	(4) Quantity required f/initial operation	(5) Quantity required f/8 hrs operation	(6) Notes
0101 Crankcase		OIL, LUBRICATING: 55 gallon drums as follows:			1. Includes quantity of oil to fill crankcase, lines and filter.
	9150-265-9437	OE-30	370 Gal (1)	-----	2. Refer to freezing points for mixture.
	9150-242-7604	Arctic (OES)	370 Gal (1).	-----	
					3. Radiator capacity, includes lines and engine.
0306 Fuel Tank		FUEL, DIESEL: Bulk			
	9140-286-5294	DF-2		888 Gal	
	9140-286-5286	DF-1		888 Gal	
	9140-286-5283	DF-A		888 Gal	
0501 Radiator		ANTIFREEZE: 55 gallon drums as follows:			
	6850-664-1409	Ethylene Glycol (2)	310 Gal (3)		
	6850-174-1806	Arctic	310 Gal (3)		
Grease Points		GREASE BALL AND ROLLER BEARING BR: 5 pound can			
	1950-663-9795				

APPENDIX B

MAINTENANCE ALLOCATION CHART

Section I. INTRODUCTION

B-1. General

a. This section provides a general explanation of all maintenance and repair functions authorized at various maintenance levels.

b. Section II designates overall responsibility for the performance of maintenance functions on the identified and item or component. The implementation of the maintenance functions upon the end item or component will be consistent with the assigned maintenance functions.

B-2. Explanation of Columns in Section II

a. Group Number. The functional group is a numerical group set up on a functional basis. The applicable functional grouping indexes (obtained from TB 750-93-1, Functional Grouping Codes) are listed on the MAC in the appropriate numerical sequence. These indexes are normally set up in accordance with their function and proximity to each other.

b. Functional Group. This column contains a brief description of the components of each functional group.

c. Maintenance Functions. This column lists the various maintenance functions (A through K) and indicates the lowest maintenance

category authorized to perform these functions. The symbol designations for the various maintenance categories are as follows:

C - Operator or crew

O - Organizational maintenance

F - Direct support maintenance

H - General support maintenance

D - Depot maintenance

The maintenance functions are defined as follows:

A - INSPECT. To determine serviceability of an item by comparing its physical, mechanical, and electrical characteristics with established standards.

B - TEST. To verify serviceability and to detect electrical or mechanical failure by use of test equipment.

C - SERVICE. To clean, to preserve, to charge, to paint, and to add fuel, lubricate, cooling agents, and air.

D - ADJUST. To rectify to the extent necessary to bring into proper operating range.

E - ALIGN. To adjust specified variable elements of an item to bring to optimum performance.

F - CALIBRATE. To determine the corrections to be made in the readings of instruments or test equipment used in precise measurement. Consists of the comparisons of two instruments,

one of which is a certified standard of known accuracy, to detect and adjust any discrepancy in the accuracy of the instrument being compared with the certified standard.

G - INSTALL. To set up for use in an operational environment such as an emplacement, site, or vehicle.

H - REPLACE. To replace unserviceable items with serviceable assemblies, subassemblies, or parts.

I - REPAIR. To restore an item to serviceable condition. This includes, but is not limited to inspection, cleaning, preserving, adjusting, replacing, welding, riveting, and strengthening.

J - OVERHAUL. To restore an item to a completely serviceable condition as prescribed by maintenance serviceability standards using the Inspect and Repair Only as Necessary (IROAN) technique.

K - REBUILD. To restore an item to a standard as nearly as possible to original or new condition in appearance, performance, and life expectancy. This is accomplished through complete disassembly of the item inspection of all parts or components, repair or replacement of worn or unserviceable elements (items) using original manufacturing tolerances and specifications, and subsequent reassembly of the item.

d. Tools and Equipment. This column is provided for referencing by code the special tools and test equipment required to perform the maintenance functions.

e. Remarks. This column is provided for referencing by code the remarks pertinent to the maintenance functions.

MAINTENANCE ALLOCATION CHART
FOR

SECTION II - MAINTENANCE ASSIGNEMENT

(1) FUNCTIONAL GROUP NUMBER	(2) COMPONENTS ASSEMBLY NOMENCLATURE	MAINTENANCE FUNCTIONS											NOTE REFERENCE	
		A INSPECT	B TEST	C SERVICE	D ADJUST	E ALIGN	F CALIBRATE	G INSTALL	H REPLACE	I REPAIR	J OVERHAUL	K REBUILD	L TOOLS AND EQUIPMENT	M REMARKS
01	ENGINE													
0100	Engine Assembly:													
	Engine, diesel 1	C	F	C	--	--	--	--	--	F	F	H		
	Bracket mounting	--	--	--	--	--	--	--	--	F				
0101	Crankcase, Cylinder Head:													
	Crankcase	--	--	--	--	--	--	--	--	H	H			
	Head, cylinder	--	--	--	--	--	--	--	--	F	F			
0102	Crankshaft:													
	Bearings	--	--	--	--	--	--	--	--	H				
	Crankshaft	--	--	--	--	--	--	--	--	H	D			
	Pulley	--	--	--	--	--	--	--	--	F				
	Seals	--	--	--	--	--	--	--	--	H				
	Damper, vibration	--	--	--	--	--	--	--	--	F				
0103	Flywheel:													
	Flywheel assembly	--	--	--	--	--	--	--	--	F	H			
	Cover, dust	--	--	--	--	--	--	--	--	0				
0104	Pistons, Connecting Rod:													
	Piston assembly	--	--	--	--	--	--	--	--	H	H			
	Rod assembly	--	--	--	--	--	--	--	--	H	H			
0105	Valves, Camshafts, Timing System:													
	Arms, rocker	--	--	--	0	--	--	--	--	F				

MAINTENANCE ALLOCATION CHART
FOR

SECTION II - MAINTENANCE ASSIGNEMENT

(1) FUNCTIONAL GROUP NUMBER	(2) COMPONENTS ASSEMBLY NOMENCLATURE	MAINTENANCE FUNCTIONS											NOTE REFERENCE	
		A	B	C	D	E	F	G	H	I	J	K	L	M
		INSPECT	TEST	SERVICE	ADJUST	ALIGN	CALIBRATE	INSTALL	REPLACE	REPAIR	OVERHAUL	REBUILD	TOOLS AND EQUIPMENT	REMARKS
	Cover, valve	--	--	--	--	--	--	--	0					
	Guide, valve	--	--	--	--	--	--	--	F					
	Insert, valve seat	--	--	--	--	--	--	--	F	F				
	Valve, poppet	--	--	--	--	--	--	--	F	F				
	Rod, push	--	--	--	--	--	--	--	F					
	Lifter, valve	--	--	--	--	--	--	--	H					
	Bearings, camshaft	--	--	--	--	--	--	--	H					
	Camshaft	--	--	--	--	--	--	--	H					
	Gears, helical	--	--	--	--	--	--	--	H					
	Washer, thrust	--	--	--	--	--	--	--	H					
	Cover, gears	--	--	--	--	--	--	--	H					
0106	Engine Lubrication System:													
	Breather	--	--	--	C	--	--	--	0					
	Gage, oil level	--	--	--	--	--	--	--	C					
	Filter assembly, oil	--	--	--	C	--	--	--	0					
	Valve, relief oil filter	--	--	--	--	--	--	--	0					
	Cooler, oil	--	--	--	--	--	--	--	0					
	Pump assembly, oil	--	--	--	--	--	--	--	F	F				
	Pan, oil	--	--	--	--	--	--	--	F					
	Lines, oil	C	--	--	--	--	--	--	0					

MAINTENANCE ALLOCATION CHART
FOR

SECTION II - MAINTENANCE ASSIGNEMENT

(1) FUNCTIONAL GROUP NUMBER	(2) COMPONENTS ASSEMBLY NOMENCLATURE	MAINTENANCE FUNCTIONS											NOTE REFERENCE	
		A	B	C	D	E	F	G	H	I	J	K	L	M
		INSPECT	TEST	SERVICE	ADJUST	ALIGN	CALIBRATE	INSTALL	REPLACE	REPAIR	OVERHAUL	REBUILD	TOOLS AND EQUIPMENT	REMARKS
0108	Manifolds:													
	Manifold, intake and exhaust ..	--	--	--	--	--	--	--	0					
03	FUEL SYSTEM													
0301	Fuel injector:													
	Fuel injector.....	--	--	--	F	--	--	--	0	F				
0302	Fuel Pumps:													
	Pump, fuel transfer	--	--	0	--	--	--	--	0					
	Pump, fuel injection	--	H	--	0	--	--	--	0	F	H			
0304	Air Cleaner:													
	Cleaner, assembly, air	--	--	C	--	--	--	--	0					
0305	Turbocharger.....	--	--	--	--	--	--	--	0	H	D			
0306	Tanks, Lines, Fittings:													
	Cap, fuel tank	--	--	--	--	--	--	--	0					
	Tank, fuel.....	--	--	--	--	--	--	--	0	F				
	Float assembly, day tank	--	--	--	--	--	--	--	0					
	Lines.....	--	---	--	--	--	--	--	0					
	Tube, fuel	--	--	--	--	--	--	--	0					
0308	Governor:													
	Governor and actuator	C	--	--	F	--	--	--	0	H	H			

MAINTENANCE ALLOCATION CHART
FOR

SECTION II - MAINTENANCE ASSIGNEMENT

(1) FUNCTIONAL GROUP NUMBER	(2) COMPONENTS ASSEMBLY NOMENCLATURE	MAINTENANCE FUNCTIONS											NOTE REFERENCE	
		A	B	C	D	E	F	G	H	I	J	K	L	M
		INSPECT	TEST	SERVICE	ADJUST	ALIGN	CALIBRATE	INSTALL	REPLACE	REPAIR	OVERHAUL	REBUILD	TOOLS AND EQUIPMENT	REMARKS
0309	Fuel, Filters:													
	Filter, fuel	--	--	C	--	--	--	--	0					
0311	Engine Starting Aids:													
	Primer, fuel.....	--	--	0										
	Lines, primer.....	--	--	--	--	--	--	--	0					
0312	Throttle Controls:													
	Control throttle	--	--	--	--	--	--	--	0					
04	EXHAUST SYSTEM													
0401	Muffler and Pipes:													
	Muffler and pipes.....	--	--	--	--	--	--	--	0					
05	COOLING SYSTEM													
0501	Radiator:													
	Radiator.....	--	--	C	--	--	--	--	0	F				
	Cap, radiator.....	--	--	--	--	--	--	--	0					
	Grill, radiator.....	--	--	--	--	--	--	--	0	F				
	Shutter assembly.....	--	--	--	--	--	--	--	0	F				
	Thermostat, shutter.....	--	0	--	--	--	--	--	0					
0503	Water Manifolds, Headers, Thermostats, and Housing Gaskets:													
	Manifold, water								0					

MAINTENANCE ALLOCATION CHART
FOR

SECTION II - MAINTENANCE ASSIGNEMENT

(1) FUNCTIONAL GROUP NUMBER	(2) COMPONENTS ASSEMBLY NOMENCLATURE	MAINTENANCE FUNCTIONS											NOTE REFERENCE	
		A	B	C	D	E	F	G	H	I	J	K	L	M
		INSPECT	TEST	SERVICE	ADJUST	ALIGN	CALIBRATE	INSTALL	REPLACE	REPAIR	OVERHAUL	REBUILD	TOOLS AND EQUIPMENT	REMARKS
	Thermostat	--	0	--	--	--	--	--	0					
	Hose pipes	--	--	--	--	--	--	--	0					
0504	Water Pump:													
	Pump assembly, water	--	--	C	--	--	--	--	0	F				
0505	Fan Assembly:													
	Fan assembly	--	--	--	--	--	--	--	0					
	Belts, drive	--	--	--	C	--	--	--	0					
	Fan guard	--	--	--	--	--	--	--	0					
06	ELECTRICAL EQUIPMENT													
0603	Starting Motor:													
	Starter	--	0	0	--	--	--	--	0	F	H			
	Switch, solenoid	--	--	--	--	--	--	--	0					
0606	Engine Safety Controls:													
	Governor, overspeed	--	--	--	--	--	--	--	0	F				
	Switches, engine shutdown	--	--	--	--	--	--	--	0					
0607	Instrument or Engine Control Panel:													
	Ammeter	--	--	--	--	--	--	--	0					
	Gage, temperature, water, oil	--	--	--	--	--	--	--	0					
	Light, panel	--	--	--	--	--	--	--	0					

MAINTENANCE ALLOCATION CHART
FOR

SECTION II - MAINTENANCE ASSIGNEMENT

(1) FUNCTIONAL GROUP NUMBER	(2) COMPONENTS ASSEMBLY NOMENCLATURE	MAINTENANCE FUNCTIONS											NOTE REFERENCE	
		A	B	C	D	E	F	G	H	I	J	K	L	M
		INSPECT	TEST	SERVICE	ADJUST	ALIGN	CALIBRATE	INSTALL	REPLACE	REPAIR	OVERHAUL	REBUILD	TOOLS AND EQUIPMENT	REMARKS
	Lamp	--	--	--	--	--	--	--	--	C				
	Switch, toggle	--	--	--	--	--	--	--	0					
	Wiring harness	--	--	--	--	--	--	--	F	0				
0608	Miscellaneous Items:													
	Battery Charging Rectifier.	--	--	--	--	--	--	--	0	F				
	Receptacle, Battery, Charging	--	--	--	--	--	--	--	--	0				
0612	Batteries, storage:													
	Battery, storage	--	0	C	--	--	--	--	C					
0615	Radio Interference Suppression:													
	Strap, ground	--	--	--	--	--	--	--	0					
15	FRAME													
1501	Frame Assembly:													
	Frame assembly	--	--	--	--	--	--	--	H	F				
	Stud, ground	--	--	--	--	--	--	--	0					
	Eye, lifting	--	--	--	--	--	--	--	F					
18	BODY, CAB, HOOD AND HULL													
1801	Body, Cab, Hood and Hull Assemblies:													

MAINTENANCE ALLOCATION CHART
FOR

SECTION II - MAINTENANCE ASSIGNEMENT

(1) FUNCTIONAL GROUP NUMBER	(2) COMPONENTS ASSEMBLY NOMENCLATURE	MAINTENANCE FUNCTIONS											NOTE REFERENCE	
		A	B	C	D	E	F	G	H	I	J	K	L	M
		INSPECT	TEST	SERVICE	ADJUST	ALIGN	CALIBRATE	INSTALL	REPLACE	REPAIR	OVERHAUL	REBUILD	TOOLS AND EQUIPMENT	REMARKS
	Doors and hood	--	--	--	--	--	--	--	0					
	Panels	--	--	--	--	--	--	--	0					
	Housing	--	--	--	--	--	--	--	F					
1808	Boxes:													
	Box, Tool	-	--	--	--	--	--	--	0					
22	BODY, CHASSIS OR HULL AND ACCESSORY ITEMS													
2210	Data Plates:													
	Plates, data	--	--	--	--	--	--	--	F					
	Plates, instruction	--	--	--	--	--	--	--	0					
40	ELECTRIC GENERATORS													
4000	Generator Assembly:													
	Generator assembly	C	F	C	--	--	--	--	F	F	H			
4001	Rotor Assemblies:													
	Rotor, generator	--	H	--	--	--	--	--	H	H	D			
4002	Stator Assemblies:													
	Stator, generator	--	H	--	--	--	--	--	H	H	D			
4003	Brushes:	--	--	--	--	--	--	--	0					
4004	Ventillating System:													
	Fan, ventilating	--	--	--	--	--	--	--	F					

MAINTENANCE ALLOCATION CHART
FOR

SECTION II - MAINTENANCE ASSIGNEMENT

(1) FUNCTIONAL GROUP NUMBER	(2) COMPONENTS ASSEMBLY NOMENCLATURE	MAINTENANCE FUNCTIONS											NOTE REFERENCE	
		A	B	C	D	E	F	G	H	I	J	K	L	M
		INSPECT	TEST	SERVICE	ADJUST	ALIGN	CALIBRATE	INSTALL	REPLACE	REPAIR	OVERHAUL	REBUILD	TOOLS AND EQUIPMENT	REMARKS
	Screens	--	--	0	--	--	--	--	0					
4005	Frame Support and Housing:													
	Bearing.....	--	--	--	--	--	--	--	H					
4007	Drive Components:													
	Disc, coupling	--	--	--	--	--	--	--	F					
4009	Control Panels, Housing, Cubicles:													
	Converter	--	--	--	--	--	--	--	F					
	Lights.....	--	--	--	--	--	--	--	0					
	Lamp -	--	--	--	--	--	--	--	C					
	Panel, control	--	--	--	--	--	--	--	F					
	Meters	--	--	--	--	--	--	--	0					
	Receptacle	--	--	--	--	--	--	--	0					
	Wiring Harness.....	--	--	--	--	--	--	--	F	0				
4011	Circuit Breakers:													
	Circuit breaker assembly ..	--	--	--	--	--	--	--	F					
	Fuse holder	--	--	--	--	--	--	--	0					
	Fuse	--	--	--	--	--	--	--	C					
4012	Switches:													
	Switch, rotary.....	--	--	--	--	--	--	--	0					
	Switch, toggle	--	--	--	--	--	--	--	0					

MAINTENANCE ALLOCATION CHART
FOR

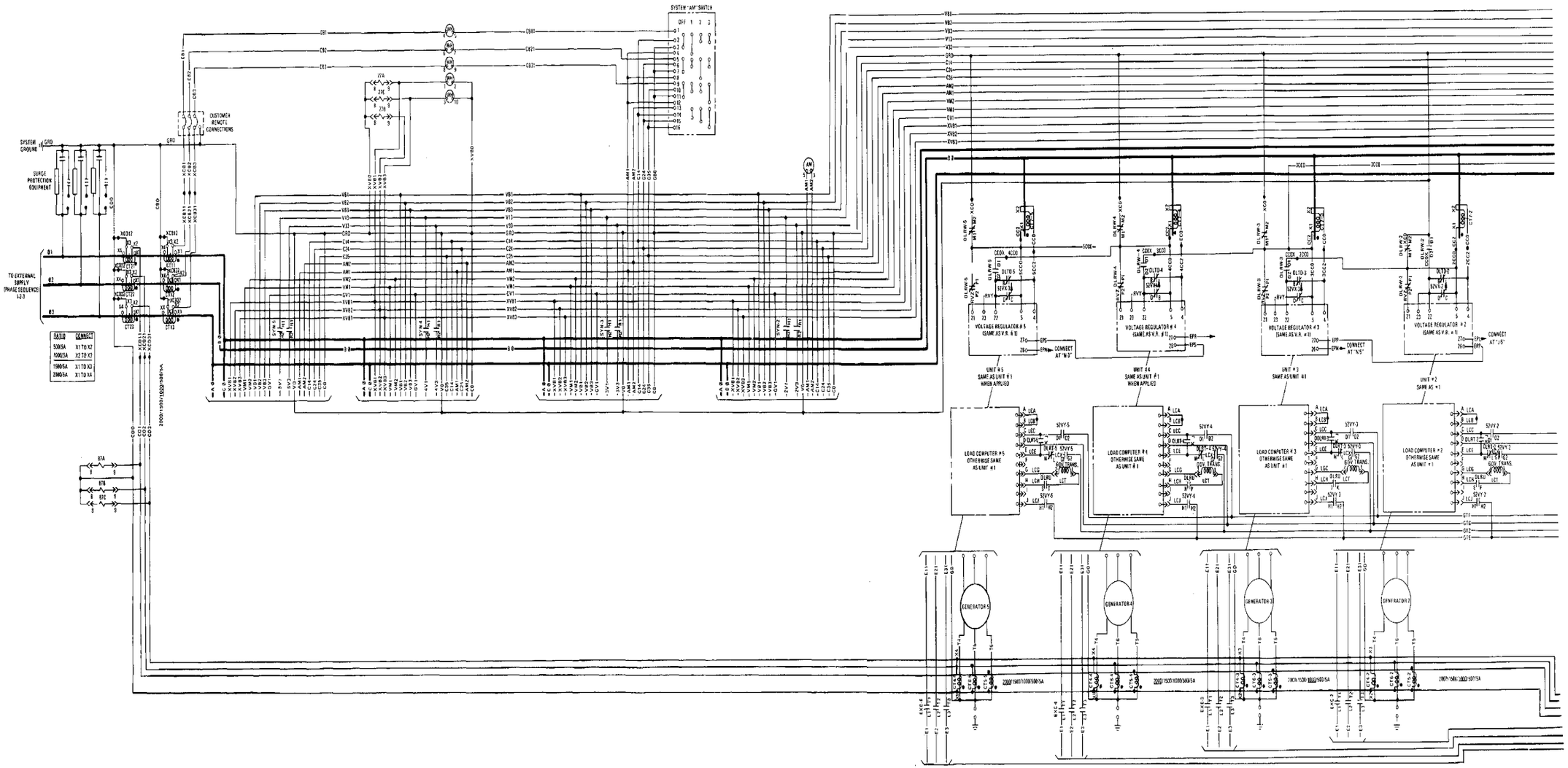
SECTION II - MAINTENANCE ASSIGNEMENT

(1) FUNCTIONAL GROUP NUMBER	(2) COMPONENTS ASSEMBLY NOMENCLATURE	MAINTENANCE FUNCTIONS											NOTE REFERENCE	
		A	B	C	D	E	F	G	H	I	J	K	L	M
		INSPECT	TEST	SERVICE	ADJUST	ALIGN	CALIBRATE	INSTALL	REPLACE	REPAIR	OVERHAUL	REBUILD	TOOLS AND EQUIPMENT	REMARKS
4013	Regulator, Voltage:													
	Regulator, voltage	--	--	--	--	--	--	--	F					
	Element	--	--	--	F	--	--	--	F					
4014	Resistors:													
	Resistor, variable.....	--	0	--	0	--	--	--	0					
	Rheostat, voltage.....	--	0	--	0	--	--	--	0					
	Resistor, fixed.....	--	F	--	--	--	--	--	F					
4015	Relay or Assembly:													
	Relay, assembly	--	F	--	--	--	--	--	F					
	Relay, heater	--	F	--	--	--	--	--	F					
4017	Transformers:													
	Transformers	--	F	--	--	--	--	--	F					
4018	Terminal Blocks:													
	Terminal board assembly..	--	--	--	--	--	--	--	F					
	Links, shorting	--	--	--	--	--	--	--	F					
	Board assembly reconnect.	--	--	--	--	--	--	--	F					
4019	Radio Interference Suppression:													
	Capacitors	--	0	--	--	--	--	--	0					
	Leads, electrical.....	--	--	--	--	--	--	--	0					
4020	Static Exciter Components:													
	Rectifier, surge	--	--	--	--	--	--	--	F					
	Insulator, assembly.....	--	--	--	--	--	--	--	F					

MAINTENANCE ALLOCATION CHART
FOR

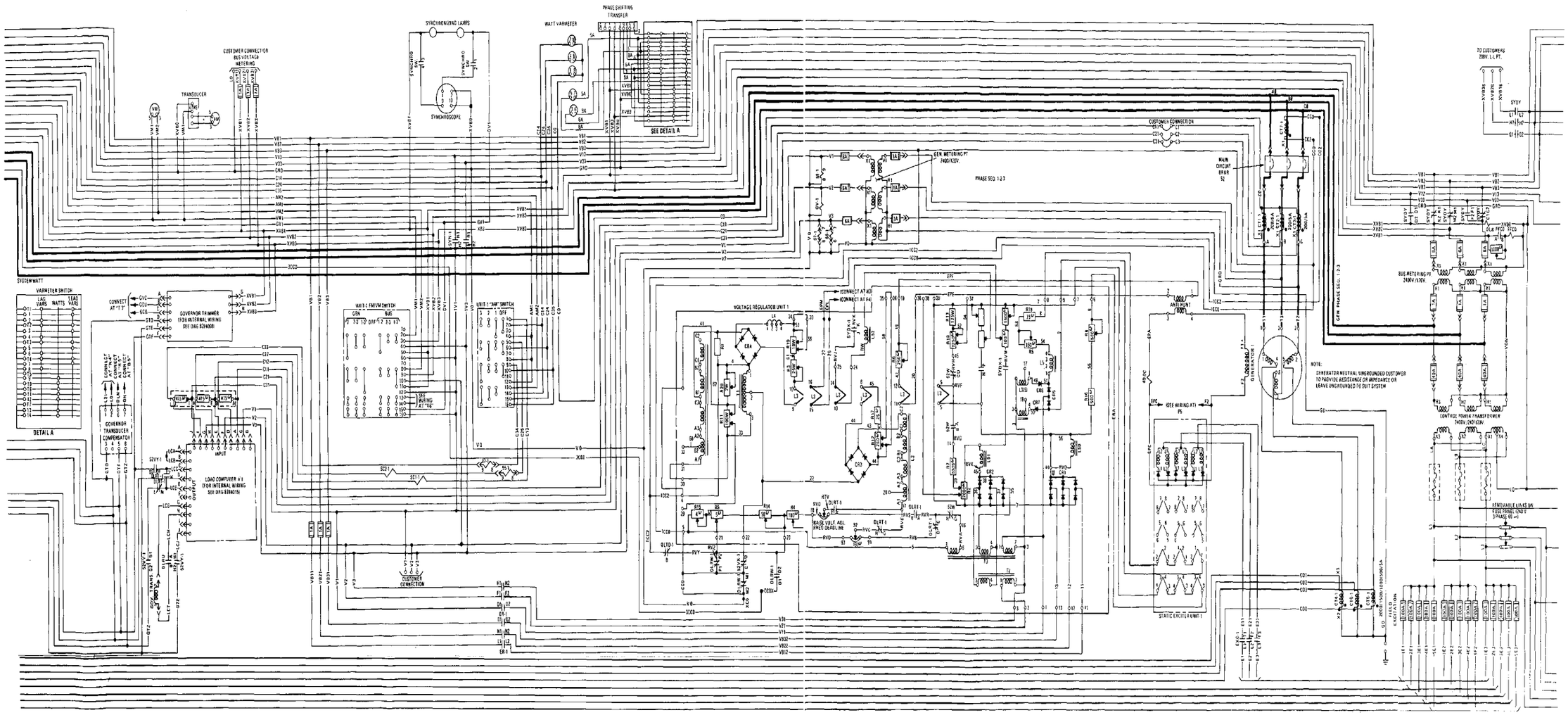
SECTION II - MAINTENANCE ASSIGNEMENT

(1) GROUP NUMBER AND EQUIPMENT	(2) COMPONENTS ASSEMBLY NOMENCLATURE REMARKS	MAINTENANCE FUNCTIONS A INSPECT	B TEST	C SERVICE	D ADJUST	E ALIGN	F CALIBRATE	G INSTALL	H REPLACE	I REPAIR	J OVERHAUL	K REBUILD	N L TOOLS
	Transformer assembly.....	--	--	--	--	--	--	--	F	F			
47	GAGES												
4702	Gages:												
	Gage, float, fuel.....	--	--	--	--	--	--	--	0				
76	FIRE FIGHTING EQUIPMENT												
7603	Fire Extinguisher:												
	Extinguisher, Fire	--	--	--	--	--	--	--	C				



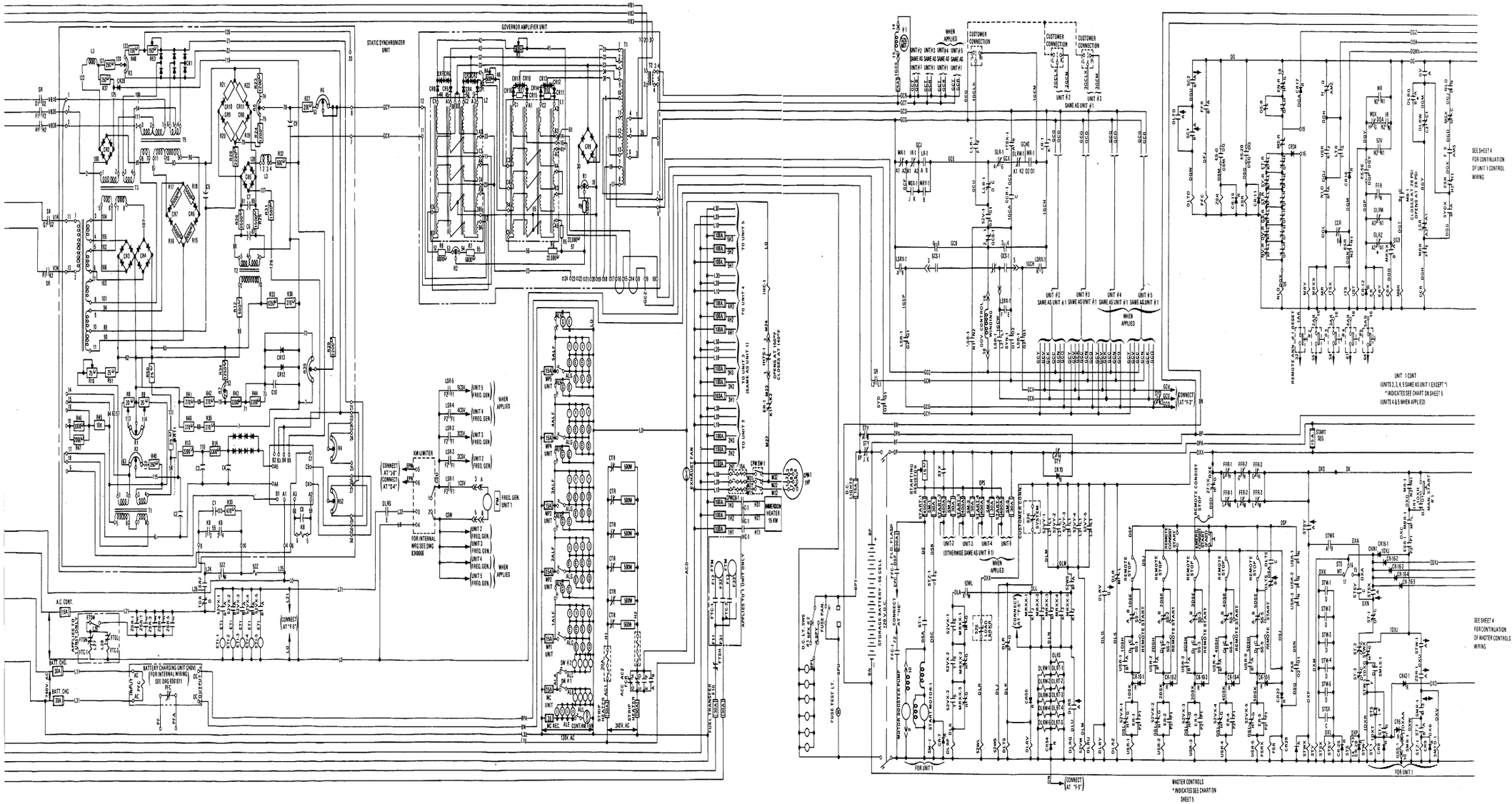
FO-1. Overall Schematic Wiring Diagram, I9658 (8386396) (Sheet 1 of 5)

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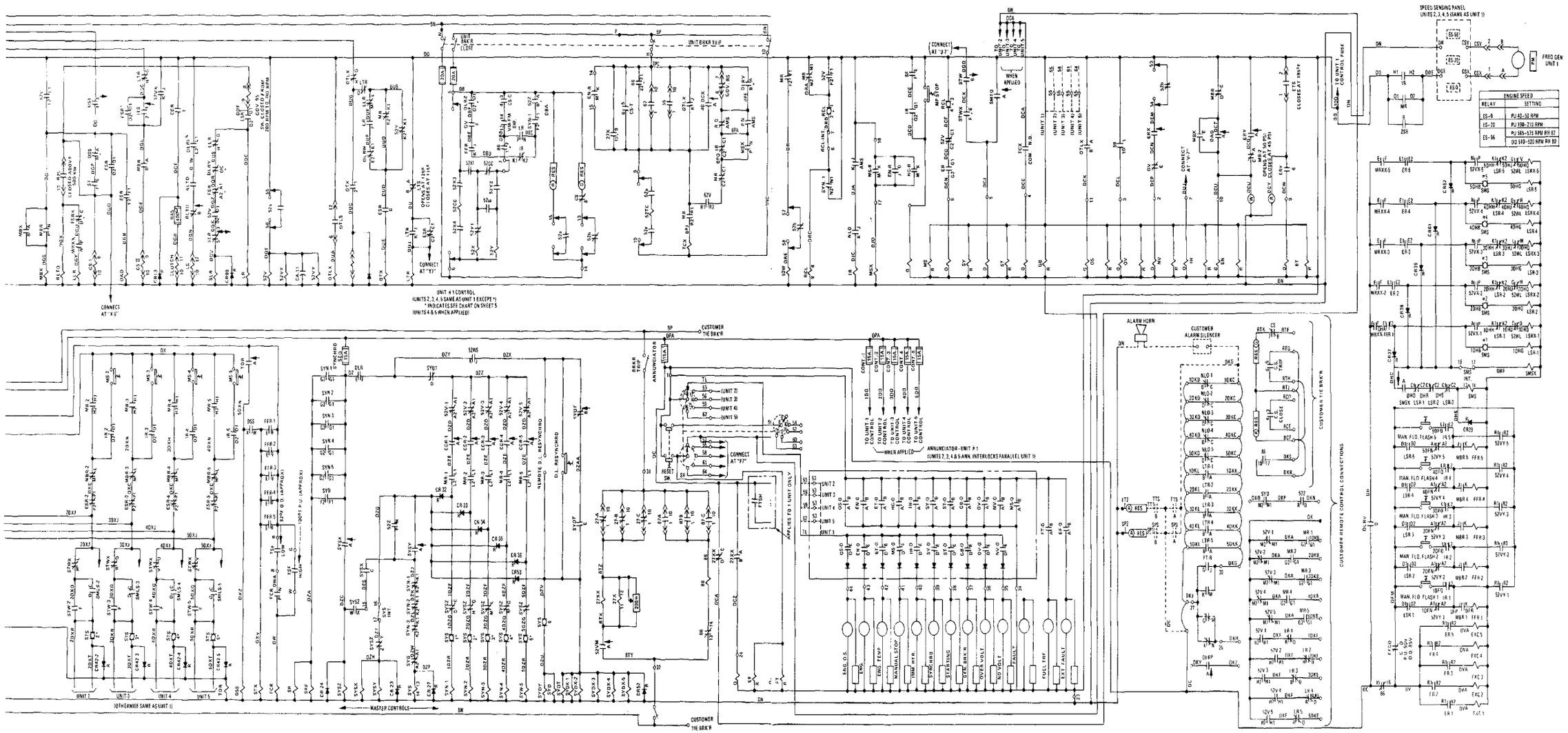


FO-2. Overall Schematic Wiring Diagram, I9658 (8386396) (Sheet 2 of 5)

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FO-3. Overall Schematic Wiring Diagram, I9658 (8386396) (Sheet 3 of 5)



FO-4. Overall Schematic Wiring Diagram, I9658 (8386396) (Sheet 4 of 5)

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LEGEND

27	UNDER VOLTAGE RELAY
27X	UNDER VOLTAGE RELAY AUX.
27XJ	
40-OC	ALTERNATOR OVER CURRENT RELAY
40-OCX	ALTERNATOR OVER CURRENT AUX. RELAY
52	MAIN CIRCUIT BREAKER
52a	AUX. SW OPEN BREAKER IS OPEN
52b	AUX. SW CLOSED, BREAKER IS OPEN
52aa	BREAKER CLOSING SOLENOID LIMIT SW
52CC	BREAKER CLOSING COIL
52TC	BREAKER TRIP COIL
52VY	BREAKER AUX. RELAY
52V, 52VM	
52VX	
52W	
52WS	SYSTEM BREAKER RELAY AUX.
52X	BREAKER CONTROL RELAY
52Y	
52Z	BREAKER CLOSING COIL RELAY
52WL	LOAD BREAKER AUX.
55	LEADING VAR RELAY
59	OVER VOLTAGE RELAY
67	REVERSE POWER RELAY
86	LOCKOUT RELAY (SEE CHART)
86 A,B,C	LOCKOUT RELAY AUX.
87	3Ø DIFFERENTIAL PROTECTION RLY.

LEGEND

A	AMMETER (A.C. OR D.C.)
AH TRF.	ANTI-HUNT TRANSFORMER
AMS	AUTOMATIC-MANUAL SWITCH (SEE CHART)
BCR	BATTERY CHARGING RELAY
CA.	CONDENSER
CCR	CLUTCH CONTROL RELAY
CPM SW.	CIRCULATING PUMP MOTOR SWITCH
CPS	CRANKCASE PRESSURE SW.
CPM	CIRCULATING PUMP MOTOR (LUBE OIL)
CR	RECTIFIER
CS	CONTROL SWITCH (SEE CHART)
CTR	CUBICLE THERMOSTAT
DLTS	DEADLINE TIMER START
DLR	DEADLINE RELAY
DSS	DELAY START RELAY
DLRV	DEADLINE RELAY AUX.
DLTS,DLRT,DLRW DLRQ,DLRY,SLRS DLRP, DLRE	
ER	EXCITATION RELAY
ERX	EXCITATION RELAY AUX.
ERY	EXCITATION RELAY AUX.
ES-Ø	ENGINE SPEED RELAY-Ø RPM
ES-20	ENGINE SPEED RELAY-200 RPM
ES-60	ENGINE SPEED RELAY-600 RPM
ES-70	ENGINE SPEED RELAY-700 RPM
ESR	ENGINE SPEED RELAY
ETS	ENGINE WATER TEMP. SW.
EXC	EXCITER CONTACTOR
ERI	ELAPSED TIME INDICATOR
FCR	FAN CONTROL RELAY
FFC	FIELD FLASHING CONTACTOR
FFCO	FIELD FLASHING CUT-OFF REY.
FFR	FIELD FLASHING RELAY
FM	FREQUENCY METER
FGO	FUEL GAS OIL SWITCH
FSR	FAST START RELAY
FSRX	FAST START RELAY AUX.
FTC	FUEL TRANSFER CONTACTOR
FTM	FUEL TRANSFER PUMP MOTOR
FTSL	FUEL TRANS. SW. LOW LEVEL (55-95 GALS)
FTSN	FUEL TRANS. SW. NORMAL (77-100 GALS)
FTSH	FUEL TRANS. SW. HIGH LEVEL (115 GALS)
FTSW	FUEL TRANS. SWITCH

LEGEND

GCS	GOVERNOR CONTROL SW. (SEE CHART)
GOV. 95	GOVERNOR SW. (CLOSED FROM 200 TO 950 RPM)
GS-I	GOVERNOR SOLENOID-IDLE
GS-II	GOVERNOR SOLENOID-60 CYCLES
GSS	GOVERNOR SOLENOID-STARTING
GV	GENERATOR VOLTAGE RELAY
GOV. R.S.	GOVERNOR RACK SWITCH (OPEN ABOVE 200 KW)
GSR	GAS SPEED RELAY
HCR	HOT CYLINDER RELAY
IH	IMMERSION HEATER
IHC	IMMERSION HEATER CONTACTOR
IHTS	IMMERSION HEATER TEMP. SW.
IR	ISOLATION RELAY
ITS	IDLE TIME (STARTING) RELAY
ITSX	IDLE TIME (STARTING) RELAY AUX.
L	REACTOR OR MAGNETIC AMPLIFIER
LLR	LOW LOAD RELAY
LR	LOADING RELAY
LTR	LOW TEMPERATURE RELAY
LSR	LOAD SHARING RELAY
LSRX	LOAD SHARING RELAY AUX.
LTS	LOW TEMP. SW.
LWS	LOW WATER SW.
MSX	MANUAL STOP RELAY AUX.
MB1	MAIN BEARING SW. (28# -30# P.U.) (18# -20# D.O.)
MB2	MAIN BEARING SW. (40# -42# P.U.) (32# -38# D.O.)
MBP	MOTOR-BOOSTER PUMP
MBR	MAIN BEARING RELAY
MBX,MBRX	MAIN BEARING RELAY AUX.
MR	MASTER RELAY
MRXX MRY	MASTER RELAY AUX.
NLO	NORMAL LOCKOUT RELAY
OAD	OIL ALARM DELAY RELAY
OLTD	OVERLOAD TIME DELAY
OTLS	OVERSPEED TRIP LIMIT SW.
OTLX	OVERSPEED TRIM LIMIT RLY.
OTS	OVERSPEED TRIM SOLENOID
OTX	OVERSPEED TRIP RELAY

LEGEND

R	RESISTOR
RCL	RECLOSURE LOCK-OUT SW.
SM	START MAGNET
SMLS	START MAGNET LIMIT SW.
SMR	START MAGNET RECYCLE
SMTO	START MAGNET TIME OUT
SPS	SUDDEN PRESSURE SW.
SR	SYNCHRONIZING RELAY
SRF	SYNCHRO. FORESTALLING RELAY
SS	START STOP SWITCH (SEE CHART)
ST	STARTING CONTACTOR
STS	STEPPING SWITCH (START) RELAY
STSX	STEPPING SWITCH RELAY AUX.
STSY	STEPPING SWITCH RELAY AUX.
STW	STARTING RELAY AUX.
STWX	STARTING RELAY AUX.
STX	STARTING CONTACTOR AUX.
STY	STARTING RELAY AUX.
STZ	STARTING RELAY AUX.
SYN	SYNCHRONIZING RELAY
SYS	STEPPING SWITCH (SYNCHRO) RELAY
SYSX	STEPPING SW. RELAY AUX.
SYSY	STEPPING SW. RELAY AUX.
SYSZ	STEPPING SW. RELAY AUX.
SYD	RESYNCHRO. RELAY
SYDT SYDX SYDY	RESYNCHRO. RELAY AUX'S
SMS	MASTER SELECTOR RELAY
SMSX	MASTER SELECTOR RELAY AUX.

LEGEND

TCX	TRIP COIL RELAY AUX.
TDR	TIME DELAY RELAY SLOW STARTING
TS1	TIMER SW.-1 HOUR
TS24	TIMER SW.-24 HOURS
TTS	TRANSFORMER TEMP. SW.
TVR	THERMO VOLTAGE RELAY (SHOWN ENERG.)
TSF	TEMPERATURE SWITCH-FAN
UST	UNIT SHUTDOWN TIMER
USR	UNIT START RELAY
VM	VOLTMETER
WH	WATTHOUR METER
WM	WATT METER
ZSR	ZERO ENG. SPEED RELAY

ANNUNCIATOR LEGEND

EF	EXTERNAL FAULT
EN	ENGINE
ET	ENGINE TEMP.
FT	FUEL TRANSFER
GB	GENERATOR BREAKER
IH	IMMERSION HEATER
MS	MANUAL STOP
NV	NO VOLTAGE
OS	ENGINE OVER SPEED
OV	OVER VOLTAGE
ST	STARTING
SY	SYNCHRONISM

LEGEND

MR ← INDICATES SOLENOID OPERATED CONTACT

MB ← INDICATES OTHER THAN SOL. OPERATED CONTACT

TD 2 SEC. P.U. — INDICATES TIME DELAY CONTACT (2 SECOND DELAY AFTER ENERGIZING)

SYS — INDICATES STEPPING SWITCH (SYS, STS & RCL) (SEE CHART FOR SEQUENCE)

INDICATES PLUG OR RECEPTACLE

— INDICATES COMMON RELAY OR SWITCH USED FOR ALL UNITS (SEE CHART FOR CONTACT ARRANGEMENT)

← (SEE TIME DELAY RELAY SETTING CHART)

PROTECTIVE RELAY SETTINGS			
RELAY	VOLT SETTING	CURRENT SETTING	TIME LEVER
SC1		2.5A. PICKUP	
59	140		1/2
40-OC		112-118 P.U. 85-90 D.O.	
SC2		2.2A. DROPOUT	
55	200 WATT TAP		1
67	40 WATT TAP		1
27	105 VOLT SETTING		2
87	1/2 AMP		1/2
VOLTAGE REGULATOR SETTING			
CURRENT LIMIT	230 AMPS. (ADJUST R11)		

ARROWS IN EITHER POSITION INDICATE PICK-UP OF T.D. INTERLOCK.

ARROWS IN EITHER POSITION INDICATE DROP-OUT OF T.D. INTERLOCK

TIME DELAY RELAY SETTINGS	
RELAY	ADJUST TO
CCR	3 TO 7 SEC PU
ERX	10 SEC. P.U.
ERY	45 SEC. P.U.
GV	1 SEC. P.U.
ITS	1 MIN. P.U.
STW	7 SEC. D.O.
OAD	1.5 MIN. P.U.
OTX	14.5 MIN. P.U.
SMR	2 SEC. P.U. - 2 SEC. D.O.
SMTO	20 SEC. P.U.
SRF	1 SEC. P.U.
STSX	1/4 SEC. P.U.
STSY	10 SEC. P.U.
SYSX	20 SEC. P.U.
SYSY	1 SEC. P.U.
ZSR	2 SEC. D.O.
MRY	1 MIN. D.O.
UST	11 MIN. D.O.
40-OCX	10 SEC. P.U.
TDR	4 SEC. P.U.
SMSX	1/4 SEC. P.U.
RLTD	30 SEC. P.U.
SYDT	40 SEC. P.U.
DLRV	20 SEC. D.O.
LLR	5 SEC. P.U.
DLRS	3 SEC. P.U.
DLTS	3 SEC. P.U.
DLRP	3 SEC. P.U.
SLR	1 SEC. P.U. - 5 SEC. D.O.
OLTD	1 MIN. P.U.
52VM	1 SEC. P.U.

STEPPING SWITCH - STS, SYS & SMS						
CONTACT	POS 1	POS 2	POS 3	POS 4	POS 5	POS 6
1	●					
2		●				
3			●			
4				●		
5					●	
6						●

SHOWN IN "POS 6"

GOV. CONTROL SW. - GCS			
CONTACTS	POSITION		
	RAISE	OFF	LOWER
1-2		●	
3-4	●		
5-6			●

SHOWN IN "OFF" POS.

GOVERNOR SETTINGS	
	ADJUST TO
GOV. R.S.	OPEN AT 400 KW
LOAD LIMIT (MECH)	1200 KW
LS	1350 KW
GSS	550 KW

CONTROL SWITCH - CS						
CONTACTS	POSITION					
	CLOSE	NORM. AFTER CLOSE	TRIP	NORM. AFTER TRIP	LAMP CUTOUT	
3-4	●					
5-6			●		●	
7-8	●	●	●	●		
9-10		●				
11-12	●	●				
13-14	●	●				

SHOWN IN "NORM AFTER TRIP" POS.

LOCKOUT RELAY 86			
CONTACT	POSITION		FOR UNIT
	TR TRIP	RESET	
1-2		●	1
3-4		●	2
5-6		●	3
7-8		●	4
9-10		●	5
11-12		●	COMM
13-14		●	COMM
15-16		●	
17-18	●		
19-20	●		
21-22	●		1
23-24	●		2
25-26	●		3
27-28	●		4
29-30	●		5
31-32	●		

SHOWN IN RESET POS.

COMMON RELAYS												
UNIT	DSS	DLRZ	27X	STWX	FSR	DLRQ	DLRY	52Z	SYSZ	52WL	DLRU	FSRX
1	A-B	D1-D2 A1-A2	9-13	E-F G-H	A1-A2 D1-D2	A-B	C-D A-B	A-B	C-D	C-D	A-B	C-D
2	E-F	F1-F2 C1-C2	1-7	L1-L C-M	L1-L2 C1-C2	E-F	G-H E-F	C-D	G-H	G-H	E-F	G-H
3	J-K	H1-H2 E1-E2	2-5	N-P Q-R	F1-F2 E1-E2	J-K	L-M J-K	E-F	L-M	L-M	J-K	L-M
4	N-P	L1-L2 K1-K2	3-6	S-T U-V	N1-N2 K1-K2	N-P	Q-R N-P	G-H	Q-R	Q-R	N-P	Q-R
5	S-T	N1-N2 M1-M2	4-8	W-X Y-Z	H1-H2 M1-M2	S-T	U-V S-T	J-K	U-V	U-V	S-T	U-V
COMM	W-X	Q1-Q2		A-B	Q1-Q2		W-X		W-X Y-Z	Y-Z		

AUTOMATIC - MANUAL SWITCH (AM)			
CONTACT	SWITCH POSITION		
	MANUAL		AUTO.
A-B	●		
C-D			●
E-F	●		
G-H			●
J-K	●		
L-M			●
N-P	●		
Q-R			●

(SHOWN IN AUTOMATIC POS)

START-STOP SWITCH (SS)			
CONTACT	SWITCH POSITION		
	LEFT	CENTER	RIGHT
A-B		●	●
C-D			●
E-F	●		
G-H	●	●	

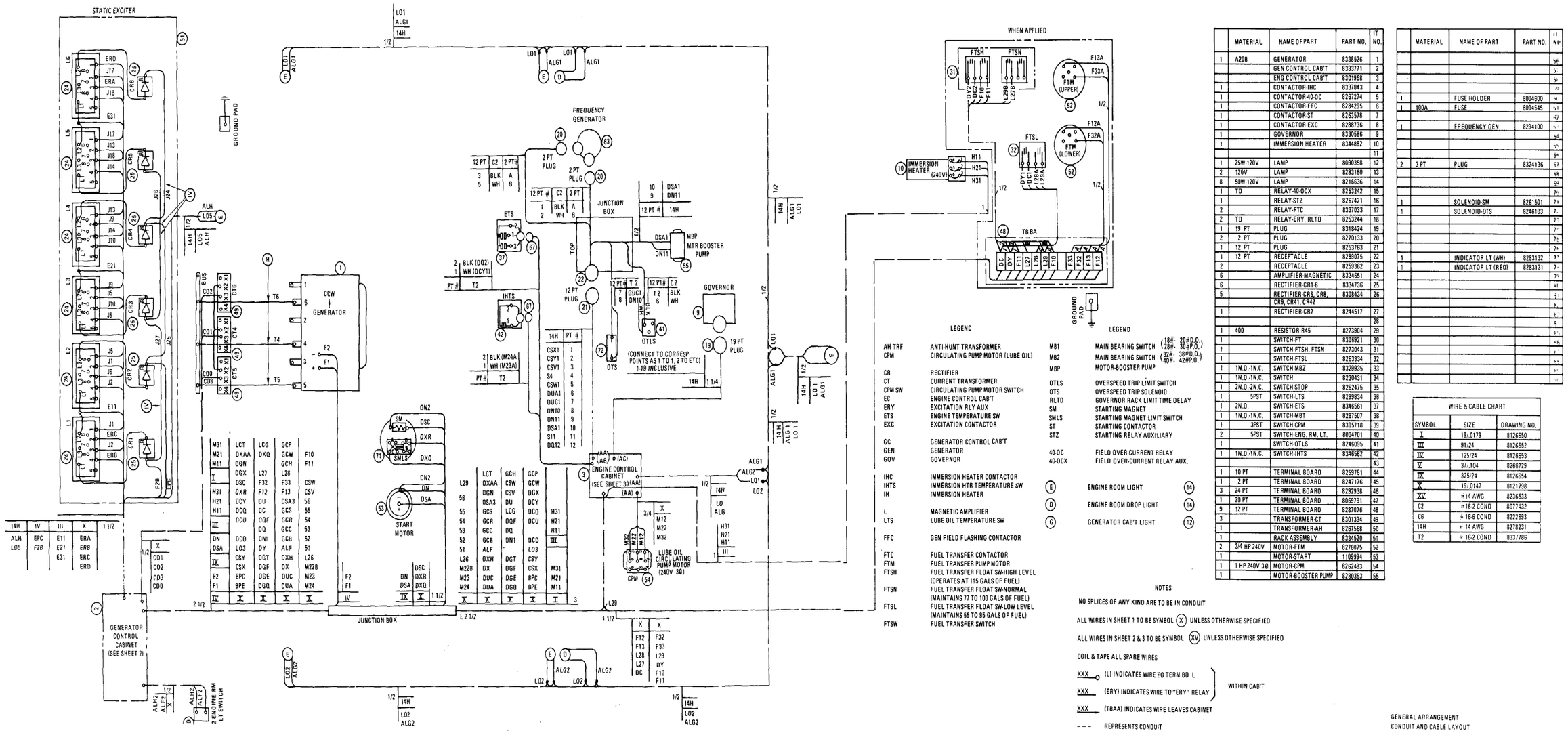
(SPRING RETURN TO CENTER)

NOTE:
ANY CIRCUITRY PERTAINING TO UNITS 4 AND 5 WILL BE "WHEN APPLIED"

REFERENCE DRAWINGS

8386397	FIELD CONNECTION W.D.
8386398	MC INTERCONNECTION W.D.
8386399	MASTER PANEL W.D.
8386400	UNIT PANEL W.D.
8386401	TRANSFER AND SWITCH GEAR CUBICLE W.D.
8386402	SW GEAR CUBICLE W.D.
8386403	MP-38A W.D.
8353201	ANNUNCIATOR-MASTER W.D.
8353202	ANNUNCIATOR-AUX W.D.

FO-5. Overall Schematic Wiring Diagram, I9658 (8386396) (Sheet 5 of 5)



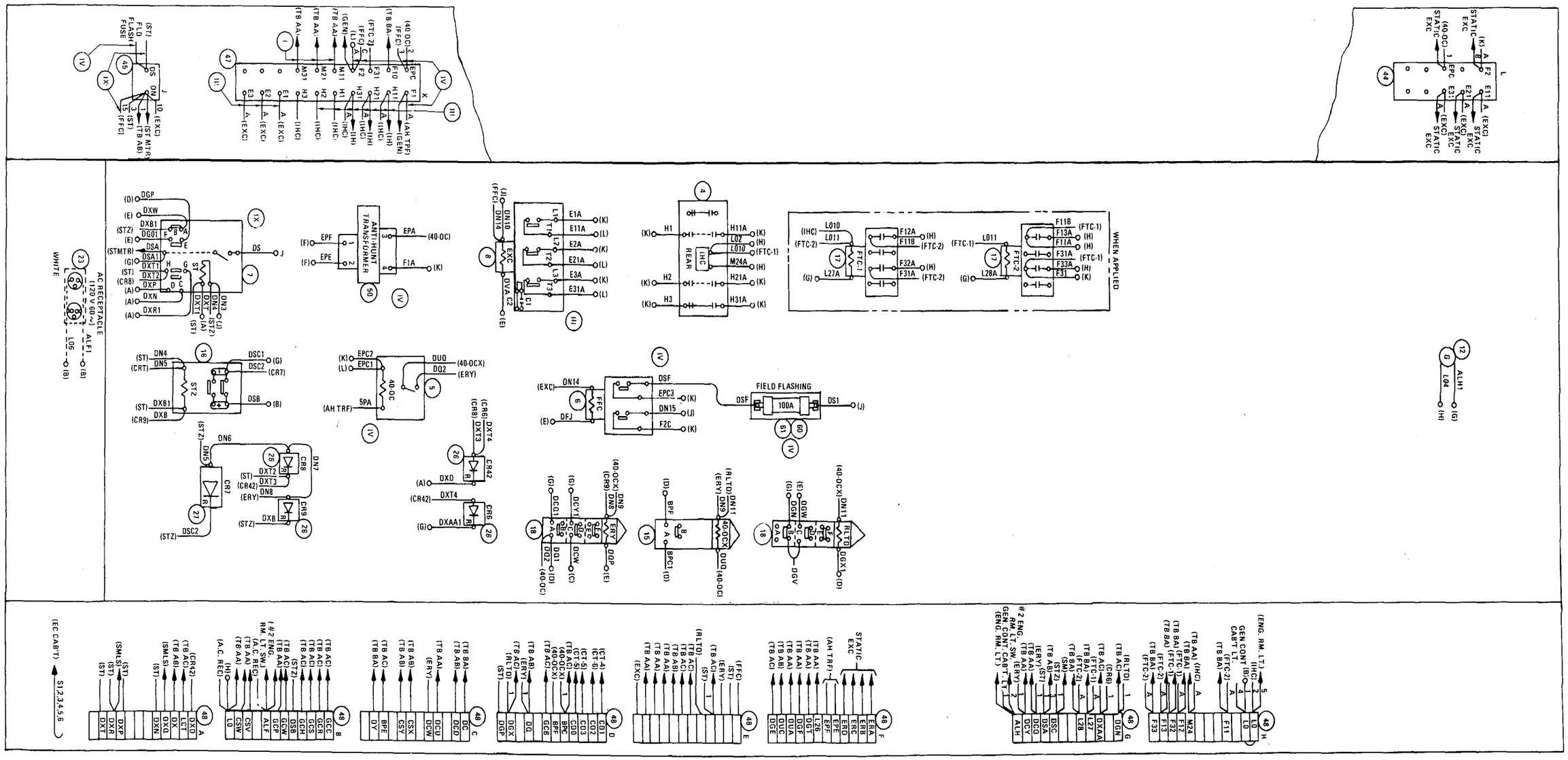
IT NO.	MATERIAL	NAME OF PART	PART NO.
1	A20B	GENERATOR	8338526
2		GEN CONTROL CAB'T	8333771
3		ENG CONTROL CAB'T	8301958
4		CONTACTOR-IHC	8337043
5		CONTACTOR-40-OC	8267274
6		CONTACTOR-FFC	8284295
7		CONTACTOR-ST	8263578
8		CONTACTOR-EXC	8288736
9		GOVERNOR	8330586
10		IMMERSION HEATER	8344882
11			
12	25W-120V	LAMP	8080358
13	120V	LAMP	8283150
14	50W-120V	LAMP	8216836
15	TD	RELAY-40-OCX	8253242
16		RELAY-STZ	8267421
17		RELAY-FTC	8337033
18	TD	RELAY-ERY, RLTD	8253244
19	19 PT	PLUG	8316424
20	2 PT	PLUG	8270133
21	12 PT	PLUG	8253763
22	12 PT	RECEPTACLE	8289075
23		RECEPTACLE	8259362
24		AMPLIFIER-MAGNETIC	8334651
25		RECTIFIER-CR1-6	8334736
26		RECTIFIER-CR5, CR8, CR9, CR41, CR42	8308434
27		RECTIFIER-CR7	8244517
28			
29	400	RESISTOR-R45	8273904
30		SWITCH-FT	8306921
31		SWITCH-FTSH, FTSN	8273043
32		SWITCH-FTSL	8263334
33	1N.O.-1N.C.	SWITCH-MBZ	8329935
34	1N.O.-1N.C.	SWITCH	8230431
35	2N.O.-2N.C.	SWITCH-STOP	8262475
36	5PST	SWITCH-LTS	8289834
37	2N.O.	SWITCH-ETS	8345561
38	1N.O.-1N.C.	SWITCH-MBT	8287507
39	3PST	SWITCH-CPM	8305718
40	5PST	SWITCH-ENG. RM. LT.	8004701
41		SWITCH-OTLS	8246095
42	1N.O.-1N.C.	SWITCH-IHTS	8346562
43			
44	10 PT	TERMINAL BOARD	8259781
45	2 PT	TERMINAL BOARD	8247176
46	24 PT	TERMINAL BOARD	8292838
47	20 PT	TERMINAL BOARD	8069791
48	12 PT	TERMINAL BOARD	8287076
49	3	TRANSFORMER-CT	8301334
50	1	TRANSFORMER-AH	8267568
51	1	RACK ASSEMBLY	8334520
52	2 3/4 HP 240V	MOTOR-FTM	8276075
53	1	MOTOR-START	1109994
54	1 HP 240V 3Ø	MOTOR-CPM	8262483
55	1	MOTOR-BOOSTER PUMP	8280352

IT NO.	MATERIAL	NAME OF PART	PART NO.
1		FUSE HOLDER	8004600
1	100A	FUSE	8004545
1		FREQUENCY GEN	8294100
2	3 PT	PLUG	8324136
1		SOLENOID-SM	8261501
1		SOLENOID-OTS	8246103
1		INDICATOR LT (WH)	8283132
1		INDICATOR LT (RED)	8283131

WIRE & CABLE CHART		
SYMBOL	SIZE	DRAWING NO.
I	19/.0179	8126650
III	91/24	8126652
IV	125/24	8126653
V	37/.104	8266729
IX	325/24	8126654
X	19/.0147	8121798
XV	# 14 AWG	8236533
C2	# 16-2 COND	8077432
C6	# 16-6 COND	8222693
14H	# 14 AWG	8278231
T2	# 16-2 COND	8337786

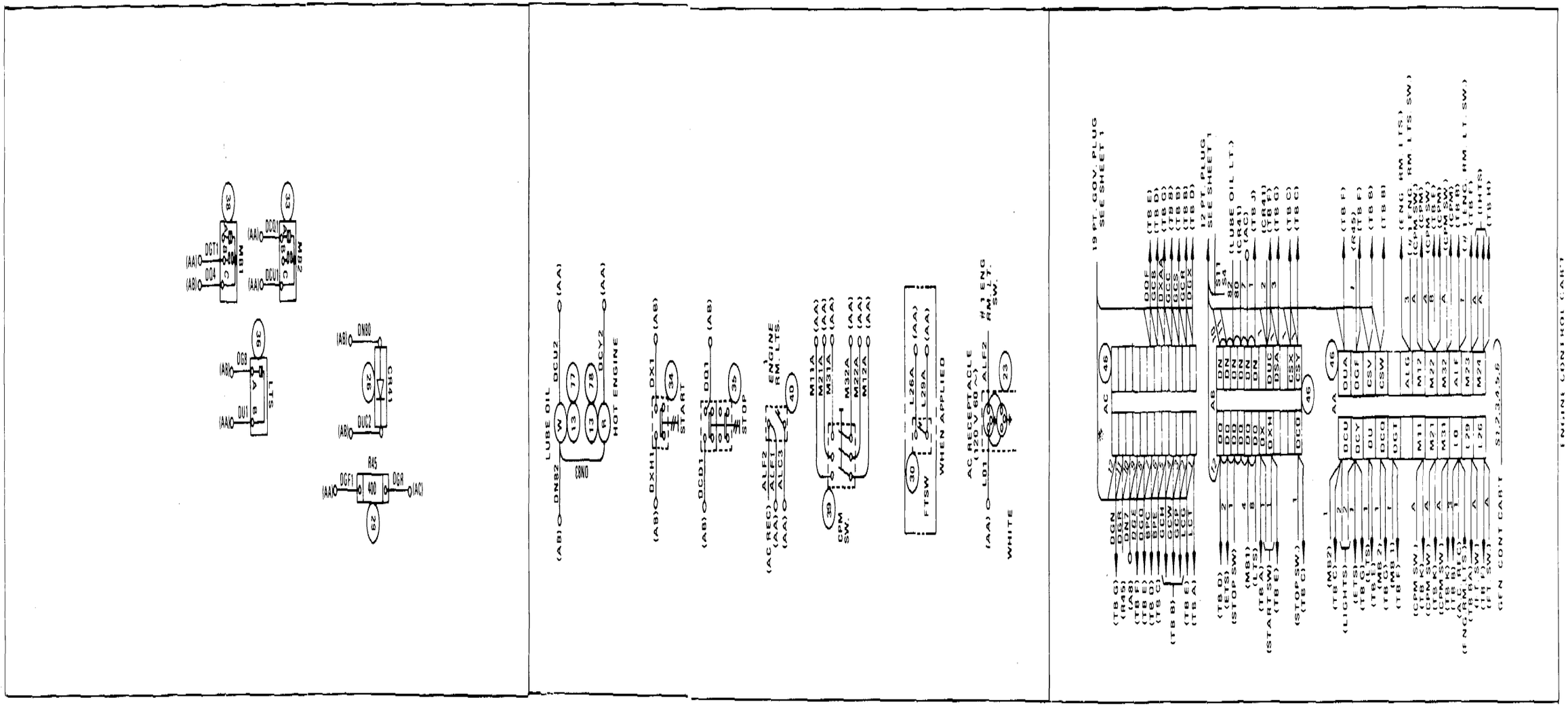
GENERAL ARRANGEMENT
CONDUIT AND CABLE LAYOUT

FO-6. MP36A Wiring Diagram (8386403) (Sheet 1 of 3)

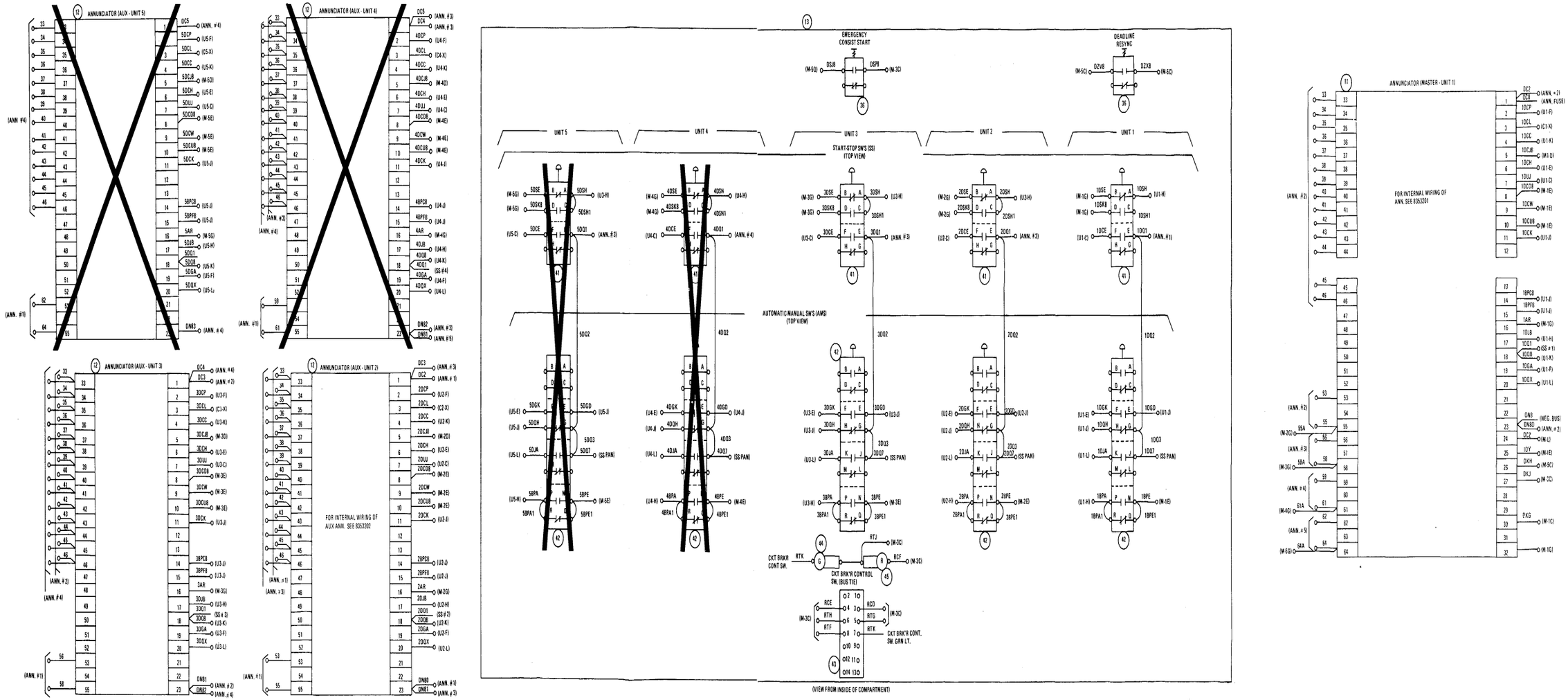


FO-7. MP36A Wiring Diagram (8386403) (Sheet 2 of 3)

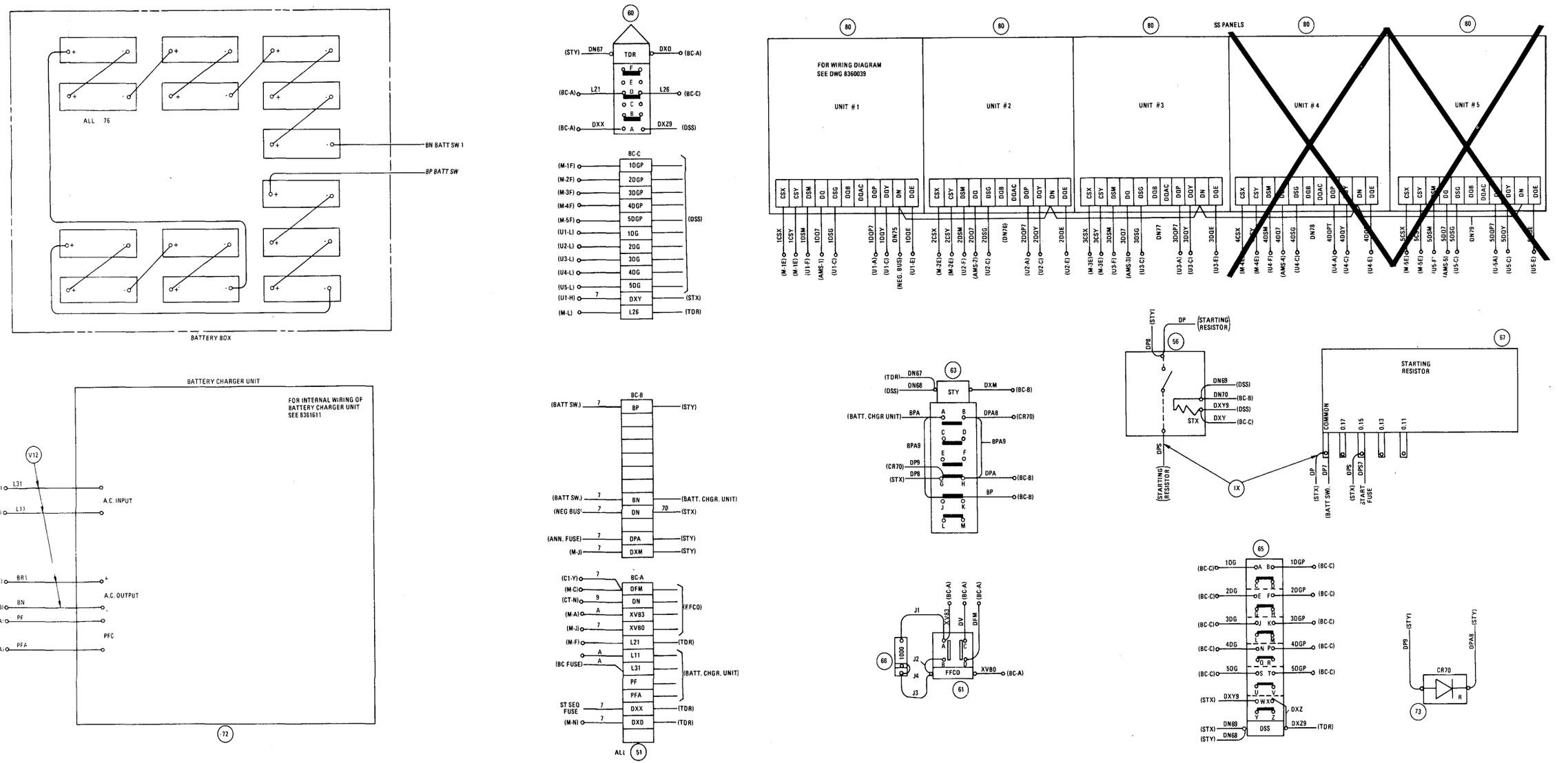
15/ (16 blank)



FO-8. MP36A Wiring Diagram (8386403) (Sheet 3 of 3)

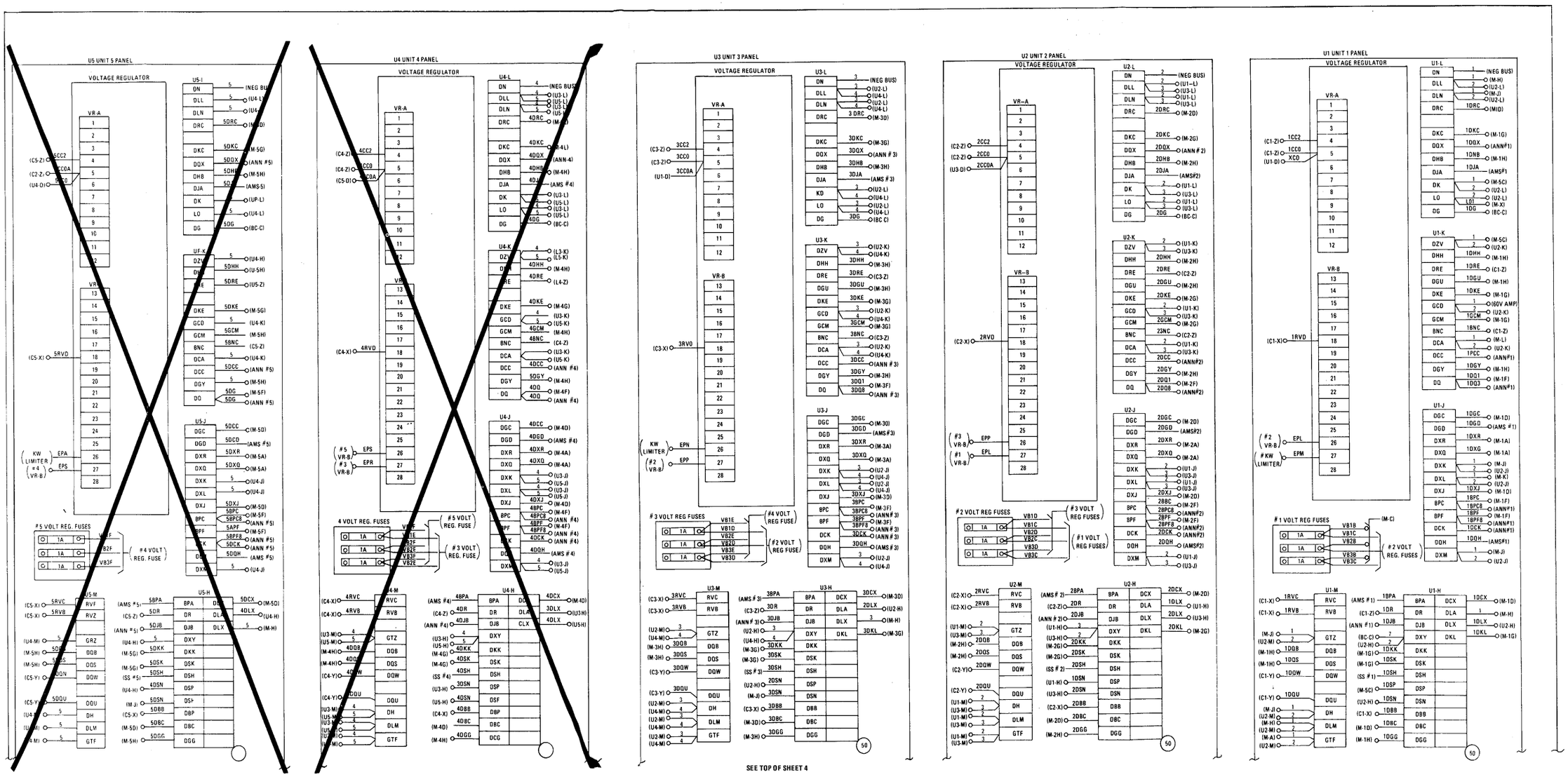


FO-9. MC-53 Interconnection Wiring Diagram (Sheet 1 of 11)
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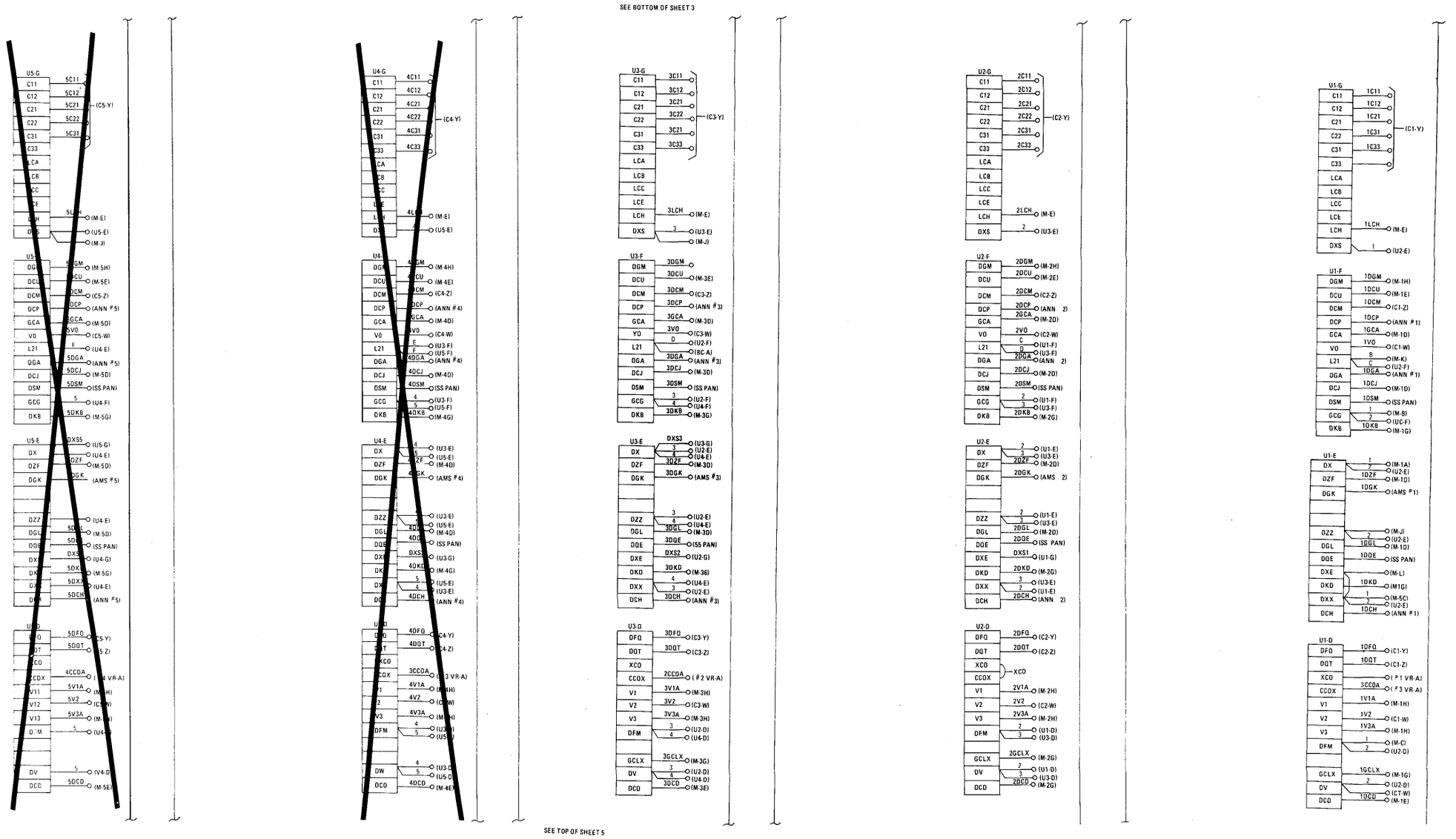
FO-10. MC-53 Interconnection Wiring Diagram (Sheet 2 of 11)

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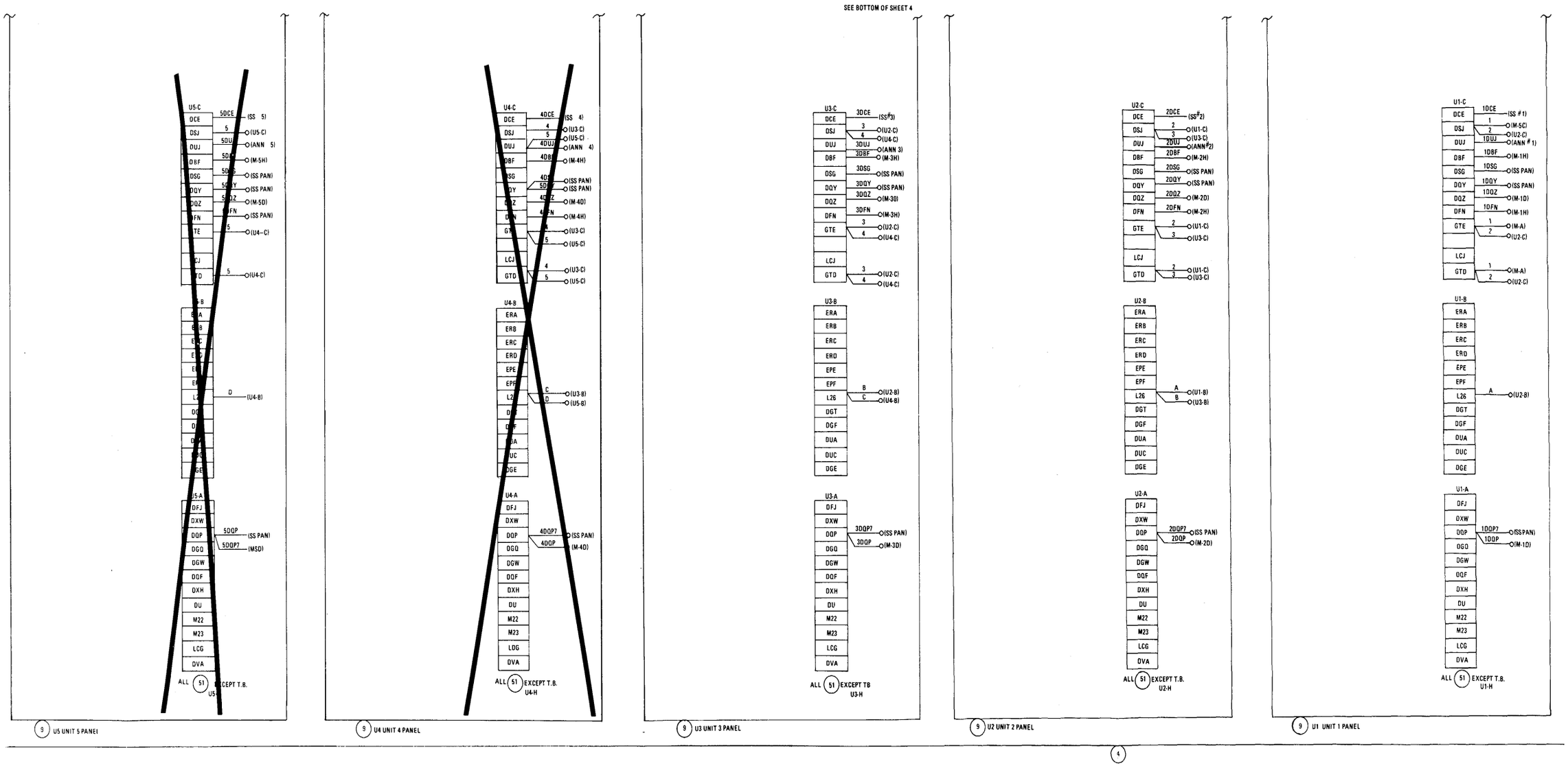
FO-11. MC-53 Interconnection Wiring Diagram (Sheet 3 of 11)

23/(24 blank)



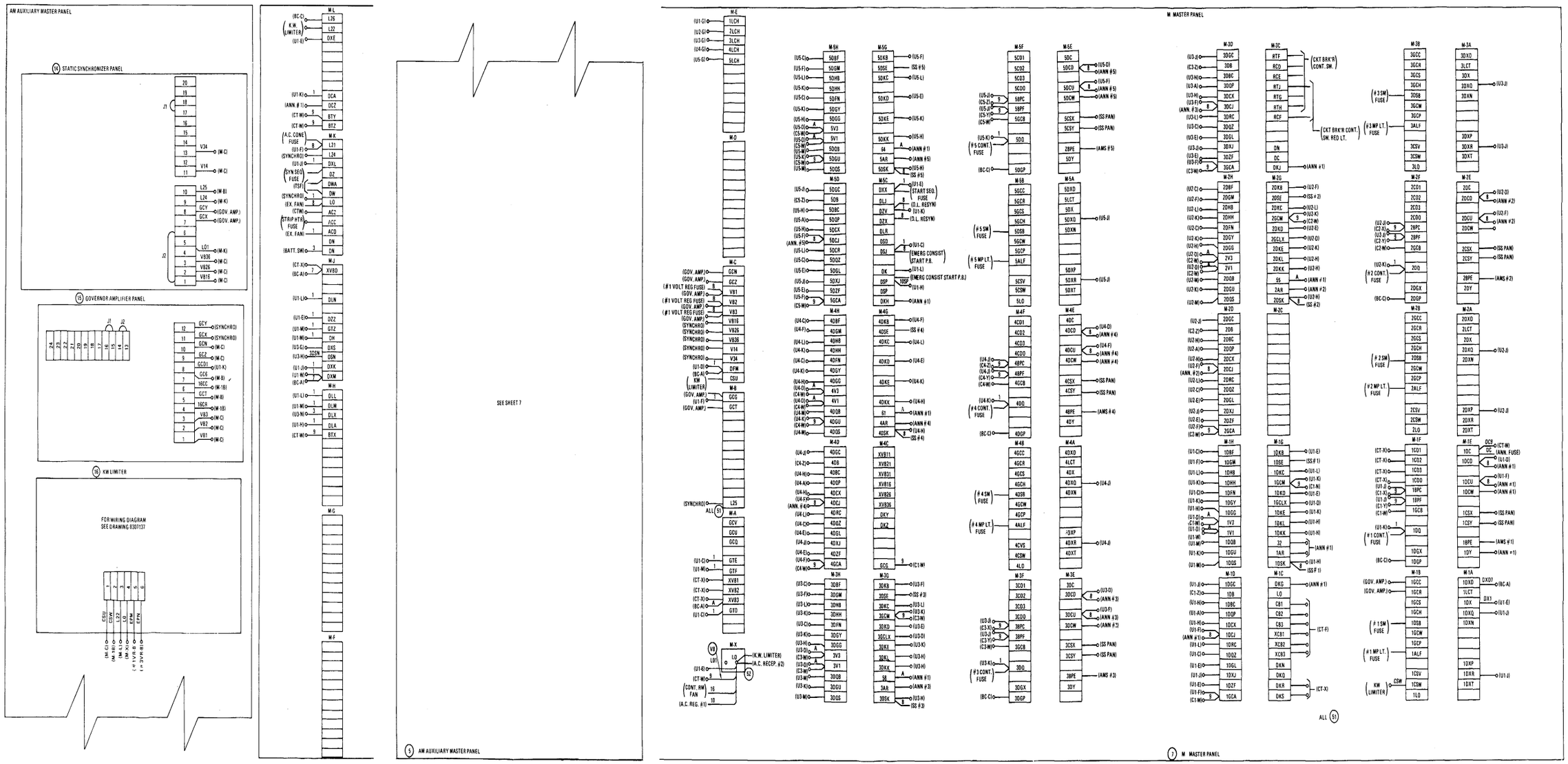
FO-12. MC-53 Interconnection Wiring Diagram (Sheet 4 of 11

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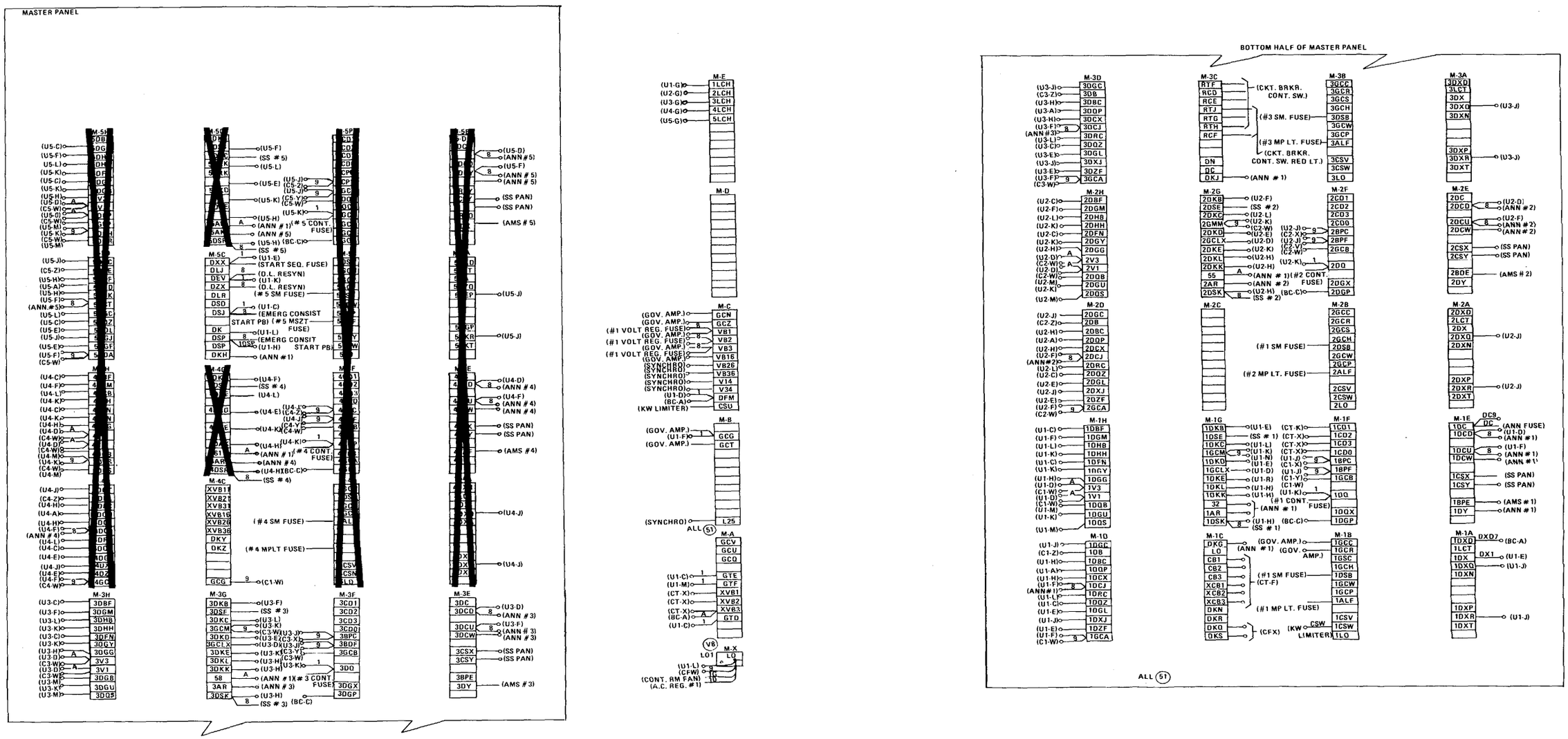
FO-13. MC-53 Interconnection Wiring Diagram (Sheet 5 of 11)

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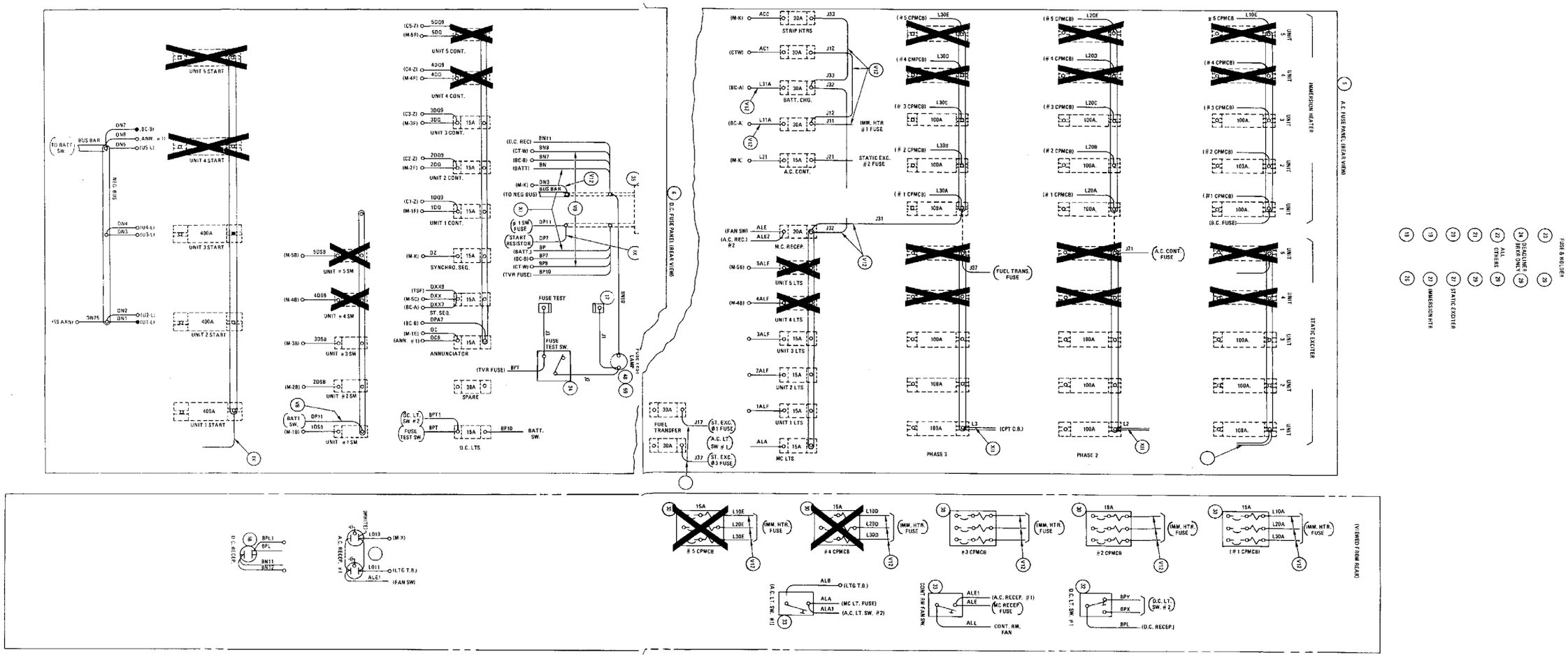
FO-14. MC-53 Interconnection Wiring Diagram (Sheet 6 of 11)

29/(30 blank)

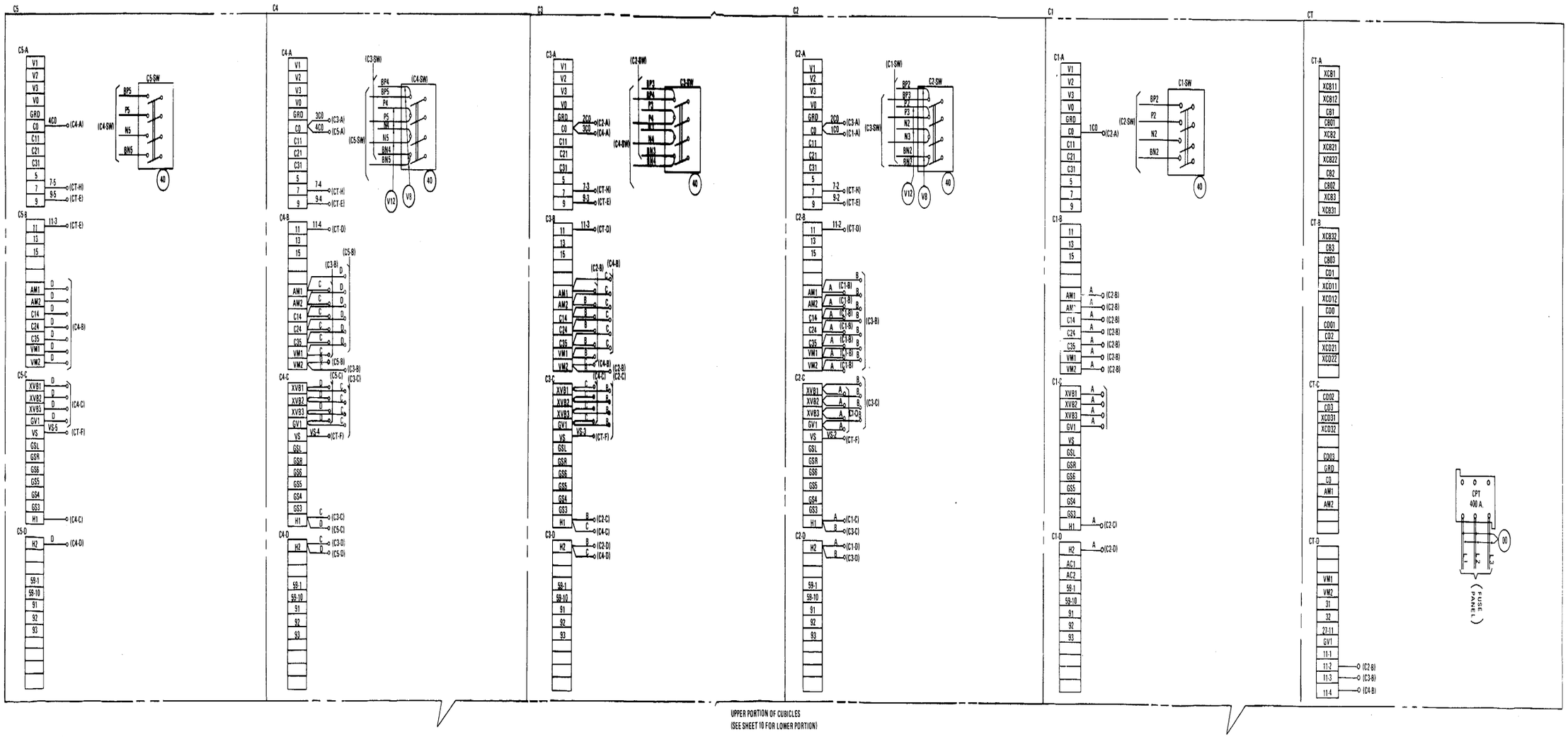


FO-15. MC-53 Interconnection Wiring Diagram Sheet 7 of 11)

31/(32 BLANK)

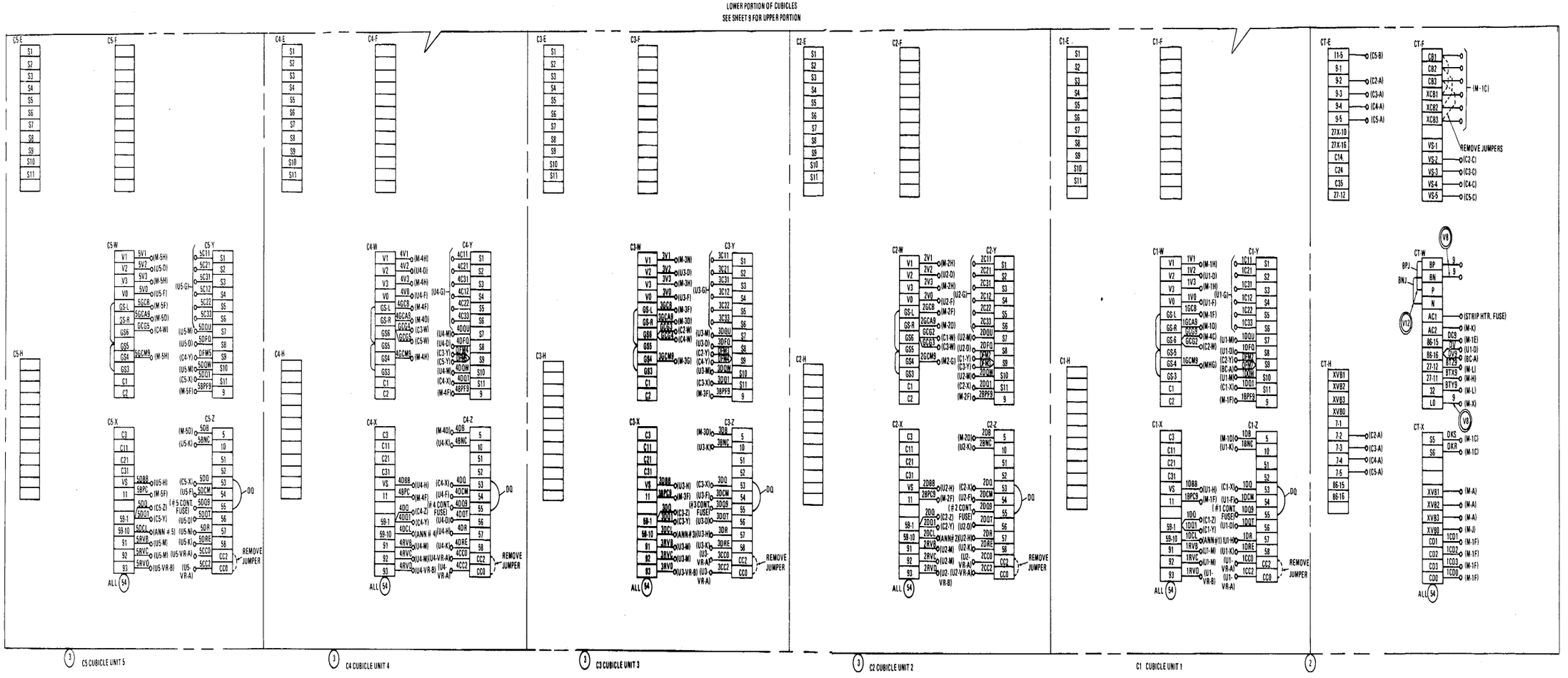


FO-16. MC-53 Interconnection Wiring Diagram (Sheet 8 of 11)

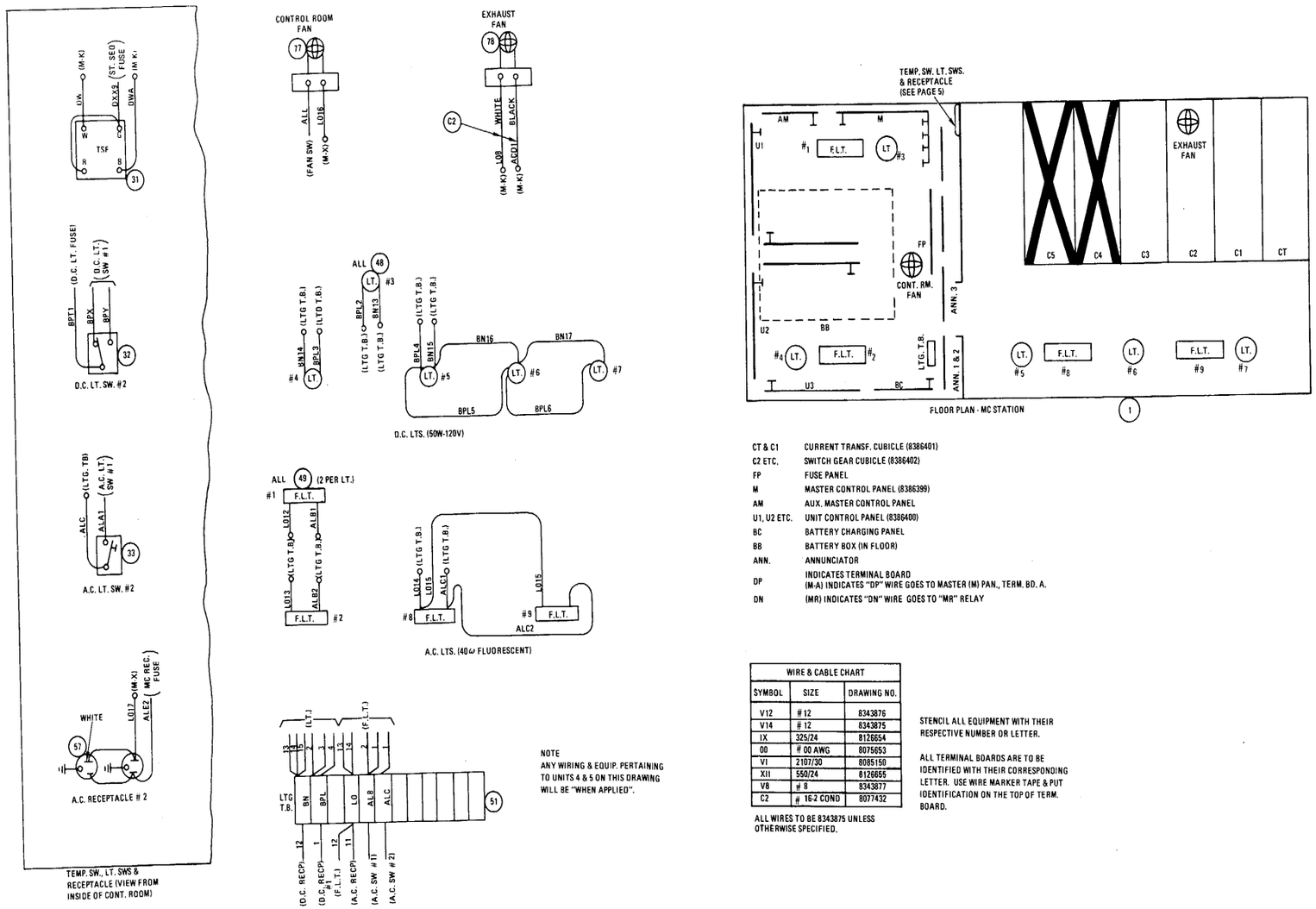


FO-17. MC-53 Interconnection Wiring Diagram (Sheet 9 of 11)

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FO-18. MC-53 Interconnection Wiring Diagram (Sheet 10 of 11)



NOTE
ANY WIRING & EQUIP. PERTAINING TO UNITS 4 & 5 ON THIS DRAWING WILL BE "WHEN APPLIED".

FLOOR PLAN - MC STATION

CT & C1	CURRENT TRANSF. CUBICLE (8386401)
C2 ETC.	SWITCH GEAR CUBICLE (8386402)
FP	FUSE PANEL
M	MASTER CONTROL PANEL (8386399)
AM	AUX. MASTER CONTROL PANEL
U1, U2 ETC.	UNIT CONTROL PANEL (8386400)
BC	BATTERY CHARGING PANEL
BB	BATTERY BOX (IN FLOOR)
ANN.	ANNUNCIATOR
DP	INDICATES TERMINAL BOARD (M-A) INDICATES "DP" WIRE GOES TO MASTER (M) PAN., TERM. BD. A.
DN	(MR) INDICATES "DN" WIRE GOES TO "MR" RELAY

WIRE & CABLE CHART		
SYMBOL	SIZE	DRAWING NO.
V12	# 12	8343876
V14	# 12	8343875
IX	325/24	8126654
00	# 00 AWG	8075653
VI	2107/30	8085150
XII	550/24	8126655
V8	# 8	8343877
C2	# 16-2 COND	8077432

ALL WIRES TO BE 8343875 UNLESS OTHERWISE SPECIFIED.

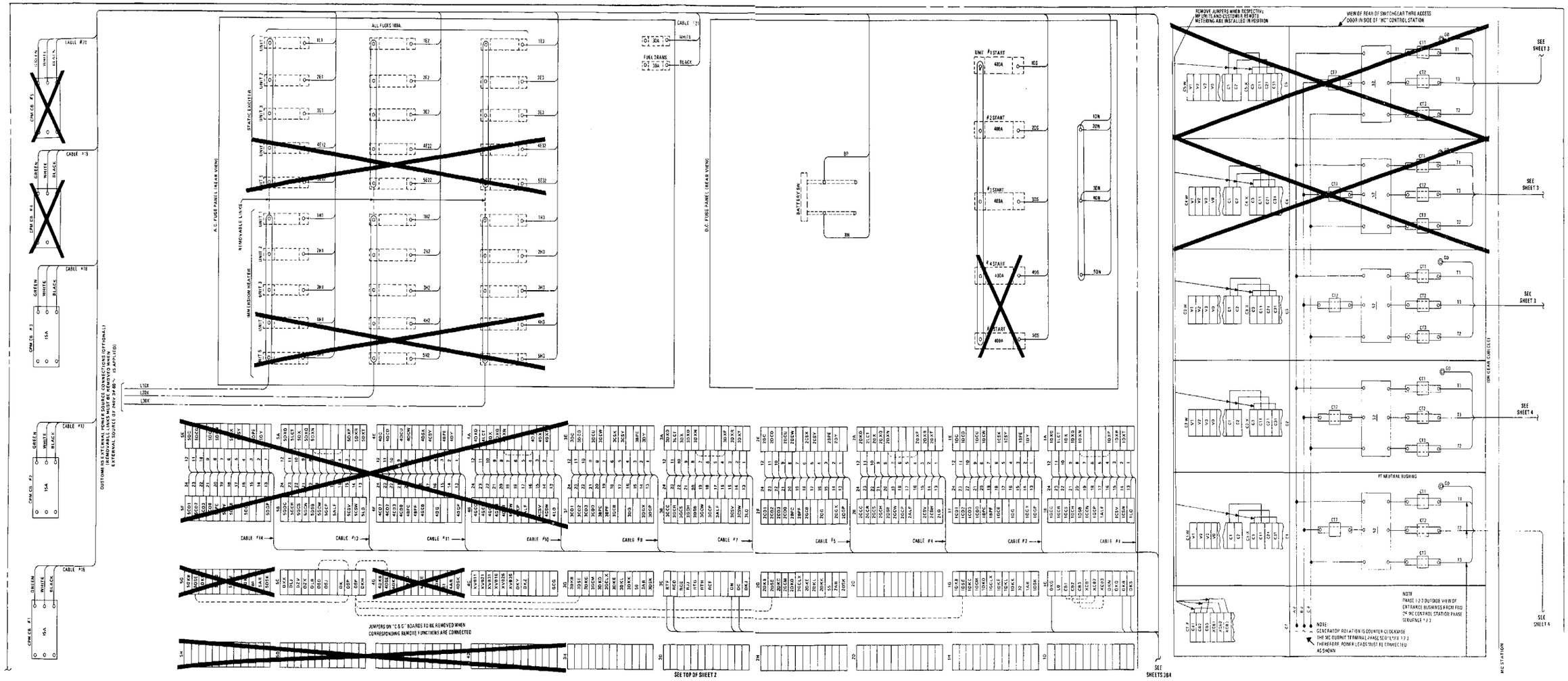
STENCIL ALL EQUIPMENT WITH THEIR RESPECTIVE NUMBER OR LETTER.

ALL TERMINAL BOARDS ARE TO BE IDENTIFIED WITH THEIR CORRESPONDING LETTER. USE WIRE MARKER TAPE & PUT IDENTIFICATION ON THE TOP OF TERM. BOARD.

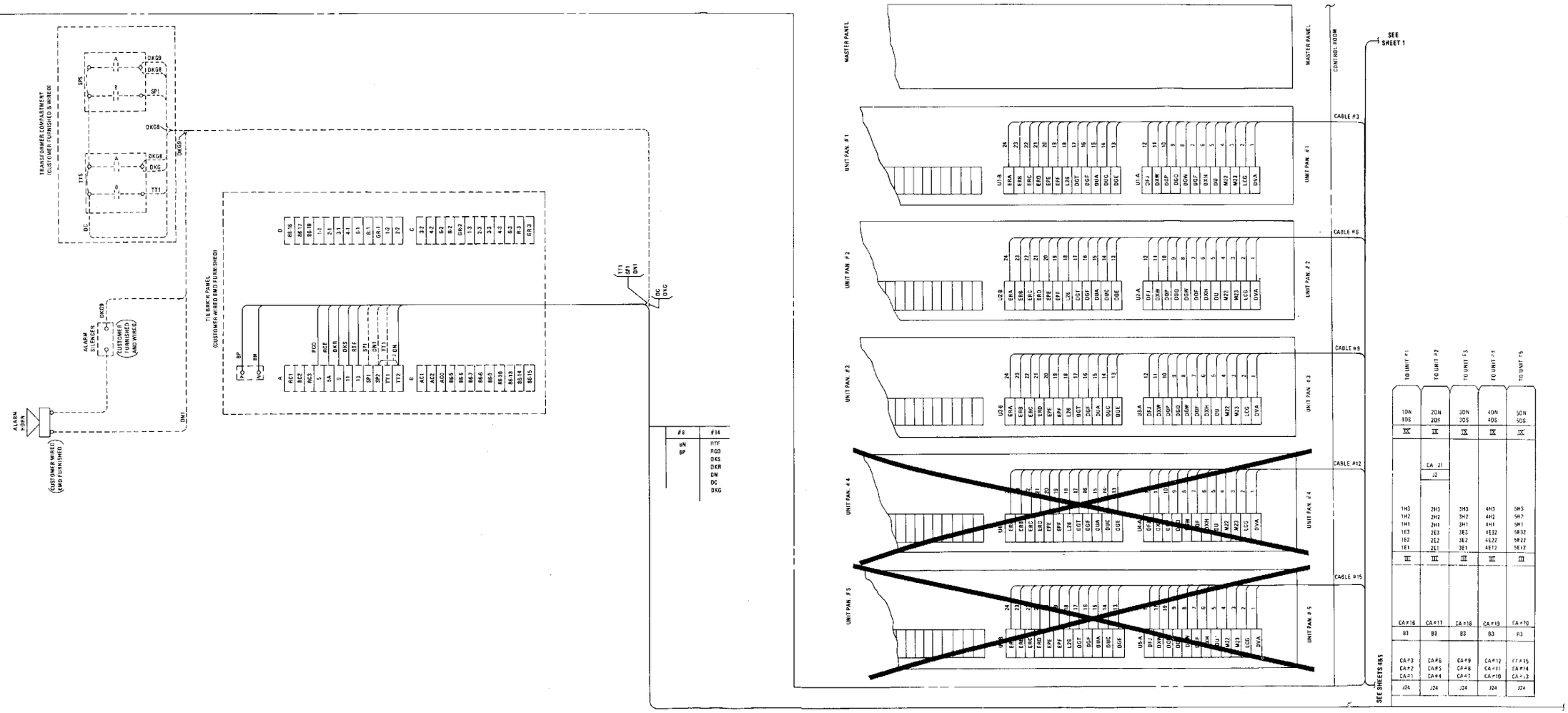
QTY	MATERIAL	NAME OF PART	PART NO.	IT. NO.
1		MC STATION	8295118	1
1		SW. GEAR CUBICLE ASSEM	8385948	2
4		SW. GEAR CUBICLE ASSEM	8385949	3
1		CONTROL RACK ASSEM	8296962	4
1		PANEL-FUSE-A.C.	8296297	5
1		PANEL-FUSE-D.C.	8296503	6
1		PANEL-MASTER CONTROL	8295601	7
1		PANEL-AUX MASTER	8295555	8
5		PANEL-UNIT CONTROL	8294558	9
1		PANEL-BAT. CHARGING	8361674	10
1		PANEL-MASTER ANN	8353253	11
4		PANEL-AUX ANN	8353252	12
1		PANEL-SWITCH PANEL	8314715	13
1		PANEL-STATIC SYNCHRO	8334653	14
1		PANEL-GOV AMPLIFIER	8298234	15
		PANEL-KW LIMITER	8340066	16
2		FUSE TEST CONTACT	8112684	17
5	400A.	FUSE	8127052	18
15	100A.	FUSE	8004548	19
15	100A. DE	FUSE	8147631	20
11	30A.	FUSE	8004548	21
1	20A.	FUSE	8225155	22
16	15A.	FUSE	8004549	23
				24
				25
10	201-400A.	FUSE HOLDER	8280182	26
60	61-100A.	FUSE HOLDER	8004540	27
				28
56	0-30A.	FUSE HOLDER	8280184	29
5	15A. 3P	CIRCUIT BREAKER	8313421	30
1		SWITCH-TSF	8299575	31
2	SPDT	SWITCH-LTS (D.C.)	8130997	32
3	SP	SWITCH-FAN & LTS (A.C.)	8004701	33
1	SP	SWITCH-FUSE TEST	8172209	34
1	DPST	SWITCH-BATTERY	8313512	35
2	1 N.O.-1 N.C. RB	SWITCH-BLK	8230431	36
				37
				38
				39
5	ALLIS-CHALMERS	SWITCH		40

QTY	MATERIAL	NAME OF PART	PART NO.	IT. NO.
5	2 N.O.-2 N.C.	SWITCH-START-STOP	8309733	41
5	4 N.O.-4 N.C.	SWITCH-AUTO.-MAN.	8309734	42
1		SW. ROTARY CKT BRKR	8275688	43
1		LIGHT & RESISTOR (GREEN)	8371273	44
1		LIGHT & RESISTOR (RED)	8371272	45
				46
				47
6	50W-120V	LAMP-F.T. & D.C. LT.	8216636	48
8	40W (FLUORESCENT)	LAMP-A.C. LT.	8298975	49
5	24 PT.	TERMINAL BOARD	8292938	50
110	12 PT.	TERMINAL BOARD	8287076	51
1	2 PT.	TERMINAL BOARD	8277959	52
				53
64	ALLIS-CHALMERS	TERMINAL BOARD		54
				55
1		CONTACTOR-STX	8357711	56
2		RECEPTACLE-A.C.	8259362	57
1		RECEPTACLE-D.C.	8260287	58
1		RECEPT.-FUSE TEST LT.	8296298	59
1		RELAY-TDR	8253244	60
1		RELAY-FFCO	8282624	61
				62
1		RELAY-STY	8227936	63
				64
1		RELAY-OSS	8269705	65
1	1000	RESISTOR	8206938	66
1		RESISTOR	8356255	67
				68
				69
				70
				71
1		BATTERY CHARGER	8361611	72
1		RECTIFIER	8263244	73
				74
				75
14		STORAGE BATTERY	8297100	76
1		FAN-CONTROL	8297049	77
1		FAN-EXHAUST	8298241	78
				79
5		SPEED SENSING PAN.	8330163	80

FO-19. MC-53 Interconnection Wiring Diagram)Sheet 11 of 11)

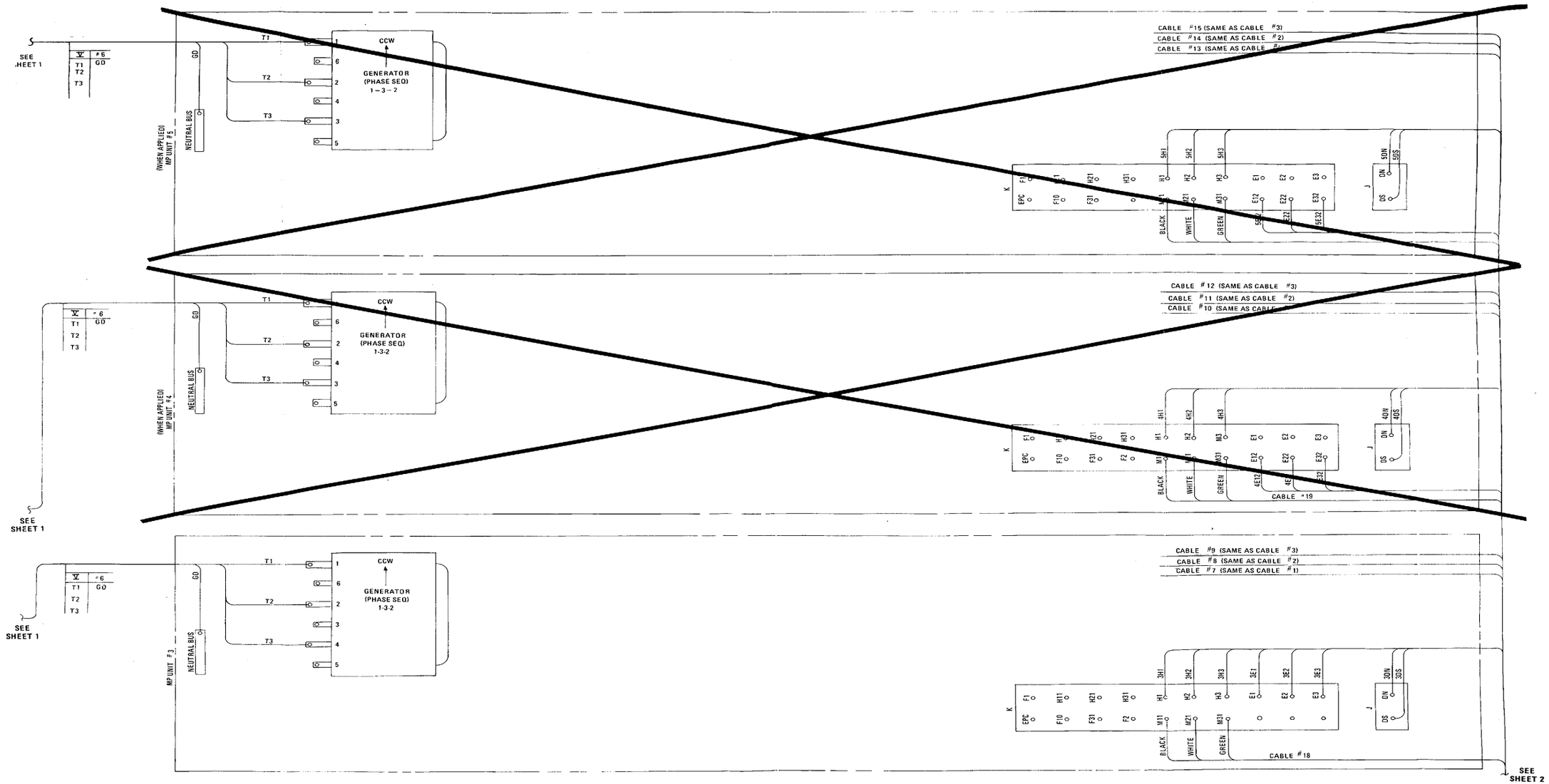


FO-20. Field Connections Wiring Diagram (838697) (Sheet 1 of 5)

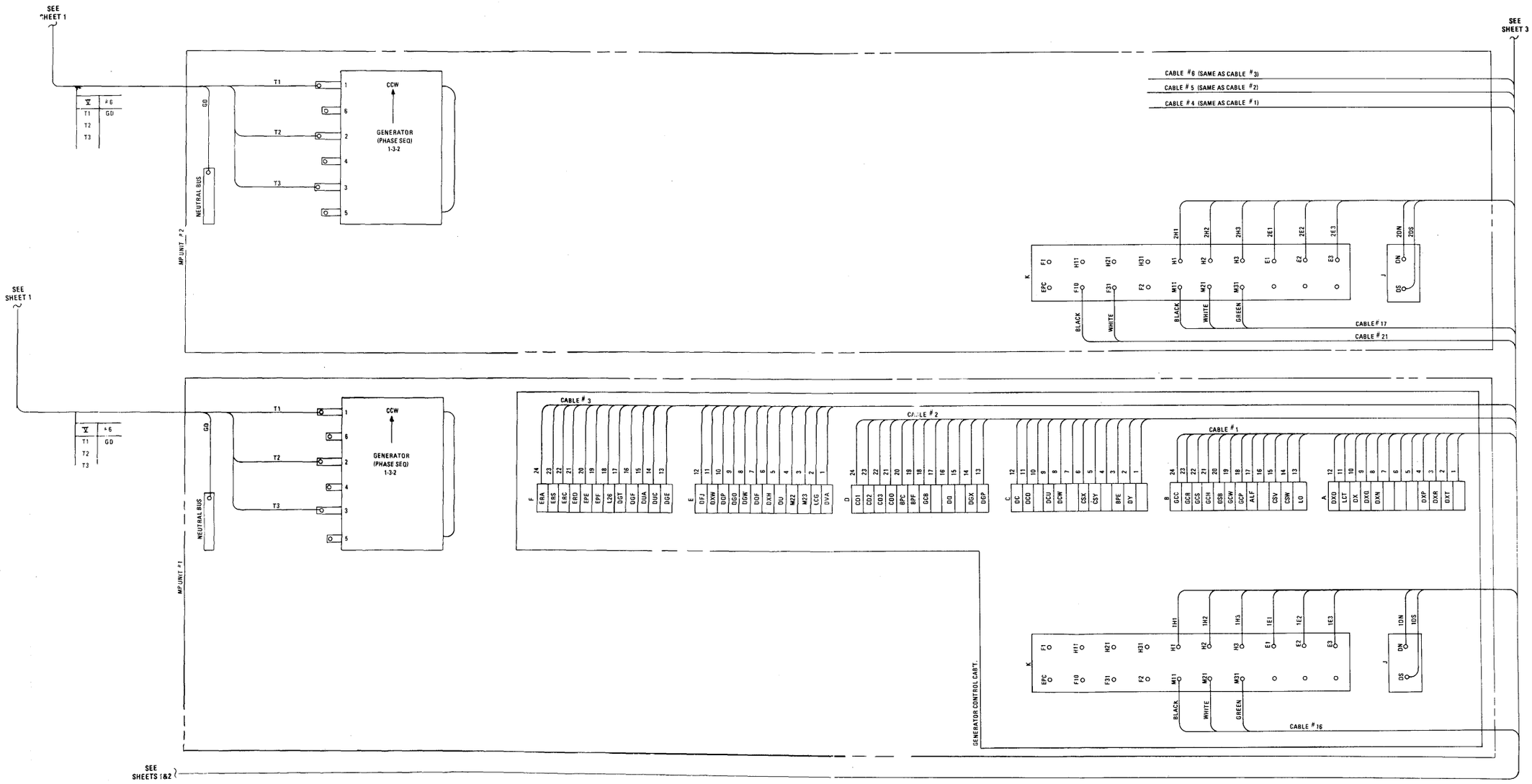


FO-21. Field Connections Wiring Diagram (838697) (Sheet 2 of 5)

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FO-22. Field Connections Wiring Diagram (838697) (Sheet 3 of 5)



FO-23. Field Connections Wiring Diagram (838697) (Sheet 4 of 5)

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CUSTOMER REMOTE CONTROL

REMOTE CONTROL CONNECTIONS FOR CONSIST OPERATION

AT MASTER PAN CONN. BETWEEN	CONTROL FUNCTIONS	AT CUSTOMERS REMOTE CONTROL POINT USE;
DSP-DSD	STOP	NC.MOMENTARY CONTACT
DSP-DSJ	START	NO. MOMENTARY CONTACT
DZX-DZV	RESYNCH.PB.	RESYNCH.PB.
XVB16	RESYNCH.VOLTAGE Ø1	208L-L3Ø PT (WYE)
XVB26	RESYNCH.VOLTAGE Ø2	208L-L3Ø PT (WYE)
XVB36	RESYNCH.VOLTAGE Ø3	208L-L3Ø PT (WYE)
DKQ-DKN	REMOTE BREAKER CLOSE	CLOSE SYSTEM BREAKER
DKR-DKS	86 RELAY-TRIP	TRIP BRK.(LOCKOUT)
DKY-DKZ	DL.BRKR.CONTROL	LOAD BRKR.CLOSE
DXX-DLR	DEADLINE MODE CONT.	LOAD BRKR-526
DXX-DLJ	DEADLINE MODE CONT.	SYSTEM BRKR-526

REMOTE CONTROL CONNECTIONS FOR UNIT OPERATION

AT MASTER PAN CONN. BETWEEN	CONTROL FUNCTIONS	AT CUSTOMERS REMOTE CONTROL POINT USE
1DSE-1DSK	UNIT #1 START	NO. MOMENTARY CONTACT
2DSE-2DSK	UNIT #2 START	NO. MOMENTARY CONTACT
3DSE-3DSK	UNIT #3 START	NO. MOMENTARY CONTACT
4DSE-4DSK	UNIT #4 START	NO. MOMENTARY CONTACT
5DSE-5DSK	UNIT #5 START	NO. MOMENTARY. CONTACT
1DSE-DSP	UNIT #1 STOP	NC. MOMENTARY CONTACT
2DSE-DSP	UNIT #2 STOP	NC. MOMENTARY CONTACT
3DSE-DSP	UNIT #3 STOP	NC. MOMENTARY CONTACT
4DSE-DSP	UNIT #4 STOP	NC. MOMENTARY CONTACT
5DSE-DSP	UNIT #5 STOP	NC. MOMENTARY CONTACT
1GCLX-1GCM-GCG	REMOTE GOV. CONTROL	NO. MOMENTARY CONTACT
2GCLX-2GCM-GCG	REMOTE GOV. CONTROL	NO. MOMENTARY CONTACT
3GCLX-3GCM-GCG	REMOTE GOV. CONTROL	NO. MOMENTARY CONTACT

REMOTE METERING CONNECTIONS

AT MASTER PAN CONN. BETWEEN	METERING FUNCTION	
CB1-XCB1	PHASE 1	POWER UNIT BUS CURRENT
CB2-XCB2	PHASE 2	POWER UNIT BUS CURRENT
CB3-XCB3	PHASE 3	POWER UNIT BUS CURRENT
C1-C11	PHASE 1	POWER UNIT #1 CURRENT
C2-C21	PHASE 2	POWER UNIT #1 CURRENT
C3-C31	PHASE 3	POWER UNIT #1 CURRENT
V1-V0	PHASE 1	POWER UNIT #1 VOLTAGE
V2-V0	PHASE 2	POWER UNIT #1 VOLTAGE
V3-V0	PHASE 3	POWER UNIT #1 VOLTAGE
1AR-32	UNIT #1 ANN.RESET	NO.MOMENTARY CONTACT
2AR-55	UNIT #2 ANN.RESET	NO.MOMENTARY CONTACT
3AR-58	UNIT #3 ANN.RESET	NO.MOMENTARY CONTACT
4AR-61	UNIT #4 ANN.RESET	NO.MOMENTARY CONTACT
5AR-64	UNIT #5 ANN.RESET	NO.MOMENTARY CONTACT
XVB11	PHASE 1	BUS VOLTAGE METERING
XVB21	PHASE 2	BUS VOLTAGE METERING
XVB31	PHASE 3	BUS VOLTAGE METERING

(UNITS 2, 3, 4, & 5 SAME AS UNIT #1)

REMOTE ALARM CONNECTIONS FOR INDIVIDUAL UNITS

AT MASTER PAN CONN.BETWEEN	REMOTE INDICATION	AT CUSTOMERS REMOTE CONTROL POINT USE,
DK-1DKB	UNIT 1 – START SIG.REC'D	VISUAL INDICATION
DK-2DKB	UNIT 2 –START SIG.REC'D	
DK-3DKB	UNIT 3 – START SIG.REC'D	
DK-4DKB	UNIT 4 – START SIG.REC'D	
DK-5DKB	UNIT 5 – START SIG.REC'D	
DN-DKG	UNITS FAULT ALL UNITS CONNECT-ED TO COMMON HORN (SEE PHYSICAL)	CUSTOMER ALARM HORN
DK-1DKE	UNIT 1 – AT FULL LOAD	VISUAL INDICATION
DK-2DKE	UNIT 2 – AT FULL LOAD	
DK-3DKE	UNIT 3 – AT FULL LOAD	
DK-4DKE	UNIT 4 – AT FULL LOAD	
DK-5DKE	UNIT 5 – AT FULL LOAD	

NOTE:
ANY WIRING PERTAINING TO UNITS 4 & 5 ON THIS DRAWING WILL BE "WHEN APPLIED"

J24 CABLE COLOR CODE

NO.	BASE	TRACER	TRACER
1	BLACK		
2	WHITE		
3	RED		
4	GREEN		
5	ORANGE		
6	BLUE		
7	WHITE	BLACK	
8	RED	BLACK	
9	GREEN	BLACK	
10	ORANGE	BLACK	
11	BLUE	BLACK	
12	BLACK	WHITE	
13	RED	WHITE	
14	GREEN	WHITE	
15	BLUE	WHITE	
16	BLACK	RED	
17	WHITE	RED	
18	ORANGE	RED	
19	BLUE	RED	
20	RED	GREEN	
21	ORANGE	GREEN	
22	BLACK	WHITE	RED
23	WHITE	BLACK	RED
24	RED	BLACK	WHITE

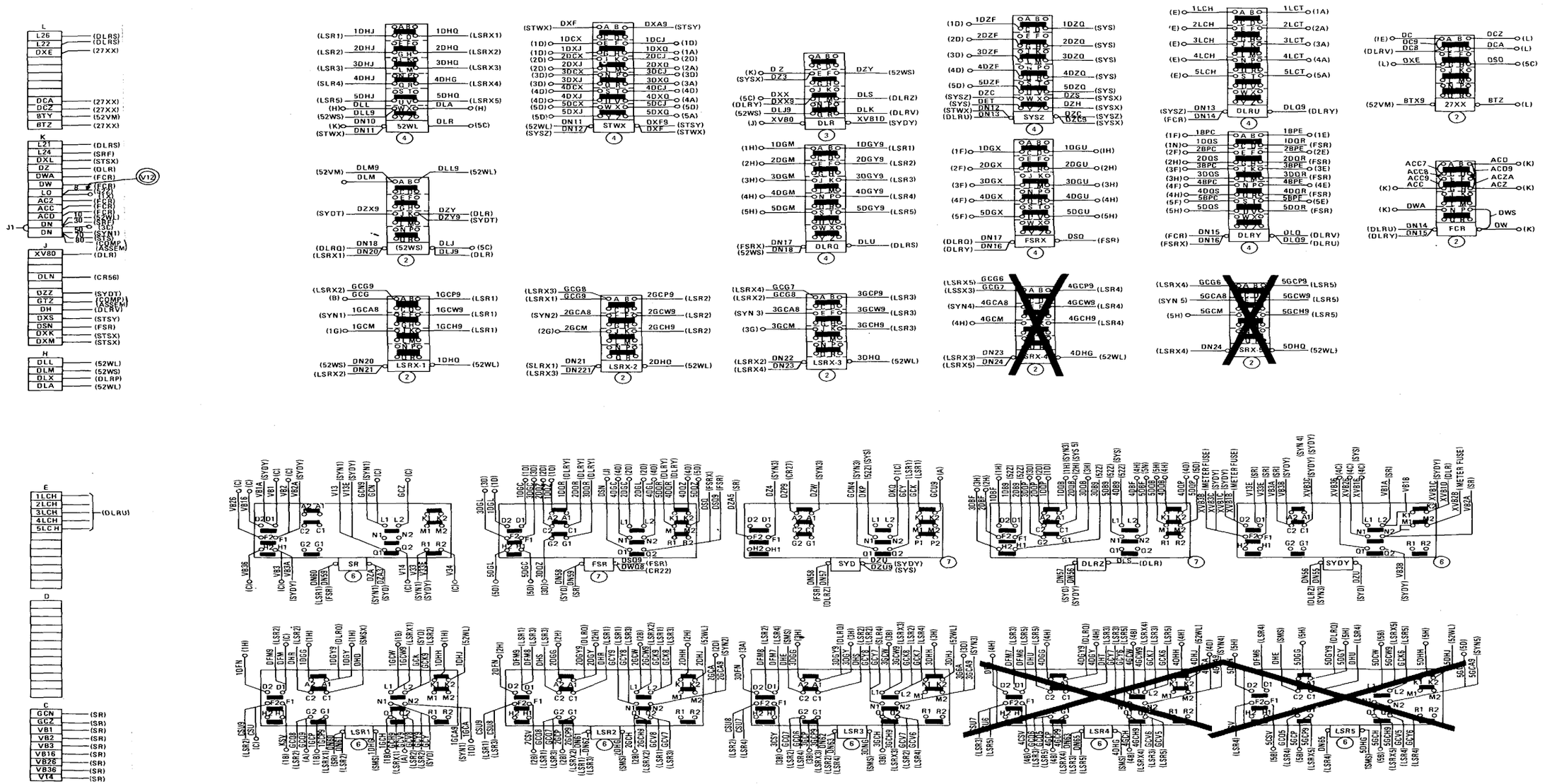
B3 CABLE COLOR CODE

NO.	BASE	TRACER	TRACER
1	BLACK		
2	WHITE		
3	GREEN		

WIRE AND CABLE

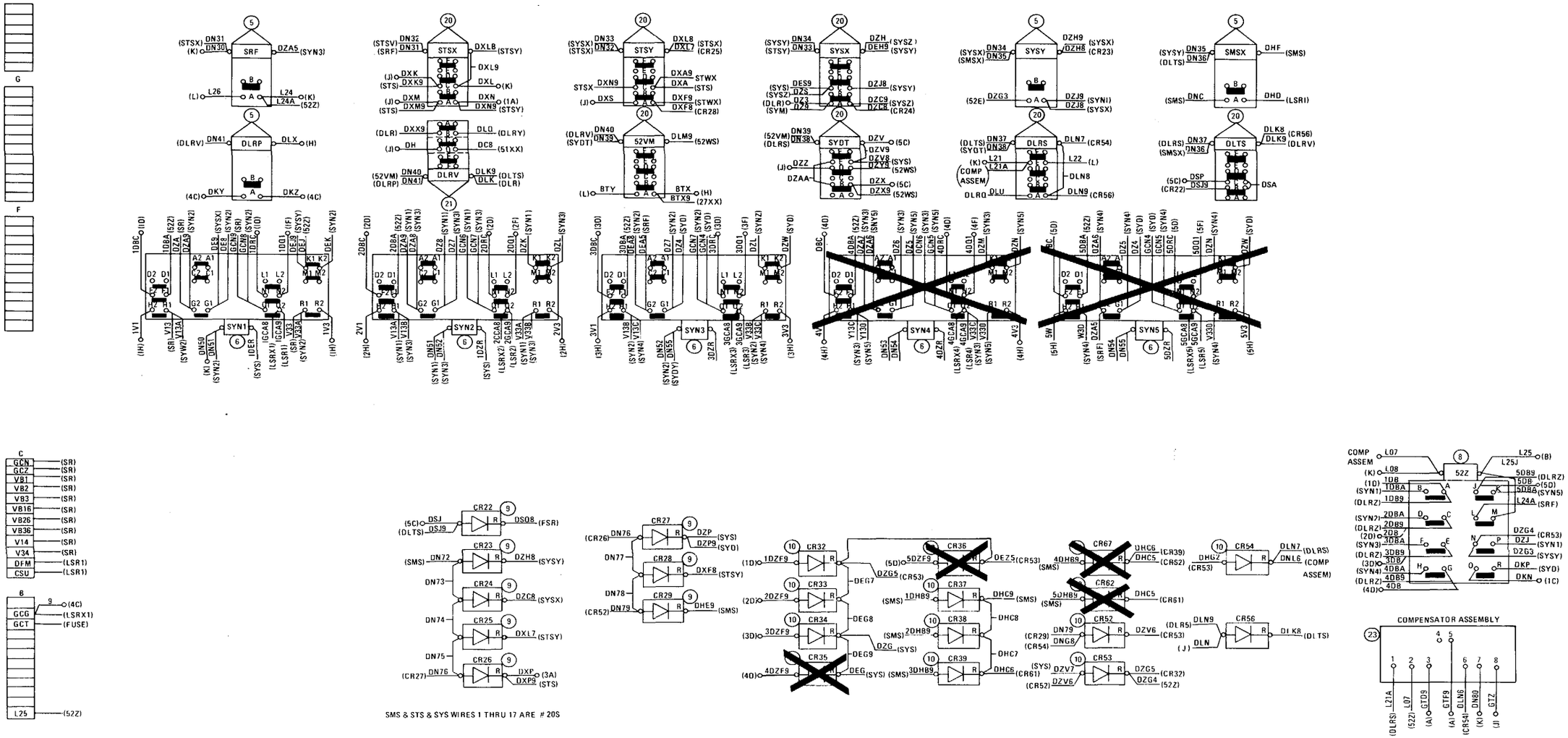
SYMBOL	CABLE SIZE		DIAMETER		TYPE OF INSULATION	PART NUMBER
	AWB OR CM.	STRANDING	OUTSIDE	BARE		
II	14,800 CM.	37/24	.305	.148	RH & N.	8126651
III	36,400 CM.	91/24	.430	.232	RH & N.	8126652
	500,000 CM.	37/.1162	1.43 (NOM)	.818	BC & N.	8378513
IX	130,000 CM.	325/24	.725	.485	RH & N.	8126654
# 6	26,250 CM.	SOLID	.650	.162	OPR & N.	8267482
B3	# 12-3 COND.	65/30 OR 84/31	.665	.094	NEOPRENE	8252769
J2	# 12-2 COND.	65/30 OR 84/31	.615	.094	NEOPRENE	8005429
J24	# 14-24 COND.	19/27	1.49	0.76	RH & N.	8283527

FO-24. Field Connections Wiring Diagram (838697) (Sheet 5 of 5)

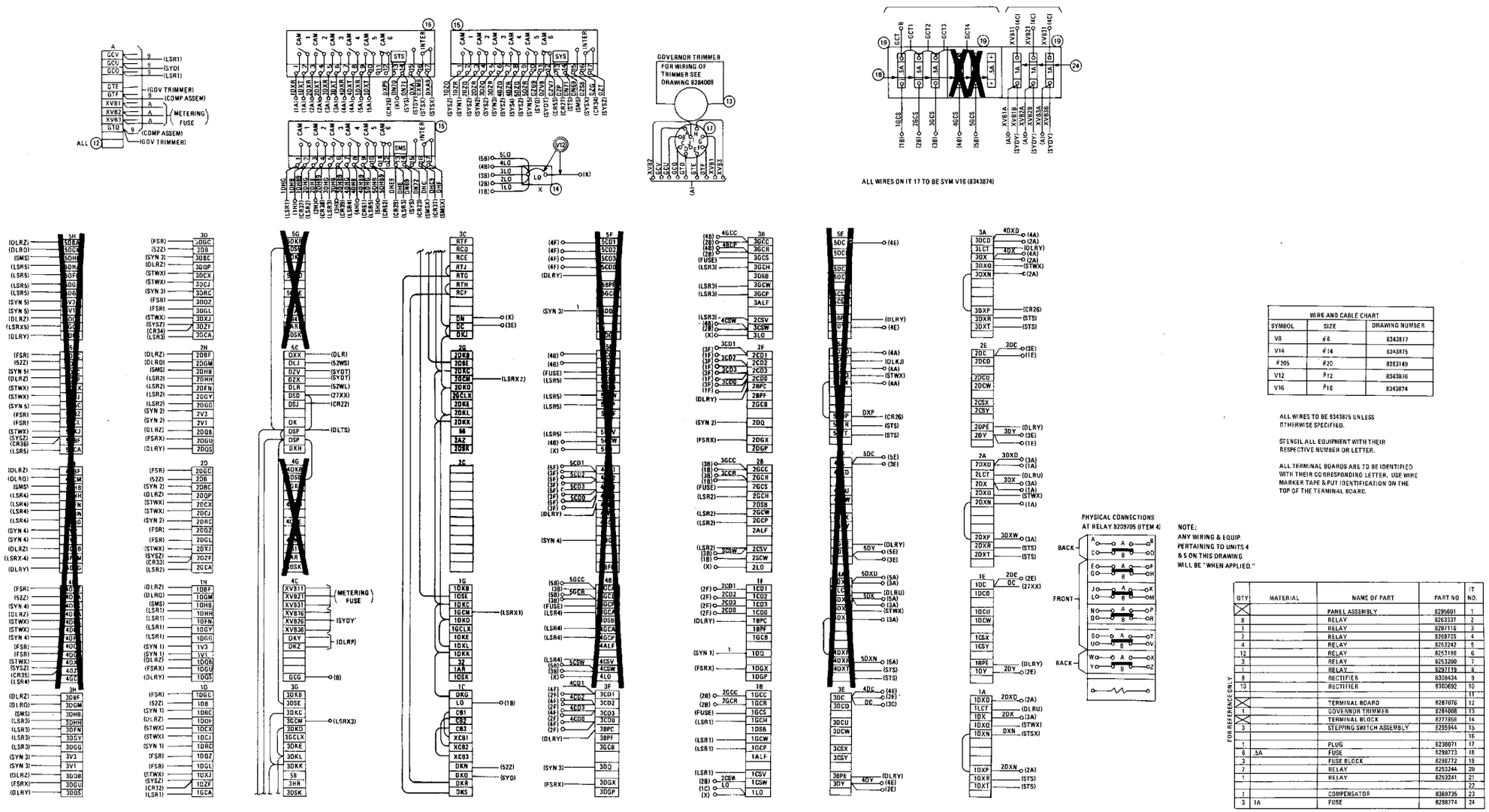


FO-25. Master Control Panel Wiring Diagram (8386399) (Sheet 1 of 3)

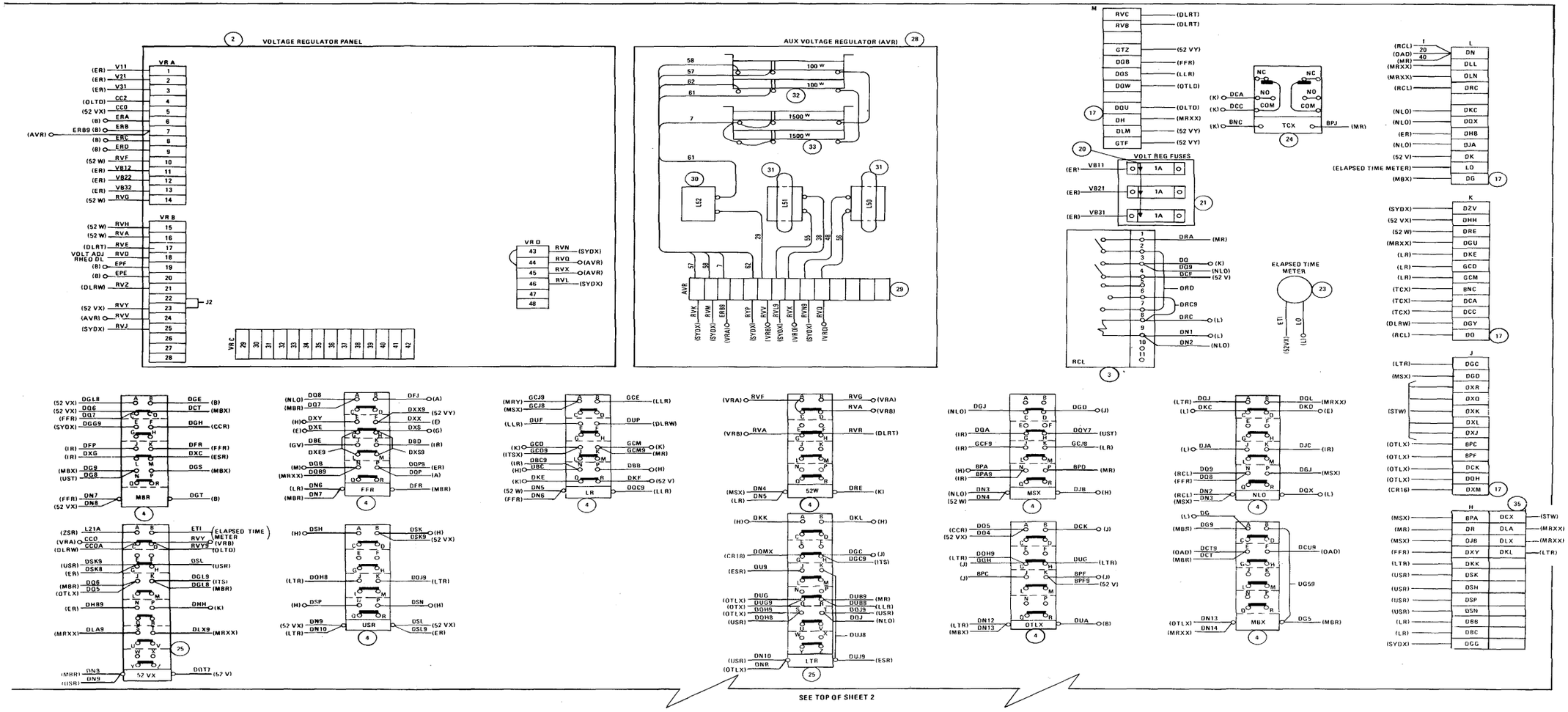
51/(52 blank)



FO-26 Master Control Panel Wiring Diagram (8386399) (Sheet 2 of 3)

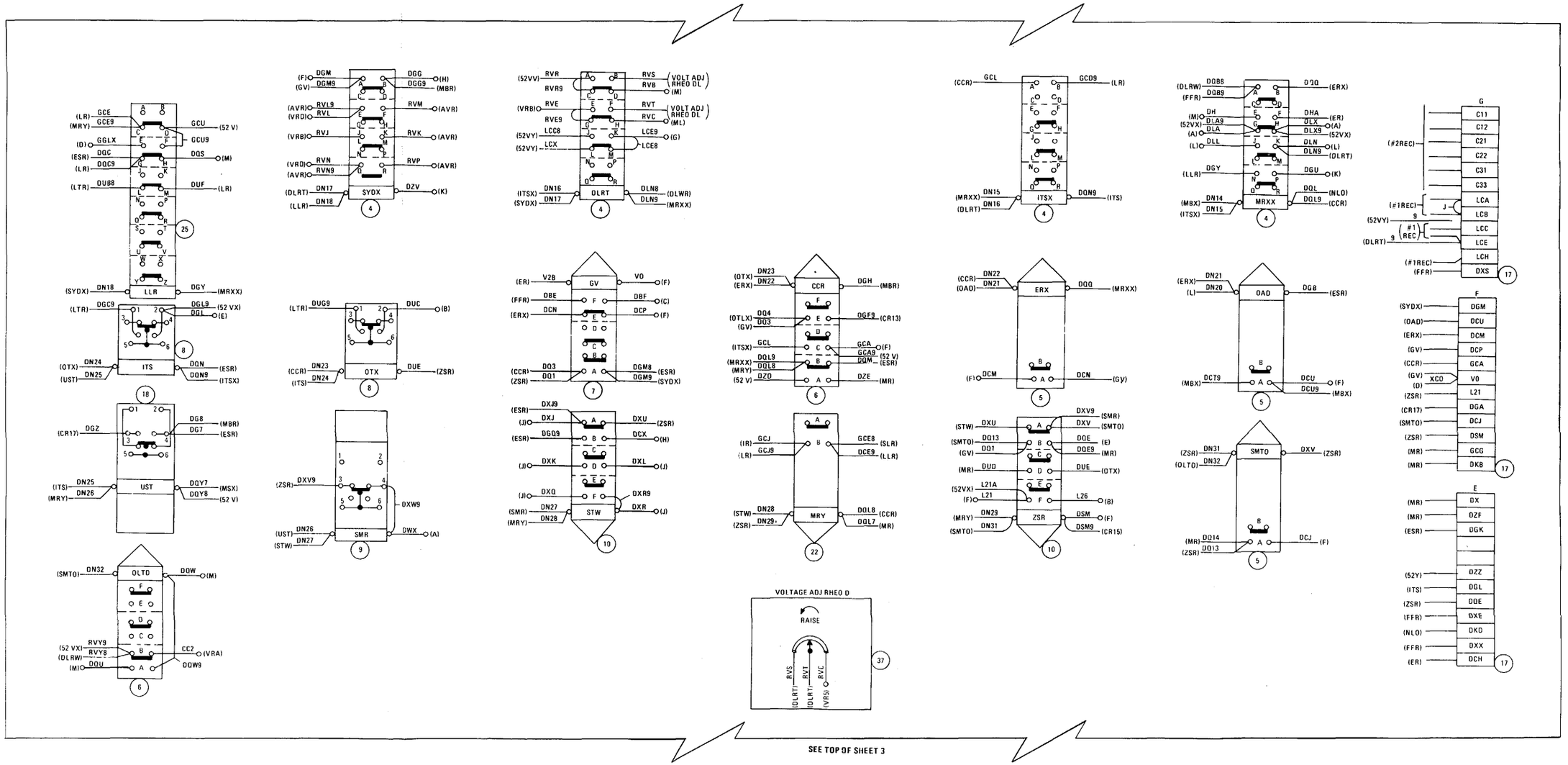


FO-27. Master Control Panel Wiring Diagram (8386399) (Sheet 3 of 3)

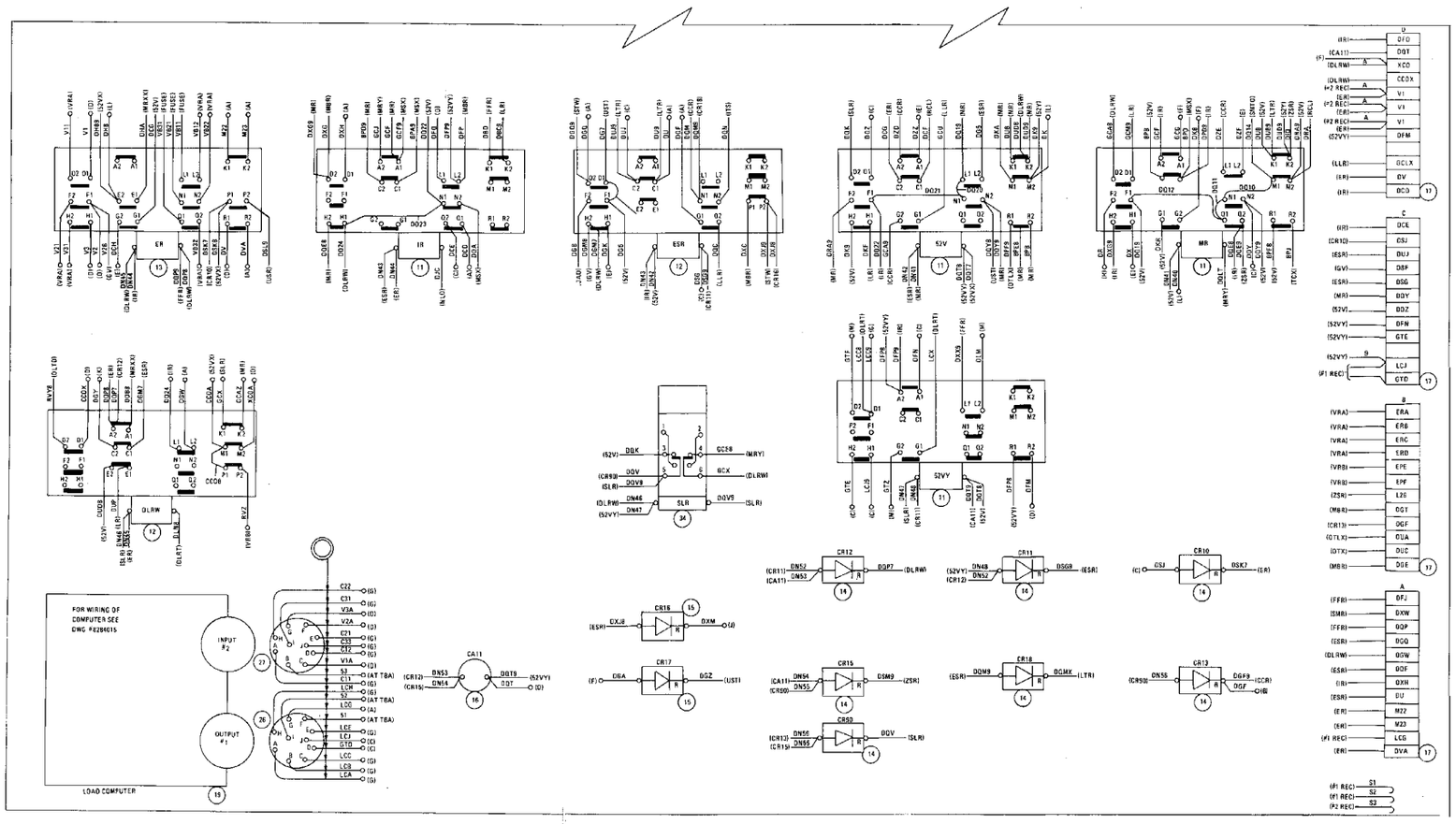


FO-28. Unit Control Panel Wiring Diagram (8386400) (Sheet 1 of 3)

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FO-29. Unit Control Panel Wiring Diagram (8386400) (Sheet 2 of 3)



WIRE & CABLE CHART		
SYMBOL	SIZE	DRAWING NO.
V14	#14	8343875
V16	#16	8343874

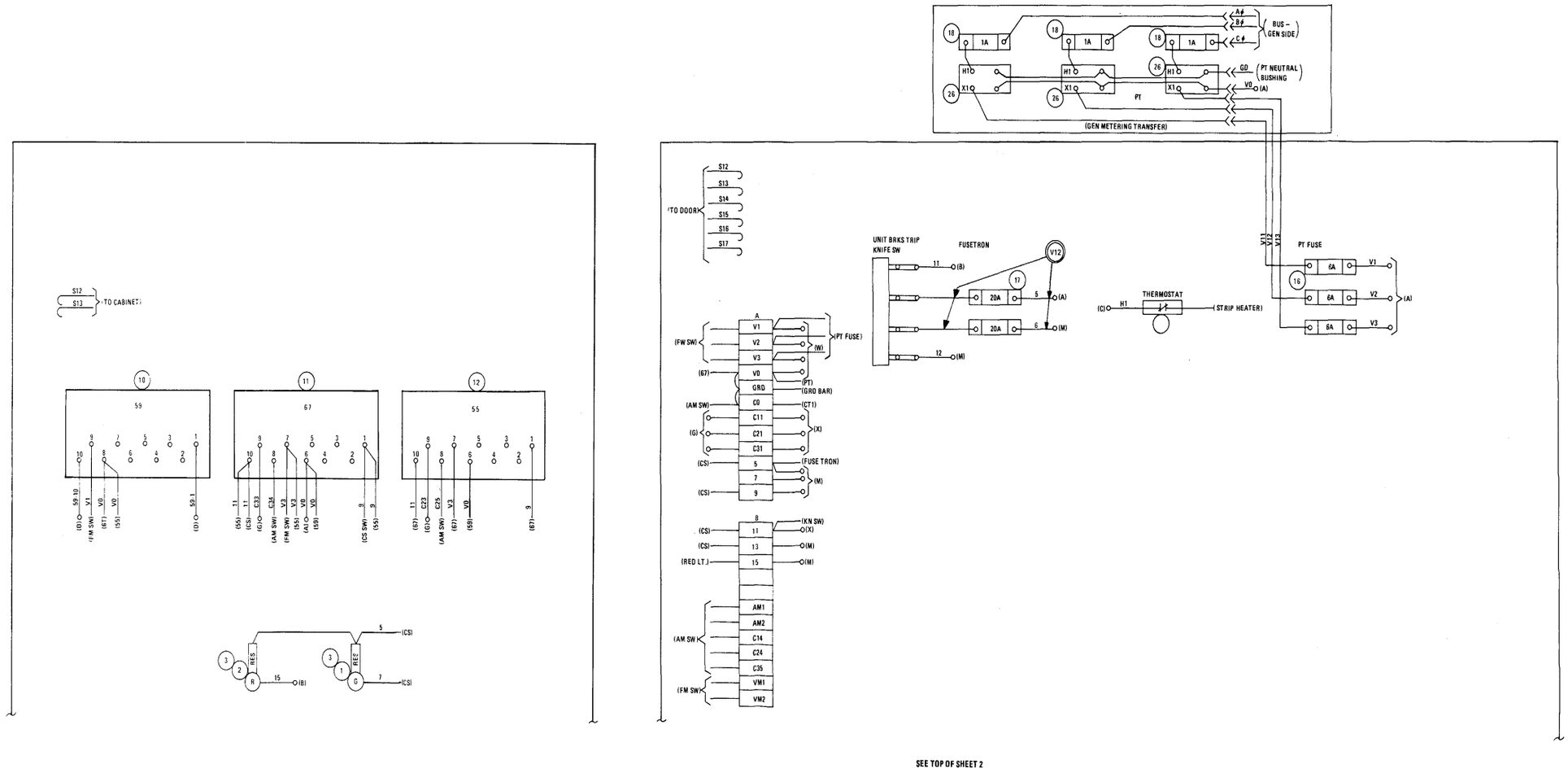
ALL WIRES TO BE 8343875 (#14 AWG) UNLESS OTHERWISE SPECIFIED.

STENCIL ALL EQUIPMENT WITH THEIR RESPECTIVE NUMBER OR LETTER.

ALL TERMINAL BOARDS ARE TO BE IDENTIFIED WITH THEIR CORRESPONDING LETTER. USE WIRE MARKER TAPE & PUT IDENTIFICATION ON THE TOP OF THE TERMINAL BOARD.

FOR REFERENCE ONLY QTY	MATERIAL	NAME OF PART	PART NO.	ITEM NO.
X		PANEL ASSEMBLY	8284550	1
1		REGULATOR PANEL	8353214	2
1		STEPPING SWITCH	8353114	3
13	4 NO - 4 NC	RELAY	8263337	4
3	T.D. PICK-UP	RELAY	8263242	5
2	T.D. PICK-UP	RELAY	8252244	6
1	T.D. PICK-UP	RELAY	8263135	7
2		RELAY	8262405	8
1		RELAY	8287537	9
2	T.D. DROP-OUT	RELAY	8253241	10
4	3 NO - 3 NC	RELAY	8252198	11
2	6 NO - 6 NC	RELAY	8253300	12
1	10 NO - 2 NC	RELAY	8285093	13
		RECTIFIER	8309414	14
2		RECTIFIER	8309092	15
1		CAPACITOR	8130932	16
X		TERMINAL BOARD	8361276	17
1		RELAY	8273763	18
1		LOAD COMPUTER	8284015	19
2	1A	FUSE	8260774	20
1		FUSE BLOCK	8290727	21
1	T.D. DROP-OUT	RELAY	8253245	22
1		METER-ELAPSED TIME	8340625	23
1	4 NO - 4 NC	RELAY	8317487	24
3	6 NO - 6 NC	RELAY	8285205	25
1		PLUG	8276877	26
1		PLUG	8276871	27
X		AUX. RSG PANEL	8290743	28
1	18 PT.	TERMINAL BOARD	8421184	29
1		FILTER CHOKE (L-52)	8289521	30
2		FILTER CHOKE (L-60, L-51)	8283022	31
1	2-100 Ω	RESISTOR ASSEM	8289825	32
1	2-150 Ω	RESISTOR ASSEM	8289830	33
1		RELAY	8346490	34
X		TERMINAL BOARD	8292838	35
				36
1		RHEOSTAT	8281908	37

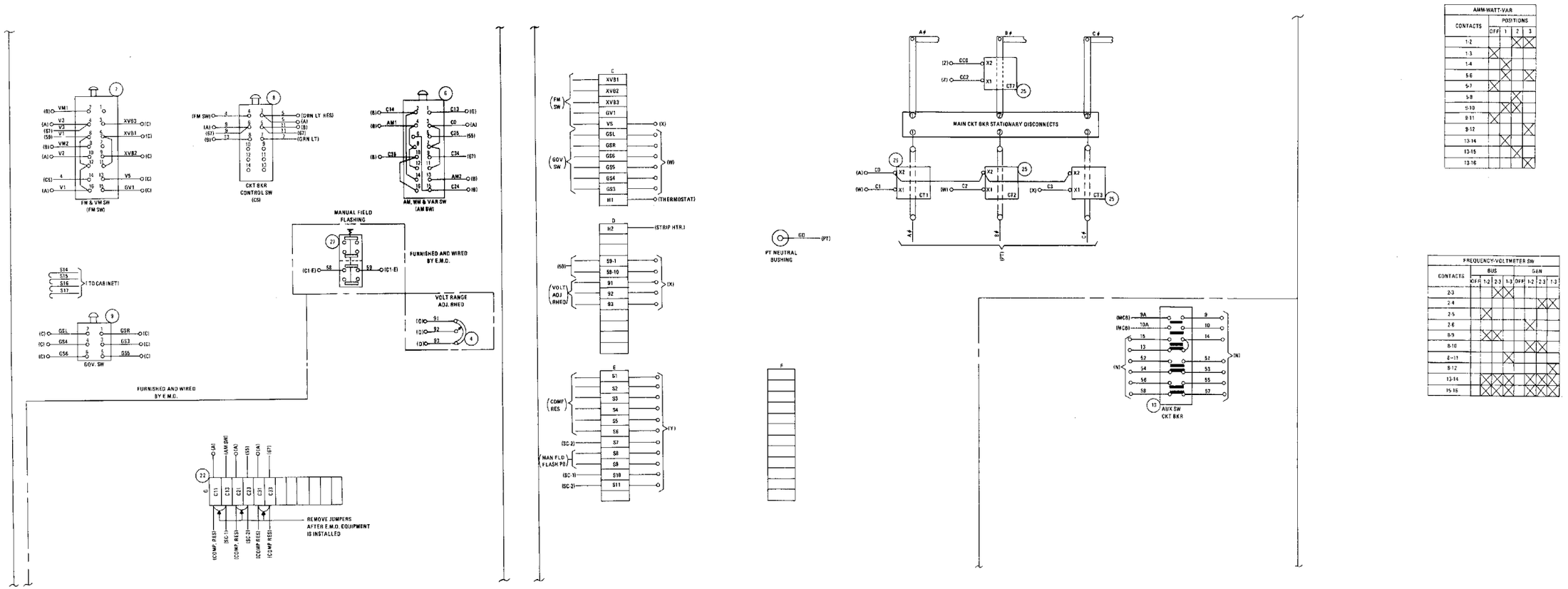
FO-30. Unit Control Panel Wiring Diagram (8386400) (Sheet 3 of 3)



GOVERNOR CONTROL SW			
CONTACTS	POSITIONS		
	RAISE	OFF	LOWER
1-2		X	
3-4	X		
5-6			X

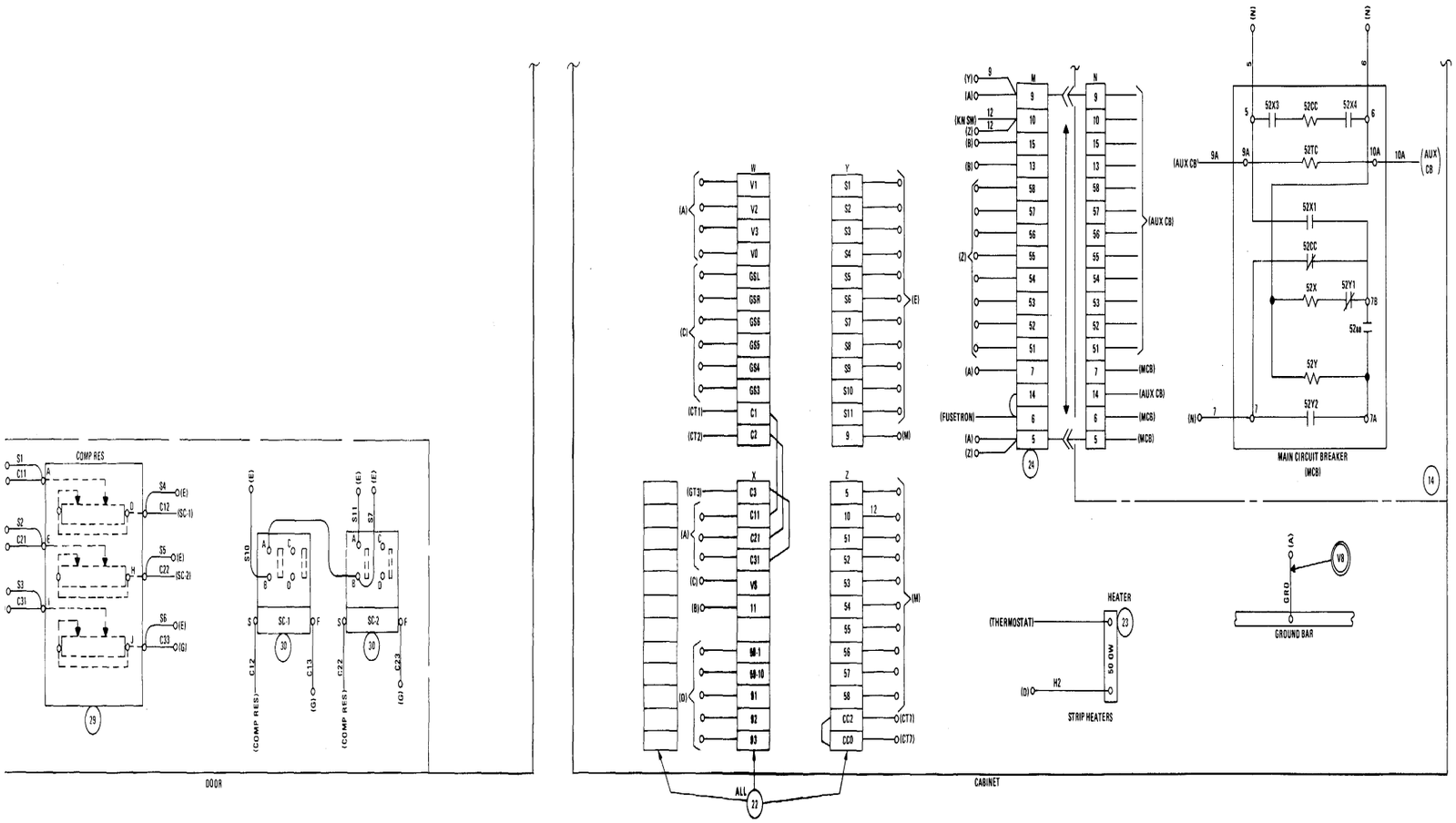
CIRCUIT BREAKER CONTROL SW					
CONTACTS	POSITIONS				
	CLOSE	NORM AFTER CLOSE	TRIP	NORM AFTER TRIP	PULL OUT IN TRIP
3-4	X				
5-6			X		X
7-8	X	X	X	X	
9-10		X		X	
11-12	X	X			
13-14	X	X			

FO-31. Switchgear Cubicle Wiring Diagram (8386402) (Sheet 1 of 3)



FO-32. Switchgear Cubicle Wiring Diagram (8386402) (Sheet 2 of 3)

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WIRE & CABLE CHART		
SYMBOL	SIZE	ORG. NO.
V14	# 14	8343875
V12	# 12	8343876
V8	# 8	8343877

*FURNISHED, MOUNTED, AND WIRED BY E.M.D.

WIRE NAME
BC1
(B)
INDICATES TERMINAL BOARD DESTINATION
INDICATES TERMINAL BOARD
WIRE NAME
GRD
(PT-3)
INDICATES EQUIPMENT DESTINATION

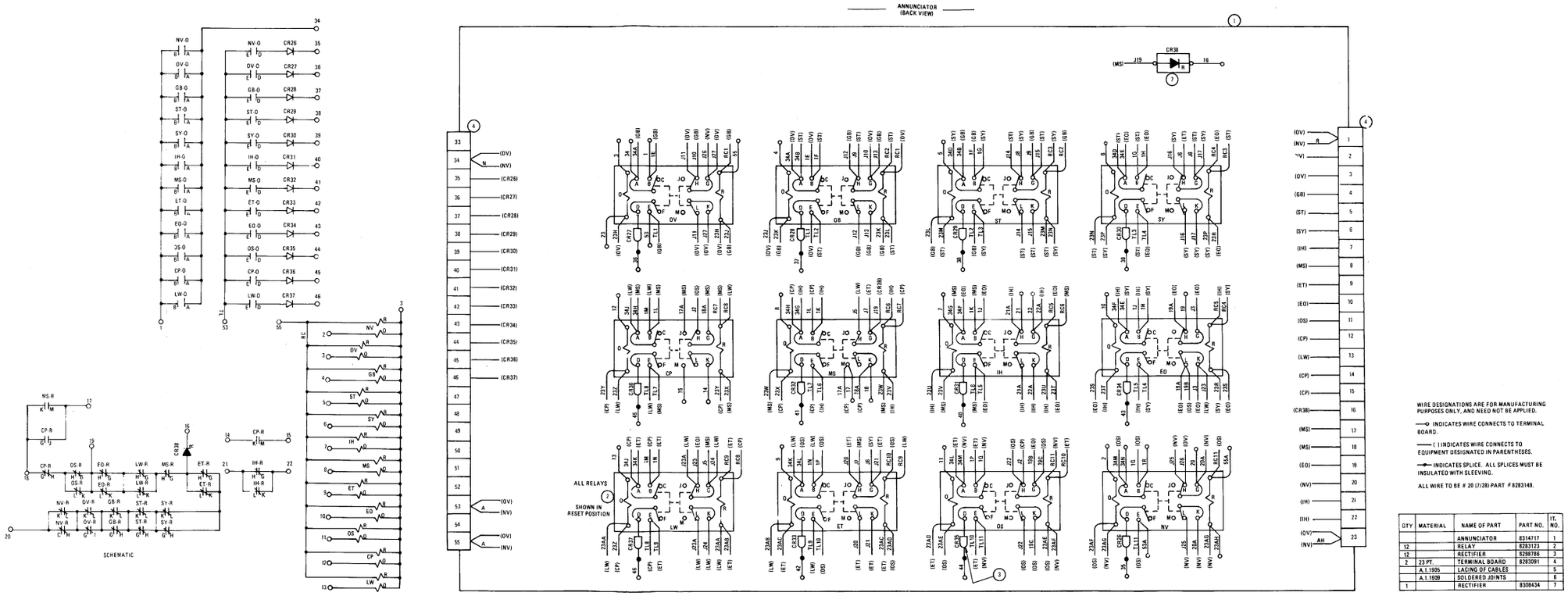
ALL WIRING TO BE A14 UNLESS OTHERWISE SHOWN

FOR REFERENCE ONLY

		MATERIAL	NAME OF PART	PART NO.	IT NO.
	1		INDICATING LIGHT GREEN	8371273	1
	1		INDICATING LIGHT RED	8371272	2
	2		LAMP	8369002	3
*	1		RHEOSTAT 150 OHMS	8315755	4
					5
	1		SWITCH AM-WATT-VAR	8314722	6
	1		SWITCH FM-VM	8314723	7
	1		SWITCH CIRCUIT BREAKER CONT	8275688	8
	1		SWITCH GOVERNOR CONT	8306927	9
	1		RELAY (59)	8340229	10
	1		RELAY (67)	8305515	11
	1		RELAY (55)	8340227	12
	1		SWITCH AUX	8305205	13
	1		CIRCUIT BRKR 250 MVA	8332804	14
	1		KNIFE SWITCH 4 POLE	8307148	15
	3		FUSE-6A	8004758	16
	2		FUSE-20A-DUAL ELEMENT	8208719	17
	3		FUSE-1A	8327970	18
	1		THERMOSTAT	8304501	19
					20
					21
	12		TERMINAL BOARD 13 POINT	8361130	22
	1		STRIP HEATER 500 WATT	8361131	23
	1		CONTACT BASE ASSEMBLY	8305145	24
	4		TRANSFORMER CURRENT	8305214	25
	3		TRANSFORMER POTENTIAL	8273991	26
*	1		SWITCH	8262475	27
					28
*	1		RESISTOR BOX	8283516	29
*	2		RELAY	8289126	30

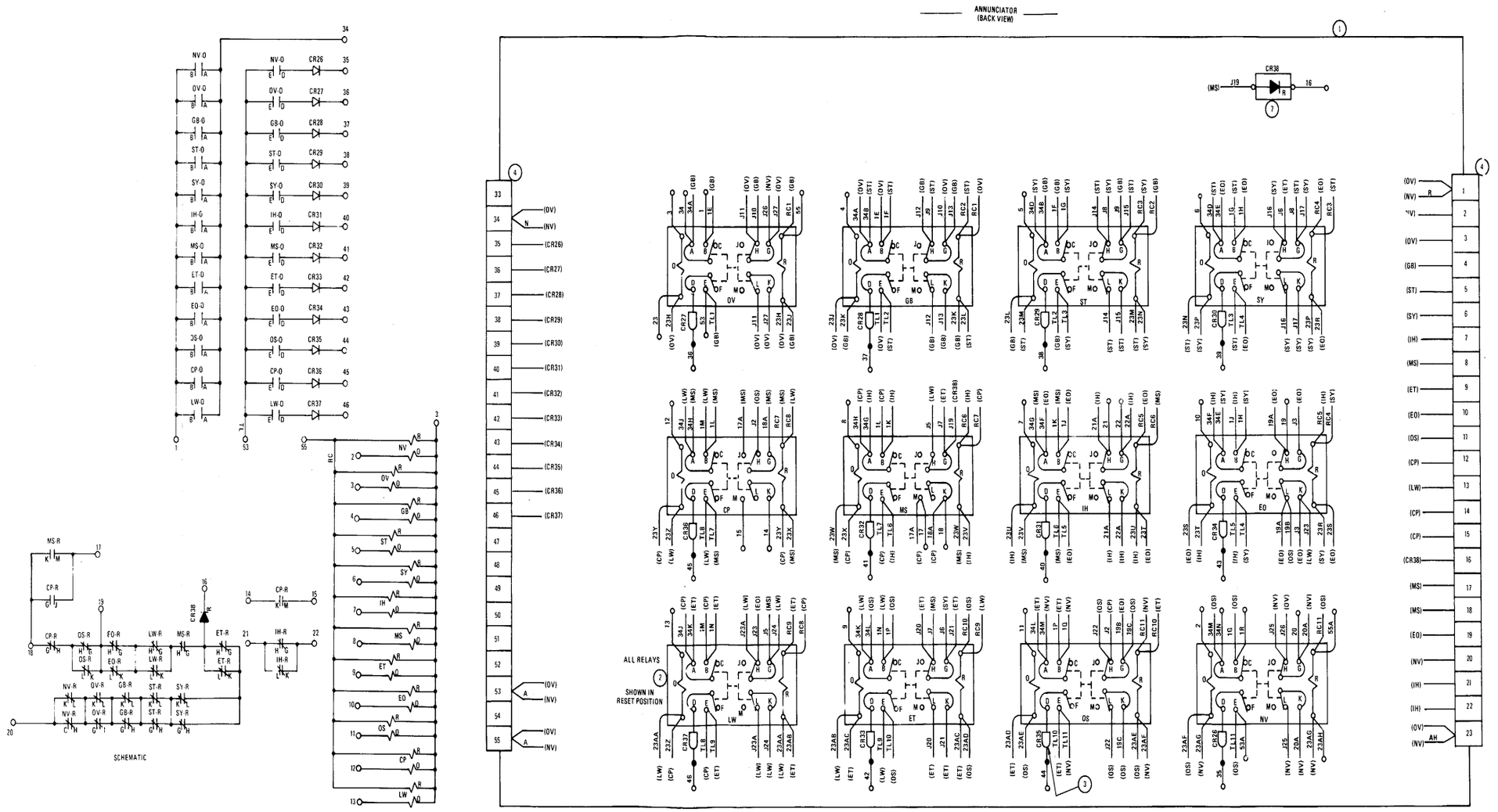
FO-31. Switchgear Cubicle Wiring Diagram (8386402) (Sheet 3 of 3)

67/(68 blank)



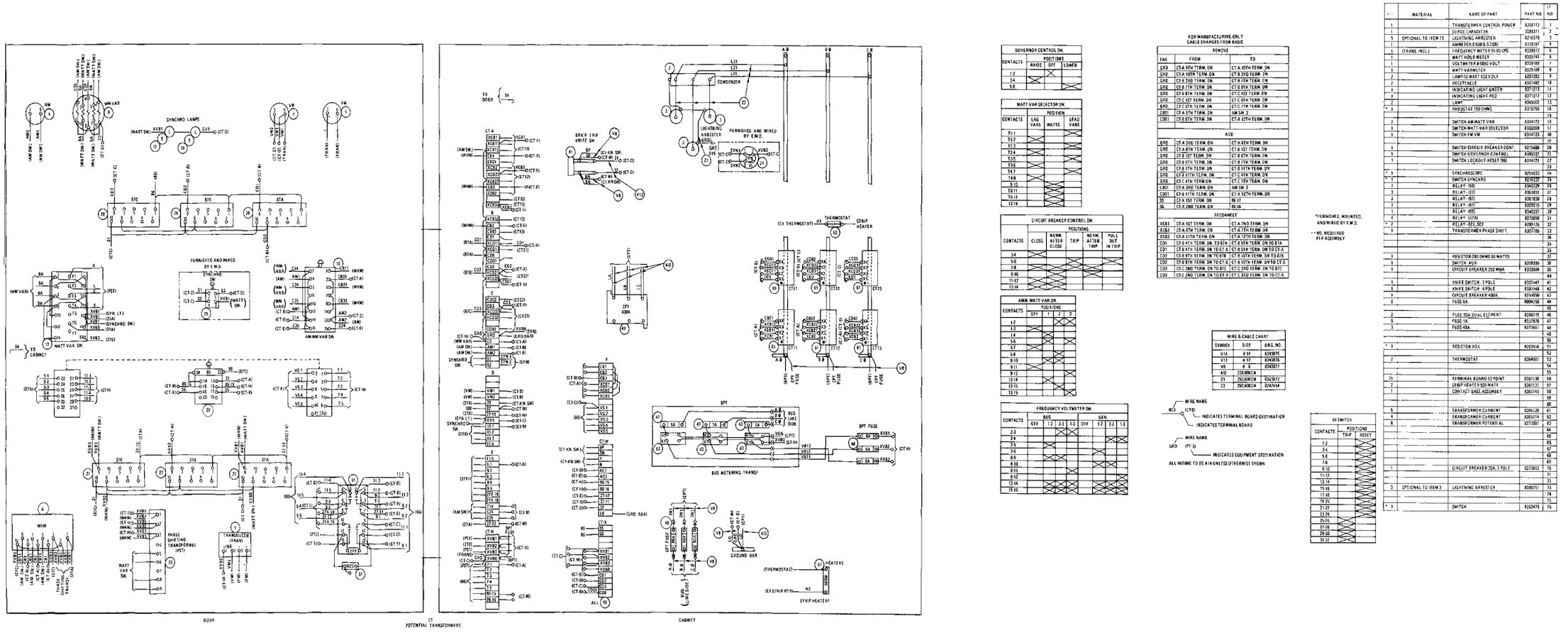
QTY	MATERIAL	NAME OF PART	PART NO.	IT. NO.
		ANNUNCIATOR	8314717	1
12		RELAY	8283123	2
12		RECTIFIER	8290786	3
2	23 PT.	TERMINAL BOARD	8283091	4
	A.1.1905	LACING OF CABLES		5
	A.1.1609	SOLDERED JOINTS		6
1		RECTIFIER	8308434	7

FO-34. Master Annunciator Wiring Diagram (8314451)



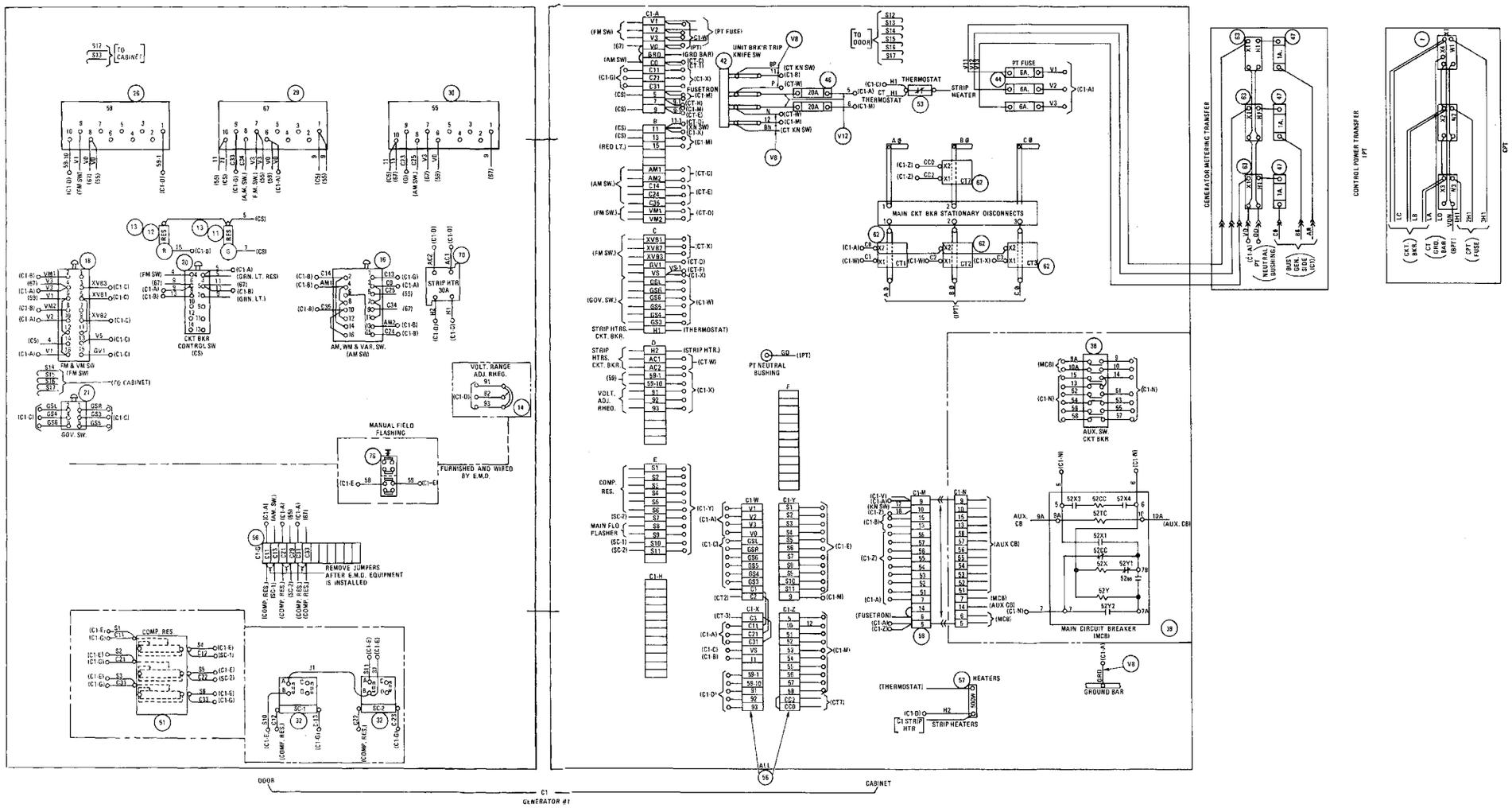
QTY	MATERIAL	NAME OF PART	PART NO.	IT. NO.
		ANNUNCIATOR	8314717	1
12		RELAY	8283123	2
12		RECTIFIER	8298786	3
2	23 PT.	TERMINAL BOARD	8283091	4
	A.I.1905	LACING OF CABLES		5
	A.I.1609	SOLDERED JOINTS		6
1		RECTIFIER	8308434	7

FO-35. Auxiliary Wiring Diagram (831445)



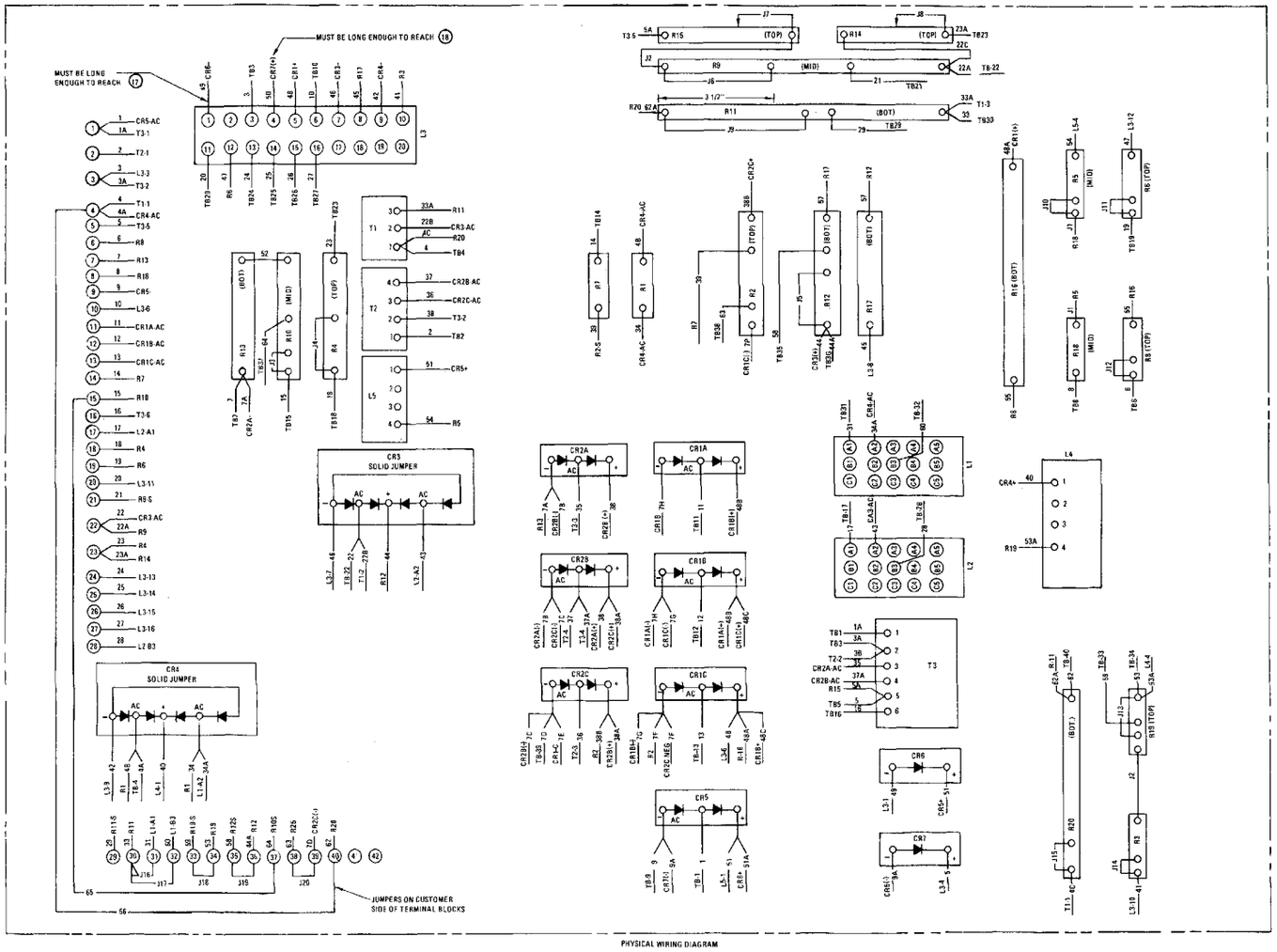
FO-36. Transformer and Switchgear Cubicle Wiring Diagram (8386401) (Sheet 1 of 2)

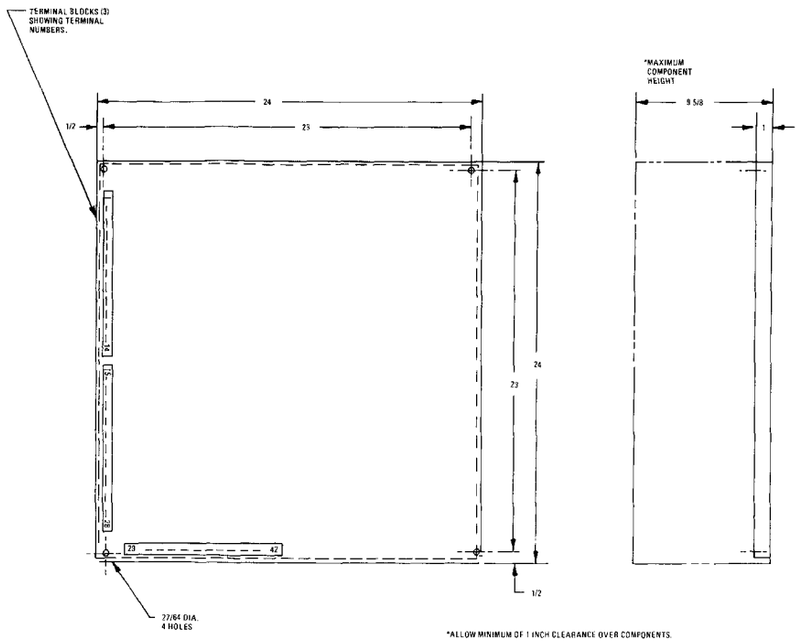
73/(74 blank)



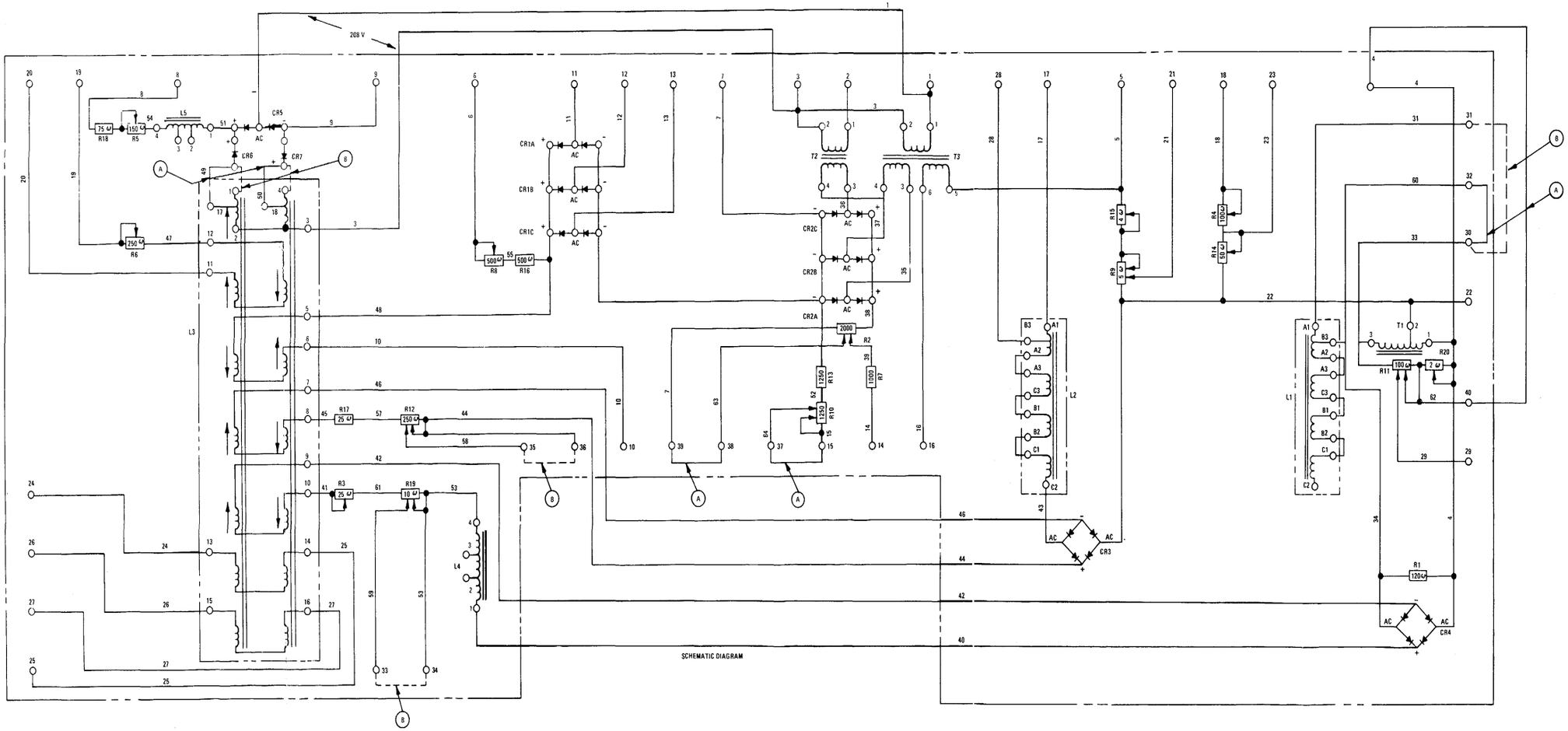
FO-37. Transformer and Switchgear Cubicle Wiring Diagram (8386401) (Sheet 2 of 2)

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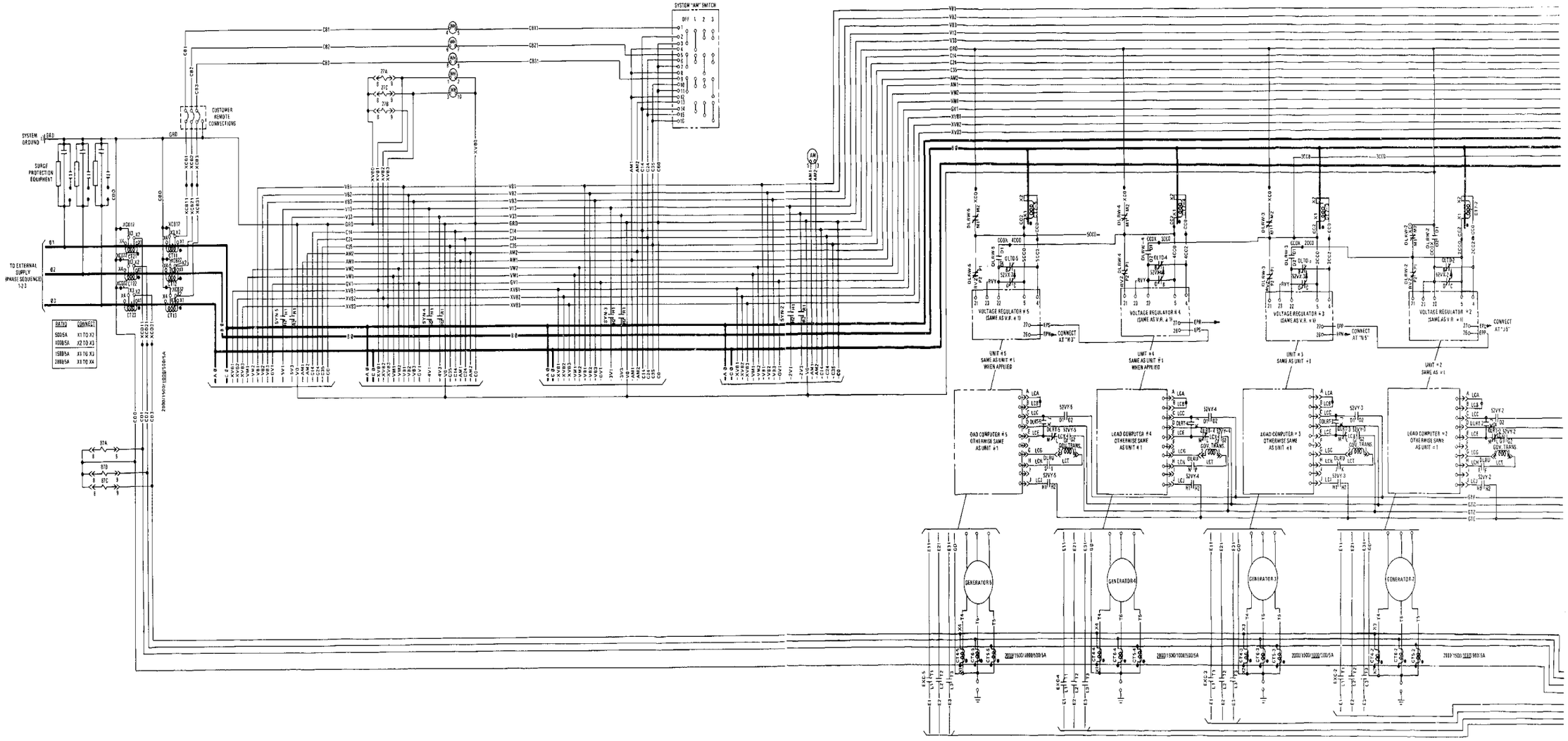
FO-38. Regulator Panel (8408214) (Sheet 1 of 2)



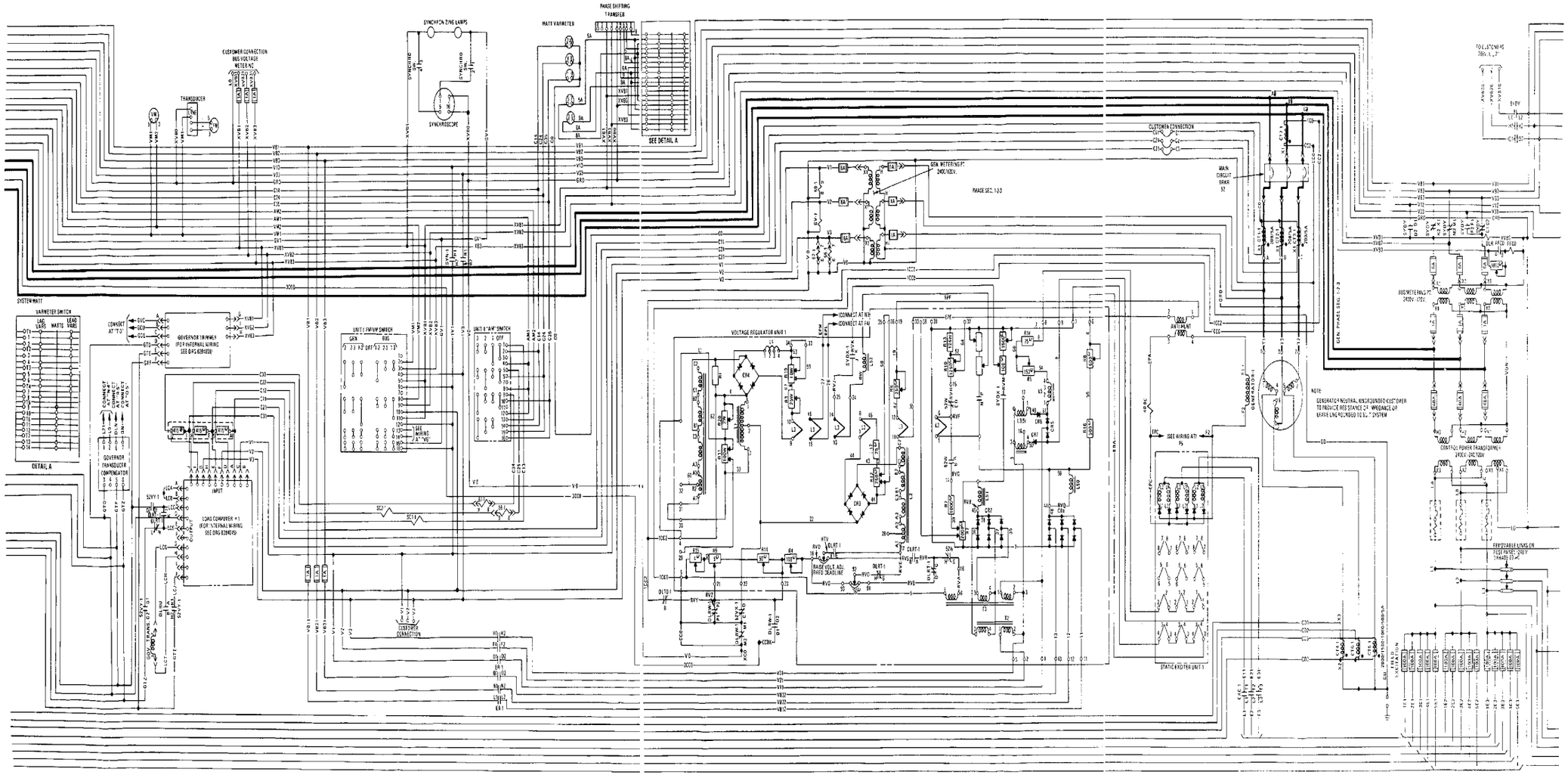
(A) THIS CONNECTION FOR 60 CPS OPERATION ONLY. DISCONNECT FOR 50 CPS OPERATION.
(B) THIS CONNECTION FOR 50 CPS OPERATION ONLY. DISCONNECT FOR 60 CPS OPERATION.
JUMPERS ON L1 & L2 ARE FACTORY ADJUSTMENTS AND MAY NOT BE AS SHOWN.

FOR 50 OR 60 CPS OPERATION

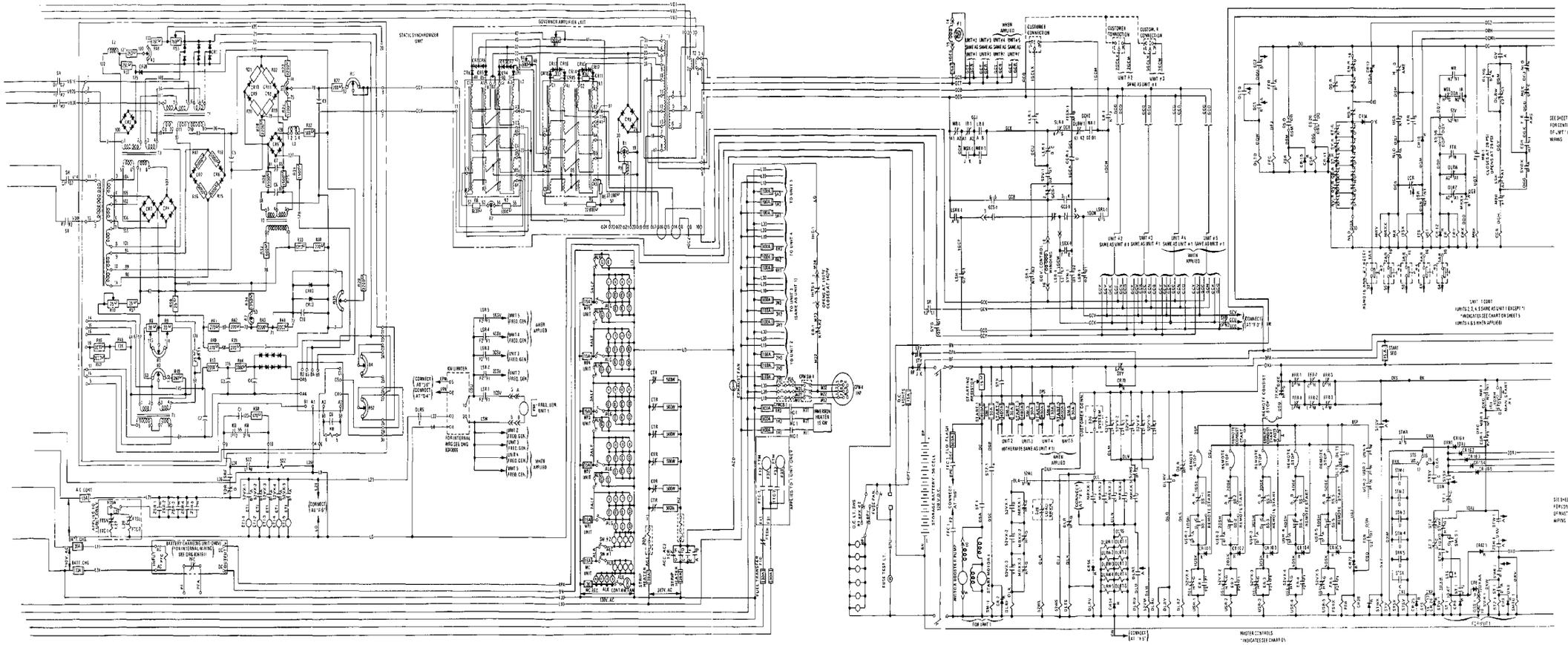
FO-39. Regulator Panel (8408214) (Sheet 2 of 2)



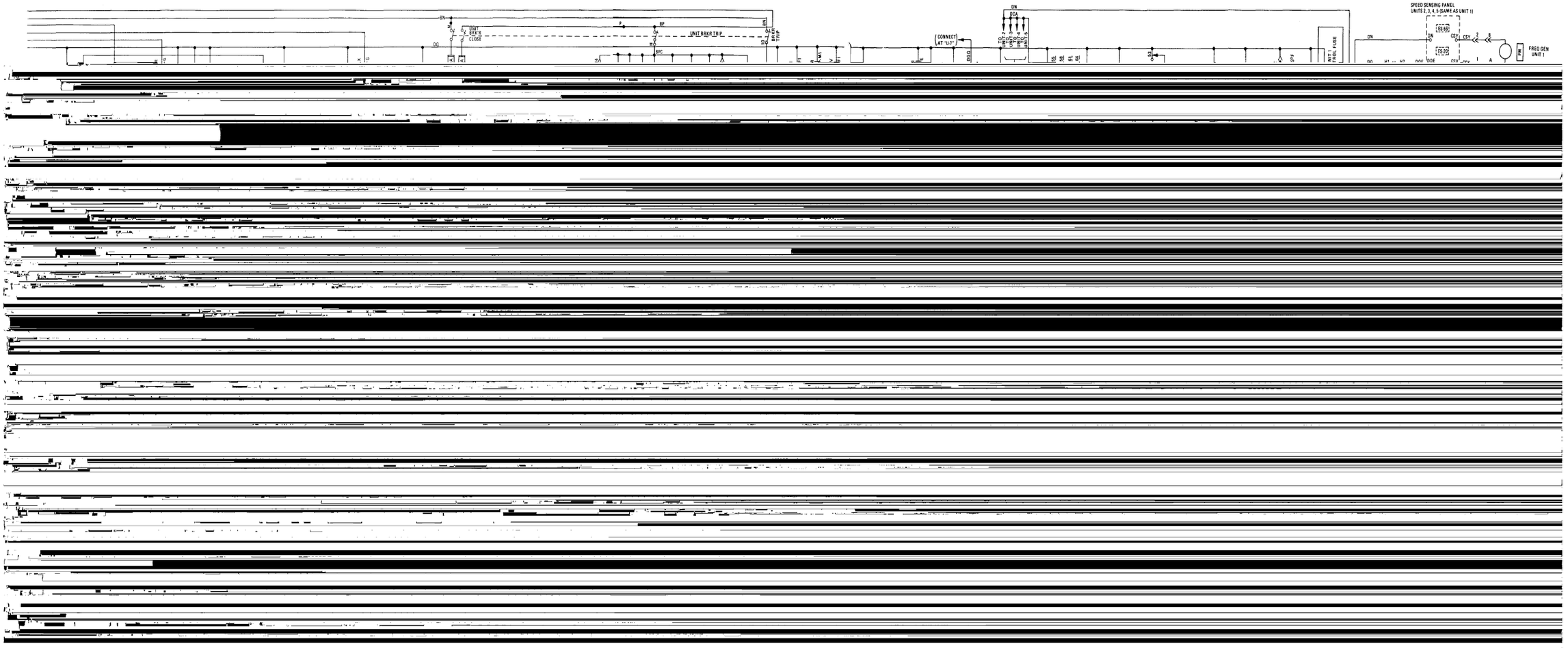
FO-40 Overall Schematic Wiring Diagram 19638 (8378789) (Sheet 1 of 5)



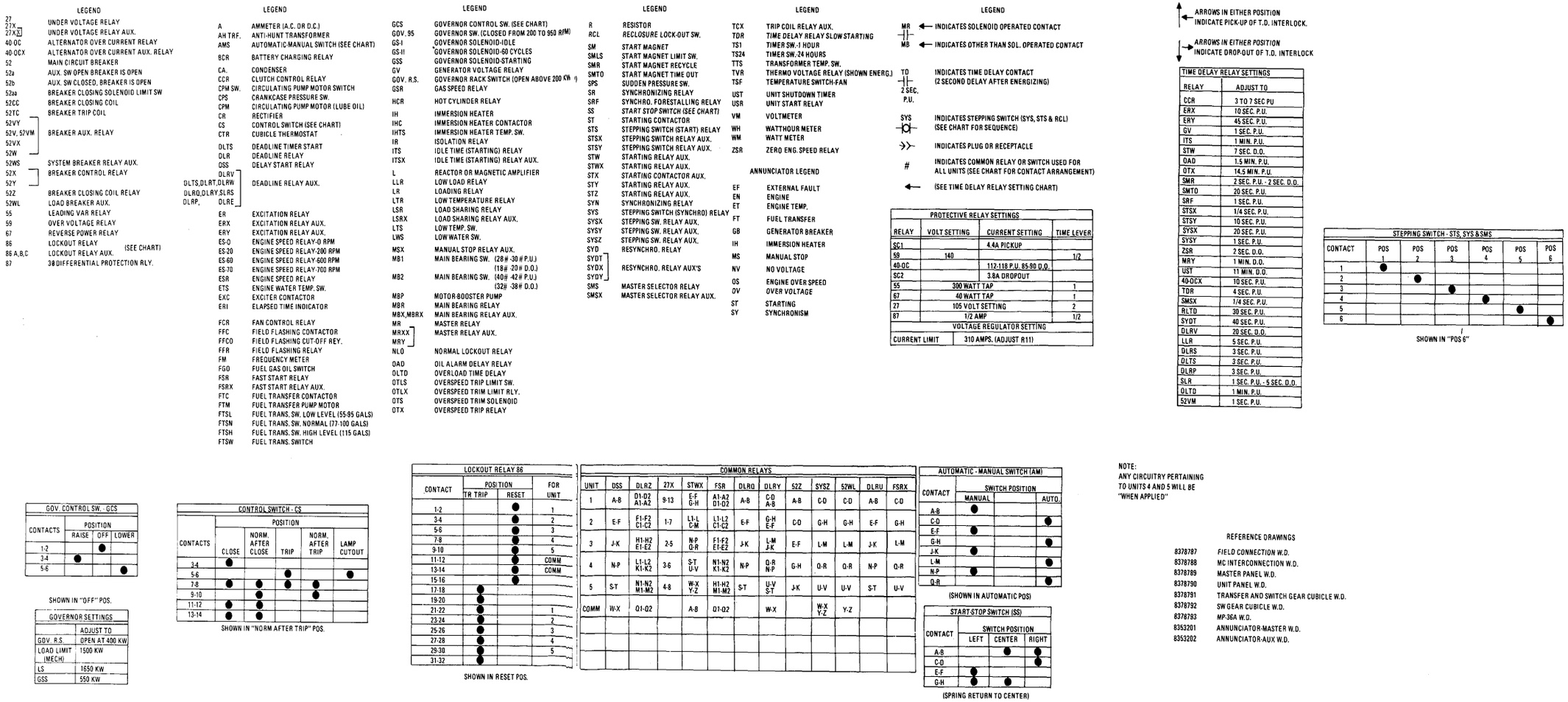
FO-41. Overall Schematic Wiring Diagram I9638 (8378789) (Sheet 2 of 5)



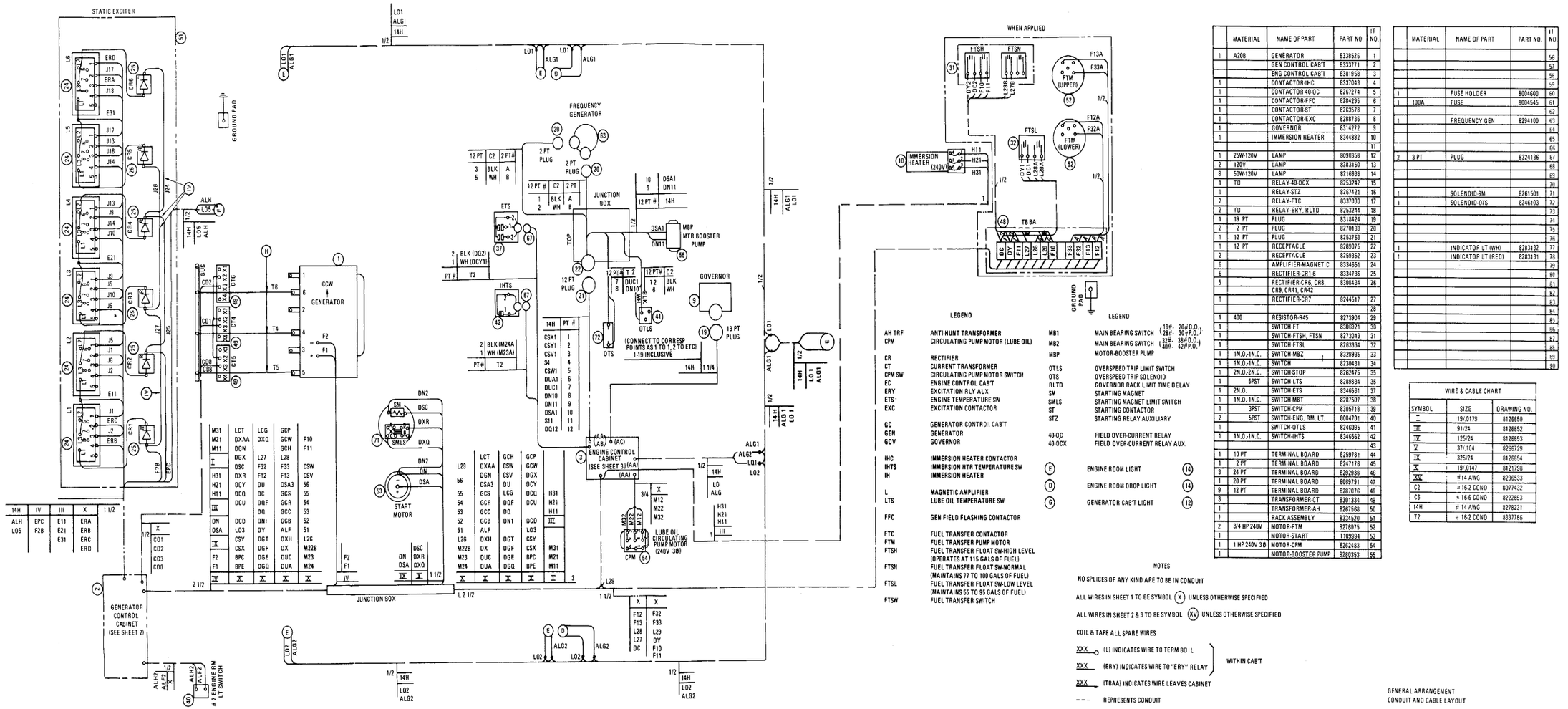
FO-42. Overall Schematic Wiring Diagram I9638 (8378789) (Sheet 3 of 5)



FO-43. Overall Schematic Wiring Diagram 19638 (8378789) (Sheet 4 of 5)



FO-44. Overall Schematic Wiring Diagram 19638 (8378789) (Sheet 5 of 5)



LEGEND

AH TRF	ANTI-HUNT TRANSFORMER
CPM	CIRCULATING PUMP MOTOR (LUBE OIL)
CR	RECTIFIER
CT	CURRENT TRANSFORMER
CPM SW	CIRCULATING PUMP MOTOR SWITCH
EC	ENGINE CONTROL CAB'T
ERY	EXCITATION RLY AUX
ETS	ENGINE TEMPERATURE SW
EXC	EXCITATION CONTACTOR
GC	GENERATOR CONTROL CAB'T
GEN	GENERATOR
GOV	GOVERNOR
IHC	IMMERSION HEATER CONTACTOR
IHTS	IMMERSION HTR TEMPERATURE SW
IH	IMMERSION HEATER
L	MAGNETIC AMPLIFIER
LTS	LUBE OIL TEMPERATURE SW
FFC	GEN FIELD FLASHING CONTACTOR
FTC	FUEL TRANSFER CONTACTOR
FTM	FUEL TRANSFER PUMP MOTOR
FTSH	FUEL TRANSFER FLOAT SW-HIGH LEVEL (OPERATES AT 115 GALS OF FUEL)
FTSN	FUEL TRANSFER FLOAT SW-NORMAL (MAINTAINS 77 TO 100 GALS OF FUEL)
FTSL	FUEL TRANSFER FLOAT SW-LOW LEVEL (MAINTAINS 55 TO 95 GALS OF FUEL)
FTSW	FUEL TRANSFER SWITCH
MB1	MAIN BEARING SWITCH (18#- 20#P.D.; 28#- 30#P.D.)
MB2	MAIN BEARING SWITCH (32#- 38#P.D.; 40#- 42#P.D.)
MBP	MOTOR-BOOSTER PUMP
OTLS	OVERSPEED TRIP LIMIT SWITCH
OTS	OVERSPEED TRIP SOLENOID
RLTD	GOVERNOR RACK LIMIT TIME DELAY
SM	STARTING MAGNET
SMLS	STARTING MAGNET LIMIT SWITCH
ST	STARTING CONTACTOR
STZ	STARTING RELAY AUXILIARY
40-OC	FIELD OVER-CURRENT RELAY
40-OCX	FIELD OVER-CURRENT RELAY AUX.
(E)	ENGINE ROOM LIGHT (14)
(D)	ENGINE ROOM DROP LIGHT (14)
(G)	GENERATOR CAB'T LIGHT (12)

NOTES

NO SPLICES OF ANY KIND ARE TO BE IN CONDUIT

ALL WIRES IN SHEET 1 TO BE SYMBOL (X) UNLESS OTHERWISE SPECIFIED

ALL WIRES IN SHEET 2 & 3 TO BE SYMBOL (XV) UNLESS OTHERWISE SPECIFIED

COIL & TAPE ALL SPARE WIRES

XXX (L) INDICATES WIRE TO TERM BD L — WITHIN CAB'T

XXX (ERY) INDICATES WIRE TO "ERY" RELAY — WITHIN CAB'T

XXX (TBAA) INDICATES WIRE LEAVES CABINET

--- REPRESENTS CONDUIT

IT NO.	MATERIAL	NAME OF PART	PART NO.
1	A208	GENERATOR	8338526
2		GEN CONTROL CAB'T	8333771
3		ENG CONTROL CAB'T	8301958
4	1	CONTACTOR-IHC	8337043
5	1	CONTACTOR-40-OC	8267274
6	1	CONTACTOR-FFC	8284295
7	1	CONTACTOR-ST	8263578
8	1	CONTACTOR-EXC	8288736
9	1	GOVERNOR	8314272
10	1	IMMERSION HEATER	8344882
11			
12	1	25W-120V LAMP	8090358
13	2	120V LAMP	8283150
14	8	50W-120V LAMP	8716636
15	1	TD RELAY-40-OCX	8253242
16	1	RELAY-STZ	8267421
17	2	RELAY-FTC	8337033
18	2	TD RELAY-ERY, RLTD	8253244
19	1	19 PT PLUG	8318424
20	2	2 PT PLUG	8270133
21	1	12 PT PLUG	8253763
22	1	12 PT RECEPTACLE	8289075
23	2	RECEPTACLE	8259362
24	6	AMPLIFIER-MAGNETIC	8334651
25	6	RECTIFIER-CR1-6	8334736
26	5	RECTIFIER-CR5, CR8, CR9, CR41, CR42	8308434
27	1	RECTIFIER-CR7	8244517
28			
29	1	400 RESISTOR-R45	8273904
30	1	SWITCH-FT	8308921
31	1	SWITCH-FTSH, FTSN	8273043
32	1	SWITCH-FTSL	8263334
33	1	1N.O.-1N.C. SWITCH-MBZ	8329935
34	1	1N.O.-1N.C. SWITCH	8230431
35	1	2N.O.-2N.C. SWITCH-STOP	8262475
36	1	5PST SWITCH-LTS	8289834
37	1	2N.O. SWITCH-ETS	8346561
38	1	1N.O.-1N.C. SWITCH-MBT	8287507
39	1	3PST SWITCH-CPM	8305718
40	2	5PST SWITCH-ENG. RM. LT.	8004701
41	1	SWITCH-OTLS	8246095
42	1	1N.O.-1N.C. SWITCH-IHTS	8346562
43			
44	1	10 PT TERMINAL BOARD	8259761
45	1	2 PT TERMINAL BOARD	8247176
46	3	24 PT TERMINAL BOARD	8282936
47	2	20 PT TERMINAL BOARD	8069781
48	9	12 PT TERMINAL BOARD	8287076
49	3	TRANSFORMER-CT	8301334
50	1	TRANSFORMER-AH	8267568
51	1	RACK ASSEMBLY	8334520
52	2	3/4 HP 240V MOTOR-FTM	8276075
53	1	MOTOR-START	1109694
54	1	1 HP 240V 3Ø MOTOR-CPM	8262483
55	1	MOTOR-BOOSTER PUMP	8280353

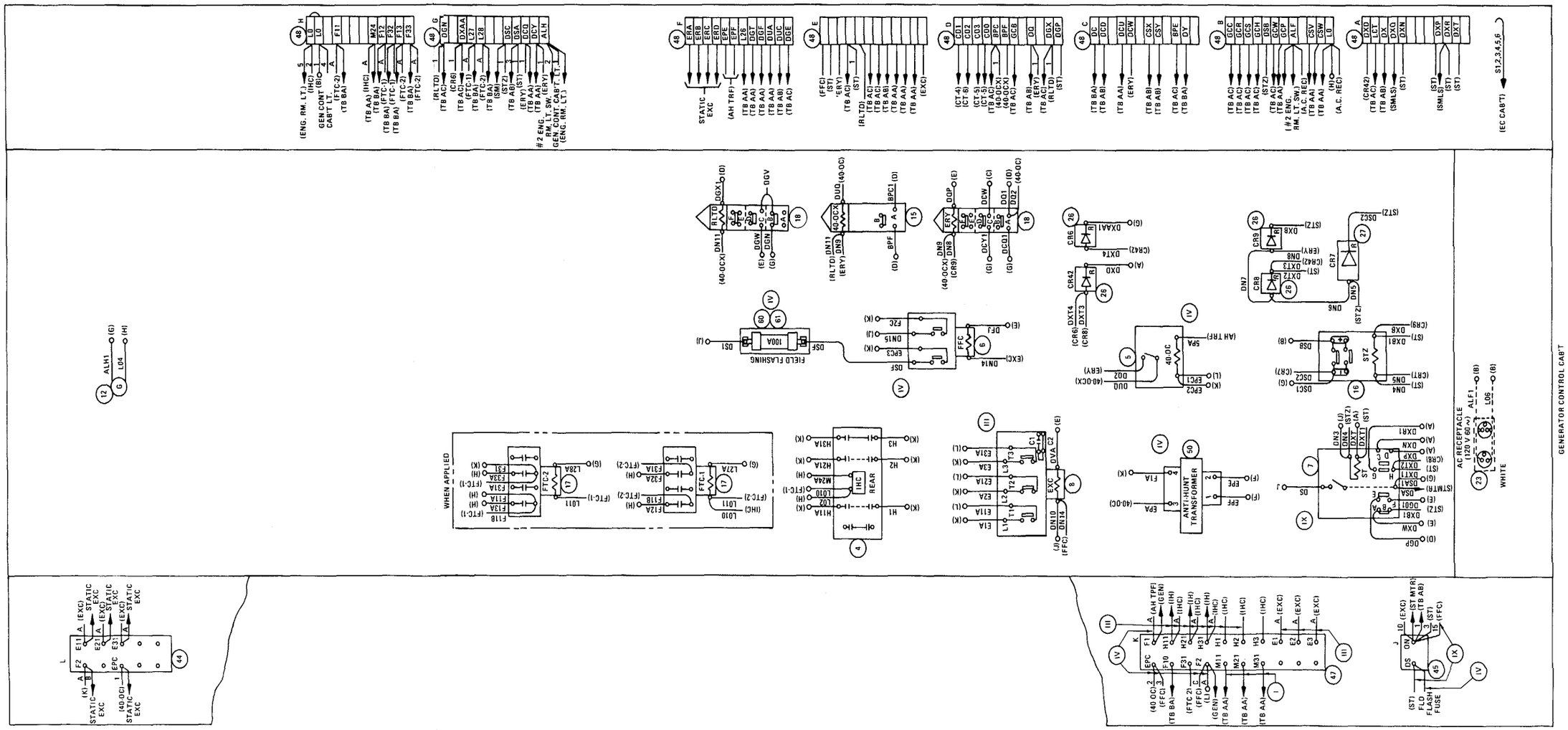
IT NO	MATERIAL	NAME OF PART	PART NO.
56			
57			
58			
59			
60	1	FUSE HOLDER	8004600
61	1 100A	FUSE	8004545
62			
63	1	FREQUENCY GEN	8294100
64			
65			
66			
67	2 3 PT	PLUG	8324136
68			
69			
70			
71	1	SOLENOID-SM	8261501
72	1	SOLENOID-OTS	8246103
73			
74			
75			
76			
77	1	INDICATOR LT (WH)	8283132
78	1	INDICATOR LT (RED)	8283131
79			
80			
81			
82			
83			
84			
85			
86			
87			
88			
89			
90			

WIRE & CABLE CHART

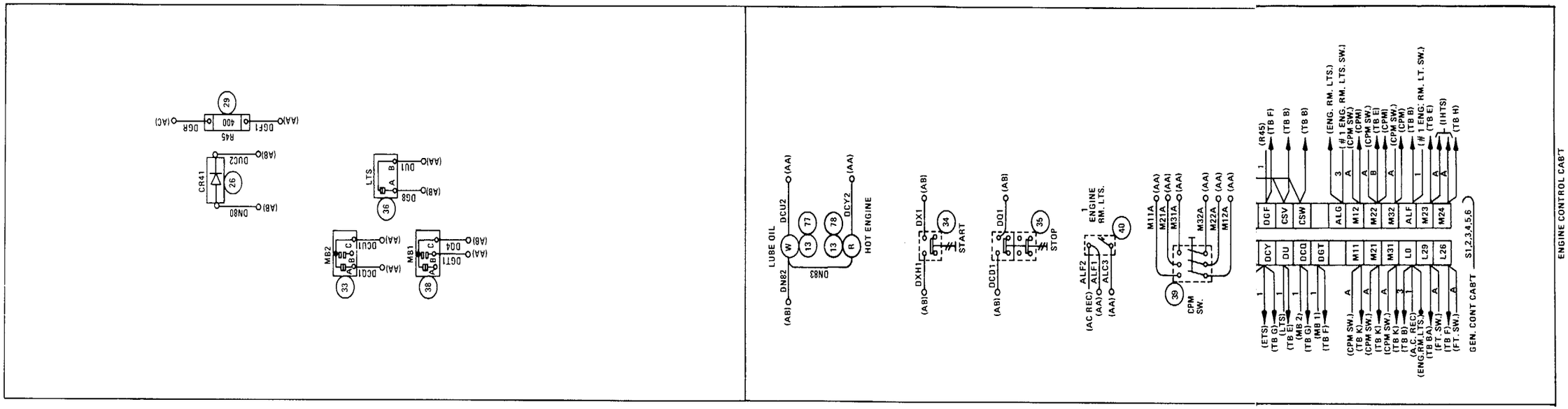
SYMBOL	SIZE	DRAWING NO.
I	19/.0179	8126650
III	91/24	8126652
IV	125/24	8126653
V	37/.104	8266729
IX	325/24	8126654
X	19/.0147	8121798
XV	#14 AWG	8236533
C2	#16-2 COND	8077432
C6	#16-6 COND	8222693
14H	#14 AWG	8278231
T2	#16-2 COND	8337786

GENERAL ARRANGEMENT
CONDUIT AND CABLE LAYOUT

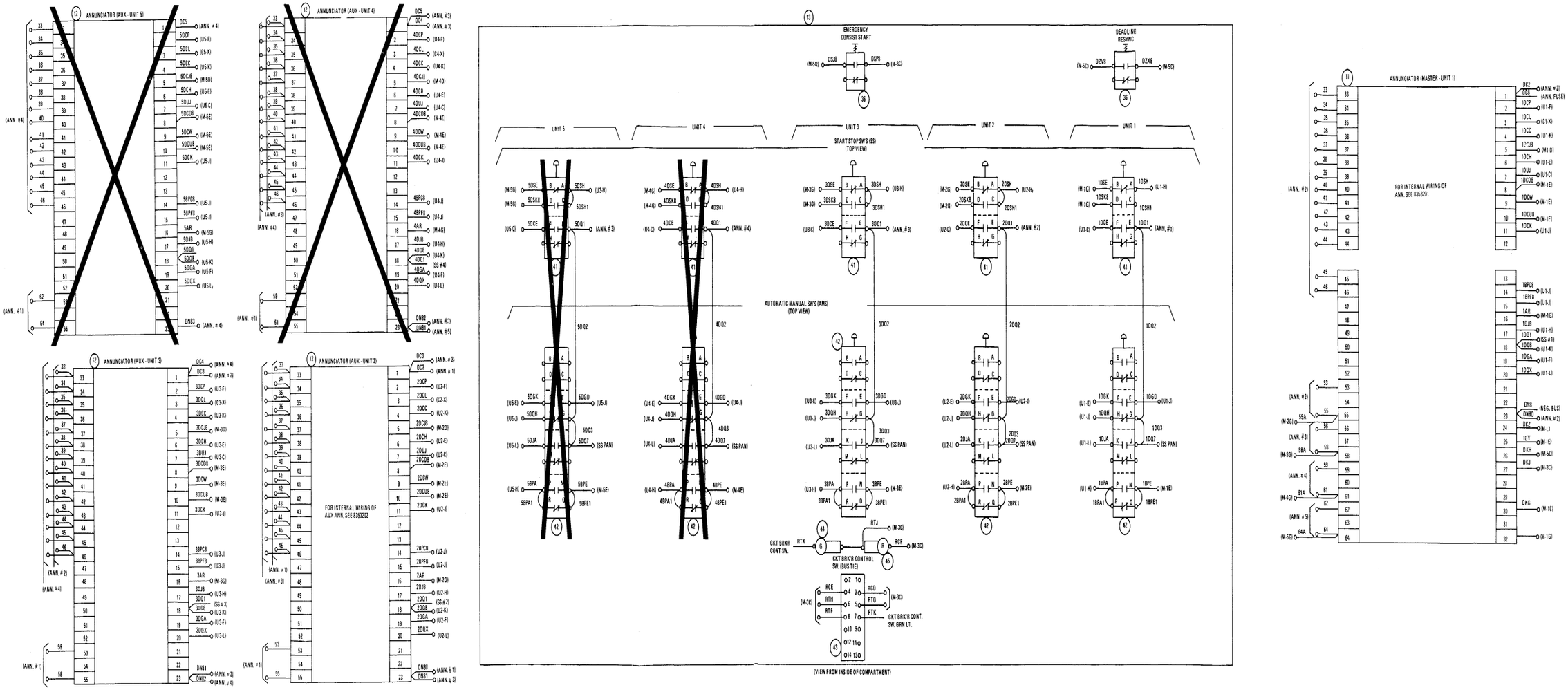
FO-45. MP36A Wiring Diagram (8378793) (Sheet 1 of 3)



FO-46. MP36A Wiring Diagram (8378793) (Sheet 2 of 3)

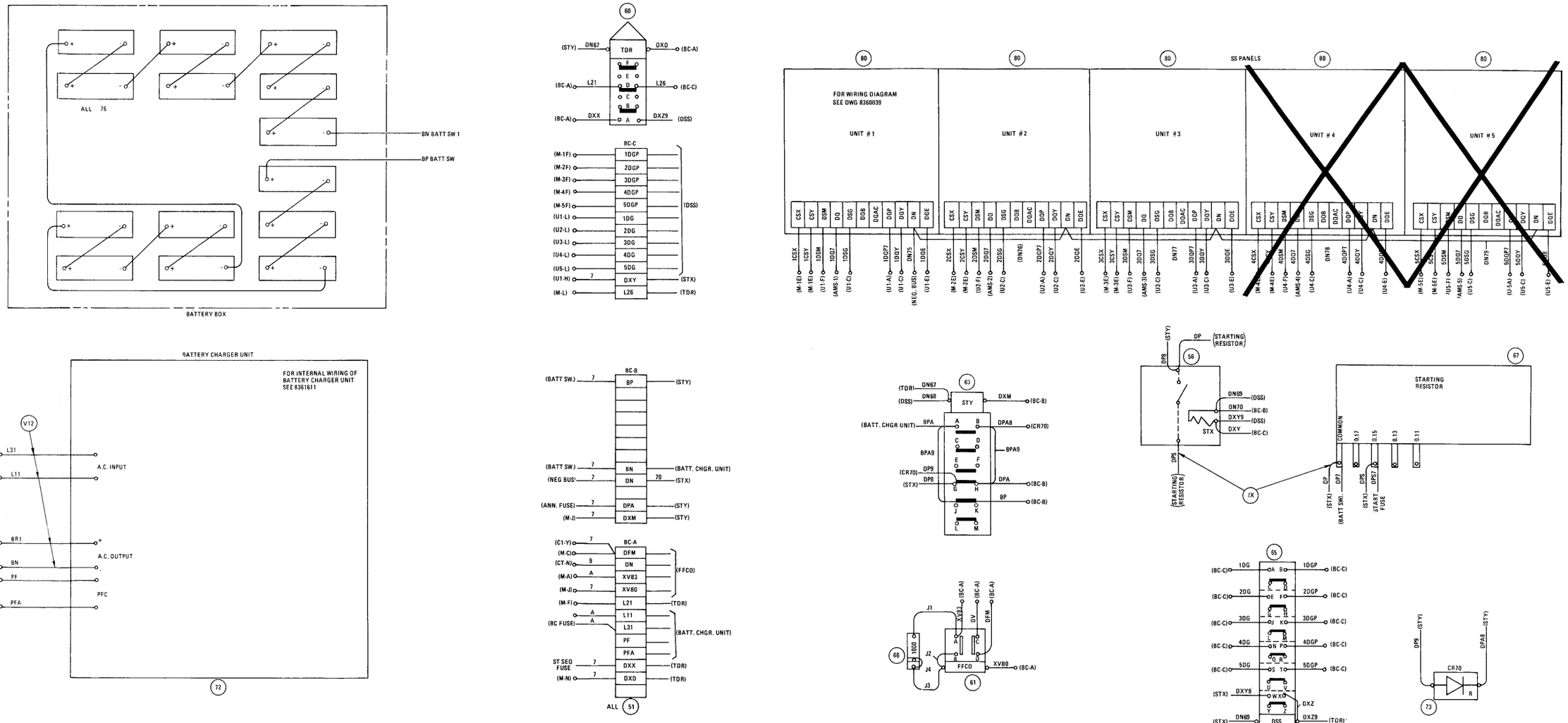


FO-47. MP36A Wiring Diagram (8378793) (Sheet 3 of 3)



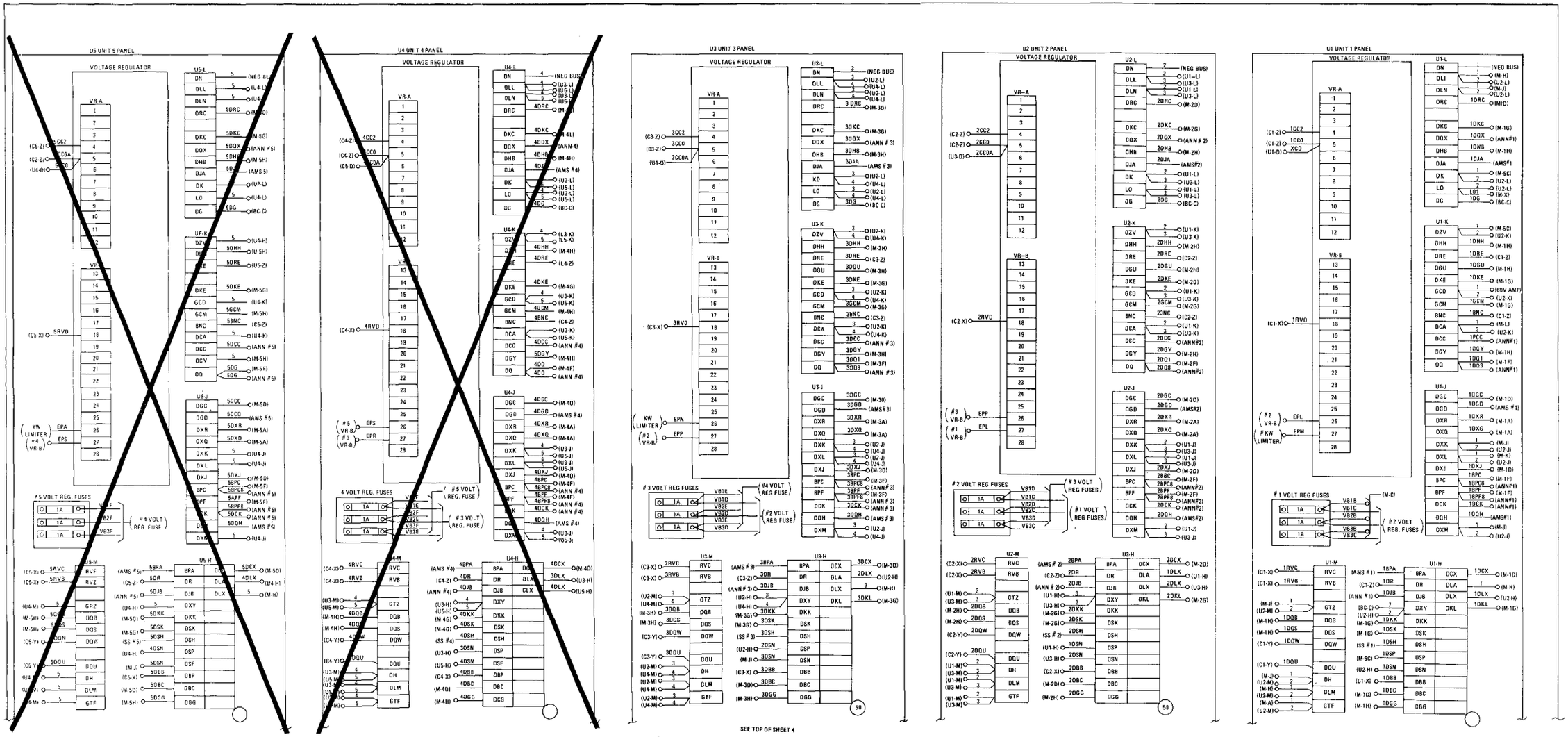
FO-48. MC-53 Interconnection Wiring Diagram (8378788) (Sheet 1 of 11)

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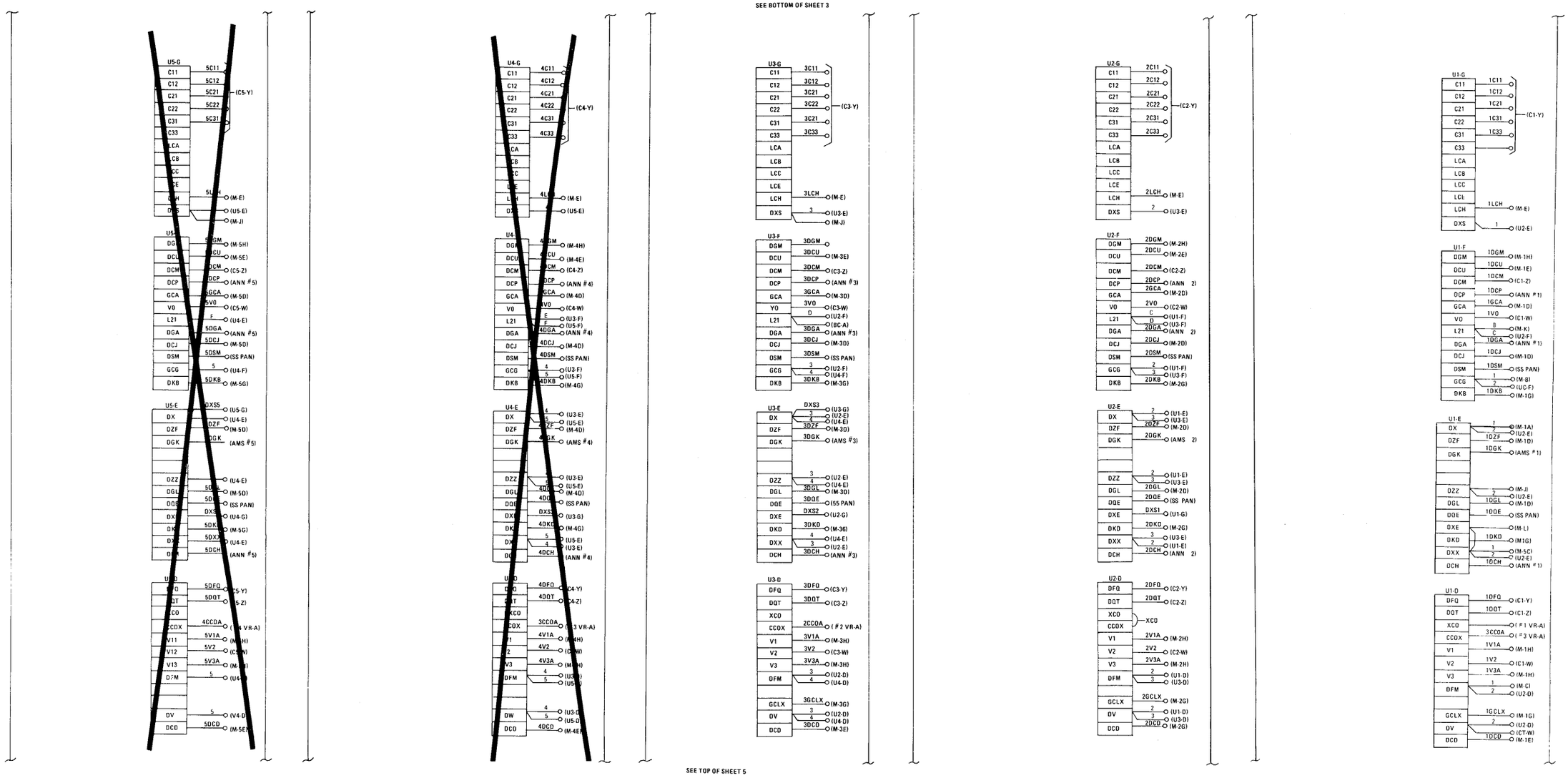
FO-49. MC-53 Interconnection Wiring Diagram (8378788) (Sheet 2 of 11)

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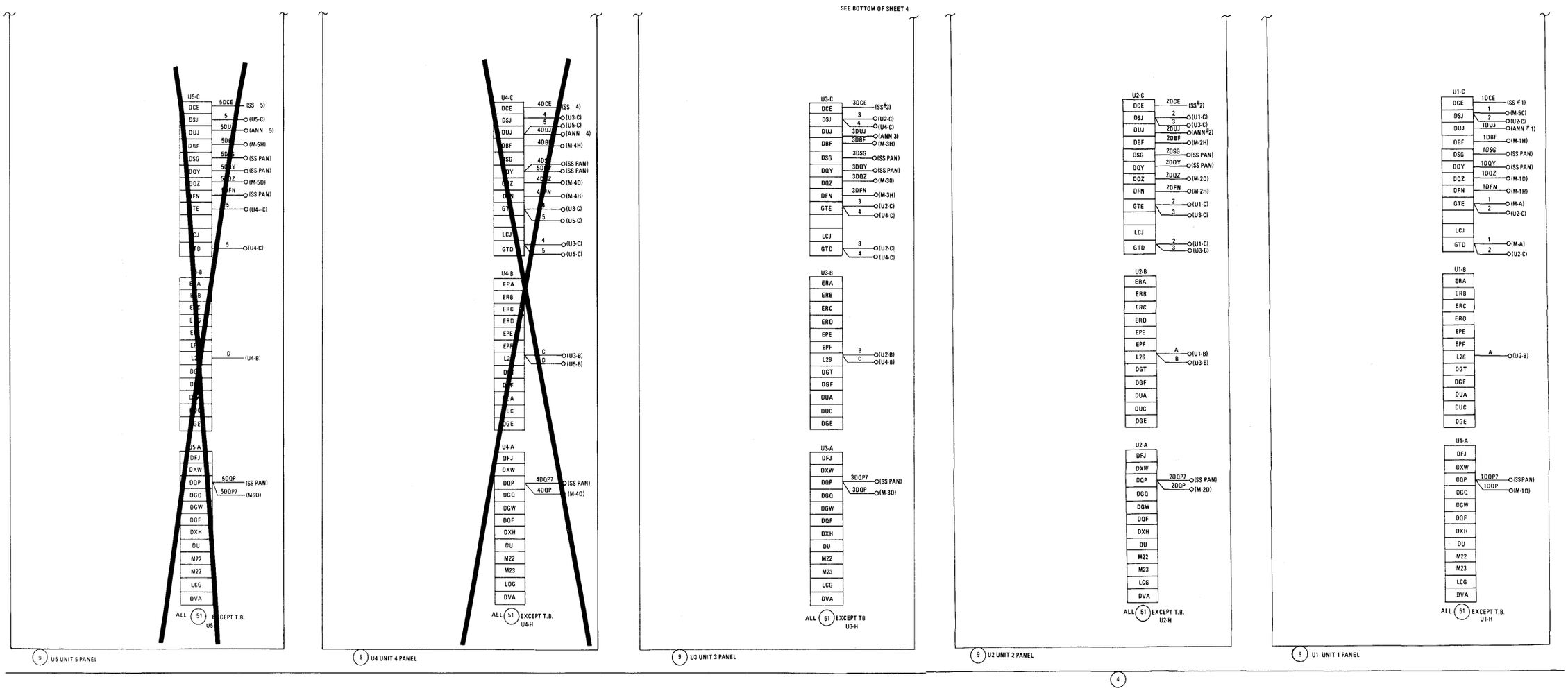
FO-50. MC-53 Interconnection Wiring Diagram (8378788) (Sheet 3 of 11)

101/(102 blank)



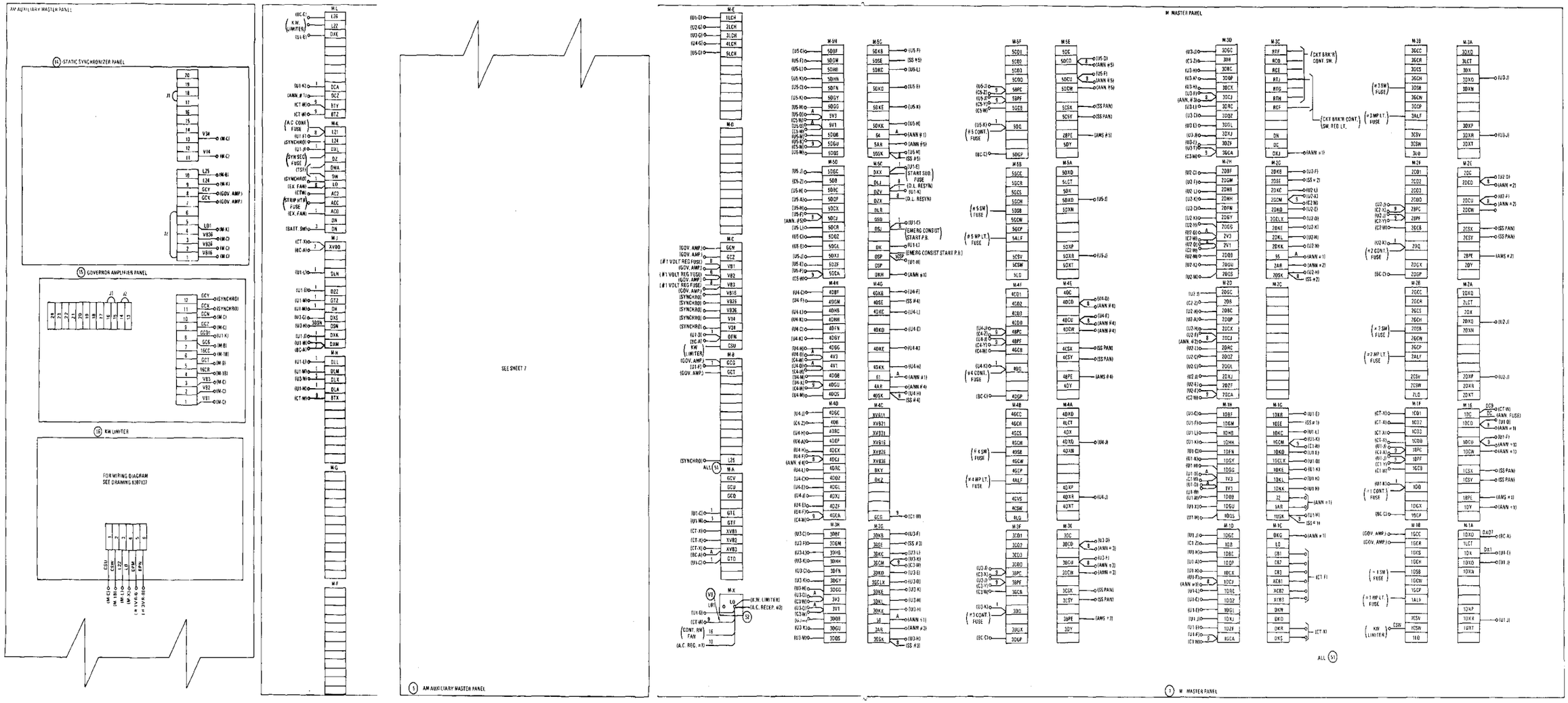
FO-51. MC-53 Interconnection Wiring Diagram (8378788) (Sheet 4 of 11)

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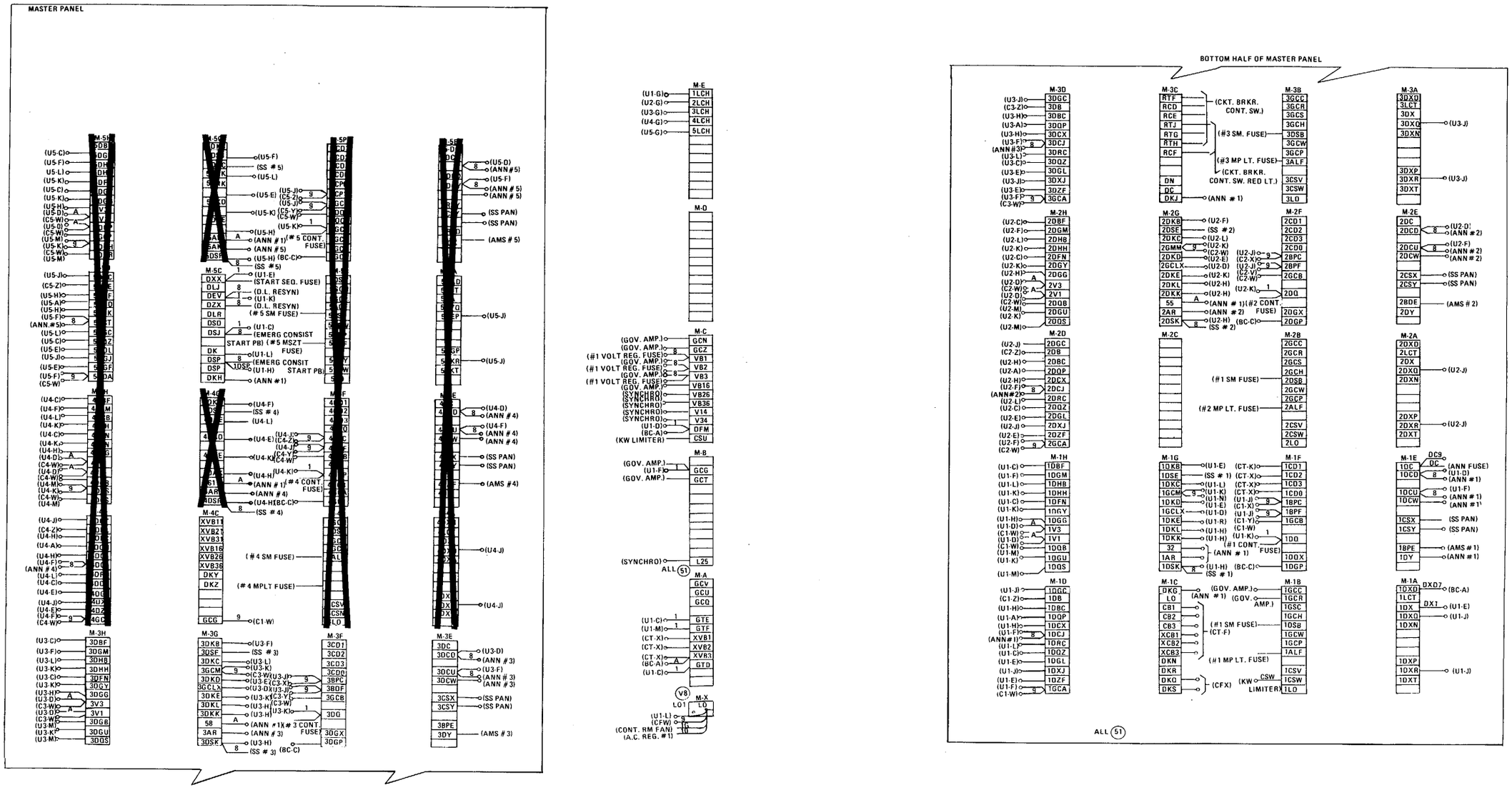
FO-52. MC-53 Interconnection Wiring Diagram (8378788) (Sheet 5 of 11)

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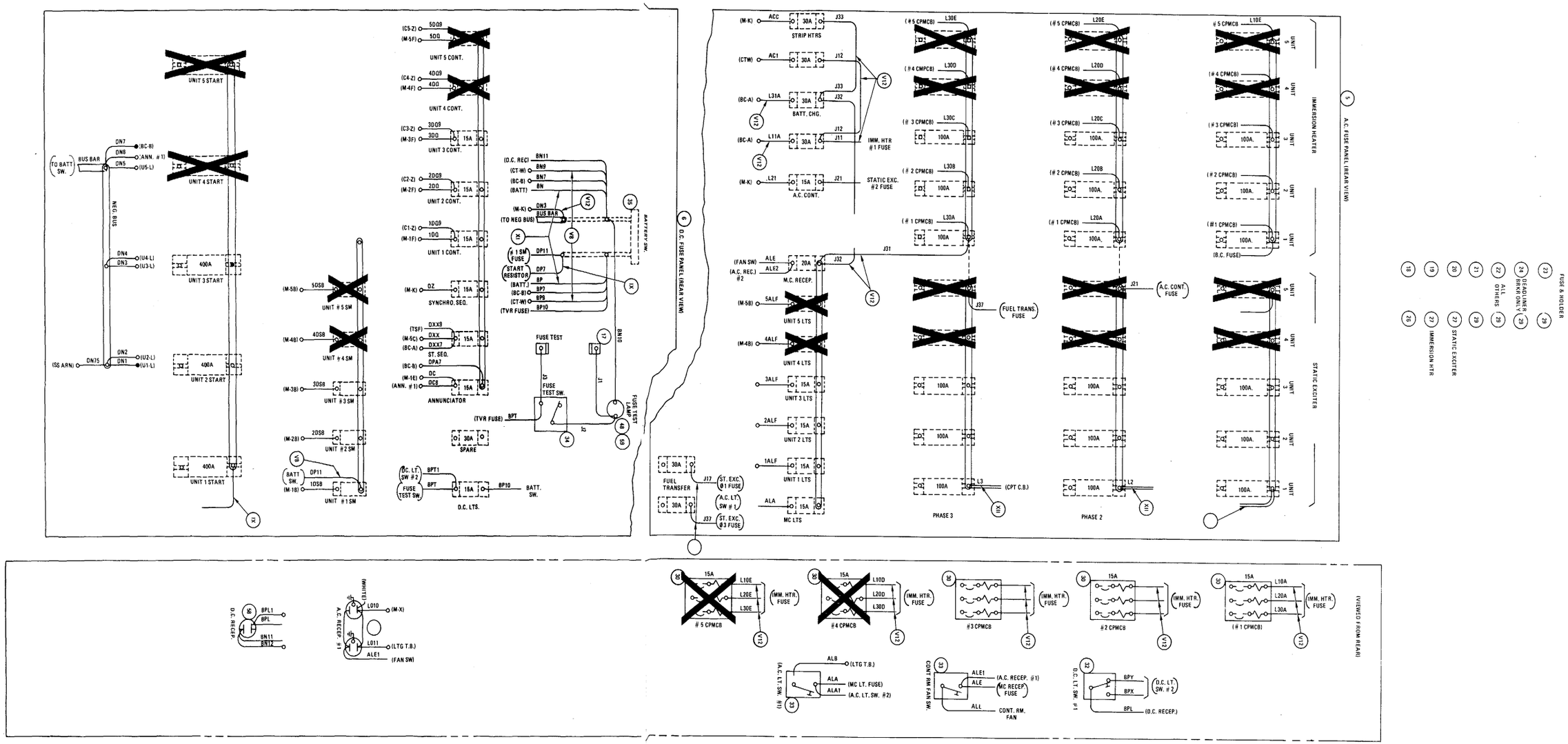


FO-53. MC-53 Interconnection Wiring Diagram (8378788) (Sheet 6 of 11)

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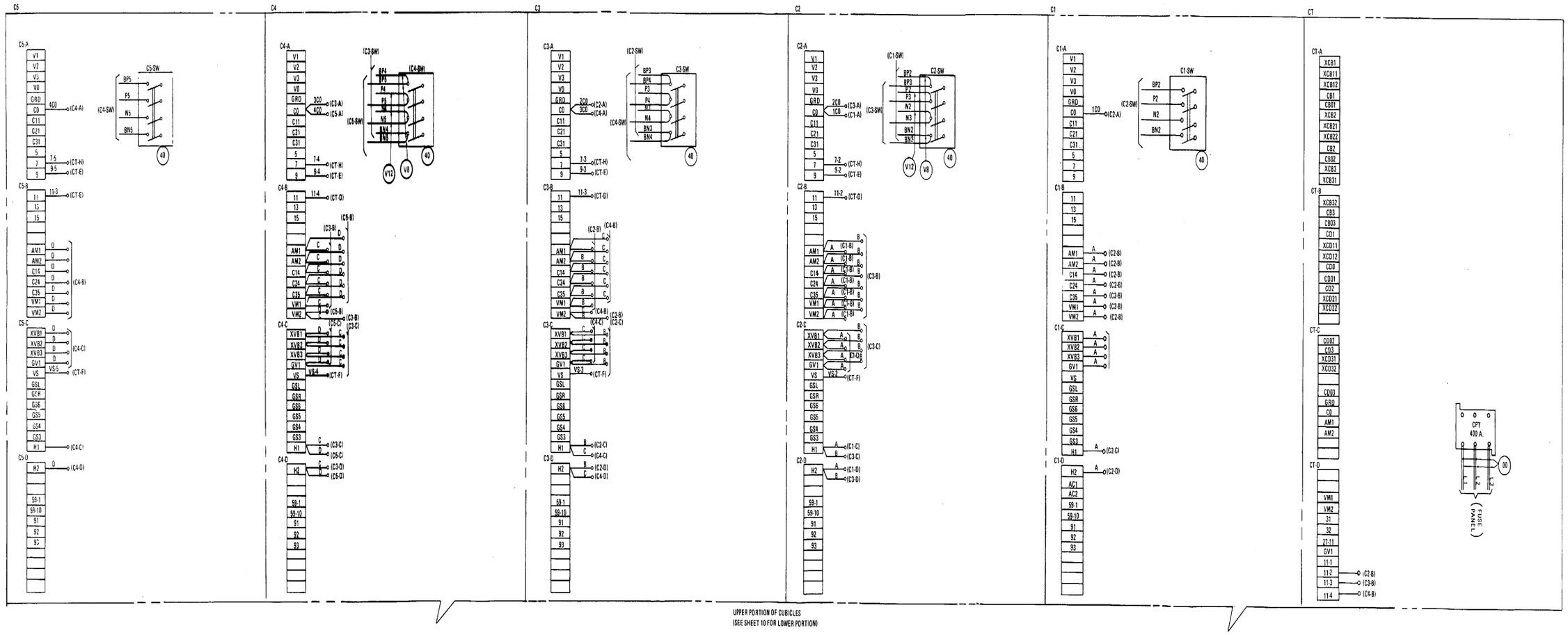


FO-54. MC-53 Interconnection Wiring Diagram (8378788) (Sheet 7 of 11)

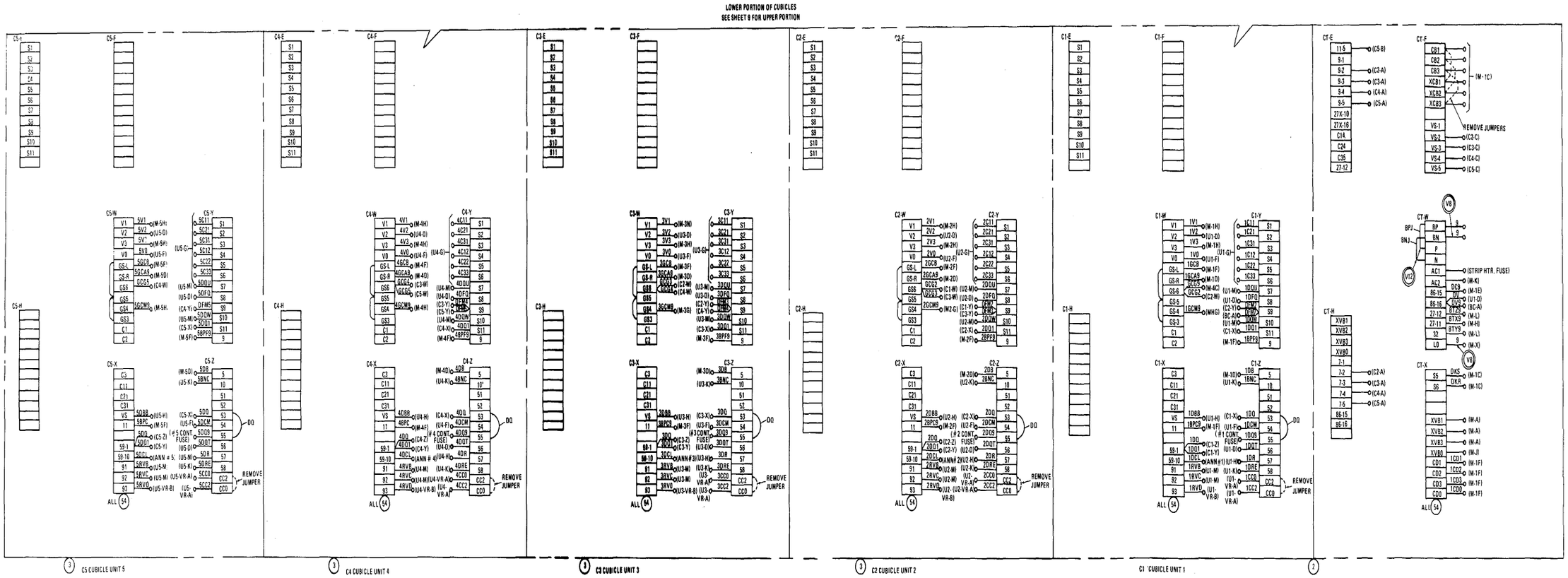


FO-55. MC-53 Interconnection Wiring Diagram (8378788) (Sheet 8 of 11)

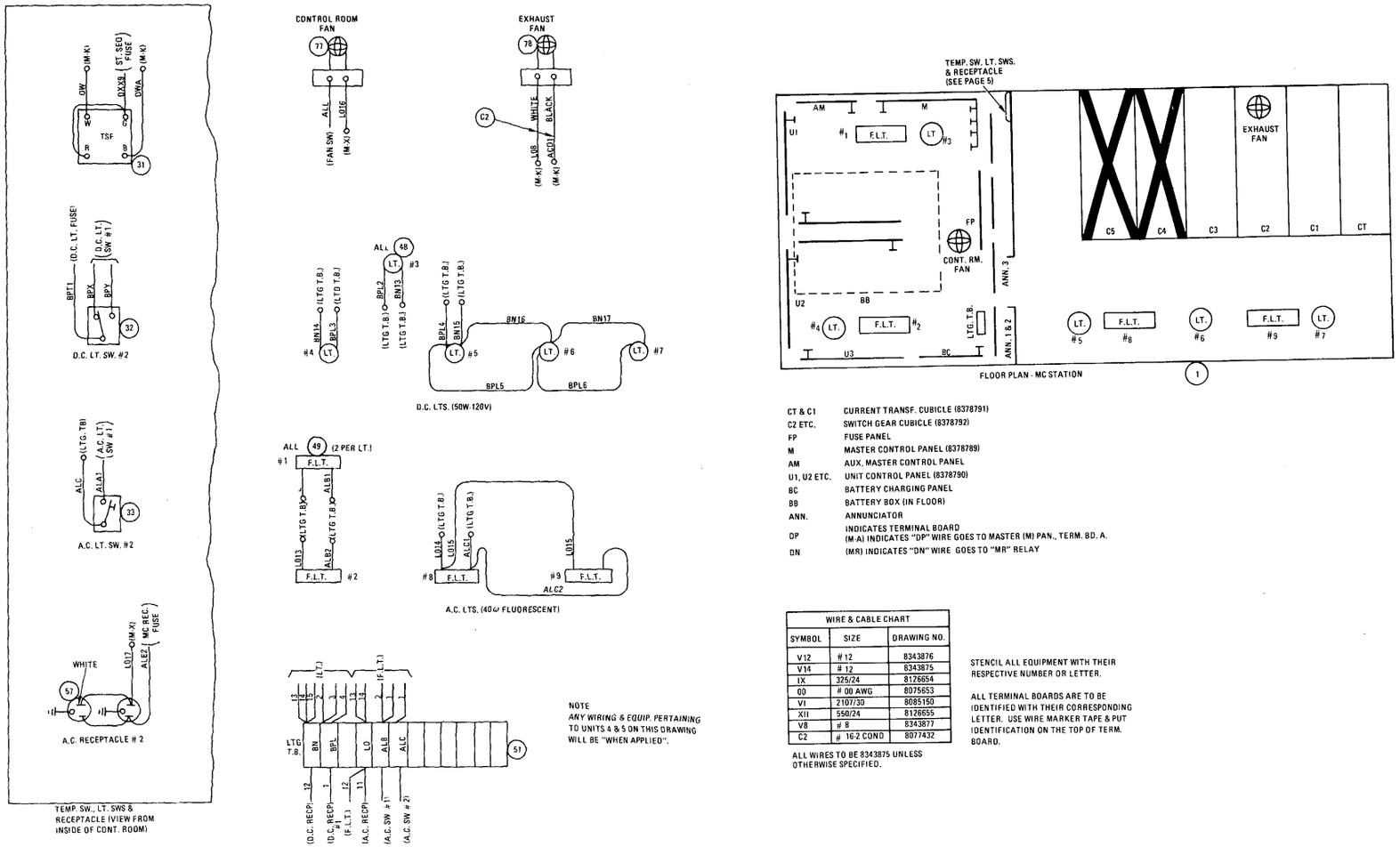
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FO-56. MC-53 Interconnection Wiring Diagram (8378788) (Sheet 9 of 11)



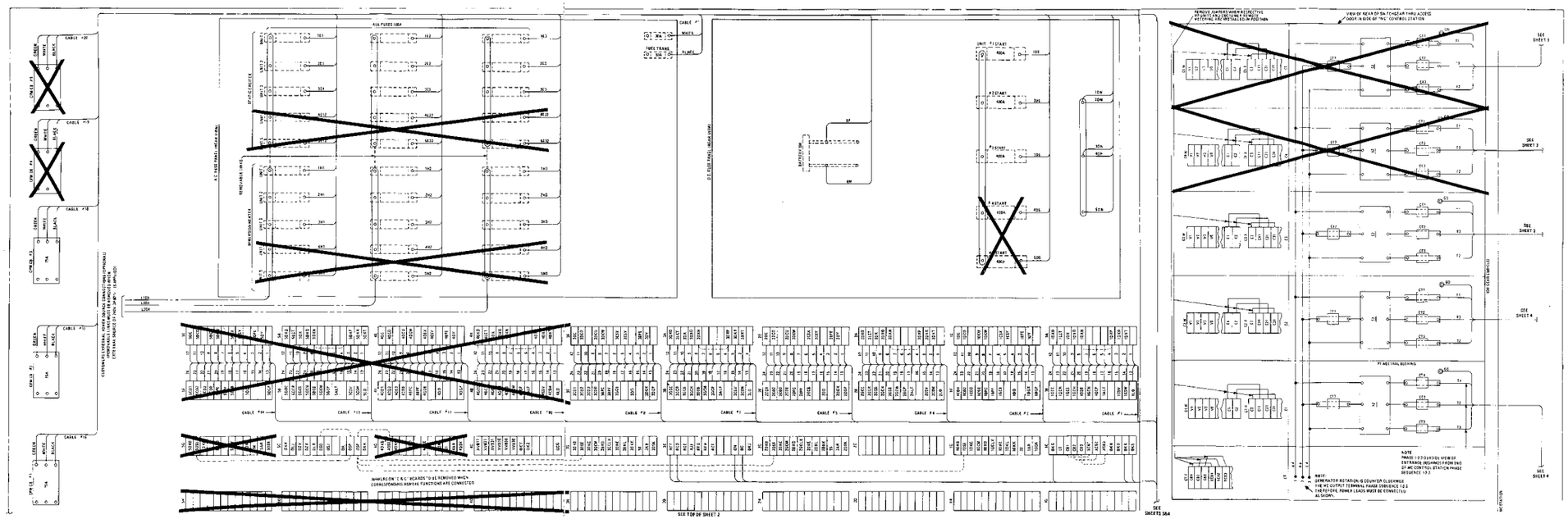
FO-57. MC-053 Interconnection Wiring Diagram (8378788) (Sheet 10 of 11)



QTY	MATERIAL	NAME OF PART	PART NO.	IT. NO.
1		MC STATION	8296526	1
1		SW. GEAR CUBICLE ASSEM	8296535	2
4		SW. GEAR CUBICLE ASSEM	8385949	3
1		CONTROL RACK ASSEM	8296962	4
1		PANEL-FUSE-A.C.	8296297	5
1		PANEL-FUSE-D.C.	8296503	6
1		PANEL-MASTER CONTROL	8295601	7
1		PANEL-AUX MASTER	8295555	8
5		PANEL-UNIT CONTROL	8294558	9
1		PANEL-BAT. CHARGING	8361674	10
1		PANEL-MASTER ANN	8353253	11
4		PANEL-AUX ANN	8353252	12
1		PANEL-SWITCH PANEL	8314715	13
1		PANEL-STATIC SYNCHRO	8306219	14
1		PANEL-GOV AMPLIFIER	8298233	15
		PANEL-KW LIMITER	8329920	16
2		FUSE TEST CONTACT	8112684	17
5	400A.	FUSE	8127052	18
15	100A.	FUSE	8004548	19
15	100A. DE	FUSE	8147631	20
11	30A.	FUSE	8004548	21
1	20A.	FUSE	8225155	22
16	15A.	FUSE	8004549	23
1	20A.	FUSE	8208719	24
				25
10	201-400A.	FUSE HOLDER	8280182	26
60	61-100A.	FUSE HOLDER	8004540	27
				28
56	0-30A.	FUSE HOLDER	8280184	29
5	15A. 3P	CIRCUIT BREAKER	8313421	30
1		SWITCH-TSF	8299575	31
2	SPDT	SWITCH-LTS (D.C.)	8130997	32
3	SP	SWITCH-FAN & LTS (A.C.)	8004701	33
1	SP	SWITCH-FUSE TEST	8172209	34
1	DPST	SWITCH-BATTERY	8313512	35
2	1 N.O.-1 N.C. RB	SWITCH-BLK	8230431	36
				37
				38
				39
5	ALLIS-CHALMERS	SWITCH		40

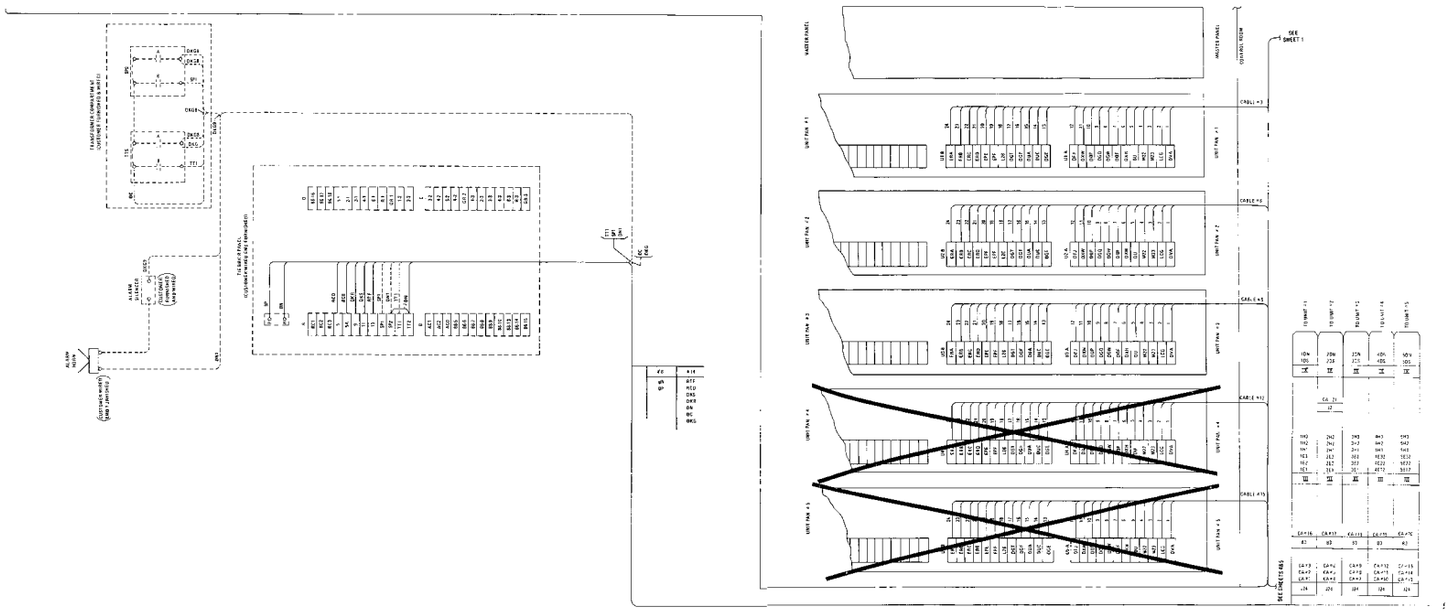
QTY	MATERIAL	NAME OF PART	PART NO.	IT. NO.
5	2 N.O.-2 N.C.	SWITCH-START-STOP	8309733	41
5	4 N.O.-4 N.C.	SWITCH-AUTO.-MAN.	8309734	42
1		SW. ROTARY CKT BRKR	8275688	43
1		LIGHT & RESISTOR (GREEN)	8371273	44
1		LIGHT & RESISTOR (RED)	8371272	45
				46
				47
6	50W-120V	LAMP-F.T. & D.C. LT.	8216636	48
8	40W (FLUORESCENT)	LAMP-A.C. LT.	8296975	49
5	24 PT.	TERMINAL BOARD	8292938	50
110	12 PT.	TERMINAL BOARD	8287076	51
1	2 PT.	TERMINAL BOARD	8277959	52
				53
64	ALLIS-CHALMERS	TERMINAL BOARD		54
				55
1		CONTACTOR-STX	8357711	56
2		RECEPTACLE-A.C.	8259362	57
1		RECEPTACLE-D.C.	8260287	58
1		RECEPT.-FUSE TEST LT.	8296298	59
1		RELAY-TDR	8253244	60
1		RELAY-FFCD	8282624	61
				62
1		RELAY-STY	8227936	63
				64
1		RELAY-OSS	8269705	65
1	1000	RESISTOR	8206938	66
1		RESISTOR	8356255	67
				68
				69
				70
				71
1		BATTERY CHARGER	8361611	72
1		RECTIFIER	8263244	73
				74
				75
14		STORAGE BATTERY	8297100	76
1		FAN-CONTROL	8297049	77
1		FAN-EXHAUST	8298241	78
				79
5		SPEED SENSING PAN.	8330163	80

FO-58. MC-53 Interconnection Wiring Diagram (8378788) (Sheet 11 of 11)



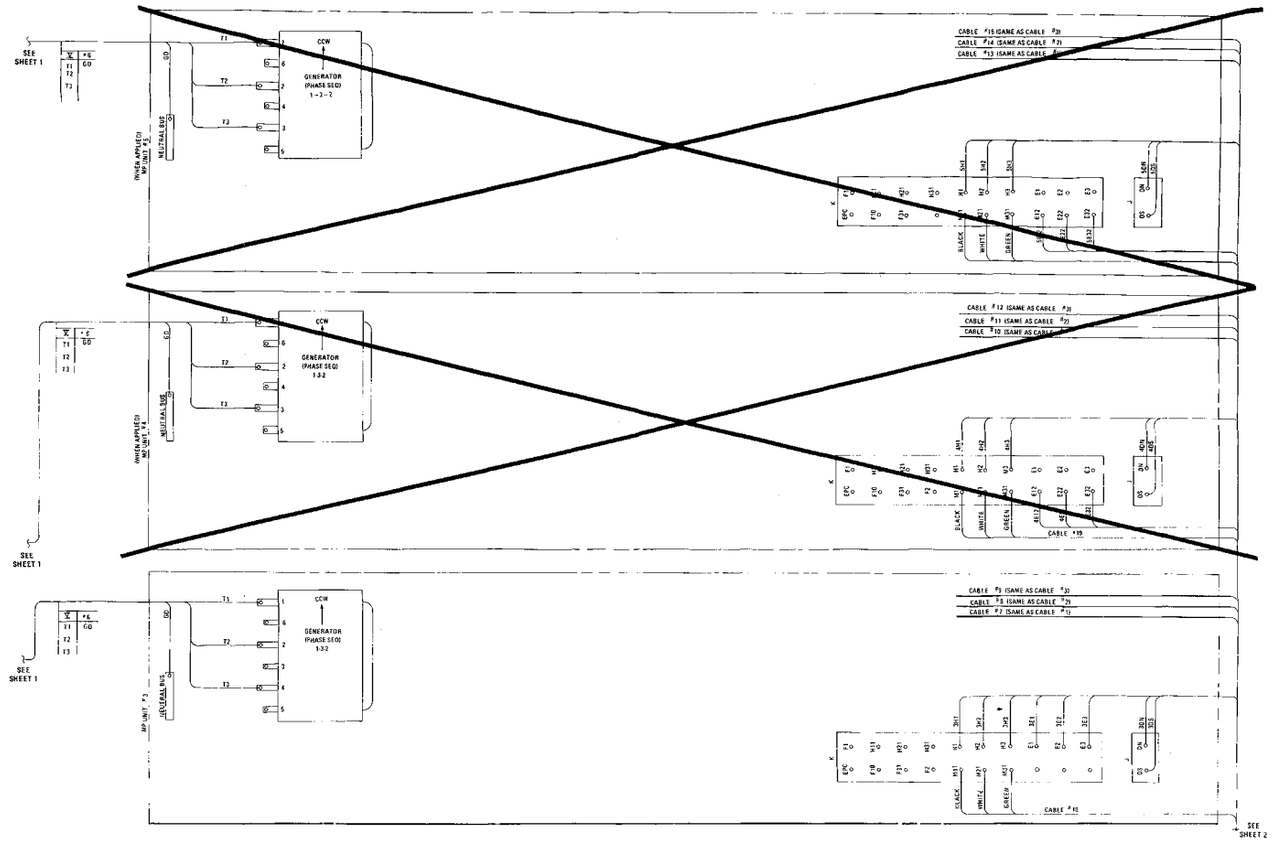
FO- 59. Field Connection Wiring Diagram (8378787) (Sheet 1 of 5)

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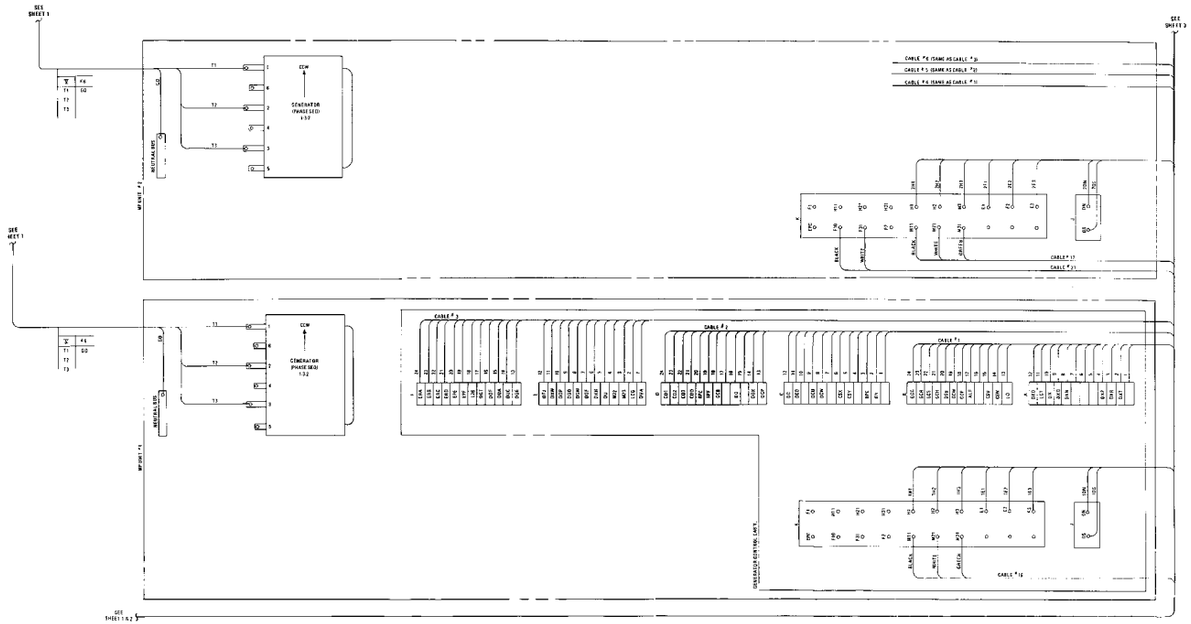


FO- 59. Field Connection Wiring Diagram (8378787) (Sheet 2 of 5)

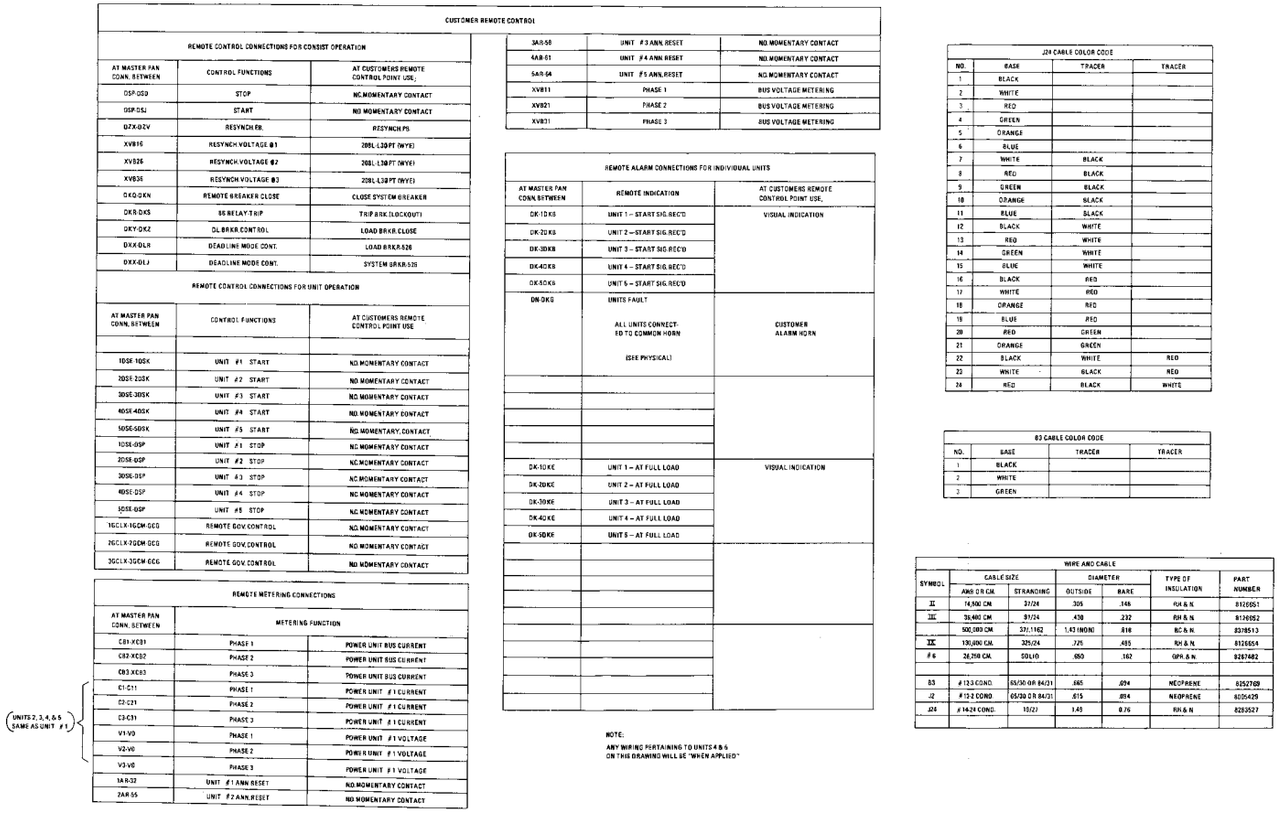
121/(122 blank)



FO-60. Field Connection Wiring Diagram (8378787) (Sheet 3 of 5)



FO-61. Field Connection Wiring Diagram (8378787) (Sheet 4 of 5)



CUSTOMER REMOTE CONTROL

REMOTE CONTROL CONNECTIONS FOR CONSIST OPERATION

AT MASTER PAN CONN. BETWEEN	CONTROL FUNCTIONS	AT CUSTOMERS REMOTE CONTROL POINT USE.
0SP-0SD	STOP	NC MOMENTARY CONTACT
0SP-0SJ	START	NO MOMENTARY CONTACT
0ZX-0ZV	RESYNCH EB	RESYNCH PS
XVB16	RESYNCH VOLTAGE @1	208L-L3 0PT (WYE)
XVB26	RESYNCH VOLTAGE @2	208L-L3 0PT (WYE)
XVB36	RESYNCH VOLTAGE @3	208L-L3 0PT (WYE)
0XQ-0KN	REMOTE BREAKER CLOSE	CLOSE SYSTEM BREAKER
0XR-0XS	SS RELAY TRIP	TRIP BRK (LOCKOUT)
0XY-0XZ	DL BRKR CONTROL	LOAD BRKR CLOSE
0XX-0LR	DEADLINE MODE CONT.	LOAD BRKR 52B
0XX-0LJ	DEADLINE MODE CONT.	SYSTEM BRKR 52B

REMOTE CONTROL CONNECTIONS FOR UNIT OPERATION

AT MASTER PAN CONN. BETWEEN	CONTROL FUNCTIONS	AT CUSTOMERS REMOTE CONTROL POINT USE
1DSK-1DSK	UNIT #1 START	NO MOMENTARY CONTACT
2DSK-2DSK	UNIT #2 START	NO MOMENTARY CONTACT
3DSK-3DSK	UNIT #3 START	NO MOMENTARY CONTACT
4DSK-4DSK	UNIT #4 START	NO MOMENTARY CONTACT
5DSK-5DSK	UNIT #5 START	NO MOMENTARY CONTACT
1DSK-0SP	UNIT #1 STOP	NC MOMENTARY CONTACT
2DSK-0SP	UNIT #2 STOP	NC MOMENTARY CONTACT
3DSK-0SP	UNIT #3 STOP	NC MOMENTARY CONTACT
4DSK-0SP	UNIT #4 STOP	NC MOMENTARY CONTACT
5DSK-0SP	UNIT #5 STOP	NC MOMENTARY CONTACT
1GCLX-1GCM-GCG	REMOTE GOV CONTROL	NO MOMENTARY CONTACT
2GCLX-2GCM-GCG	REMOTE GOV CONTROL	NO MOMENTARY CONTACT
3GCLX-3GCM-GCG	REMOTE GOV CONTROL	NO MOMENTARY CONTACT

REMOTE METERING CONNECTIONS

AT MASTER PAN CONN. BETWEEN	METERING FUNCTION	
C01-XC01	PHASE 1	POWER UNIT BUS CURRENT
C02-XC02	PHASE 2	POWER UNIT BUS CURRENT
C03-XC03	PHASE 3	POWER UNIT BUS CURRENT
C1-C11	PHASE 1	POWER UNIT #1 CURRENT
C2-C21	PHASE 2	POWER UNIT #1 CURRENT
C3-C31	PHASE 3	POWER UNIT #1 CURRENT
V1-V0	PHASE 1	POWER UNIT #1 VOLTAGE
V2-V0	PHASE 2	POWER UNIT #1 VOLTAGE
V3-V0	PHASE 3	POWER UNIT #1 VOLTAGE
1AR-32	UNIT #1 ANN RESET	NO MOMENTARY CONTACT
2AR-55	UNIT #2 ANN RESET	NO MOMENTARY CONTACT
3AR-58	UNIT #3 ANN RESET	NO MOMENTARY CONTACT
4AR-61	UNIT #4 ANN RESET	NO MOMENTARY CONTACT
5AR-64	UNIT #5 ANN RESET	NO MOMENTARY CONTACT
XVB11	PHASE 1	BUS VOLTAGE METERING
XVB21	PHASE 2	BUS VOLTAGE METERING
XVB31	PHASE 3	BUS VOLTAGE METERING

UNITS 2, 3, 4, & 5 SAME AS UNIT #1

REMOTE ALARM CONNECTIONS FOR INDIVIDUAL UNITS

AT MASTER PAN CONN. BETWEEN	REMOTE INDICATION	AT CUSTOMERS REMOTE CONTROL POINT USE.
DK-1DKS	UNIT 1 – START SIG. REC'D	VISUAL INDICATION
DK-2DKS	UNIT 2 – START SIG. REC'D	
DK-3DKS	UNIT 3 – START SIG. REC'D	
DK-4DKS	UNIT 4 – START SIG. REC'D	
DK-5DKS	UNIT 5 – START SIG. REC'D	
DN-DKS	UNITS FAULT ALL UNITS CONNECTED TO COMMON HORN (SEE PHYSICAL)	CUSTOMER ALARM HORN
DK-1DKE	UNIT 1 – AT FULL LOAD	VISUAL INDICATION
DK-2DKE	UNIT 2 – AT FULL LOAD	
DK-3DKE	UNIT 3 – AT FULL LOAD	
DK-4DKE	UNIT 4 – AT FULL LOAD	
DK-5DKE	UNIT 5 – AT FULL LOAD	

NOTE:
ANY WIRING PERTAINING TO UNITS 4 & 5 ON THIS DRAWING WILL BE "WHEN APPLIED"

J24 CABLE COLOR CODE

NO.	BASE	TRACER	TRACER
1	BLACK		
2	WHITE		
3	RED		
4	GREEN		
5	ORANGE		
6	BLUE		
7	WHITE	BLACK	
8	RED	BLACK	
9	GREEN	BLACK	
10	ORANGE	BLACK	
11	BLUE	BLACK	
12	BLACK	WHITE	
13	RED	WHITE	
14	GREEN	WHITE	
15	BLUE	WHITE	
16	BLACK	RED	
17	WHITE	RED	
18	ORANGE	RED	
19	BLUE	RED	
20	RED	GREEN	
21	ORANGE	GREEN	
22	BLACK	WHITE	RED
23	WHITE	BLACK	RED
24	RED	BLACK	WHITE

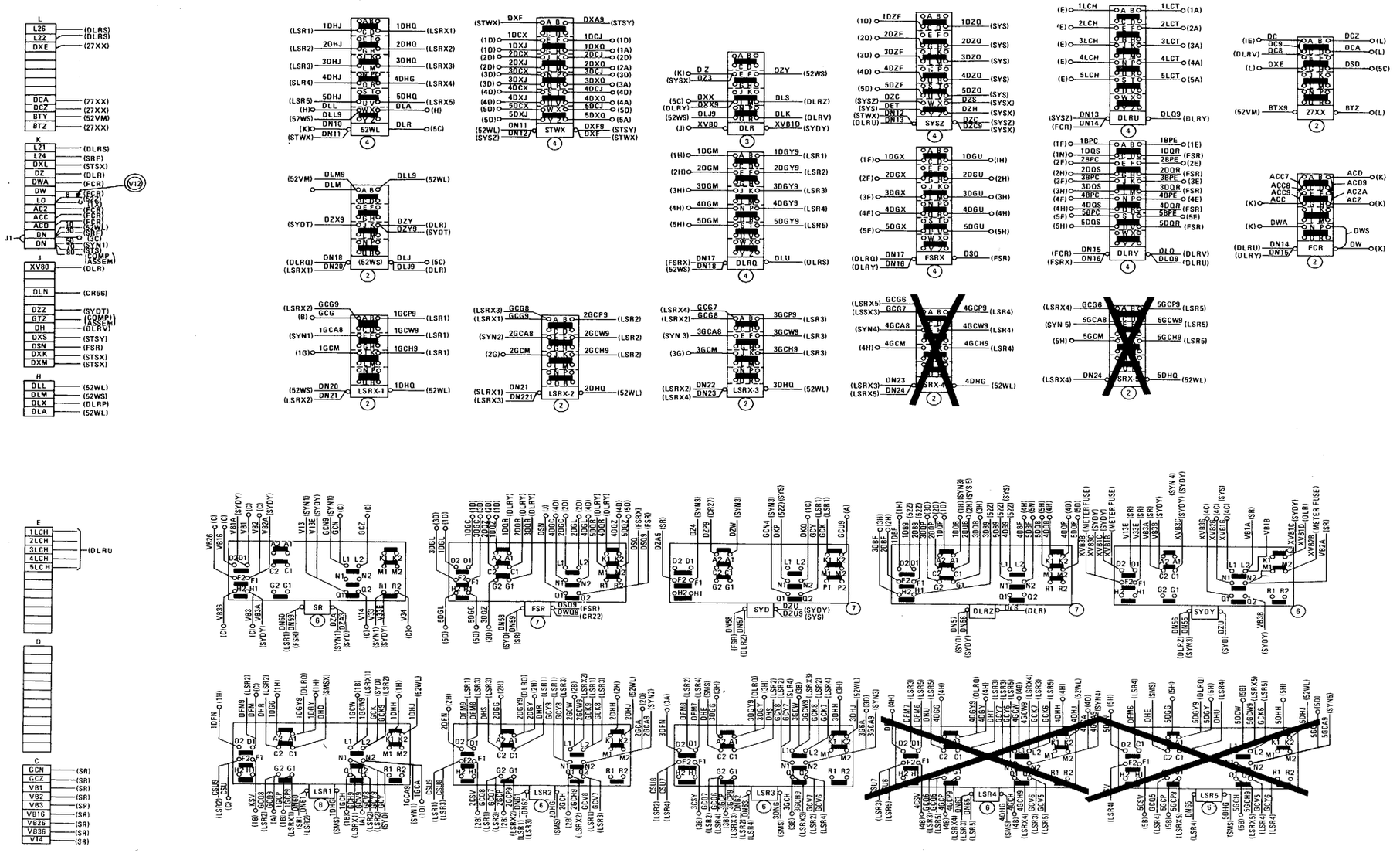
83 CABLE COLOR CODE

NO.	BASE	TRACER	TRACER
1	BLACK		
2	WHITE		
3	GREEN		

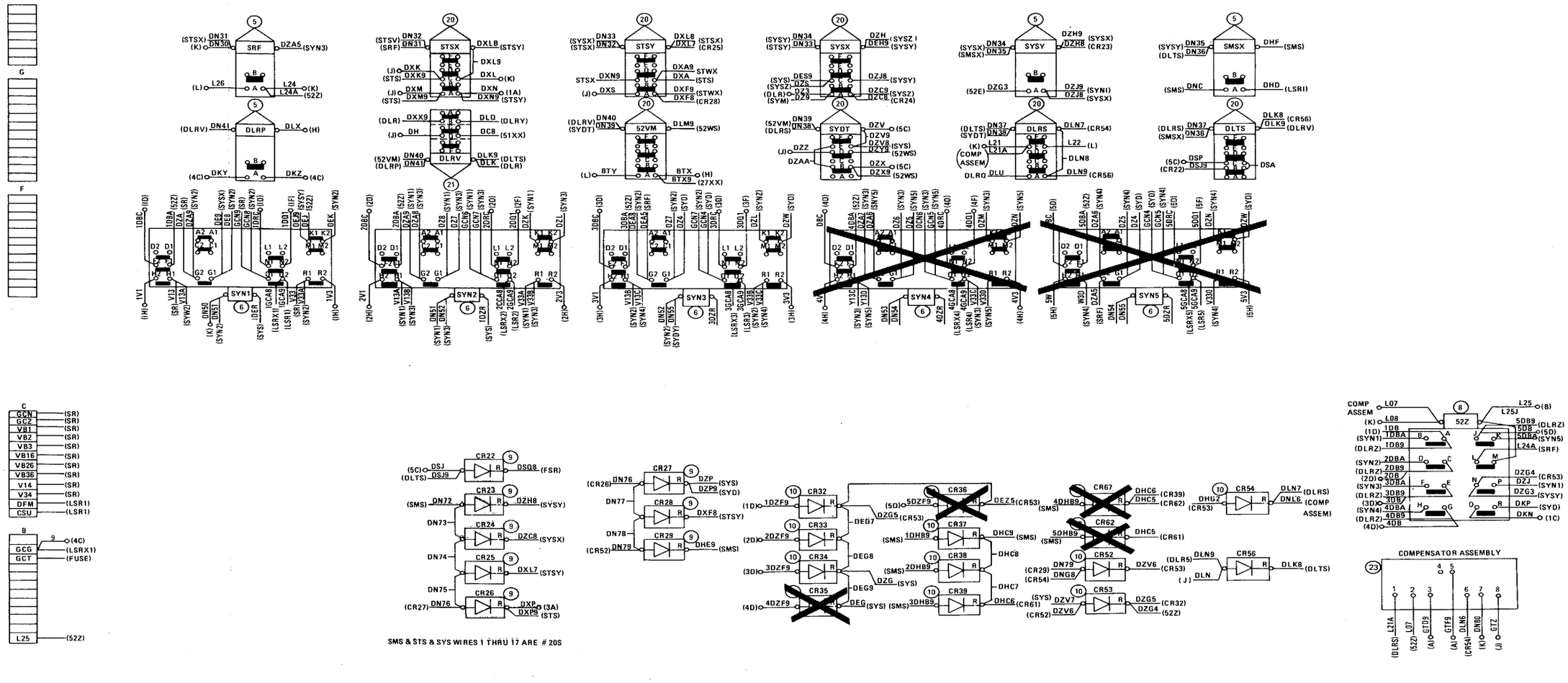
WIRE AND CABLE

SYMBOL	CABLE SIZE		DIAMETER		TYPE OF INSULATION	PART NUMBER
	AWG OR CM.	STRANDING	OUTSIDE	BARE		
II	14,500 CM	37/24	.305	.146	RH & N.	8126051
III	26,400 CM	91/24	.430	.232	RH & N.	8126052
	500,000 CM	37/1162	1.43 (NOM)	.810	RC & N.	8378513
IX	130,600 CM.	325/24	.725	.485	RH & N.	8126054
# 6	26,250 CM.	SOLID	.650	.162	GPR & N.	9267482
B3	# 13-3 COND.	65/30 OR 84/31	.565	.094	NEOPRENE	8257709
J2	# 13-2 COND.	65/30 OR 84/31	.615	.094	NEOPRENE	8259429
J24	# 14-24 COND.	10/27	1.45	0.76	RH & N.	8283527

FO-62. Field Connection Wiring Diagram (8378787) (Sheet 5 of 5)

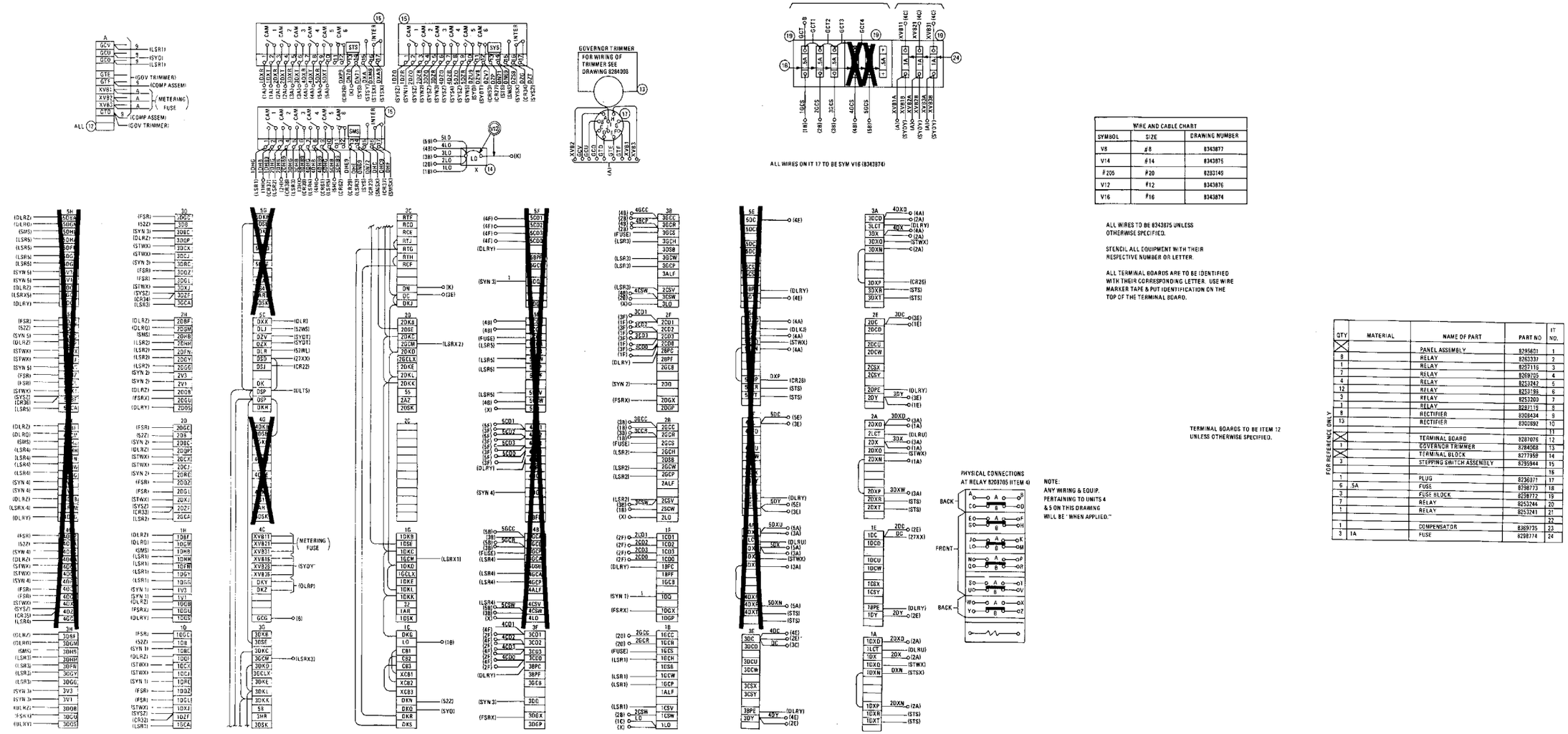


FO-64. Master Control Panel Wiring Diagram (8378789) Sheet 1 of 3)



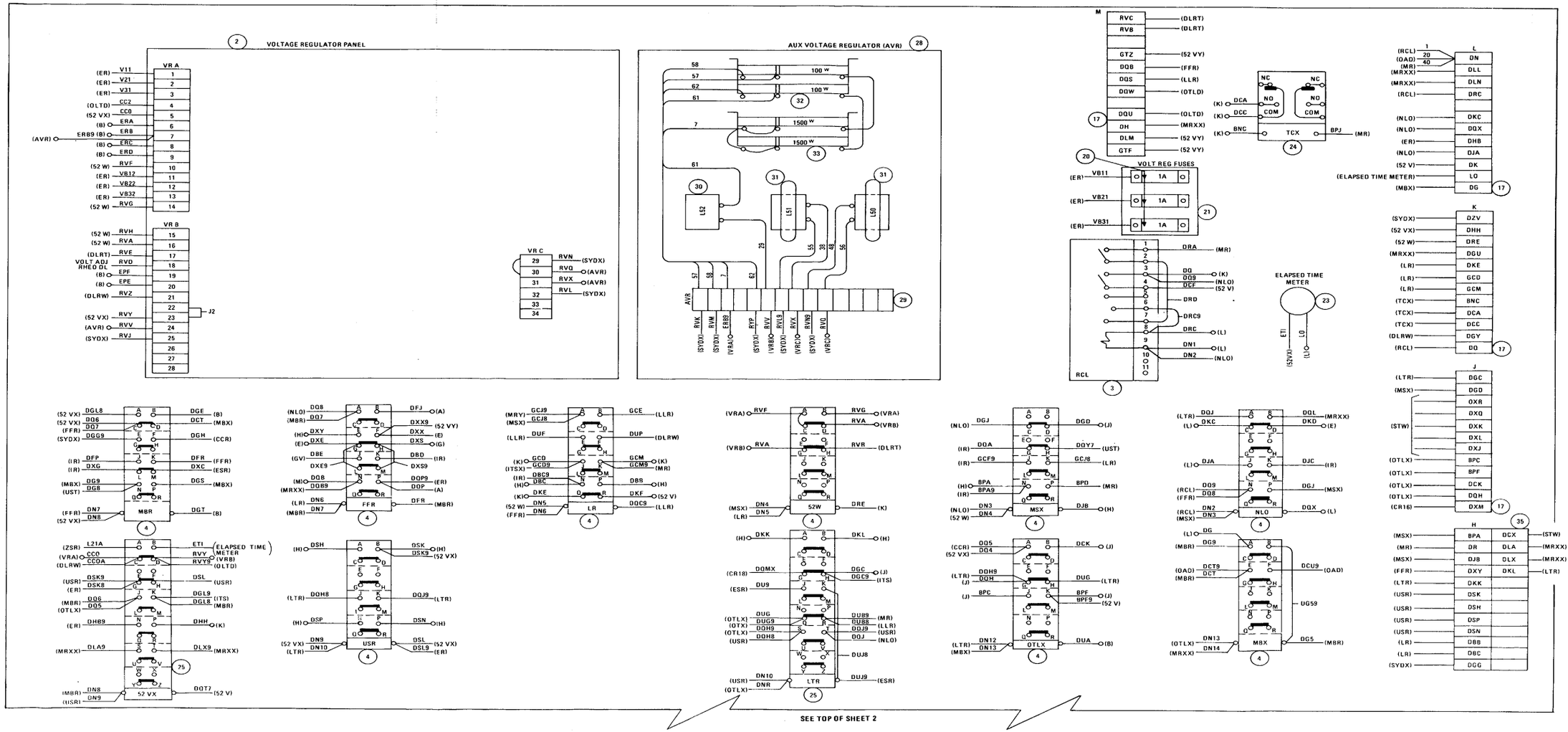
FO-65. Master Control Panel Wiring Diagram (8378789) (Sheet 2 of 3)

131/(132 blank)



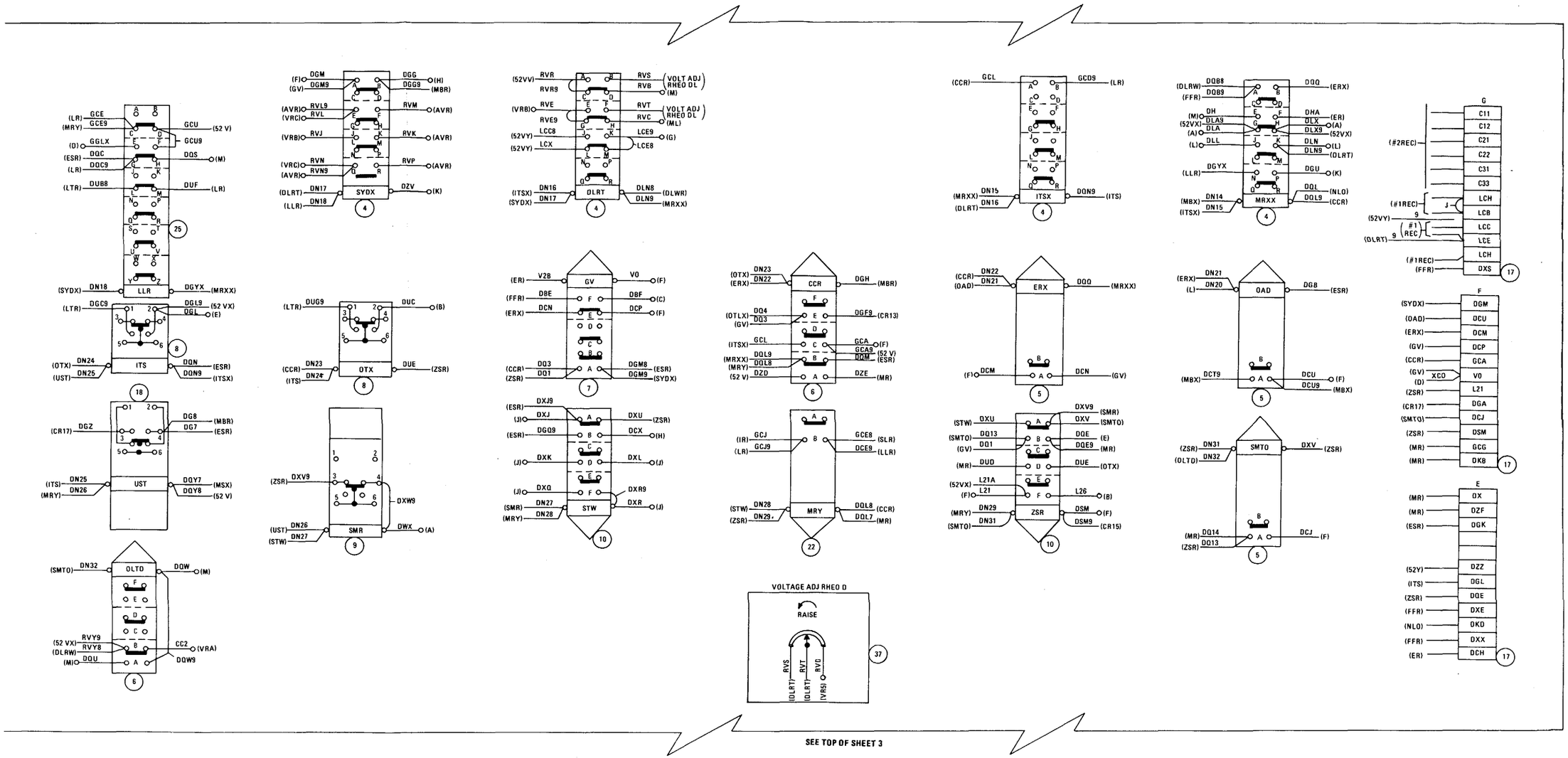
FO-66. Master Control Panel Wiring Diagram (8378789) (Sheet 3 of 3)

133/ (134 blank)



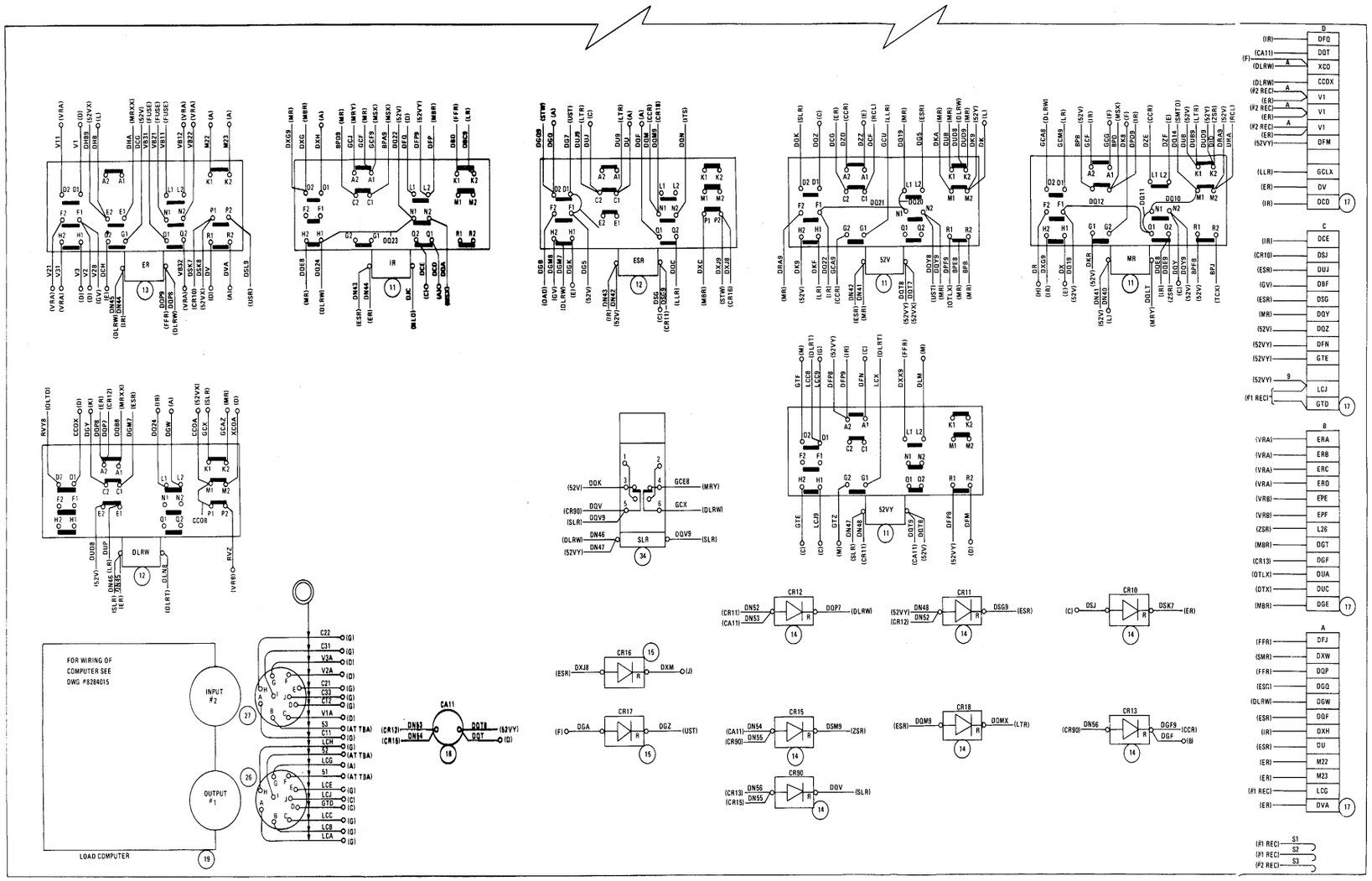
FO-67. Unit Control Panel Wiring Diagram (8378790) (Sheet 1 of 3)

135/ (136 blank)



FO-68. Unit Control Panel Wiring Diagram (837890) (Sheet 2 of 3)

137/ (138 blank)



WIRE & CABLE CHART		
SYMBOL	SIZE	DRAWING NO.
V14	#14	8343875
V16	#16	8343874

ALL WIRES TO BE 8343875 (#14 AWG) UNLESS OTHERWISE SPECIFIED.

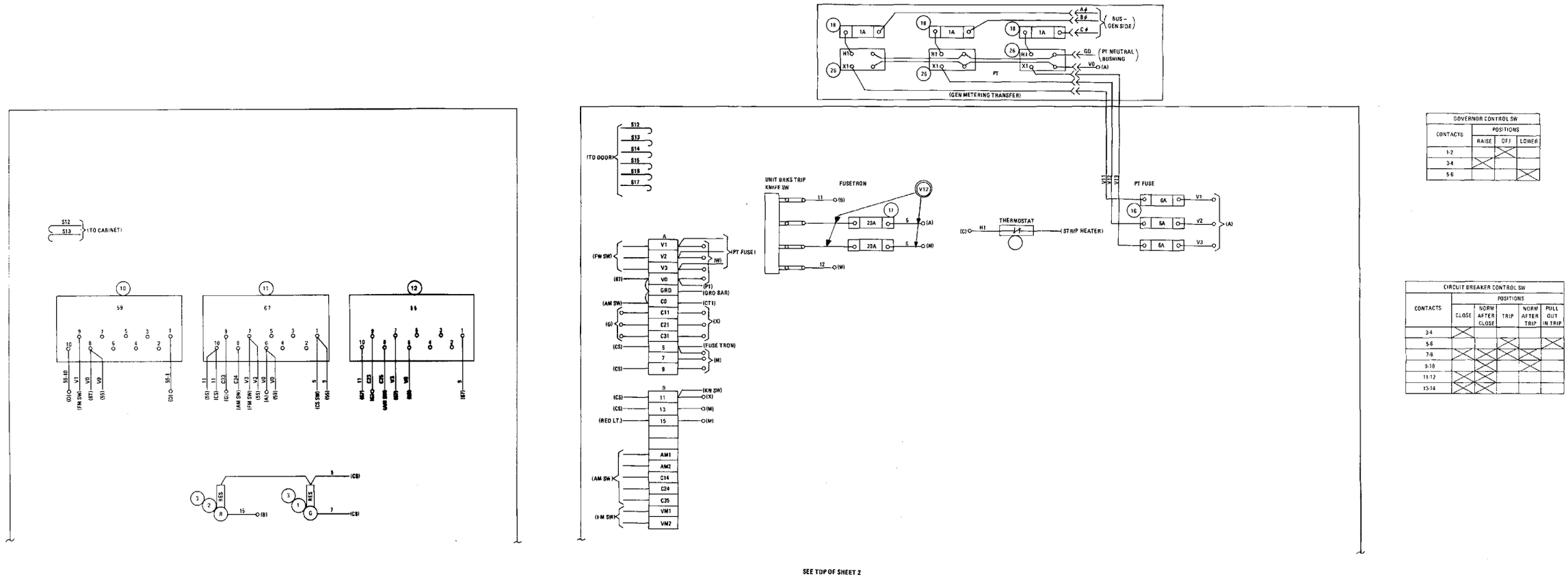
STENCIL ALL EQUIPMENT WITH THEIR RESPECTIVE NUMBER OR LETTER.

ALL TERMINAL BOARDS ARE TO BE IDENTIFIED WITH THEIR CORRESPONDING LETTER.USE WIRE MARKER TAPE & PUT IDENTIFICATION ON THE TOP OF THE TERMINAL BOARD.

FOR REFERENCE ONLY

QTY	MATERIAL	NAME OF PART	PART NO.	IT NO.
X		PANEL ASSEMBLY	8294559	1
1		REGULATOR PANEL	8323479	2
1		STEPPING SWITCH	8253514	3
13	4 NO - 4 NC	RELAY	8263337	4
3	T.D. PICK-UP	RELAY	8252242	5
2	T.D. PICK-UP	RELAY	8252244	6
1	T.D. PICK-UP	RELAY	8262425	7
2		RELAY	8287485	8
1		RELAY	8267532	9
2	T.D. DROP-OUT	RELAY	8252241	10
4	8 NO - 4 NC	RELAY	8253198	11
2	6 NO - 6 NC	RELAY	8252200	12
1	10 NO - 2 NC	RELAY	8285061	13
		RECTIFIER	8308434	14
2		RECTIFIER	8300692	15
1		CAPACITOR	8126822	16
X		TERMINAL BOARD	8287076	17
1		RELAY	8279762	18
1		LOAD COMPUTER	8284015	19
3	1A	FUSE	8298774	20
1		FUSE BLOCK	8298772	21
1	T.D. DROP-OUT	RELAY	8252245	22
1		METER-ELAPSED TIME	8303104	23
1	4 NO - 4 NC	RELAY	8317487	24
3	6 NO - 6 NC	RELAY	8263705	25
1		PLUG	8276672	26
1		PLUG	8276671	27
X		AUX. REG PANEL	8290243	28
1	14 PT.	TERMINAL BOARD	8271184	29
1		FILTER CHOKE (L-52)	8289921	30
2		FILTER CHOKE (L-50, L-51)	8289922	31
1	2-100 Ω	RESISTOR ASSEM	8289829	32
1	2-1500 Ω	RESISTOR ASSEM	8289930	33
1		RELAY	8346490	34
X		TERMINAL BOARD	8292938	35
				36
1		RHEOSTAT	8290106	37

FO-69. Unit Control Panel Wiring Diagram (8378790) (Sheet 3 of 3)

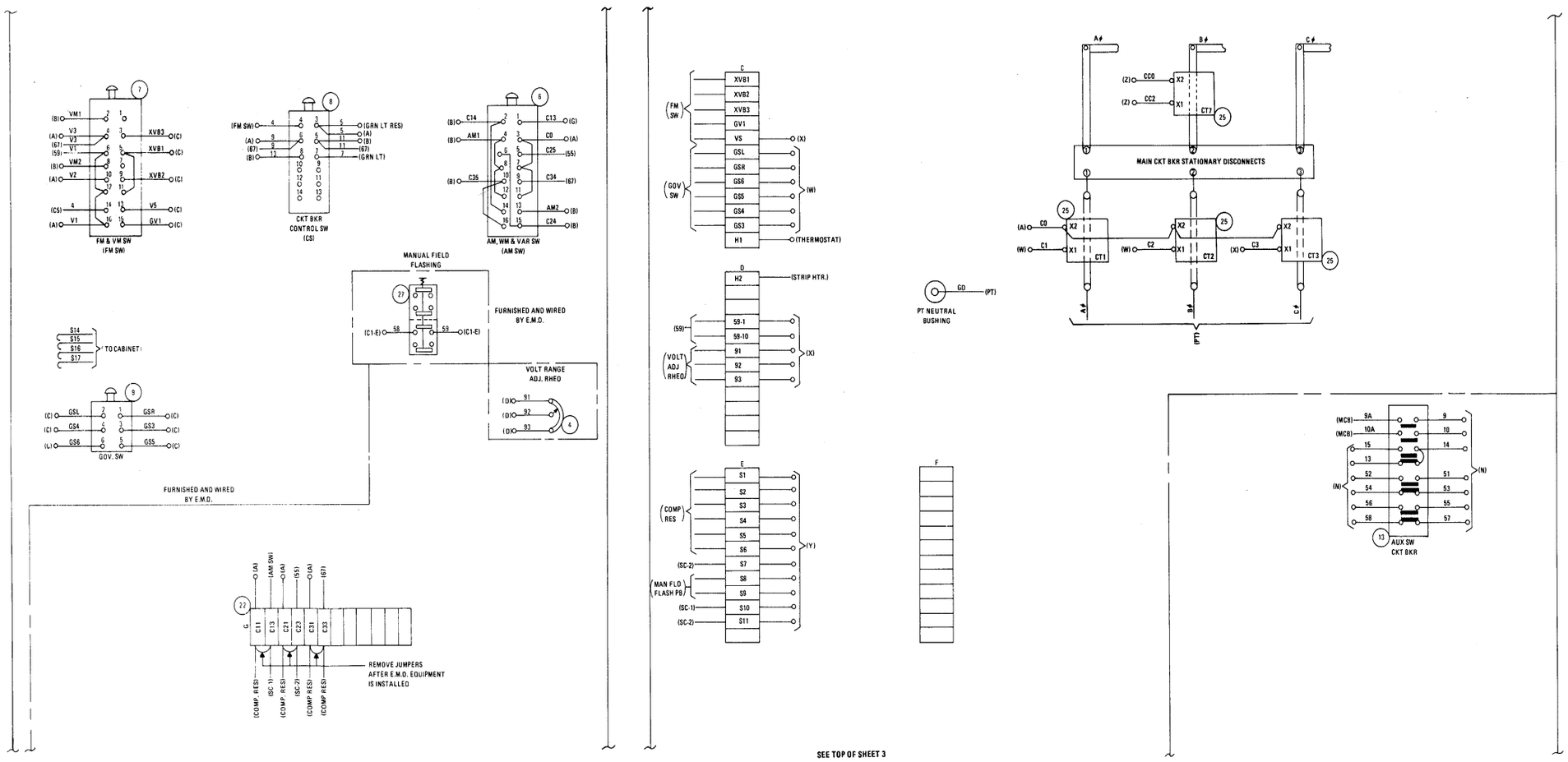


GOVERNOR CONTROL SW			
CONTACTS	POSITIONS		
	RAISE	OFF	LOWER
1-2	X		
3-4		X	
5-6			X

CIRCUIT BREAKER CONTROL SW					
CONTACTS	POSITIONS				
	CLOSE	NORM AFTER CLOSE	TRIP	NORM AFTER TRIP	PULL OUT IN TRIP
3-4	X				
5-6			X		X
7-8	X			X	
9-10		X		X	
11-12		X			
13-14	X	X			

FO-70. Switchgear Cubicle Wiring Diagram (8378792) (Sheet 1 of 3)

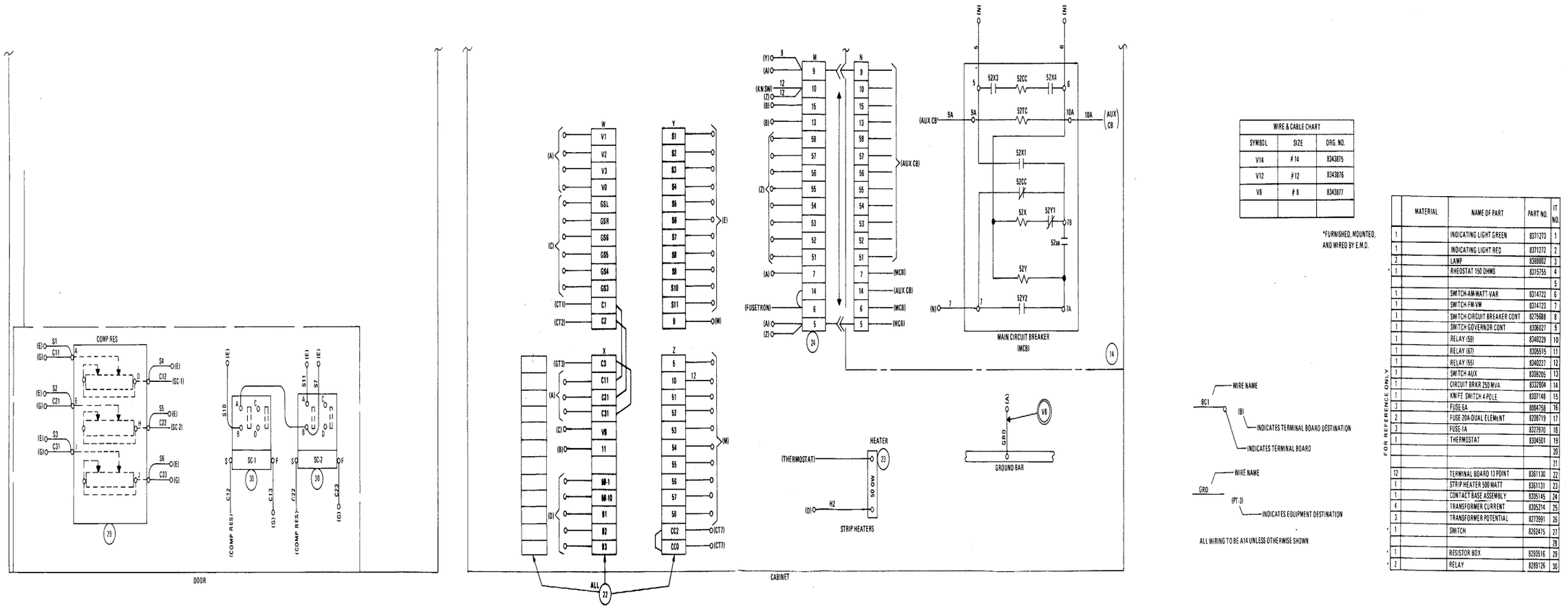
141/ (142 blank)



AMM-WATT-VAR				
CONTACTS	POSITIONS			
	OFF	1	2	3
1-2			X	X
1-3	X			
1-4		X		
5-6		X		X
5-7	X			
5-8			X	
9-10		X	X	
9-11	X			
9-12				X
13-14		X		
13-15			X	
13-16				X

FREQUENCY-VOLTMETER SW							
CONTACTS	BUS				GEN		
	OFF	1-2	2-3	1-3	OFF	1-2	2-3	1-3
2-3			X	X				
2-4						X	X	
2-5		X						
2-6						X		
8-9		X	X					
8-10						X	X	
8-11				X				
8-12								X
13-14		X	X	X				X
15-16		X	X	X		X	X	X

FO-71. Switchgear Cubicle Wiring Diagram (8378792) (Sheet 2 of 3)



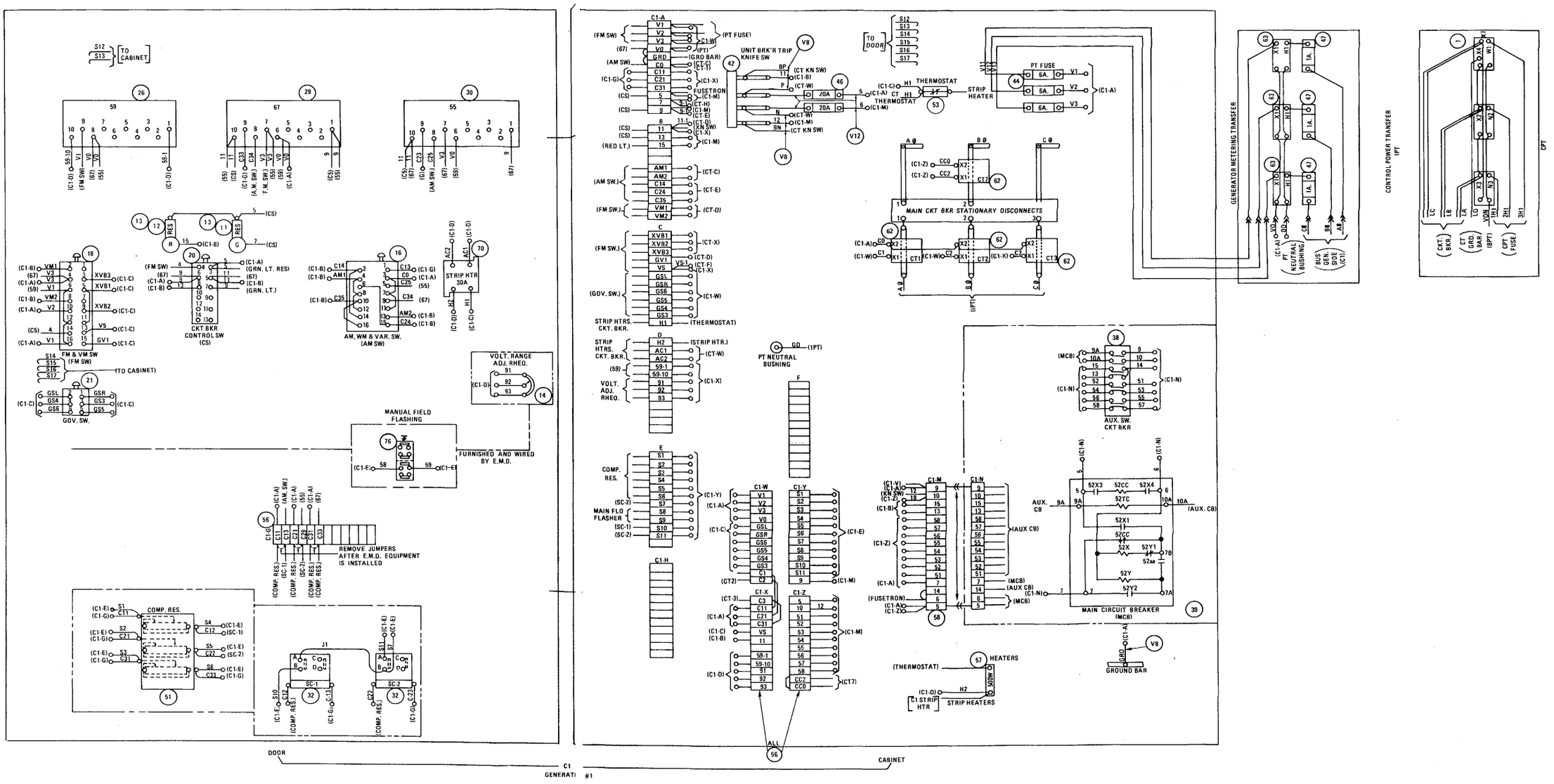
WIRE & CABLE CHART		
SYMBOL	SIZE	DRG. NO.
V14	# 14	8343875
V12	# 12	8343876
V8	# 8	8343877

*FURNISHED, MOUNTED, AND WIRED BY E.M.D.

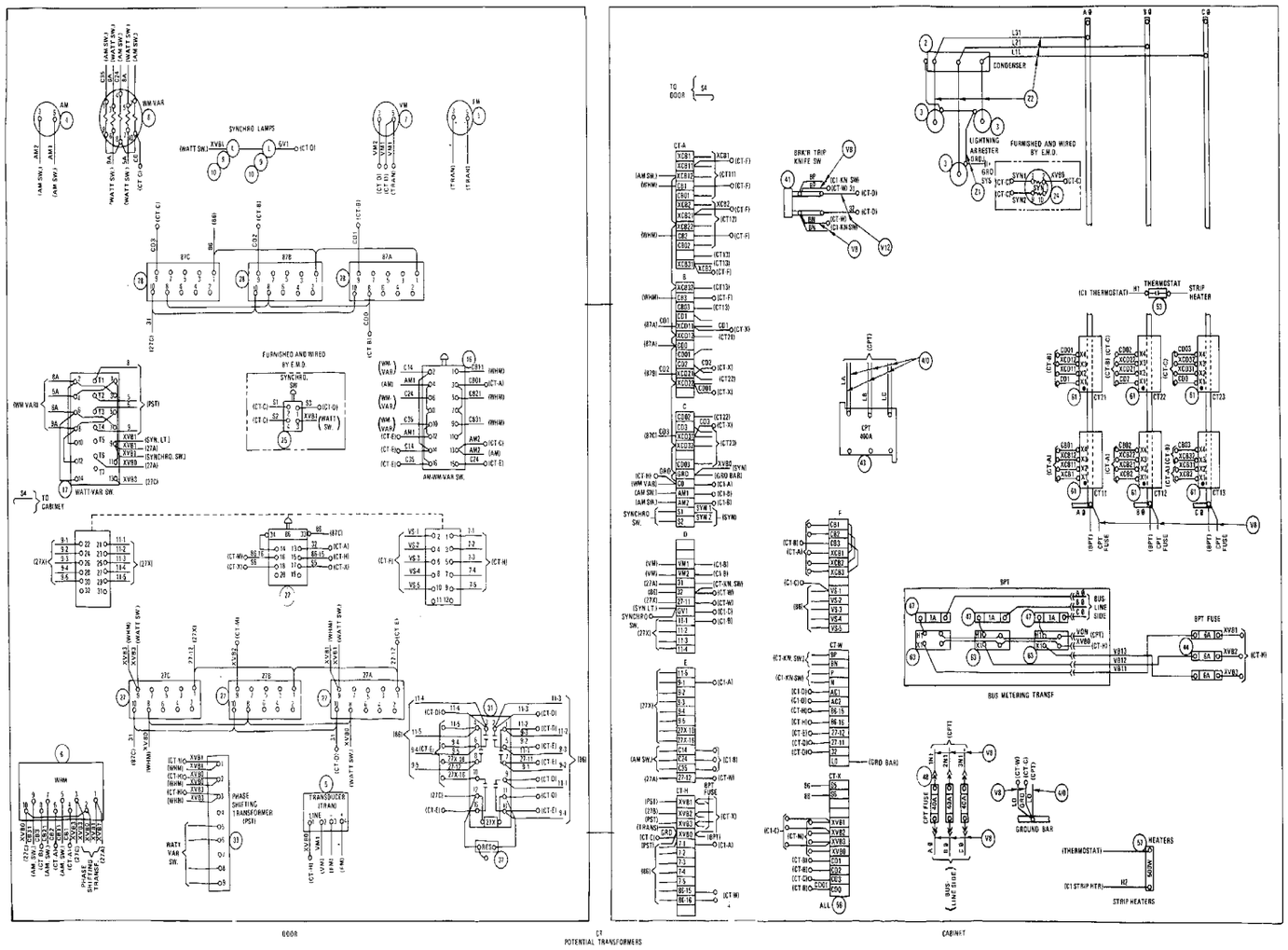
FOR REFERENCE ONLY

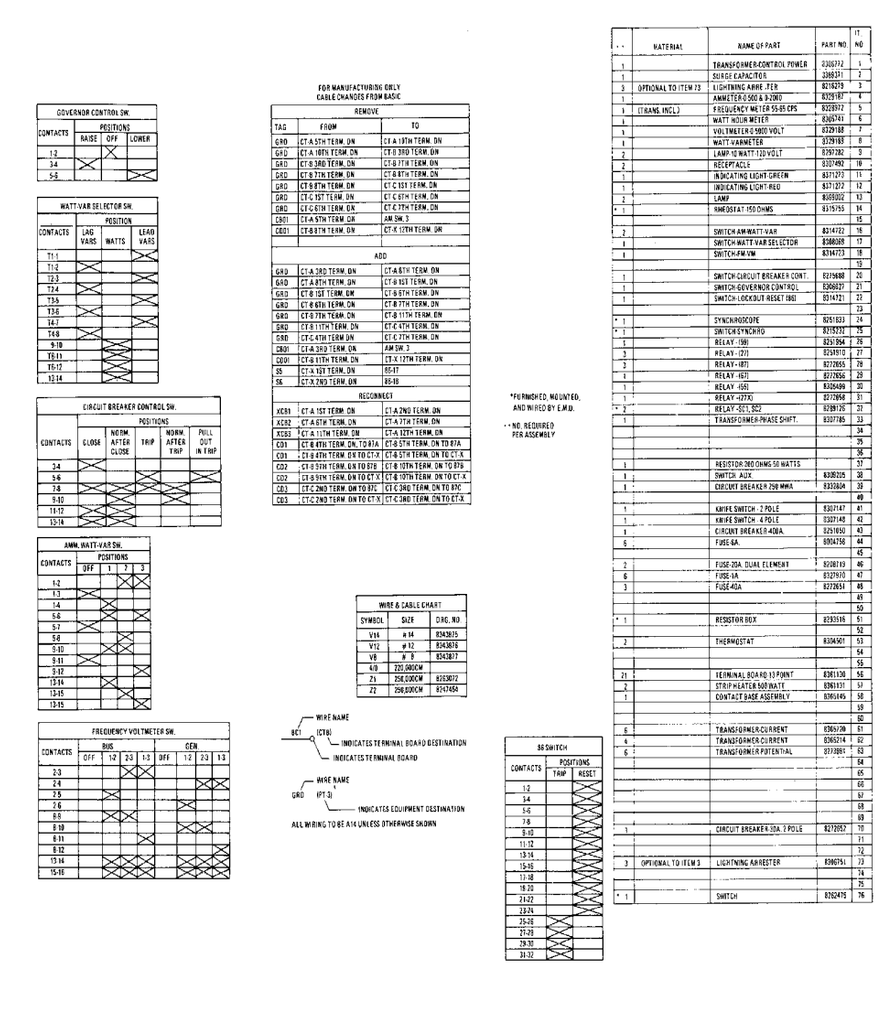
IT NO.	QTY	MATERIAL	NAME OF PART	PART NO.
1	1		INDICATING LIGHT GREEN	8371273
2	1		INDICATING LIGHT RED	8371272
3	2		LAMP	8388007
4	1		RHEOSTAT 150 OHMS	8315755
5				
6	1		SWITCH-AM-WATT-VAR	8314722
7	1		SWITCH-FM-VM	8314723
8	1		SWITCH-CIRCUIT BREAKER CONT	8275088
9	1		SWITCH GOVERNOR CONT	8306027
10	1		RELAY (59)	8340229
11	1		RELAY (67)	8305515
12	1		RELAY (55)	8340227
13	1		SWITCH AUX	8308705
14	1		CIRCUIT BRKR 250 MVA	8332804
15	1		KNIFE SWITCH 4 POLE	8307148
16	3		FUSE-6A	8004758
17	2		FUSE-20A-DUAL ELEMENT	8208719
18	3		FUSE-1A	8327970
19	1		THERMOSTAT	8304501
20				
21				
22	12		TERMINAL BOARD 13 POINT	8361130
23	1		STRIP HEATER 500 WATT	8361131
24	1		CONTACT BASE ASSEMBLY	8305145
25	4		TRANSFORMER CURRENT	8305214
26	3		TRANSFORMER POTENTIAL	8273991
27	1		SWITCH	8262475
28				
29	1		RESISTOR BOX	8293516
30	2		RELAY	8289126

FO-72. Switchgear Cubicle Wiring Diagram (8378792) (Sheet 3 of 3)



FO-73. Transformer and Switchgear Cubicle Wiring Diagram (83787891) (Sheet 1 of 2)





FO-74. Transformer and Switchgear cubicle Wiring Diagram (8378791) (Sheet 2 of 2)

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Chief of Staff

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