TECHNICAL MANUAL

OPERATOR' S, UNIT, INTERMEDIATE (DS) AND INTERMEDIATE (GS) MAINTENANCE MANUAL

FOR

ENGINE, DIESEL, CATERPILLAR, MODEL 3508 NSN 2815-01-216-0938

HEADQUARTERS, DEPARTMENT OF THE ARMY

25 JULY 1986

⚠ WARNING

IMPORTANT SAFETY NOTICE

Proper repair-is important to the safe and reliable operation of this product. This Service Manual outlines basic recommended procedures, some of which require special tools, devices or work methods. Although not necessarily all inclusive, a list of additional skills, precautions and knowledge required to safely perform repairs is provided in the SAFETY section of this Manual.

Improper repair procedures can be dangerous and could result in injury or death.

READ AND UNDERSTAND ALL SAFETY PRECAUTIONS AND WARNINGS BEFORE PERFORMING REPAIRS

Basic safety precautions, skills and knowledge are listed in the SAFETY section of this Manual and in the descriptions of operations where hazards exist. Warning labels have also been put on to provide instructions and identify specific hazards which if not heeded could cause bodily injury or death to you or other persons. These labels identify hazards which may not be apparent to a trained mechanic. There are many potential hazards during repair for a untrained mechanic and there is no way to label the product against all such hazards. These warnings in the Service Manual and on the product are identified by this symbol:

⚠ WARNING

Operations that may result only in mechanical damage are identified by labels on the product and in the Service Manual by the word CAUTION or NOTICE.

Caterpillar can not anticipate every possible circumstance that might involve a potential hazard. The warnings in this Manual are therefore not all inclusive. If a procedure, tool device or work method not specifically recommended by Caterpillar is used, you must satisfy yourself that it is safe for you and others. You should also ensure that the product will not be damaged or made unsafe by the procedures you choose.

IMPORTANT

The information, specifications and illustrations in this book are on the basis of information available at the time it was written. The specifications, torque, pressures of operation, measurements, adjustments, illustrations and other items can change at any time. These changes can affect the service given to the product. Get the complete and most current information before you start any job. Caterpillar Dealers have the most current information available. For a list of the most current modules and form numbers available for each Service Manual, see the SERVICE MANUAL CONTENTS MICROFICHE REG1139F.

SAFETY

⚠ WARNING

Improper performance of lubrication or maintenance procedures is dangerous and could result in injury or death. Read and understand the lubrication and maintenance procedures, recommended by Caterpillar, that are outlined in the OPERATION GUIDE and/or OWNER'S MANUAL for this product before performing any lubrication or maintenance.

Do not operate this product unless you have read and understood the instructions. Improper operation is dangerous and could result in injury or death.

The servicemen or mechanic may be unfamiliar with many of the components and systems of this product. This makes it important to use caution when performing service work. A knowledge of the system and/or components is important before the removal or disassembly of any component.

Because of the size of some components, the serviceman or mechanic should check the weights noted in this Manual. Use proper lifting procedures when removing any components.

Following is a list of basic precautions that should always be observed.

1. Read and understand all Warning plates and decals before operating, lubricating or repairing this product.

2. Make sure the work area around the product is made safe and be aware of hazardous conditions that may exist.

3. Always wear protective glasses and protective shoes when working. In particular, wear protective glasses when a hammer or sledge is used for pounding to make repairs. Use welders gloves, hood/goggles, apron and other protective clothing appropriate to the welding job being performed. Do not wear loose-fitting or torn clothing. Remove all rings from fingers when working on machinery.

4. If an engine must be started to make pressure or speed checks, be sure all guards and shields are installed. To help prevent an accident caused by parts in rotation, work carefully around machinery that has been put into operation.

5. If an engine has been running and the coolant is hot, loosen the filler cap slowly and let the pressure out of the cooling system, before any caps, plugs or lines are removed or disconnected.

6. Corrosion inhibitor contains alkali. Avoid contact with eyes. Avoid prolonged or repeated contact with skin. Do not take internally. In case of contact, immediately wash skin with soap and water. For eyes, flush with large amounts of water for at least 15 minutes. CALL PHYSICIAN. KEEP OUT OF REACH OF CHILDREN.

7. Do not smoke when an inspection of the battery electrolyte level is made. Never disconnect any charging unit circuit or battery circuit cable from the battery when the charging unit is operating. A spark can cause an explosion from the flammable vapor mixture of hydrogen and oxygen that is released from the electrolyte through the battery outlets. Do not let electrolyte solution make contact with skin or eyes. Electrolyte solution is an acid. In case of contact, immediately wash skin with soap and water. For eyes, flush with large amounts of water for at least 15 minutes. CALL PHYSICIAN. KEEP OUT OF REACH OF CHILDREN.

8. Disconnect battery and discharge any capacitors before starting any repair work. Hang "Do Not Operate" tag in the Operator's compartment or on the controls.

9. Do not work on anything that is supported only by lift jacks or a hoist. Always use blocks or proper stands to support the product before performing any service work.

10. Relieve all pressure in air, oil or water systems before any lines, fittings or related items are disconnected or removed. Be alert for possible pressure when disconnecting any device from a system that utilizes pressure. Do not check for pressure leaks with your hand. High pressure oil or fuel can pierce the skin.

⚠ WARNING

11. Never bend a fuel injection line, or install a line which has been bent. Keep the fuel injection lines and connections clean. Be sure to install caps and covers anytime a line is removed or disconnected.

12. During service work, do not hit the fuel injection lines with wrenches or other tools. When lines are installed, use the correct torque to tighten connections and be sure all clamps and dampers are correctly installed.

13. Make sure all fuel injection lines and pressure oil lines have enough clearance to prevent contact with any other component. Do not put any fuel or oil lines close to a hot component.

14. To avoid back injury use a hoist or get help when lifting components which weigh 50 lb. (23 kg) or more. Make sure all chains, hooks, slings, etc., are in good condition and are of the correct capacity. Be sure hooks are positioned correctly. Lifting eyes are not to be side loaded during a lifting operation.

15. To avoid burns, be alert for hot parts on products which have just been stopped and hot fluids in lines, tubes and compartments.

16. Be careful when removing cover plates. Gradually back off the last two bolts or nuts located at opposite ends of the cover or device and pry cover loose to relieve any spring or other pressure, before removing them completely.

17. Be careful when removing filler caps, breathers and plugs on the product. Hold a rag over the cap or plug to prevent being sprayed or splashed by liquids under pressure. The danger is even greater if the product has recently been stopped because fluids can be hot.

18. Always use tools that are in good condition and be sure you understand how to use them before performing any service work. Use only Caterpillar replacement parts.

19. Reinstall all fasteners with same part number. Do not use a lesser quality fastener if replacements are necessary.

20. Repairs which require welding should be performed only with the benefit of the appropriate reference information and by personnel adequately trained and knowledgeable in welding procedures. Make reference to “Techniques of Structural Repair Course” form number JEG03719. Determine type of metal being welded and select correct welding procedure and electrodes, rods or wire to provide a weld metal strength equivalent at least to that of parent metal.

21. Before doing electrical work, disconnect battery. Do not damage wiring during removal operations. Reinstall the wiring so it is not damaged nor will it be damaged in operation by contacting sharp corners, or by rubbing against some object or hot surface. Do not connect wiring to a line containing fluid.

22. Be sure all protective devices including guards and shields are properly installed and functioning correctly before starting a repair. If a guard or shield must be removed to perform the repair work, use extra caution. After the repair is completed, reinstall any guard or shield that was removed.

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⚠ WARNING

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⚠ WARNING

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Proper repair is important to the safe and reliable operation of a machine. This Service Manual outlines basic recommended procedures, some of which require special tools, devices or work methods. Although not necessarily all inclusive, a list of additional skills, precautions and knowledge required to safely perform repairs is provided in the SAFETY section of this Manual.

Improper repair procedures can be dangerous and could result in injury or death.

READ AND UNDERSTAND ALL SAFETY PRECAUTIONS AND WARNINGS BEFORE PERFORMING REPAIRS ON THIS MACHINE

Basic safety precautions, skills and knowledge are listed in the SAFETY section of this Manual and in the descriptions of operations where hazards exist. Warning labels have also been put on the machine to provide instructions and identify specific hazards which if not heeded could cause bodily injury or death to you or other persons. These labels identify hazards which may not be apparent to a trained mechanic. There are many potential hazards during repair for an untrained mechanic and there is no way to label. the machine against all such hazards. These warnings in the Service Manual and on the machine are identified by this symbol:

⚠ WARNING

Operations that may result only in machine damage are identified by labels on the machine and in the Service Manual by the word **NOTICE**.

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⚠ WARNING

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Improper repair procedures can be dangerous and could result in injury or death.

READ AND UNDERSTAND ALL SAFETY PRECAUTIONS AND WARNINGS BEFORE PERFORMING REPAIRS ON THIS MACHINE

Basic safety precautions, skills and knowledge are listed in the SAFETY section of this Manual and in the descriptions of operations where hazards exist. Warning labels have also been put on the machine to provide instructions and identify specific hazards which if not heeded could cause bodily injury or death to you or other persons. These labels identify hazards which may not be apparent to a trained mechanic. There are many potential hazards during repair for an untrained mechanic and there is no way to label ,the machine against all such hazards. These warnings in the Service Manual and on the machine are identified by this symbol:

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67200-1 X1

⚠ WARNING

SAFETY

⚠ WARNING

Improper performance of lubrication or maintenance procedures is dangerous and could result in injury or death. Read and understand the lubrication and maintenance procedures, recommended by Caterpillar, that are outlined in the OPERATION GUIDE and/or OWNER'S MANUAL for this product before performing any lubrication or maintenance.

Do not operate this product unless you have read and understood the instructions. Improper operation is dangerous and could result in injury or death.

The servicemen or mechanic may be unfamiliar with many of the components and systems of this product. This makes it important to use caution when performing service work. A knowledge of the system and/or components is important before the removal or disassembly of any component.

Because of the size of some components, the serviceman or mechanic should check the weights noted in this Manual. Use proper lifting procedures when removing any components.

Following is a list of basic precautions that should always be observed.

1. Read and understand all Warning plates and decals before operating, lubricating or repairing this product.

2. Make sure the work area around the product is made safe and be aware of hazardous conditions that may exist.

3. Always wear protective glasses and protective shoes when working. In particular, wear protective glasses when a hammer or sledge is used for pounding to make repairs. Use welders gloves, hood/goggles, apron and other protective clothing appropriate to the welding job being performed. Do not wear loose-fitting or torn clothing. Remove all rings from fingers when working on machinery.

4.

4. If an engine must be started to make pressure or speed checks, be sure all guards and shields are installed. To help prevent an accident caused by parts in rotation, work carefully around machinery that has been put into operation.

5. If an engine has been running and the coolant is hot, loosen the filler cap slowly and let the pressure out of the cooling system, before any caps, plugs or lines are removed or disconnected.

6. Corrosion inhibitor contains alkali. Avoid contact with eyes. Avoid prolonged or repeated contact with skin. Do not take internally. In case of contact, immediately wash skin with soap and water. For eyes, flush with large amounts of water for at least 15 minutes. CALL PHYSICIAN. KEEP OUT OF REACH OF CHILDREN.

7. Do not smoke when an inspection of the battery electrolyte level is made. Never disconnect any charging unit circuit or battery circuit cable from the battery when the charging unit is operating. A spark can cause an explosion from the flammable vapor mixture of hydrogen and oxygen that is released from the electrolyte through the battery outlets. Do not let electrolyte solution make contact with skin or eyes. Electrolyte solution is an acid. In case of contact, immediately wash skin with soap and water. For eyes, flush with large amounts of water for at least 15 minutes. CALL PHYSICIAN. KEEP OUT OF REACH OF CHILDREN.

8. Disconnect battery and discharge any capacitors before starting any repair work. Hang "Do Not Operate" tag in the Operator's compartment or on the controls.

9. Do not work on anything that is supported only by lift jacks or a hoist. Always use blocks or proper stands to support the product before performing any service work.

10. Relieve all pressure in air, oil or water systems before any lines, fittings or related items are disconnected or removed. Be alert for possible pressure when disconnecting any device from a system that utilizes pressure. Do not check for pressure leaks with your hand. High pressure oil or fuel can pierce the skin.

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12. During service work, do not hit the fuel injection lines with wrenches or other tools. When lines are installed, use the correct torque to tighten connections and be sure all clamps and dampers are correctly installed.

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15. To avoid burns, be alert for hot parts on products which have just been stopped and hot fluids in lines, tubes and compartments.

16. Be careful when removing cover plates. Gradually back off the last two bolts or nuts located at opposite ends of the cover or device and pry cover loose to relieve any spring or other pressure, before removing them completely.

17. Be careful when removing filler caps, breathers and plugs on the product. Hold a rag over the cap or plug to prevent being sprayed or splashed by liquids under pressure. The danger is even greater if the product has recently been stopped because fluids can be hot.

18. Always use tools that are in good condition and be sure you understand how to use them before performing any service work. Use only Caterpilla, replacement parts.

19. Reinstall all fasteners with same part number. Do not use a lesser quality fastener if replacements are necessary.

20. Repairs which require welding should be performed only with the benefit of the appropriate reference information and by personnel adequately trained and knowledgeable in welding procedures. Make reference to "Techniques of Structural Repair Course" form number JEG03719. Determine type of metal being welded and select correct welding procedure and electrodes, rods or wire to provide a weld metal strength equivalent at least to that of parent metal.

21. Before doing electrical work, disconnect battery. Do not damage wiring during removal operations. Reinstall the wiring so it is not damaged nor will it be damaged in operation by contacting sharp corners, or by rubbing against some object or hot surface. Do not connect wiring to a line containing, fluid.

22. Be sure all protective devices including guards and shields are properly installed and functioning correctly before starting a repair. If a guard or shield must be removed to perform the repair work, use extra caution. After the repair is completed, reinstall any guard or shield that was removed.

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IMPORTANT SAFETY INFORMATION

Most accidents involving engine operation and maintenance are caused by failure to observe basic safety rules or precautions. An accident can often be avoided by recognizing potentially hazardous situations before an accident occurs.

Read and understand all safety precautions and warnings before operating or performing lubrication and maintenance on this engine.

Basic safety precautions are outlined in the "Safety" section of this guide and in the description of operations where hazards exist. WARNING labels have also been put on the engine to provide instructions and to identify specific hazards which if not heeded could cause bodily injury or death to you or other persons. These warnings in the guide and on the engine labels are identified by the symbol



Operations that may cause only engine damage are identified by NOTICE labels on the engine and in the guide.

Caterpillar cannot anticipate every possible circumstance that might involve a potential hazard. The warnings in this guide and on the engine are therefore not all inclusive. If a procedure, tool or work method or operating technique not specifically recommended by Caterpillar is used, you must satisfy yourself that it is safe for you and others. You should also ensure that the engine will not be damaged or made unsafe by the method of operation or maintenance procedures you choose.

⚠ WARNING

Improper operation, lubrication or maintenance of this engine can be dangerous and could result in injury or death.

Do not operate this engine until you read and understand the instructions in the "Operation" section of the Operation and Maintenance Guide or the Owner's Manual.

Do not perform any lubrication and maintenance on this engine until you read and understand the instructions in the "Maintenance" section of the Operation and Maintenance Guide or the Owner's Manual.

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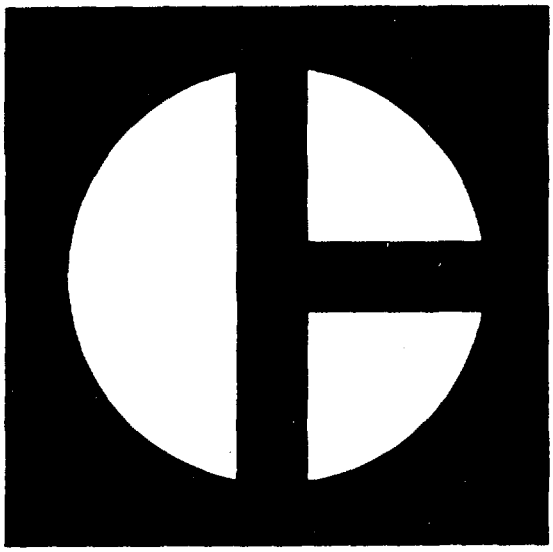
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FOR USE IN SERVICE MANUALS:
3500 INDUSTRIAL ENGINES,
SENR2573
VOLUME I SPECIFICATIONS,
REGO1312



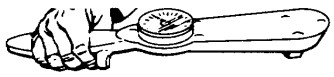
SPECIFICATIONS

FOR

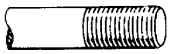
3500 INDUSTRIAL
ENGINE ATTACHMENTS

49Y1-UP	65Z1-UP
95Y1-UP	68Z1-UP
27Z1-UP	71Z1-UP

GENERAL TIGHTENING TORQUE FOR BOLTS, NUTS AND TAPERLOCK STUDS



The following charts give the standard torque values for bolts, nuts and taperlock studs of SAE Grade 5 or better quality. Exceptions are given in other sections of the Service Manual where needed.

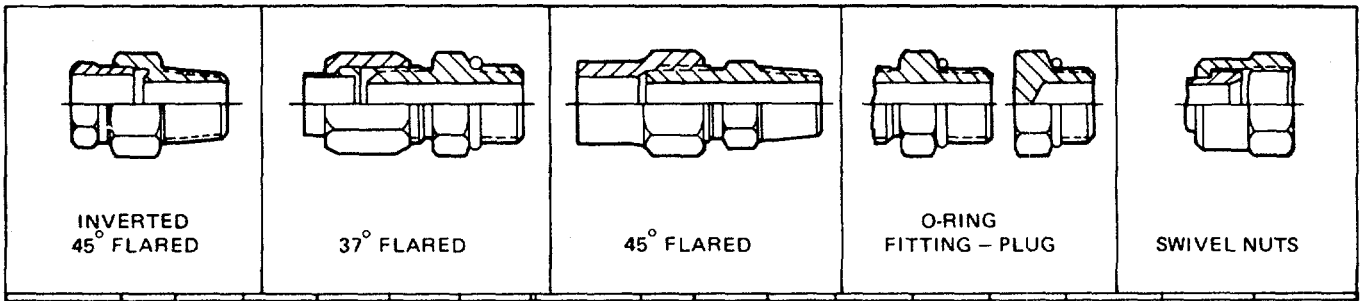
THREAD DIAMETER		STANDARD TORQUE	
inches	millimeters	lb. ft.	N·m*
Standard thread 		Use these torques for bolts and nuts with standard threads (conversions are approximate).	
1/4	6.35	9 ± 3	12 ± 4
5/16	7.94	18 ± 5	25 ± 7
3/8	9.53	32 ± 5	45 ± 7
7/16	11.11	50 ± 10	70 ± 15
1/2	12.70	75 ± 10	100 ± 15
9/16	14.29	110 ± 15	150 ± 20
5/8	15.88	150 ± 20	200 ± 25
3/4	19.05	265 ± 35	360 ± 50
7/8	22.23	420 ± 60	570 ± 80
1	25.40	640 ± 80	875 ± 100
1 1/8	28.58	800 ± 100	1100 ± 150
1 1/4	31.75	1000 ± 120	1350 ± 175
1 3/8	34.93	1200 ± 150	1600 ± 200
1 1/2	38.10	1500 ± 200	2000 ± 275
		Use these torques for bolts and nuts on hydraulic valve bodies.	
5/16	7.94	13 ± 2	20 ± 3
3/8	9.53	24 ± 2	35 ± 3
7/16	11.11	39 ± 2	50 ± 3
1/2	12.70	60 ± 3	80 ± 4
5/8	15.88	118 ± 4	160 ± 6
Taperlock stud 		Use these torques for studs with Taperlock threads.	
1/4	6.35	5 ± 2	7 ± 3
5/16	7.94	10 ± 3	15 ± 5
3/8	9.53	20 ± 3	30 ± 5
7/16	11.11	30 ± 5	40 ± 10
1/2	12.70	40 ± 5	55 ± 10
9/16	14.29	60 ± 10	80 ± 15
5/8	15.88	75 ± 10	100 ± 15
3/4	19.05	110 ± 15	150 ± 20
7/8	22.23	170 ± 20	230 ± 30
1	25.40	260 ± 30	350 ± 40
1 1/8	28.58	320 ± 30	400 ± 40
1 1/4	31.75	400 ± 40	550 ± 50
1 3/8	34.93	480 ± 40	650 ± 50
1 1/2	38.10	550 ± 50	750 ± 70

*1 newton meter (N·m) is approximately the same as 0.1 mkg.

T95416-7

TORQUE FOR FLARED AND O-RING FITTINGS

The torques shown in the chart that follows are to be used on the part of 37° Flared, 45° Flared and Inverted Flared fittings (when used with steel tubing), O-ring plugs and O-ring fittings.



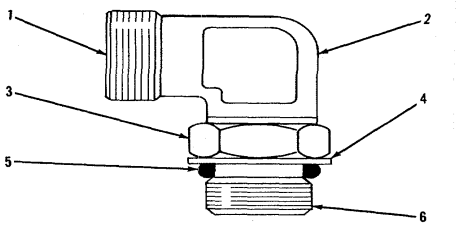
TUBE SIZE (O.D.)	mm	3.18	4.78	6.35	7.92	9.52	TUBE SIZE (O.D.)	mm	12.70	15.88	19.05	22.22	25.40	31.75	38.10	50.80
	in.	.125	.188	.250	.312	.375		in.	.500	.625	.750	.875	1.000	1.250	1.500	2.000
THREAD SIZE (in.)		5/16	3/8	7/16	1/2	9/16 5/8	THREAD SIZE (in.)		3/4	7/8	1 1/16	1 3/16 1 1/4	1 5/16	1 5/8	1 7/8	2 1/2
TORQUE N·m		5 ±1	11 ±1	16 ±2	20 ±2	25 ±3	TORQUE N·m		50 ±5	75 ±5	100 ±5	120 ±5	135 ±10	180 ±10	225 ±10	320 ±15
TORQUE lb.in.		45 ±10	100 ±10	145 ±20	175 ±20	225 ±25	TORQUE lb.ft.		35 ± 4	55 ± 4	75 ± 4	90 ± 4	100 ± 7	135 ± 7	165 ± 7	235 ± 10

ASSEMBLY OF FITTINGS WITH STRAIGHT THREADS AND O-RING SEALS

1. Put locknut (3), backup washer (4) and O-ring seal (5) as far back on fitting body (2) as possible. Hold these components in this position. Turn the fitting into the part it is used on, until backup washer (4) just makes contact with the face of the part it is used on.

NOTE: If the fitting is a connector (straight fitting) or plug, the hex on the body takes the place of the locknut. To install this type fitting tighten the hex against the face of the part it goes into.

2. To put the fitting assembly in its correct position turn the fitting body (2) out (counterclockwise) a maximum of 359°. Tighten locknut (3) to the torque shown in the chart.y



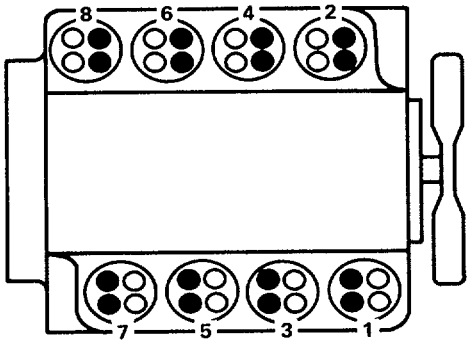
ELBOW BODY ASSEMBLY

1. End of fitting body (connects to tube). 2. Fitting body. 3. Locknut. 4. Backup washer. 5. O-ring seal. 6. End of fitting that goes into other part.

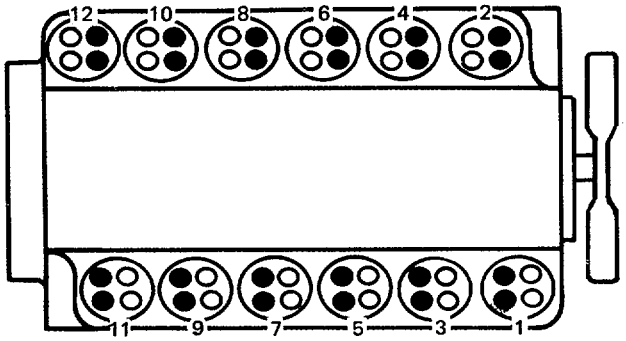
A71009X3

ENGINE DESIGN

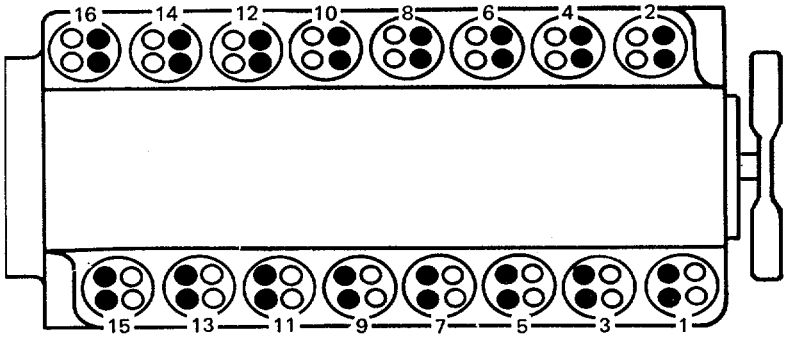
CYLINDER AND VALVE LOCATION



3508



3512



3516

○ INTAKE	● EXHAUST
0.38mm (.015 in.)	0.76mm (.030 in.)

B62374X1

ENGINE DESIGN

SPECIFICATIONS		ENGINE		
		3508	3512	3516
NUMBER AND ARRANGEMENT		60° V-8	60° V-12	60° V-16
OF CYLINDERS				
VALVES PER CYLINDER		4	4	4
DISPLACEMENT		34.5 LITER	51.8 LITER	69.1 LITER
		(2105 cu. in.)	(3158 cu. in.)	(4210 cu. in.)
BORE			170mm (6.7 in.)	
STROKE		190mm (7.5 in.)		
COMPRESSION RATIO		13:1		
TYPE OF COMBUSTION		Direct Injection		
VALVE	Intake	0.38mm (.015 in.)		
SETTING	Exhaust	0.76mm (.030 in.)		

FIRING ORDER (INJECTION SEQUENCE)		
ENGINE	SAE STANDARD ROTATION*	SAE OPPOSITE ROTATION*
3508	1-2-7-3-4-5-6-8	1-8-7-2-6-5-4-3
3512	1-12-9-4-5-8-11-2-3-10-7-6	14-9-8-5-2-11 -10-3-6-7-12
3516	1-2-5-6-3-4-9-10-15-16-11-12-13-14-7-8	1-6-5-4-3-10-9-16-15-12-11-14-13-8-7-2

* Direction of Rotation (as viewed from flywheel end):
SAE Standard Rotation ----------Counterclockwise
SAE Opposite Rotation ----------Clockwise

NOTE: Front end of engine is opposite the flywheel end.
Left side and right side of engine are as seen from flywheel end.
No. 1 cylinder is the front cylinder on the right side.
No. 2 cylinder is the front cylinder on the left side. B62375X1

INTRODUCTION

The specifications given in this book are on the basis of information available at the time it was written. The specifications torques, pressures of operation, measurements, adjustments and other items can change at any time. These changes can effect the service given to the product. Get the complete and most current information before you start any job. Caterpillar Dealers have the most current information which is available. For a list of the most current modules and form numbers available for each Service Manual, see the SERVICE MANUAL CONTENTS MICROFICHE REG 1139F.

When the words "use again" are in the description, the specification given can be used to determine if a part can be used again. If the part is equal to or within the specification given, use the part again.

When the word "permissible" is in the description, the specification given is the "maximum or minimum" tolerance permitted before adjustment, repair and/or new parts are needed.

A comparison can be made between the measurements of a worn part, and the specifications of a new part to find the amount of wear. A part that is worn can be safe to use if an estimate of the remainder of its service life is good. If a short service life is expected, replace the part.

77200X2

NOTE: For Systems Operation and Testing and Adjusting, make reference to 3500 INDUSTRIAL ENGINES, Form No. SENR2352.

FUEL INJECTION

(1) Torque for locknut for rocker arm adjustment screw .... 70 + 15 N•m (50 ± 11 lb. ft.)

(2) Diameter of rocker arm shaft..... 37.084 ± 0.013 mm (1.4600 + .0005 in.)
Bore in bearing for rocker arm shaft ..... 37.140 ± 0.015 mm (1.4622 ± .0006 in.)

(3) Injector installation:

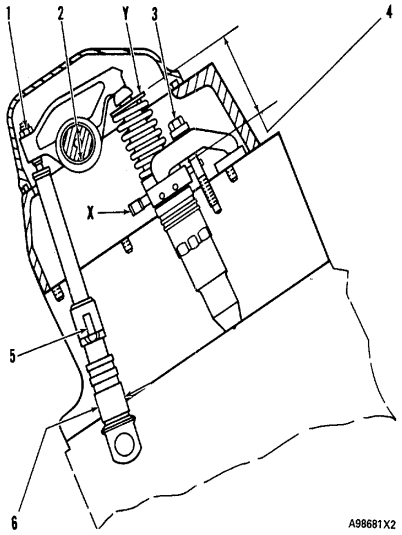
a. Put multipurpose type grease in bore of cylinder head for lubrication of the O-ring seals.

b. Put injector in bore. Use bolt and clamp to push injector into the correct position.

NOTE:Do not tap (hit) surface "Y" to install injector.

c. Tighten bolt that holds fuel injector clamp to..... 65 ± 7 N-m (48 ± 5 lb. ft.)

d. After clamp is tightened, injector rack "X" must move freely.



(4) Fuel timing dimension set by gauge. See FUEL SETTING AND RELATED INFORMATION FICHE for the correct dimension to use.

(5) Guide springs must not be used again. Always install new guide springs.

(6) Diameter of valve lifter (new)..... 29.937 ± 0.010 mm (1.1786 ± .0004 in.)

Bore in head for valve lifter..... 30.000 ± 0.025 mm (1.1811 ± .0010 in.)

FUEL PRESSURE REGULATOR (Earlier)

(1) Fuel manifold adapter on right hand front fuel manifold

(2) 9N4053 Spring for fuel pressure regulator valve plunger

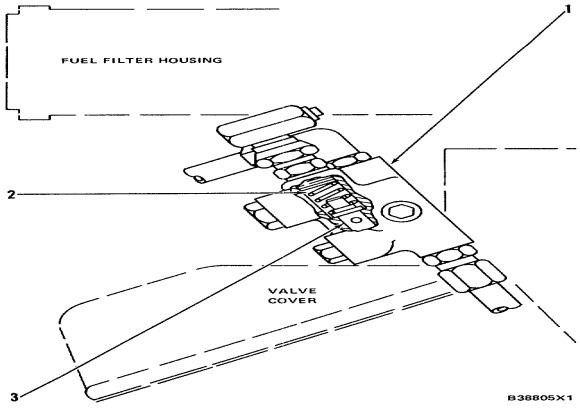
Length under test force ..... 28 5 mm (1.12 in.)

Test force .....40 8 ± 2 1 N (9 17 ± 46 lb)

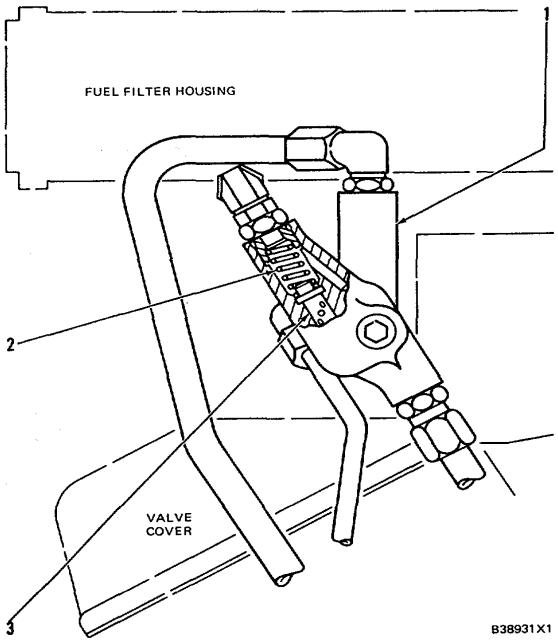
Free length after test ..... 57 2 mm (2 25 In)

Outside diameter ..... 15 24 mm (600 in)

(3) Regulator valve plunger. Regulator valve to hold fuel manifold pressure at ..... 415 to 620 kPa (60 to 90 psi)



FUEL PRESSURE REGULATOR (Later)



(1) Fuel manifold adapter on right hand front fuel manifold.

(2) 9N4053 Spring for fuel pressure regulator valve plunger

Length under test force ..... 28.5 mm (1.12 in.)

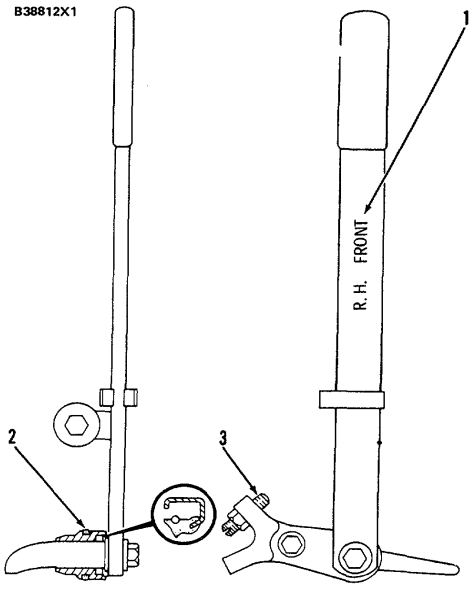
Test force .....40.8 ± 2 1 N (9.17 ± .46 lb.)

Free length after test ..... 57.2 mm (2.25 in)

Outside diameter ..... 15.24 mm (600 in.)

(3) Regulator valve plunger. Regulator valve to hold fuel manifold pressure at
..... 415 to 450 kPa (60 to 65 psi)

MANUAL SHUTOFF GROUP



NOTE: The shutoff group must be installed on the same side of the engine that the governor is installed.

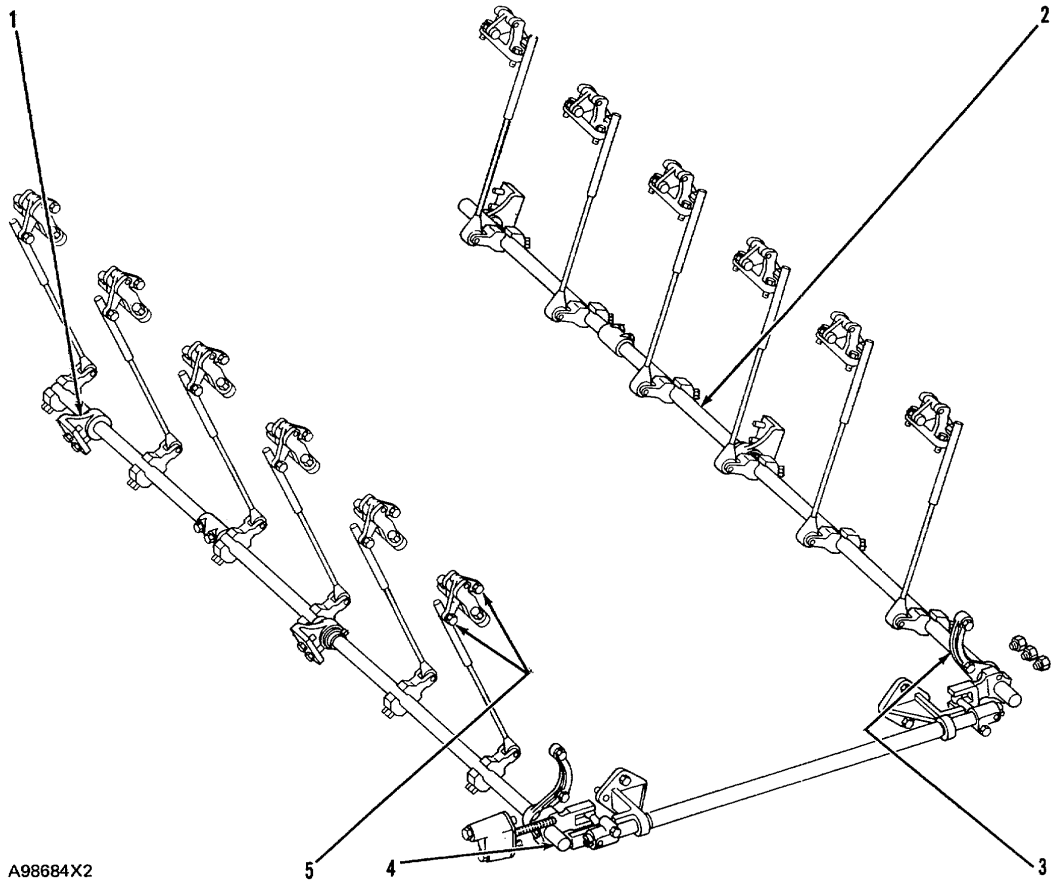
(1) When right hand mounted, "RH FRONT" should be visible from front of engine. When left hand mounted, "LH FRONT" should be visible from front of engine.

(2) Put clean engine oil on the O-ring seal and lip-type seal at assembly.

(3) Pull shutoff lever until governor linkage stops against internal stop. Turn adjustment screw until it makes contact with lever. Turn adjustment screw one complete turn more and tighten locknut.

NOTE: FOR TORQUE VALUES NOT GIVEN, SEE THE FIRST PAGE OF SPECIFICATIONS FOR GENERAL TIGHTENING TORQUES

FUEL INJECTION CONTROL GROUP



(1) Bore of the bearings in the bracket assemblies (after assembly)
..... 21.925 ± 0.015 mm (.8632 ± .0006 in.)

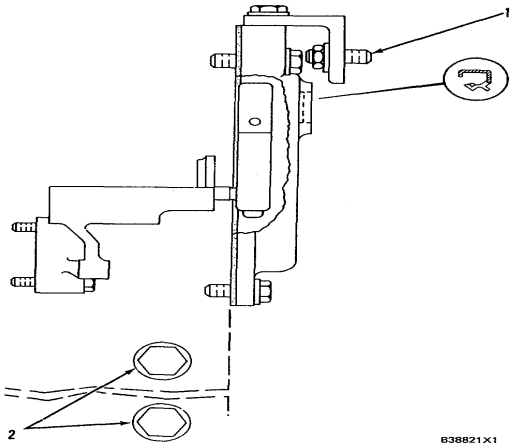
(2) Diameter of the surfaces for the bearings and rod assemblies on the shafts
..... 21.850 ± 0.015 mm (.8602 ± .0006 In)

(3) Bore of the bearings in the two support assemblies (after
assembly}21.925 ± 0.015 mm (.8632 ± .0006 in.)

(4) Clearance between the lever assemblies on the front cross shaft and the side shafts
.....0 80 ± 0.10 mm (.031 ± .004 in.)

(5) Tighten locknuts at each end of bellcrank to a torque of.....8 ± 2 N-m (6 ± 1 lb. ft.)

GOVERNOR FASTENER GROUP (UG8L & 3161 Governors)



(1) Torque for:

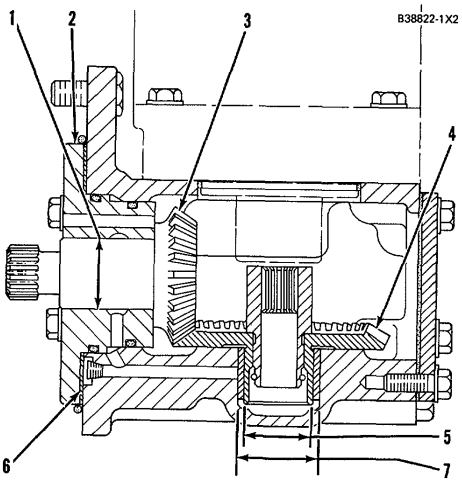
Bolts (3161) ..... 45 ± 7 N-m (32 ± 5 lb. ft.)

Studs (UG8) ..... 30 ± 5 N-m (22 ± 4 lb. ft.)

(2) Torque for plugs ..... 70 ± 15 N-m (50 ± 11 lb. ft.)

GOVERNOR DRIVE

7N1889 & 8N9662 Drive Groups Used With UG8-L Woodward Governors
1W2135 Drive Group Used With Caterpillar 3161 Governors



(1) Diameter of bore in adapter
..... 34.072 ± 0.025 mm (1.3414 ± .0010 in.)

Diameter of shaft on governor drive pinion (3)
..... 34.000 ± 0.013 mm (1.3386 ± .0005 in.)

(2) Adapter.

(3) Governor drive pinion.

(4) Bevel gear.

(5) Diameter of shaft on bevel gear

..... 34.000 + 0.013 mm (1.3386 + .0005 in.)

Diameter of bore in bearing after assembly in drive housing
..... 34.072 ± 0.039 mm (1.3414 ± .0015 in.)

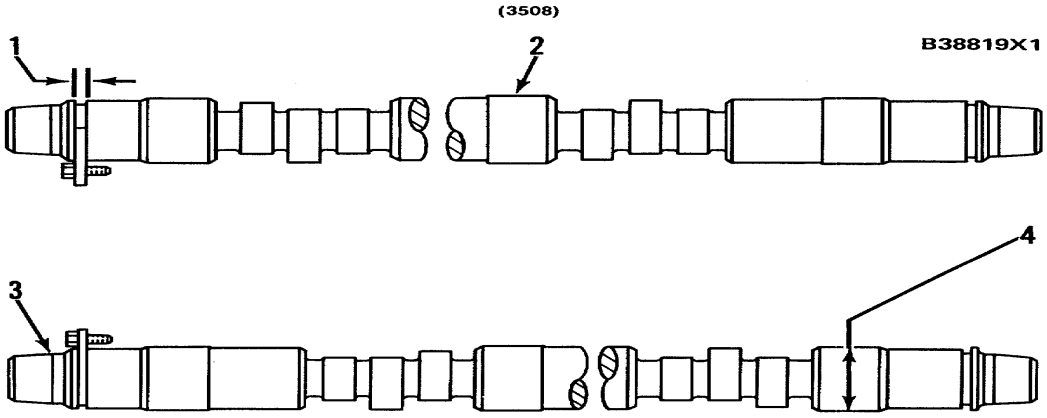
(6) Shims. Use as required to get a gear clearance (backlash) between pinion (3) and gear (4) of .....
0.00 ± 0.050 or -0.025 mm (.0039 +.0020 or -.0010 in.)

(7) Diameter of bore in drive housing
..... 40.432 ± 0.025 mm (1.5918 ± .0010 in.)

Diameter of bearing
..... 40.545 ± 0.013 mm (1.5963 ± .0005 in.)

NOTE: FOR TORQUE VALUES NOT GIVEN, SEE THE FIRST PAGE OF SPECIFICATIONS FOR GENERAL TIGHTENING TORQUES

CAMSHAFTS



(1) Thickness of washer
(new)..... 8.50 ± 0 05 mm (335 ± .002 in.)

Thickness of groove In camshaft
(new)..... 8.75 ± 0 05 mm(344 ± .002 in.)

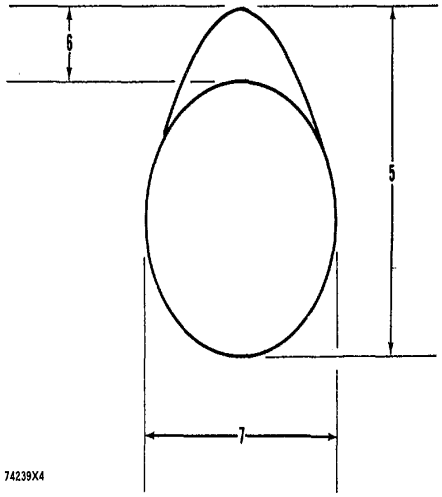
End play for the camshafts
(new)..... 0.15 to 0.35 mm (.006 to .014 in.)

(2) L. H. camshaft.

(3) R. H. camshaft.

(4) Diameter of the surfaces (journals) for the camshaft bearings (new)
..... 85.88 ± 0.02 mm (3.381 ± .001 in.)

Bore in the bearings for the camshafts (after assembly) ..... 86.00 ± 0.06 mm (3.386 ± .002 in.)



(5) Height of camshaft lobes. To find lobe height, use the procedure that follows:

A Measure camshaft lobe height (5).

B Measure base circle (7).

C. Subtract base circle (STEP B) from lobe height (STEP A) The difference is actual lobe lift.

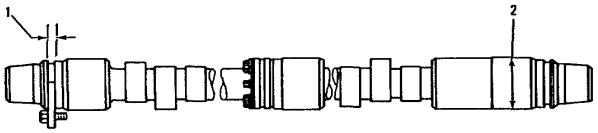
D. Specified camshaft lobe lift (6) is:

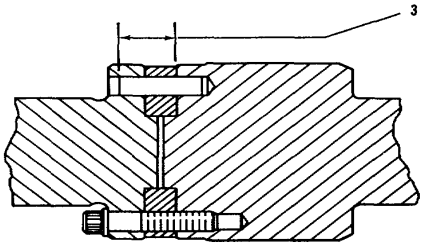
a. Exhaust lobe..... 9.078 mm (3574 in.)

b. Intake lobe..... 9.314 mm (.3667 in.)

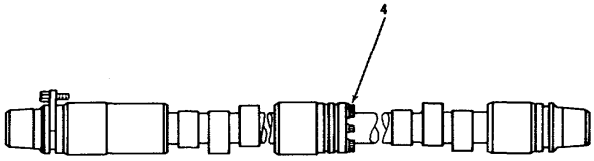
c. Injector lobe..... 13.678 mm (5385 in.)

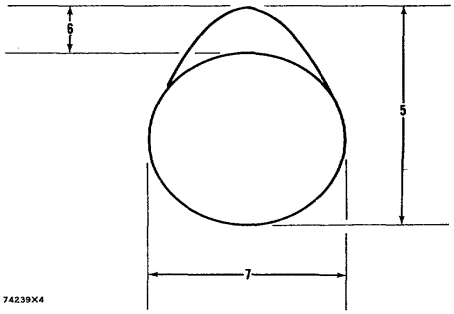
CAMSHAFTS
(3512 and 3516)





A96939X1





74239X4

(1) Thickness of washer
(new)..... 8.50 ± 0.05 mm (.335 ± 002 In.)

Thickness of groove in camshaft
(new)..... 8.75 ± 0005 mm (3441 ± 002 in.)

End play for the camshafts
(new)..... 015 to 0.35 mm (.006 to 014 In)

(2) Diameter of the surfaces (journals) for the camshaft earings
(new)..... 85 88 ± 002 mm (3 381 ± .001 in.)

Bore in the bearings for the camshafts (after assembly) ..... 86.00 ± 0 06 mm (3.386 ± 002 in)

(3) Distance dowel is extended from end of R H rear and L H front camshafts
..... 22.0 ± 0 5 mm (87 ± .02 In)

(4) Clean the threads of the bolts and the contact surfaces of the parts thoroughly Put 9S3263 Thread Lock on the bolt threads and hand tighten only to a torque of ..... 45 ± 7 N•m (33 ± 5 lb ft)

(5) Height of camshaft lobes

To find lobe height, use the procedure that follows:

A Measure camshaft lobe height (5).

B Measure base circle (7)

C. Subtract base circle (STEP B) from lobe height (STEP A). The difference is actual lobe lift.

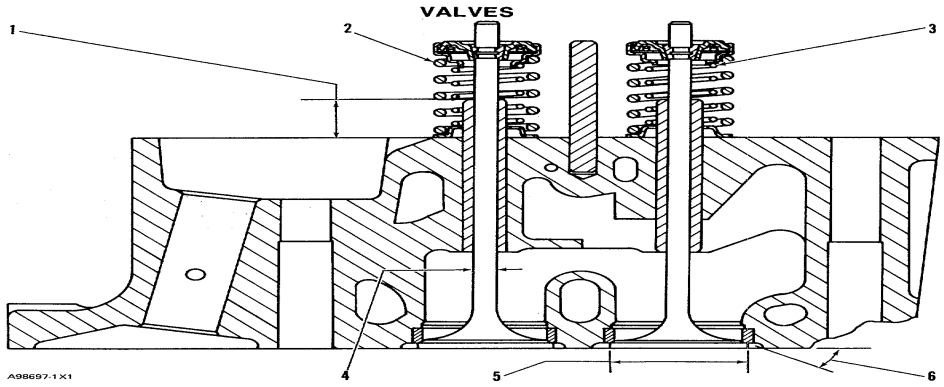
D. Specified camshaft lobe lift (6) is:

a. Exhaust lobe ..... 9 078 mm (.3574 in.)

b. Intake lobe ..... 9.314 mm (.3667 in.)

c. Injector lobe ..... 13 678 mm (.5385 in.)

NOTE: FOR TORQUE VALUES NOT GIVEN, SEE THE FIRST PAGE OF SPECIFICATIONS FOR GENERAL TIGHTENING TORQUES



(1) Height to top of valve guides
..... 26.00 ± 2.00 mm (1.024 ± .079 in.)

(2) 7N1904 Spring (outer) for valve:

Length under test force ..... 56.36 mm (2.219 in.)
Test force .....254 ± 25 N (56.9 ± 5.6 lb.)

Use again minimum load at length under test force .....229 N (51.5 lb.)

Length of spring at valve open position
..... 40.36 mm (1.589 in.)

Use again minimum load at valve open position
.....800 N (180 lb.)

Free length after test ..... 62.50 mm (2.461 in.)

Outside diameter ..... 43.96 mm (1.731 in.)

Spring must not be bent more than
..... 2.18 mm (.086 in.)

(3) 7N1903 Spring (inner) for valve:

Length under test force ..... 45.49 mm (1.791 in.)

Test force .....125 ± 12 N (28 + 2.7 lb.)

Use again minimum load at length
under test force .....113 N (25.4 lb.)

Length of spring at valve
open position ..... 29.49 mm (1.161 in.)

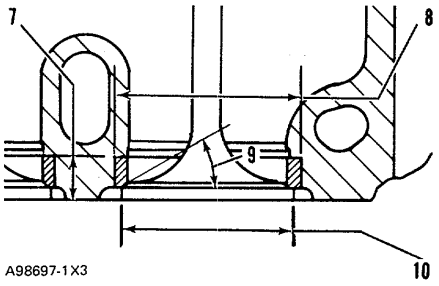
Use again minimum load at valve
open position .....397 N (89.3 lb.)

Free length after test ..... 51.54 mm (2.029 in.)

Outside diameter ..... 29.24 mm (1.151 in.)

Spring must not be bent
more than ..... 1.83 mm (.072 in.)

(4) Diameter of valve stems
(new) .....9.441 ± 0.008 mm (.3717 ± .0003 in.)



Bore in valve guides with guides installed in the head
(new) .....9.487 ± 0.025 mm (.3735 ± .0010 in.)

Use again maximum bore in valve guides with guides installed in the head
.....9.540 mm (.3755 in.)

(5) Diameter of valve
heads .....56.00 ± 0.15 mm (2.205 ± .006 in.)

(6) Angle of valve faces.....291/4 ± 1/4°

(7) Depth of bore in head for valve
seat inserts.....14.00 ± 0.15 .lm (.551 ±.006 in.)

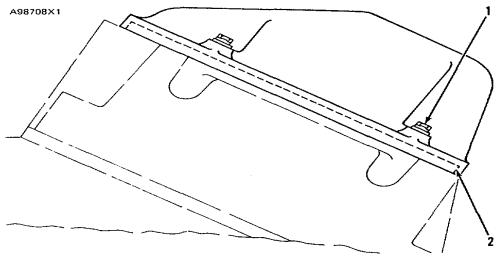
(8) Diameter of valve seat
inserts....60.119 ± 0.015 mm (2.3669 ± .0006 in.)

Bore in head for valve seat
inserts....60.000 ± 0.025 mm (2.3622 ± .0010 in.)

(9) Angle of face of valve seat
inserts.....3014 ± 1/2°

(10) Outside diameter of the face of valve seat
inserts.....55.14 ± 1.48 mm (2.171 ± .058 in.)

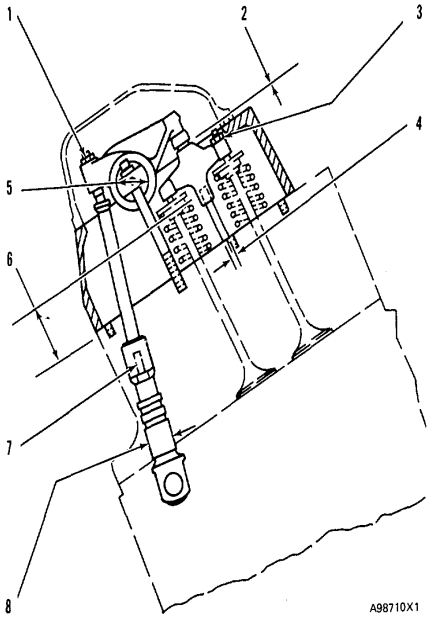
VALVE COVERS



(1) Torque for bolts that hold valve cover in position ..... 20 ± 3 N•m (15 ± 2 lb. ft)

(2) Cut seal to fit at assembly

VALVE ROCKER ARMS, LIFTERS, AND BRIDGES



(1) Torque for valve adjustment screw locknut ..... 70 ± 15 N•m (50 ± 11 lb. ft.)

(2) Clearance for valves:
Intake valves ..... 0.38 mm (.015 in.)

Exhaust valves ..... 0.76 mm (.030 in.)

(3) Torque for bridge adjustment screw locknut ..... 30 ± 4 N•m (22 ± 3 lb. ft.)

(4) Diameter of dowel (new)..... 11.008 ± 0.003 mm (.4334 ± .0001 in.)

Bore In bridge for dowel (new)..... 12.00 ± 0.25 mm (.472 ± .010 in.)

Bore in head for dowel ..... 10.968 ± 0.020 mm (.4318 ± .0008 in.)

(5) Diameter of rocker arm shaft..... 37.084 ± 0.013 mm (1.4600 ± .0005 in.)

Bore In bearings for rocker arm shaft ..... 37.140 ± 0.015 mm (1.4622 ± .0006 in.)

(6) Height to top of dowel ..... 66.5 ± 0.5 mm (2.62 ± .02 in.)

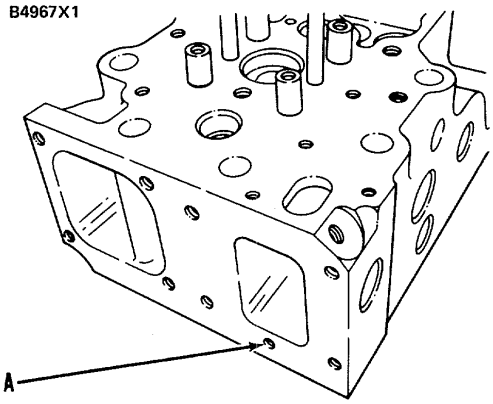
(7) Guide springs must not be used again. Always install new guide springs.

(8) Diameter of valve lifter (new)..... 29.937 ± 0.010 mm (1.1786 ± .0004 in.)

Bore In head for valve lifter..... 30.000 ± 0.025 mm (1 1811 ± .0010 in.)

NOTE: FOR TORQUE VALUES NOT GIVEN, SEE THE FIRST PAGE OF SPECIFICATIONS FOR GENERAL TIGHTENING TORQUES

CYLINDER HEADS



NOTICE

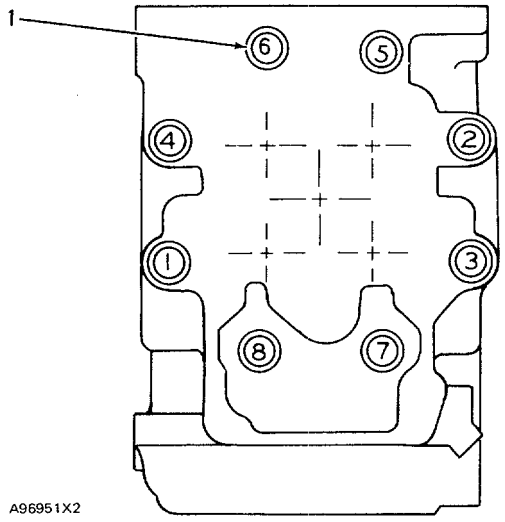
Before installation of this cylinder head on an engine that has water cooled manifolds, the plug at location (A) MUST be removed. If the engine has dry manifolds the plug at location (A) MUST NOT be removed.

(1) Put 5P3931 Anti-Seize Compound on the threads of the bolts and tighten them as follows:

a. Tighten all the bolts to 30 ± 5 N•m (22 ± 4 lb. ft.)

b. Tighten bolts 1 through 8 in number sequence to ..... 270 ± 35 N•m (200 ± 26 lb. ft.)

c. Tighten bolts 1 through 8 In number sequence to ..... 450 ± 20 N•m (330 ± 15 lb. ft.)



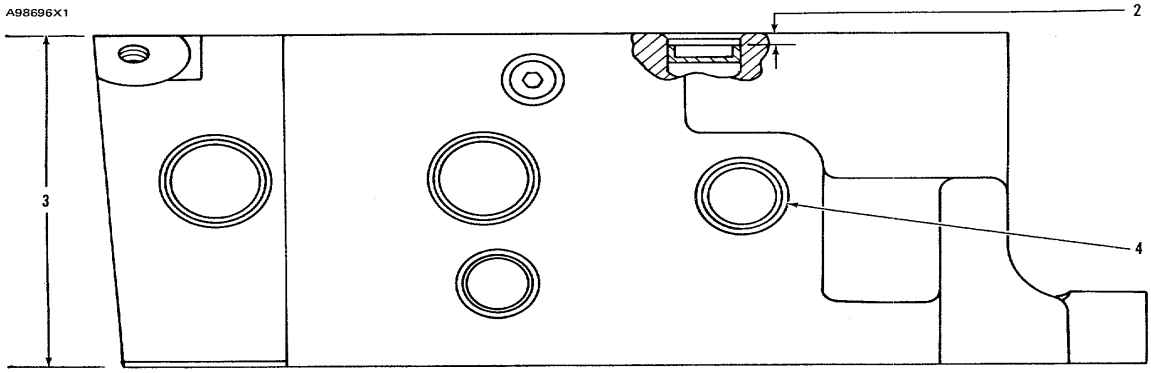
(2) Depth that two plugs are installed in top of cylinder head ..... 9.0 ± 0.5 mm (.35 ± .02 in)

Use 6V1541 Quick Cure Primer and 9S3265 Retaining Compound in the plug bores at assembly.

(3) Height of cylinder head (new)..... 142.00 ± 0.15 mm (5.591 ± .006 in.)

(4) Depth below bottom of chamfer that the seven plugs are installed In cylinder head..... 1.0 ± 0.5 mm (.04 ± .02 In.)

Use 6V1541 Quick Cure Primer and 9S3265 Retaining Compound in the plug bores at assembly.



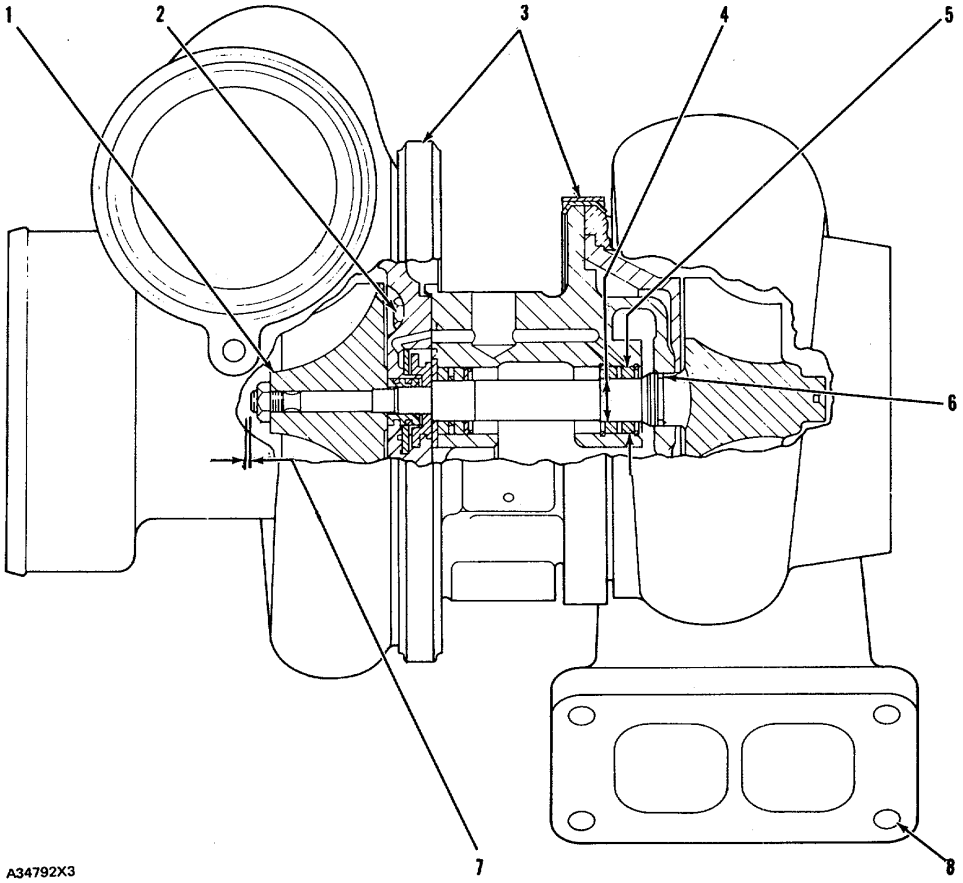
TURBOCHARGER IMPELLER INSTALLATION

INSTALLATION PROCEDURE CHART					
	TURBOCHARGER MODELS				
Step by Step Procedure	T04, T04B, T04C, TW4B, TW4C TL4B, TL4C	TM51 TM54	T12, TV61, TW61, TL61	T18, TV81, TW81, TL81, TV72, TW72, TL72, TV78, TW78, TL78	TV91, TW91, TL91, TV92, TW92, TL92
A. Put impeller on the shaft.					
B. Put a small amount of clean oil on the threads and impeller face area that contacts the nut.					
C. Install and tighten the nut to:	2.25 N•m (20 lb. in.)	5 N•m (50 lb. in.)	17 N•m (13 lb. ft.)	17 N•m (13 lb. ft.)	31 N•m (23 lb. ft.)
NOTICE					
Do not bend or add stress to					
the shaft when the nut is loosened or tightened.					
D. Loosen the nut on the shaft.	•	•			
E. Now tighten the nut to:	•	•	3.5 N•m (30 lb. in.)	3.5 N•m (30 lb. in.)	5 N•m (50 lb. in.)
F. Tighten the nut more:	110°	120°	120°	120°	135°
G. Remove the nut from the shaft.					
H. Use 6V1541 Quick Cure Primer on the threads of the shaft and nut.					
J. Put 9S3265 Retaining Compound on the threads of the shaft and nut.					
K. Install and tighten the nut to:	2.25 N•m (20 lb. in.)	5 N•m (50 lb. in.)	3.5 N•m (30 lb. in.)	3.5 N•m (30 lb. in.)	5 N•m (50 lb. in.)
L. Tighten the nut more:	110°	120°	120°	1200	135°

• Does not apply to these turbochargers.

NOTE: FOR TORQUE VALUES NOT GIVEN, SEE THE FIRST PAGE OF SPECIFICATIONS FOR GENERAL TIGHTENING TORQUES

TURBOCHARGER TV61



(1) Nut for impeller (See TURBOCHARGER IMPELLER INSTALLATION).

NOTICE

Do not bend or add stress to the shaft when the nut is loosened or tightened.

(2) Torque for the bolts that hold the backplate .....10 ± 1 N•m (90 ± 10 lb. in.)

(3) Torque for the clamp bolts.....14.0 ± 1.5 N•m (120 ± 13 lb. in.)
Lightly hit all around clamp with a soft faced hammer and again tighten to.....14 0 +_1.5 N•m (120 +_13 lb. in.)

(4) Bore in the bearings ..... 15.921 to 15.931 mm (.6268 to .6272 in.)

Diameter for the surfaces (journals) on the shaft for the bearings ..... 15.E875 to 15.885 mm (.6250 to .6254 in.)

(5) Bore in the housing .....24.961 to 24.973 mm (.9827 to .9832 in.)

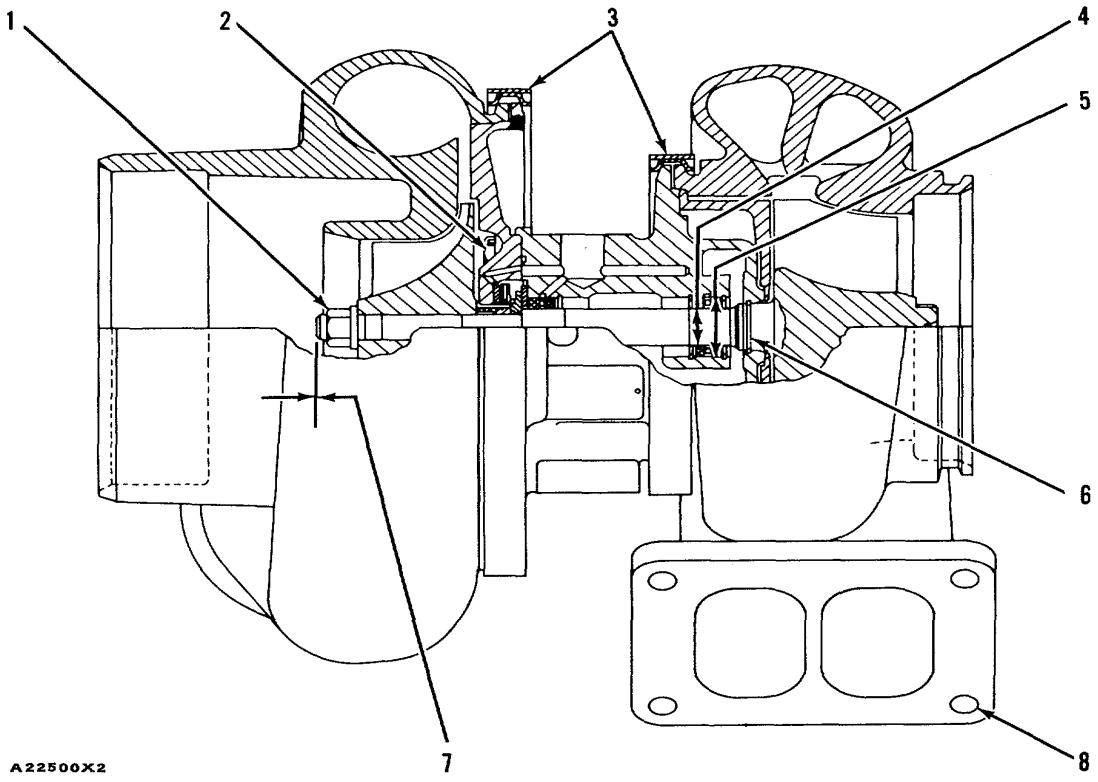
Outside diameter of the bearings .....24.846 to 24.859 mm (.9782 to .9787 in.)

(6) Clearance between the ends of the oil seal ring (when installed in its bore) .....0.20 to 0.38 mm (.008 to .015 in.)

(7) End play for the shaft ..... 0.08 to 0.25 mm (.003 to .010 in.)

(8) Torque for bolts and nuts that hold the turbocharger to the exhaust manifold (put 5P3931 Anti-Seize Compound on the threads) 54 ± 5 N•m (40 • 4 lb. ft.)

TURBOCHARGER TV81



(1) Nut for impeller (See TURBOCHARGER IMPELLER INSTALLATION).

NOTICE

Do not bend or add stress to the shaft when the nut is loosened or tightened.

(2) Torque for the bolts that hold the backplate
.....10 ± 1 N•m (90 ± 10 lb. in.)

(3) Torque for the clamp
bolts.....14.0 ± 1.5 N•m (120 ± 13 lb. in.)
Lightly hit all around clamp with a soft faced hammer and again tighten to.....14.0 ± 1.5 N•m (120 ± 13 lb. in)

(4) Bore in the bearings
..... 15.921 to 15.931 mm (.6268 to .6272 in.)

Diameter for the surfaces (journals) on the shaft for the bearings
.....15.875 to 15.885 mm (.6250 to .6254 in.)

(5) Bore in the housing
.....24.961 to 24.973 mm (.9827 to .9832 in

Outside diameter of the bearings
.....24.846 to 24.859 mm (.9782 to .9787 in.)

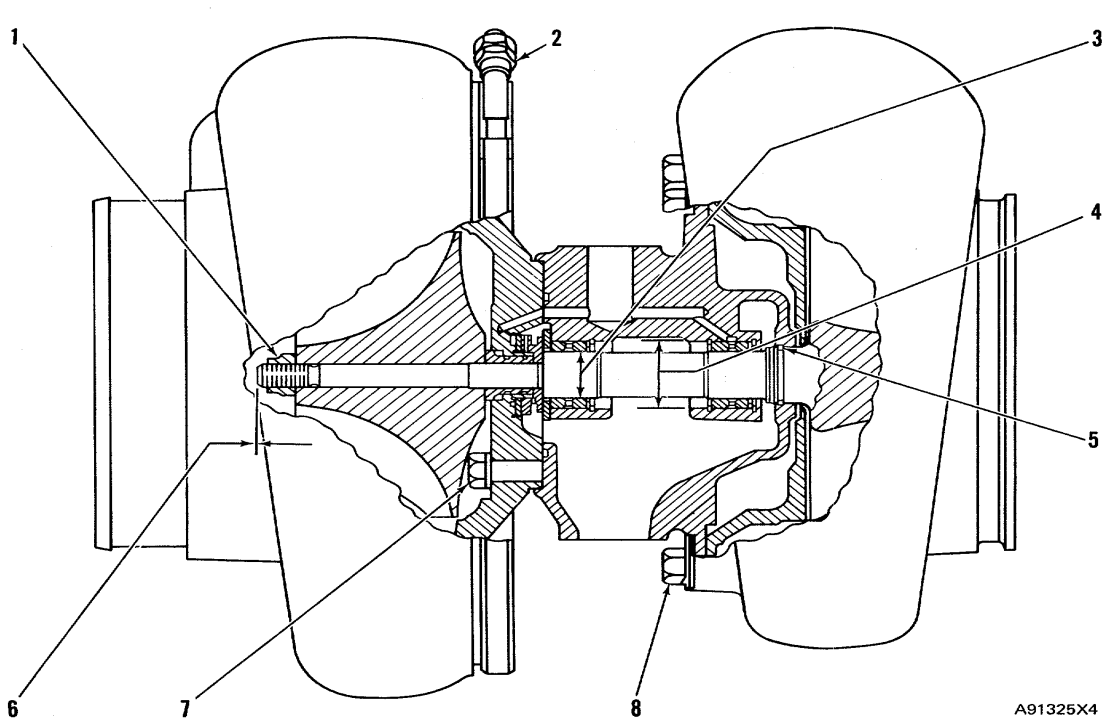
(6) Clearance between the ends of the oil seal ring (when installed in its bore)
.....0.20 to 0.38 mm (.008 to .015 in.)

(7) End play for the shaft
.....0.08 to 0.25 mm (.003 to .010 in.)

(8) Torque for bolts and nuts that hold the turbocharger to the exhaust manifold (put 5P3931 Anti-Seize Compound on the threads)
.....54 ± 5 N•m (40 ± 4 lb ft.)

NOTE: FOR TORQUE VALUES NOT GIVEN, SEE THE FIRST PAGE OF SPECIFICATIONS FOR GENERAL TIGHTENING TORQUES

TURBOCHARGER TV91



(1) Nut for impeller (See TURBOCHARGER IMPELLER INSTALLATION).

NOTICE

Do not bend or add stress to the shaft when the nut is loosened or tightened.

(2) Torque for the clamp bolt..... 14.0 ± 1.5 N•m (10 ± 1 lb. ft.)
Hit lightly all around clamp with a soft faced hammer and again tighten to
..... 14.0 ± 1.5 N•m (10 ± 1 lb. ft.)

(3) Bore in the bearings
..... 21.585 to 21.595 mm (.8498 to .8502 in.)

Diameter of the surfaces (journals) on the shaft
..... 21.539 to 21.549 mm (.8480 to .8484 in.)

(4) Bore in the housing
..... 30.594 to 30.607 mm (1.2045 to 1.2050 in.)

Outside diameter of bearings
..... 30.467 to 30.480 mm (1.1995 to 1.2000 in.)

(5) Clearance between the ends of oil seal ring (when installed in its bore
.....0.20 to 0.38 mm (.008 to .015 in.)

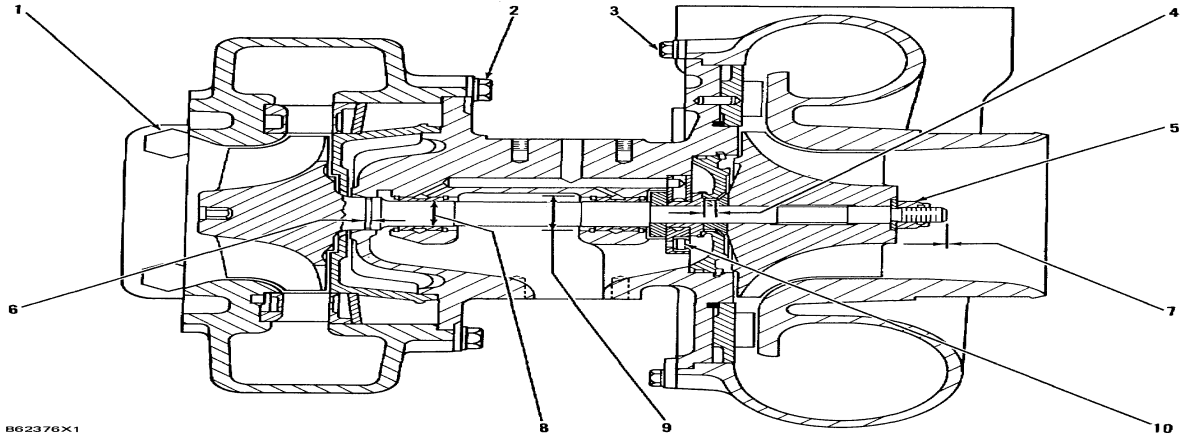
(6) End play for the shaft
.....0.165 ± 0.063 mm (.0065 ± .0025 in.)

(7) Torque for the bolts that hold the backplate
.....40 ± 2 N•m (30 ± 1 lb. ft.)

(8) Torque for the bolts that hold the turbine housing to the cartridge housing (put 5P3931 Anti-Seize Cornpound on the threads
.....40 ± 2 N•m (30 ± 1 lb. ft.)

Torque for the bolts and nuts that hold the turbocharger to the exhaust manifold (put 5P3931 Anti-Seize Compound on the threads
.....54 ± 5 N•m (40 ± 4 lb. ft.)

TURBOCHARGER C153



(1) Torque for the bolts and nuts that hold the turbocharger to the exhaust manifold (put 5P3931 Anti-Seize Compound on threads)..... 270 ± 25 N-m (200 ± 18 lb. ft.)

(2) Torque for the bolts that hold the turbine housing to the cartridge housing..... 48 ± 3 N•m (35 ± 2 lb. ft.)

(3) Torque for the bolts that hold the compressor housing to the cartridge housing (put 5P3931 Anti-Seize Compound on the threads) ..... 25 ± 5 N-m (18 ±4 lb. ft.)

(4) Width of oil seal ring at compressor end.....2.500 ± 0.010 mm (.0984 ± .0004 in.)

Width of oil seal ring groove at compressor end..... 2.635 ±0.035 mm (.1037 ± .0014 in.)

(5) Turbocharger impeller installation:

a. Put impeller on the shaft.

b. Put a small amount of 2P2506 Thread Lubricant on the threads and impeller face that will be under the nut.

c. Tighten the nut to..... 95 ±5 N-m (70 ±4 lb. ft.)

NOTICE

Do not bend or add stress to the shaft when the nut Is loosened or tightened.

(6) Width of oil seal ring at turbine end .....2.500 ± 0.010 mm (.0984 ±.0004 in.)

Width of oil seal ring groove at turbine end .....2.550 + 0.030 - 0.010 mm (.1004 + .0012 - .0004 in.)

(7) End play for the shaft ..... 0.090 to 0.130 mm (.0035 to .0051 mm)

(8) Bore in the bearings..... 24.020 +0.010-0.0mm (.9457 + .0004 - .00 in.)

Diameter of the surfaces (journals) on the shaft .....24.000 + 0.0 - 0.009 mm (.9449 + .00 - .0004 in.)

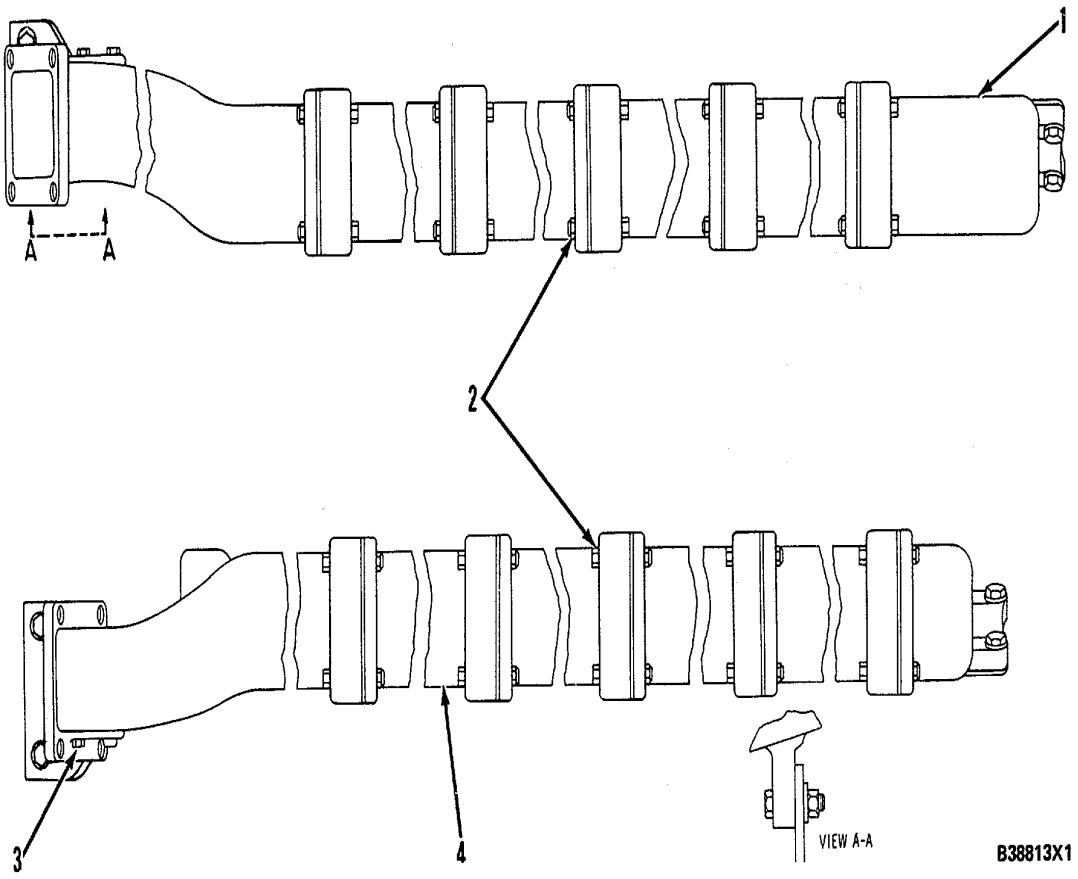
(9) Bore in the housing .....32.000 + 0.016 - 0.0 mm (1.2598 + .0006 - .00 in.)

Outside diameter of the bearings ....31.890 + 0.0 - 0.010 mm (1.2555 + .00 - .0004 in.)

(10) Torque for the three bolts that hold the thrust bearing..... 10 ± 2 N•m (7 ±1 lb. ft.)

NOTE: FOR TORQUE VALUES NOT GIVEN, SEE THE FIRST PAGE OF SPECIFICATIONS FOR GENERAL TIGHTENING TORQUES

EXHAUST MANIFOLDS



(3512 EXHAUST MANIFOLDS ILLUSTRATED)

(1) Left exhaust manifolds.

(2) Put 5P3931 Anti-Seize Compound on the threads of all exhaust manifold bolts, nuts and plugs (3).

Torque for all exhaust manifold
bolts and nuts ..... 45 ±7 N-m (32 ±5 lb. ft.)

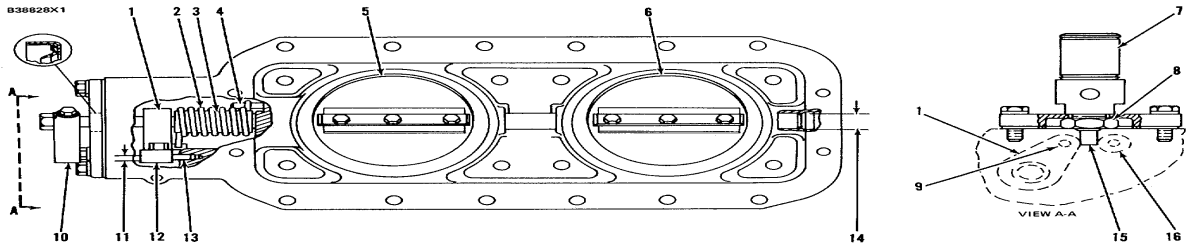
(3) 5B7890 Plugs.

Torque for exhaust manifold
plugs ..... 35 N•m (25 lb. ft.)

(4) Right exhaust manifolds

AIR INTAKE SHUTOFF

(5N9060)



(1) Install shaft assembly in housing as follows

a. Install spacer (3) and spring (2) on shaft assembly (1).
b. Install the assembly in the housing Turn spring (2) until It engages correctly with pin (4)

c Install handle (10) on the shaft assembly (1) Turn shaft assembly (1) upward and install pin (13) so handle (10) can rest on pin (13).

d. With the shaft assembly and handle (10) In contact with pin (13), Install plate assemblies (5) and (6) on the shaft assembly.
e. Remove pin (13) to release the handle and let plate assemblies (5) and (6) move to the "shutoff" position. A 0.076 mm (.003 in) feeler gauge should not pass between each plate assembly and the housing.

f. Remove handle (10) and Install spacer assembly (12), pin, (13), the gasket, cover assembly and handle (10).

(2) Spring

(3) Spacer for spring (2).

Bore In spacer for shaft.. 20 80 ±0 25 mm (819 +.010 in)
Diameter of shaft..... 18.94 ±0.02 mm (.746 + .001 In)

(4) Pin

(5) Plate assembly

(6) Plate assembly

(7) Hydraulic cylinder must be Installed before the air shutoff can be installed on the engine. Put the air shutoff group in the "open" position and install the gasket, flange and cylinder with cylinder shaft (15) between the spacer assembly in the shaft lever and spacer assembly (16). The bolts that hold the unit to the aftercooler housing can now be installed.

(8) Torque for nut that holds cylinder to flange .....45 ±7 N•m (33 ± 5 lb ft

(9) Diameter of pin6.299 ±0.008 mm (2480 ±.0003 In)

Bore in spacer bushing for pin (after assembly) ..... 6.314 ±0.011 mm (2486 ±.0004 n)

Bore in spacer for bushing. .....7.938 ±0.013 mm (.3125 ±.0005 In.)

(10) Handle

(11) Diameter of pin (13) ..... .6.299 ±.0.008 mm (2480 ±.0003 in)

Bore in housing for pin ..... 6.408 ±0.051 mm (.2523 ±.0020 in)

Bore in spacer bushing for pin (after assembly) ..... 6.314 ±0.011 mm (.2486 ±.0004 in.)

Bore in spacer for bushing .....7.938 ± 0.013 mm (.3125±.0005 in)

(12) Spacer.

(13) Pin.

(14) Diameter of shaft ..... 18.94 ±0.02 mm (.746 ±.001 In)
Inside diameter of bushings for shaft ..... 19.050 ±0.044 mm (.7500 ±.0017 In)

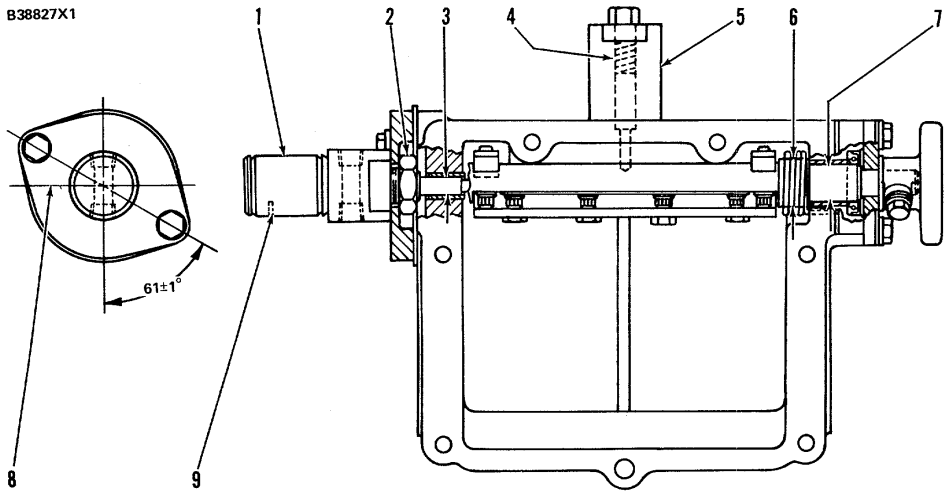
(15) Hydraulic cylinder shaft

(16) Spacer assembly

NOTE: FOR TORQUE VALUES NOT GIVEN, SEE THE FIRST PAGE OF SPECIFICATIONS FOR GENERAL TIGHTENING TORQUES

AIR INTAKE SHUTOFF

(2W7163)



(1) Hydraulic shutoff cylinder. Make an alignment of cylinder port and vent hole (9) in a vertical downward position at assembly.

(2) Torque for nut that holds cylinder (1) to the flange ..... 45 ±7 N•m (33 ±5 lb. ft.)

(3) Diameter of cylinder rod ..... 7.920 ± 0.013 mm (.3118 ± .0005 in.)

Bore in bushing after assembly ..... 7.996 ± 0.044 mm (.3148 ± .0017 in.)

Bore in housing for bushing ..... 9.525 ± 0.013 mm (.3750 ±.0005 in.)
Install bushing with split along centerline (8) toward front or rear.

(4) 2V244 Spring for shutoff actuator pin:

Length under test force ..... 29.2 mm (1.15 in.)
Test force ..... 8.9 ± 0.7 N (2.00 ±.16 lb.)
Free length after test ..... 54.6 mm (2.15 in.)
Outside diameter ..... 9.04 mm (.356 in.)

(5) Torque for carrier (put 2P2506 Thread Lubricant on the threads) ..... 70 ± 10 N•m (50 ± 7 lb. ft.)

(6) Bore in spring bushing..... 19.30 ± 0.25 mm (.760 ±.010 in.)

Diameter of shaft ..... 18.97 ±0.02 mm (.747± .001 in.)

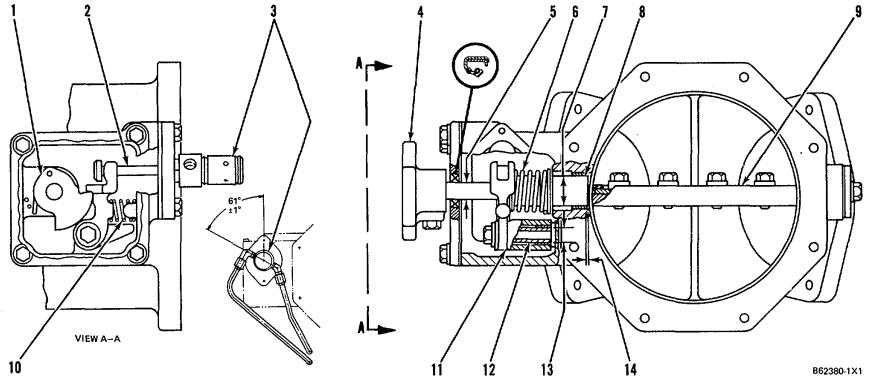
(7) Diameter of shaft ..... 18.97 ±0.02 mm (.747 ± .001 in.)

Bore in two shaft bushings (after assembly) ..... 19.050 ±0.044 mm (.7500 + .0017 in.)

Bore in housing for bushings ..... .22.205 ±0.013 mm (.8742 0005 in.)

AIR INTAKE SHUTOFF

(2W5216)



(1) Latch.

(2) Shutoff cylinder rod.

(3) Install shutoff cylinder as follows:

a. Assemble shutoff cylinder on the flange at the angle shown.

b. Tighten the nut that holds the shutoff cylinder to the flange to a torque of.... 45 ± 7 N•m (33 ±5 lb. ft.)

c. Install the flange on the air shutoff housing. Make sure cylinder rod (2) is engaged in the notch of lever (11).

NOTE: The cylinder vent hole, between the ports, must be in the downward position.

(4) Knob.

(5) Diameter of shaft assembly at seal ..... 15.88 ±0.05 mm (.625 ±.002 in.)

(6) Air shutoff spring.

(7) Diameter of shaft assembly ..... 24.88 ±0.02 mm (.980 ±.001 in.)

Bore in bushings for shaft assembly (after assembly)..... 25.017 ±0.040 mm (1.0035 ±0016 in.)

Bores in housing for bearings ..... 27.997 ±0.010 mm (1.1230 ±.0004 in.)

(8) Shaft assembly.

(9) Plate assembly.

NOTE: With plate assembly (9) in closed (shutoff) position, a 0.8 mm (.03 in.) feeler gauge must not pass between the plate assembly and the housing bore at any position.

(10) Lever return spring.

(11) Lever.

(12) Sleeve.

(13) Diameter of sleeve..... 4.945 ± 0.009 mm (.5995 ±0004 in.)

Bore in bushing (after assembly).....5.024 ±0.034 mm (.6026 ±.0014 in.)

Bore in lever for

bushing.....7.009 ±0.009 mm (.6823 ±.0004 in.)

NOTE : Install both bushings to a dimension of 0.8 ±0.3 mm (.03 ±.01 in.) below the surface of lever ends.

(14) Dimension to install end of two bushings from machined

housing bore ...0.35 ±0.15 mm (.014 ±.006 in.)

NOTE: FOR TORQUE VALUES NOT GIVEN, SEE THE FIRST PAGE OF SPECIFICATIONS FOR GENERAL TIGHTENING TORQUES

OIL PUMP
(2W5474)

Rotation of drive gear (as seen from drive end) ..... Clockwise

(1) Length of gears
(new) ..... 54.000 ±0.015 mm (2.1260 ±.0006 in.)

Depth of bores for gears
(new) ..... 54.150 ±0.020 mm (2.1319 ±.0008 in.)

(2) Diameter of gear shafts (new).... 31.742 ±0.008 mm (1.2497 ±.0003 in.)

Bore in bearings for gear shafts (after assembly) ..... 31.811 ±0.013 mm (1.2524 ±.0005 in.)

(3) Distance dowels extend from cover. ..... 6.0 ±0.5 mm (.24 ±.02 in.)

(4) Distance from the end of the idler shafts to gear faces..... 34.0 ±0.5 mm (1.34 ±.02 in.)

(5) Distance from the end of the drive shaft to gear face. ... 47.0 ±0.5 mm (1.85 ±.02 in.)

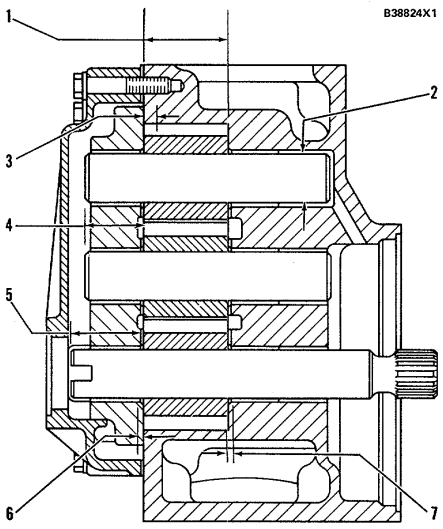
(6) Depth that bearings are installed in cover ..... 1.5 ±0.5 mm (.06 ±.02 in.)

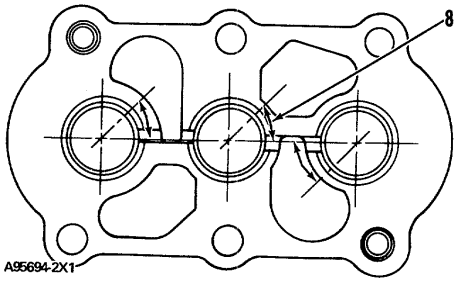
(7) Depth that bearings are installed in housing ..... 1.5 ±0.5 mm (.06 ±.02 in.)

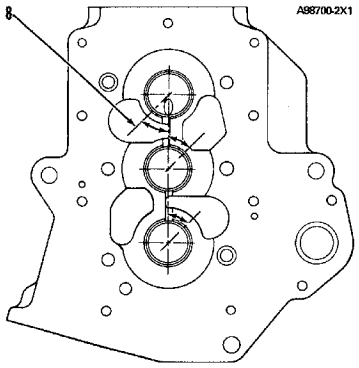
(8) The location of each bearing junction must be as shown. Position bearing junctions from the centerline through the bearing bores to an angle of ..... .45 + 15°

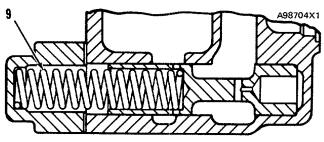
(9) 2S2760 Spring (oil pressure relief):

Length under test force.....117.9 mm (4.64 in.)
Test force ..... 490 ±27 N (110 ±6 lb.)
Free length after test ..... 52.9 mm (6.02 in.)
Outside diameter .... 27.00 mm (1.063 in.)









OIL PUMP (2W5477)

Rotation of drive gear (as seen from drive end) ..... Clockwise

(1) Length of gears (new)..... 84.000 ±0.015 mm (3.3071 ±.0006 in.)

Depth of bores for gears (new) ..... 84.150 ±0.020 mm (3.3130 ±.0008 in.)

(2) Diameter of gear shafts (new).... 31.742 ±0.008 mm (1.2497 ±.0003 in.)
Bore in bearings for gear shafts (after assembly) ..... 31.811 ±0.013 mm (1.2524 ±.0005 in.)

(3) Distance dowels extend from cover ..... 6.0 ±0.5 mm (.24 ±.02 in.)

(4) Distance from the end of the idler shafts to gear faces..... 34.0 ±0.5 mm (1.34 ±.02 in.)

(5) Distance from the end of the drive shaft to gear face .... 47.0 ±0.5 mm (1.85 ±.02 in.)

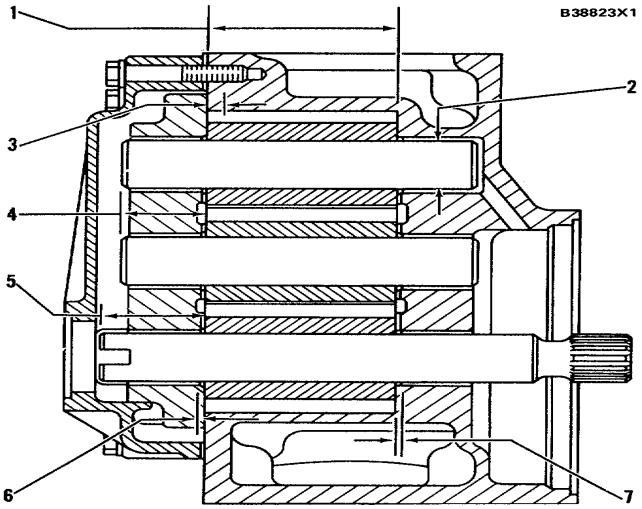
(6) Depth that bearings are installed in cover ..... 1.5 ±0.5 mm (.06 ±.02 in.)

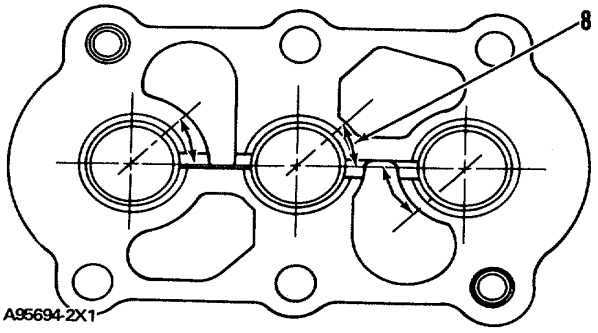
(7) Depth that bearings are installed in housing. ..... 1.5 ± 0.5 mm (.06 ±.02 in.)

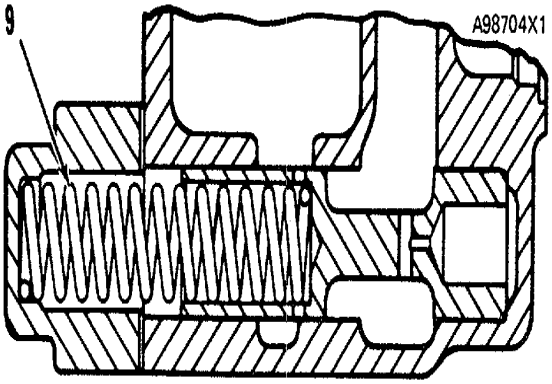
(8) The location of each bearing junction must be as shown. Position bearing junctions from the centerline through the bearing bores to an angle of .. 45 ±15°

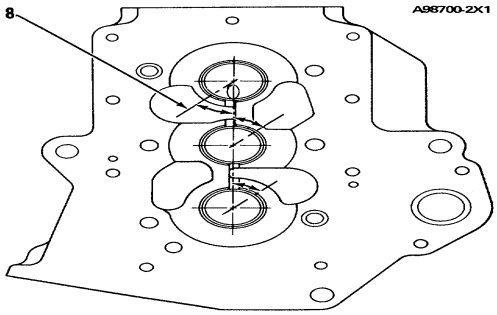
(9) 2S2760 Spring (oil pressure relief):

Length under test force. ..... 117.9 mm (4.64 in.)
Test force ..... .490 ±27 N (110 ±6 lb.)
Free length after test ..... 52.9 mm (6.02 in.)
Outside diameter. ..... 27.00 mm (1.063 in.)



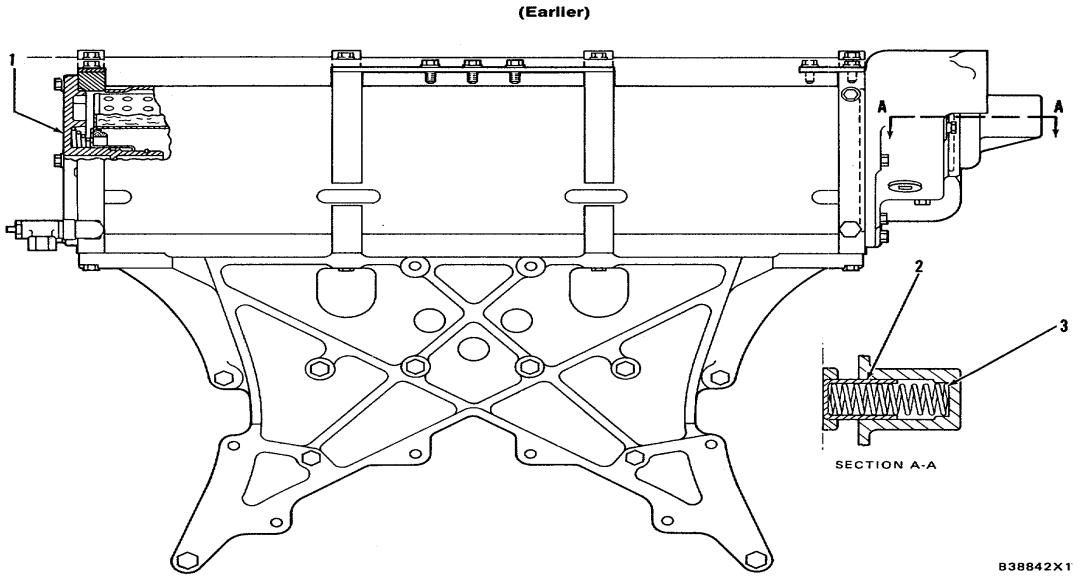






NOTE: FOR TORQUE VALUES NOT GIVEN, SEE THE FIRST 27 PAGE OF SPECIFICATIONS FOR GENERAL TIGHTENING TORQUES

OIL FILTER BYPASS VALVE



(1) Oil filter housing.

(2) Oil filter bypass valve must start to open at ..... 110 ±20 kPa (16 ±3 psi)

and fully open at ..... 325 ±20 kPa (47 ±3 psi)

(3) 3N4316 Spring for the filter bypass valve:

Length under test force. ..... 70.6 mm (2.78 in.)

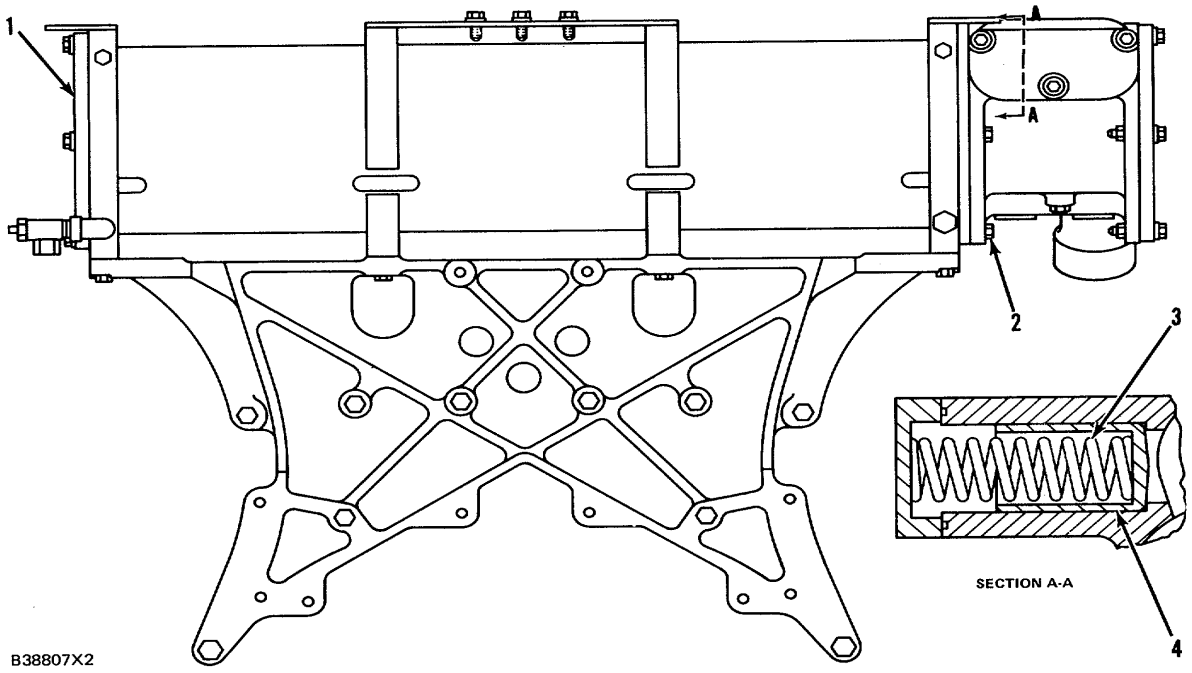
Test force. ..... 155 ±7.5 N (35.0 ±1.7 lb.)

Free length after test ..... 126.2 mm (4.97 in.)

Outside diameter. ..... 28.83 mm (1.135 in.)

OIL FILTER BYPASS VALVE

(Later)



(1) Oil filter housing.

(2) Torque for three bolts that hold bypass housing to filter housing..... 55 ±7 N•m (41 ±5 lb. ft.)

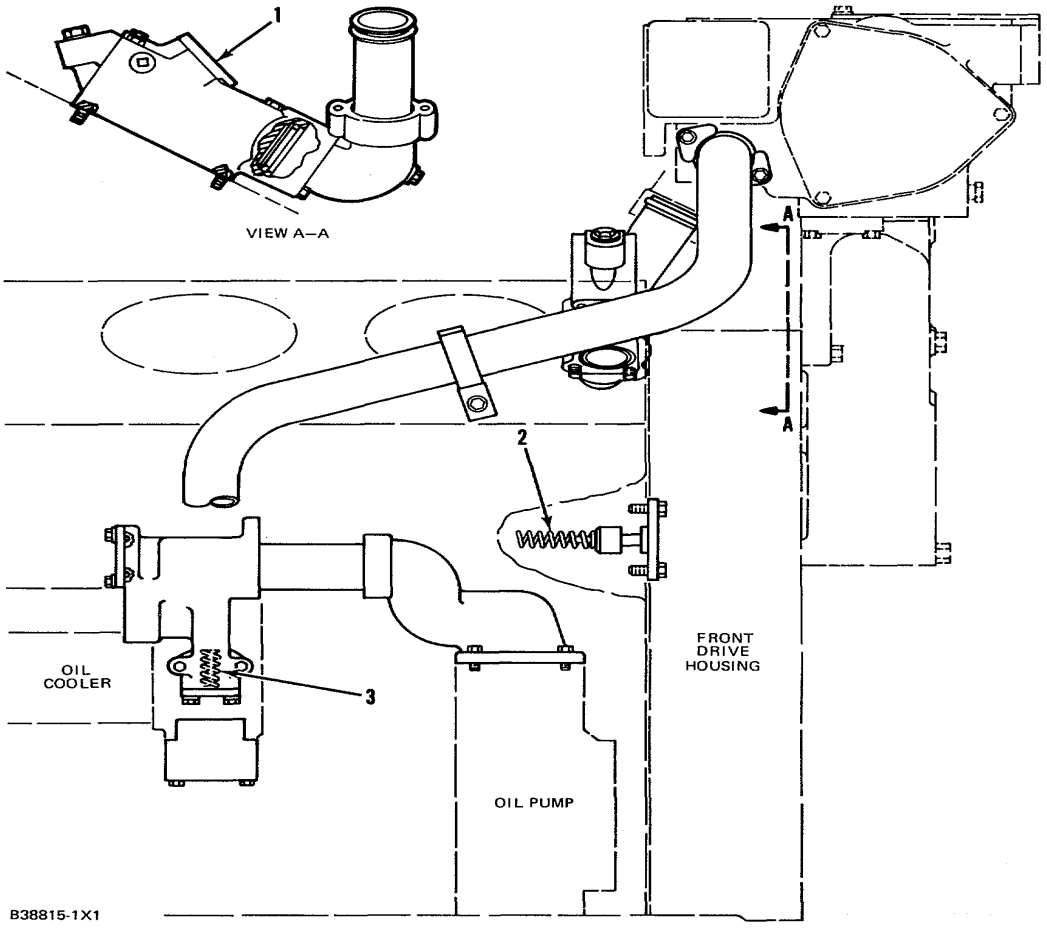
(3) 2W1635 Spring for the filter bypass valve:

Length under test force ..... 102 mm (4.02 in.)
Test force ..... 518 N (115 lb.)
Free length after test ..... 143.4 mm (5.65 in.)
Outside diameter ..... 37.25 mm (1.470 in.)

(4) Oil filter bypass valve must start to
open at ..... 287 ± 7 kPa (42 ±1 psi)
and fully open at. ..... 480 ±7 kPa (70 + 1 psi)

NOTE: FOR TORQUE VALUES NOT GIVEN, SEE THE FIRST 29 PAGE OF SPECIFICATIONS FOR GENERAL TIGHTENING TORQUES

OIL COOLER BYPASS AND COOLING JET SEQUENCE VALVES



(1) Tighten plug in elbow to a torque of. ..... 100 ± 15 N-m (75 ± 11 lb. ft.)

(2) 6B9202 Spring for cooling jet sequence valve (one at each end of block):

Length under test force ..... 68.3 mm (2.69 in.)

Test force ..... 85 to 102 N (19 to 23 lb.)

Free length after test ..... 112.7 mm (4.44 in.)

Outside diameter ..... 24.60 mm (.969 in.)

Both cooling jet sequence valves must start to open at a pressure difference of .. 130 ± 30 kPa (19 ±4.5 psi) and must be fully open at ..... 200 ±30 kPa (29 ± 4.5 psi)

(3) 8M3182 Spring for oil cooler bypass valve:

Length under test force ..... 63.5 mm (2.5 in.)

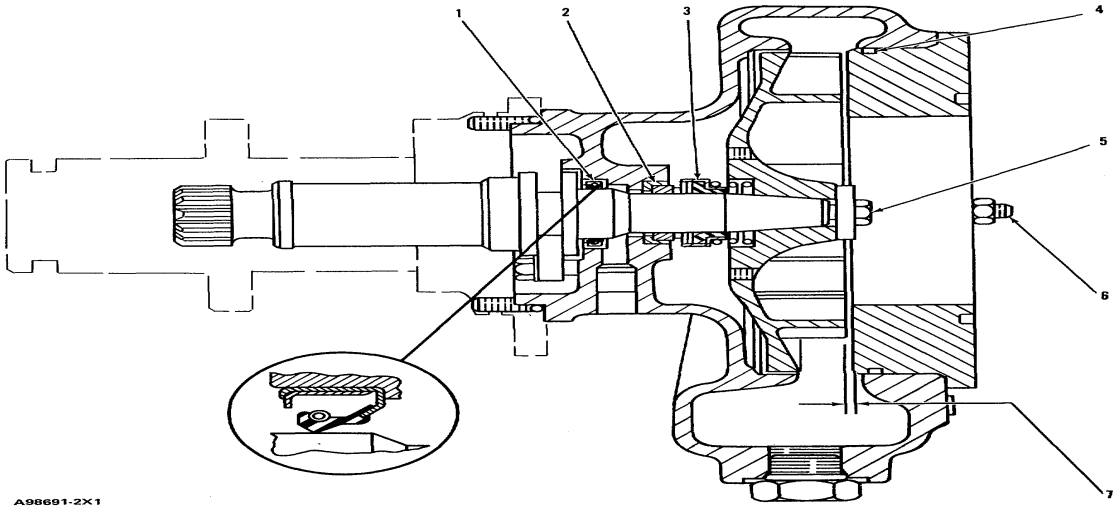
Test force .....40 N (9 lb.)

Free length after test. ..... 1.7 mm (3.61 in.)

Outside diameter ..... 20.60 mm (.810 in.)

Oil cooler bypass valve must open with a pressure difference of ..... 180 ± 20 kPa (26 ± 3 psi)

WATER PUMP



EARLIER WATER PUMP ILLUSTRATED

(1) Oil seal. Put glycerin or clean engine oil on the lip of the seal. Assemble with the lip toward the splined end of the pump shaft as shown.

(2) Ceramic ring and rubber water seal.

a. Put clean water on the seal and ring.

b. Use the seal installation tool (part of the replacement seal assembly) and hand pressure to install the rubber seal and ceramic ring as a unit in the housing bore. Make sure the identification groove of the ceramic ring is installed inside the rubber seal.

(3) Seal Assembly:

a. Remove the spring from the seal assembly.

b. Put clean water inside the seal assembly.

c. Use the seal installation tool (part of the replacement seal assembly) and hand pressure to install the seal assembly on the shaft until the carbon face makes light contact with the shiny face of the ceramic seal.

d. Install the spring.

(4) Seal. Put a light amount of clean engine oil in the bore for the seal.

(5) Earlier water pumps:

Torque for bolt that holds impeller .....90 ± 15 N•m (65 ± 11 lb. ft.)

Hit bolt with hammer and again tighten bolt to..... 90 ± 15 N•m (65 ± 11 lb. ft.)

*Later water pumps:

Torque for nut that holds impeller .....200 ± 25 N•m (150 ± 18 lb. ft.)

(6) Torque for the three studs in pump housing .....27 ± 4 N•m (20 ± 3 lb. ft.)

(7) Clearance between impeller and cover:

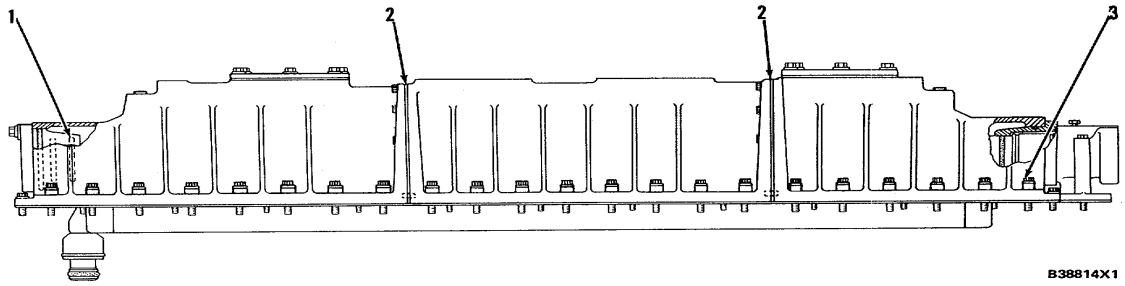
Earlier water pumps ..... 0.12 to 0.89 mm (.005 to .035 in.)

*Later water pumps ..... 0.62 to 1.39 mm (.024 to .055 in.)

*NOTE: Later water pumps have a nut that holds the impeller on the pump shaft.

NOTE: FOR TORQUE VALUES NOT GIVEN, SEE THE FIRST PAGE OF SPECIFICATIONS FOR GENERAL TIGHTENING TORQUES

AFTERCOOLER



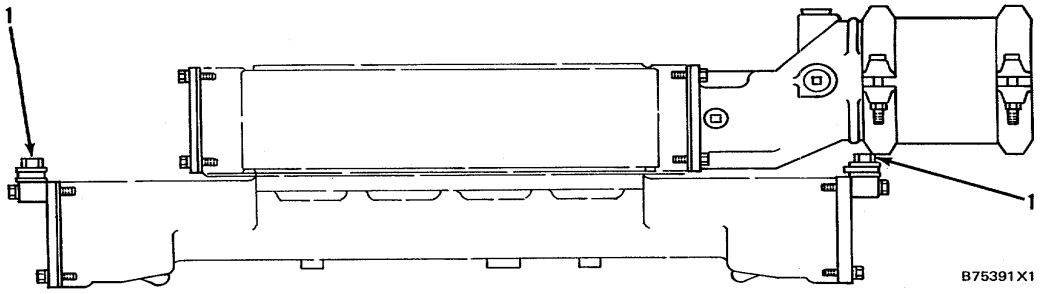
(3512 AFTERCOOLER ILLUSTRATED)

(1) Put clean engine oil or glycerin on all O-ring seals and in their bores at assembly.

(2) Cut the ends of the gaskets even with the bottom of the housings for assembly.

(3) Torque for all the bolts that hold the aftercooler housings to the cylinder block.....55 ±7 N•m (41 ±5 lb. ft.)

WATER CONNECTION GROUP - OUTLET

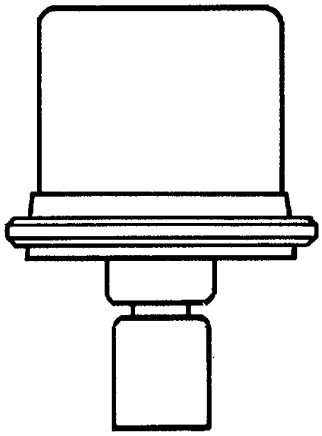


(1) Tighten bolts to a torque of...135 ±15 N•m (100 ± 11 lb. ft.)

WATER TEMPERATURE REGULATORS

Temperature when completely open ..... 2° C (197° F)

Minimum opening distance at
92° C (197° F) ..... 9 53 mm (.375 in.)



B75390X1

V-BELT TENSION CHART										
					BELT TENSION "INITIAL"*		BELT TENSION "USED"**		BORROUGHS GAGUE NUMBERS	
BELT SIZE	WIDTH BELT TOP		WIDTH TOP OF PULLEY GROOVE		GAUGE READING		GAUGE READING			
	mm	in.	mm.	in.	N	lb.	N	lb.	OLD GUAGE NO.	NEW GAUFE NO
3/8	10.72	.422	9.65	.380	445±22	100±5	400±22	90±5	BT-33-73F	BT-33-95
½	13.89	.547	12.70	.500	534±22	120±5	400±44	90±10	BT-33-96-4-16	BT-33-95
5V	15.88	.625	15.24	.600	534±22	120±5	400±44	90±10	BT-33-72-4-15	BT-33-72C
11/16	17.48	.688	15.88	.625	534±22	120±5	400±44	90±10	BT-33-72-4-15	BT-33-72C
¾	19.05	.750	17.53	.690	534±22	120±5	400±44	90±10	BT-33-72-4-15	BT-33-72C
15/16	23.83	.938	22.30	.878	534±22	120±5	400±44	90±10	BT-33-72-4-15	BT-33-72C
MEASURE TENSION OF BELT FARTHEST FROM THE ENGINE										
"'INITIAL" BELT TENSION is for a new belt. **""USED" BELT TENSION is for a belt which has more than 30 minutes of operation at rated speed of engine. A10232-1 X1										

NOTE: FOR TORQUE VALUES NOT GIVEN, SEE THE FIRST 33 PAGE OF SPECIFICATIONS FOR GENERAL TIGHTENING TORQUES

CYLINDER BLOCK

(1) Thickness of spacer plates.....2.313 ±0.025 mm (.4848 ± .0010 in.)

(2) Thickness of gasket between the cylinder block and spacer plates ..... 0.208 ± 0.025 mm (.0082 ± .0010 in.)

(3) Distance all dowels extend above block face.....20.0 ± 0.5 mm (.79 ±.02 in.)

(4) Torque for plugs....100 ± 15 N-m (75 ± 11 lb. ft.)

(5) Make reference to CYLINDER LINER PROJECTION, for the height of the liner.

(6) Bore in the block for the camshaft bearings .....92.000 ± 0.020 mm (3.6220 ± .0008 in.)

(7) Camshaft bearing junction.

(8) Centerline through oil holes in camshaft bearings. Oil holes must be positioned from horizontal at angle "X" 20 ± 5°

NOTE: All bearing oil hole centerlines (8) and bearing junctions (7) must be in position shown for each side of cylinder block.

(9) Dimension (new) from centerline of crankshaft bearing bore to top of block (top deck) ..... 586.00 mm (23.071 in.)

(10) Width of main bearing cap.....340.000 ± 0.015 mm (13.3858 ±. 0006 in.)

Width of cylinder block for main bearing cap.....340.000 ± 0.015 mm (13.3858 ± .0006 in.)

Clearance between the sides of the main bearing cap and the cylinder block.....0.030 mm (.0012 in.) tight to 0.030 mm (.0012 In.) loose

(11) Bore in the block for the main bearings:

Standard, original size (new).....69.742 ± 0.020 mm (6.6828 ±.0008 in.)

0.63 mm (.025 in.) larger than original size. .....170.372 ± 0.020 mm (6.7076 ±. 0008 in.)

(12) Dimension (new) from centerline of crankshaft bearing bore to bottom of block (pan rails)..... 230.00 mm (9.055 in.)

(13) Tighten the bolts that hold the caps for the main bearings as follows:

Install main bearing caps with "FRONT" and cast part number toward front of the block. Each cap has a number and must be installed in the same position as the correct number on the side of the cylinder block pan rail.

a. Before assembly, put Fel-Pro C100 Lubricant (if not available, use 2P2506 Thread Lubricant) on the bolt threads and all surfaces that make contact between the bolt and the cap.

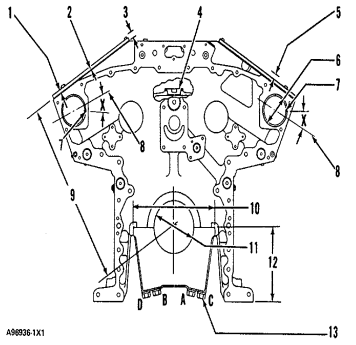
b. Tighten the bolts in letter sequence to..... 136 ± 14 N•m (100 ± 10 lb. ft.)

c. Tighten the bolts in letter sequence more 180±50

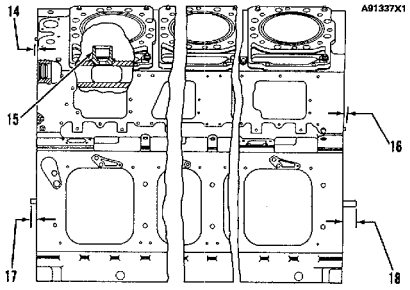
(14) Distance dowel extends from rear face of block..... 6.0 ± 0.5 mm (.24 ±.02 in.)

(15) Torque for adapter ..... 100 ± 15 N-m (75 ± 11 lb. ft.)

(16) Distance dowels extend from front face of block..... 6.0 ± 0.5 mm (.24 ± .02 in.)



FRONT VIEW OF CYLINDER BLOCK



(17) Distance dowels extend from rear face of block...19.0 ± 0.5 mm (.75 ± .02 in.)

(18) Distance dowels extend from front face of block.....40.0 ± 0.5 mm (1.58 ±.02 in.)

CYLINDER LINERS

For Installation

a. Put liquid soap on cylinder block liner bore surfaces and rubber seals on the lower part of the liner.

b. Put the filler band completely in clean engine oil for a moment.

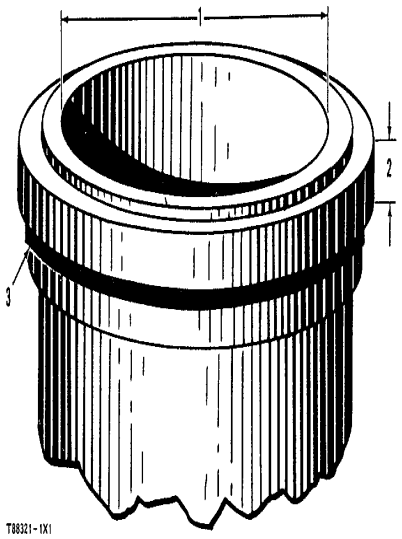
c. Install filler band (3) in the groove under the liner flange, without delay.

d. Install the liner in the bore immediately, before expansion of the filler band.

(1) Bore in liner (new)..... 170.025±0.025 mm (6 6939 ± 0010 in.)

(2) Thickness of flange on liner..... 12.65 ± 0.02 mm (.498 ± 001 in)

(3) Filler Band.



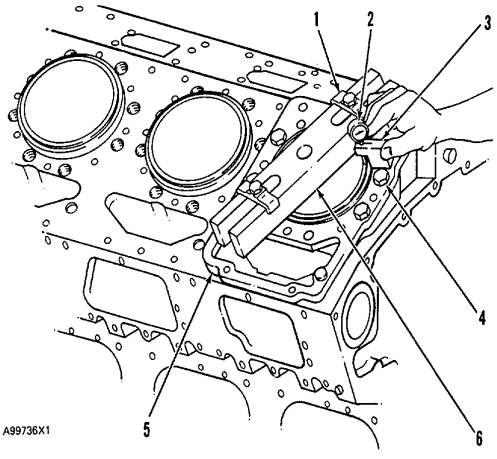
CYLINDER LINER PROJECTION

Make reference to CYLINDER LINER PROJECTION in Testing and Adjusting for the complete procedure.

1. Install the gasket and spacer plate (5). Install copper washers and bolts (4) to hold the spacer plate Tighten bolts (4) evenly in four steps.
   1st step ..... 14 N•m (10 lb. ft.)
   2nd step..... 35 N•m (25 lb. ft)
   3rd step..... 70 N•m (50 lb. ft)
   4th step..... 95 N•m (70 lb. ft)
2. Install tooling as shown. Tighten bolts for crossbar evenly in four steps.
   1st step ..... 7 N•m (5 lb ft.)
   2nd step..... 20 N•m (15 lb ft)
   3rd step..... 35 N•m (25 lb ft.)
   4th step..... 70 N•m (50 lb ft.)
3. Measure cylinder liner projection with dial indicator (2) in 1P2402 Gauge Body (3) as shown Measure at four places around each cylinder liner near the clamped area
   Average of four projection measurements from any cylinder liner must be..... 0.059 to 0 199 mm (.0023 to .0078 in.)
   Maximum permissible difference between all four measurements ..... 0.05 mm (.002 in.)

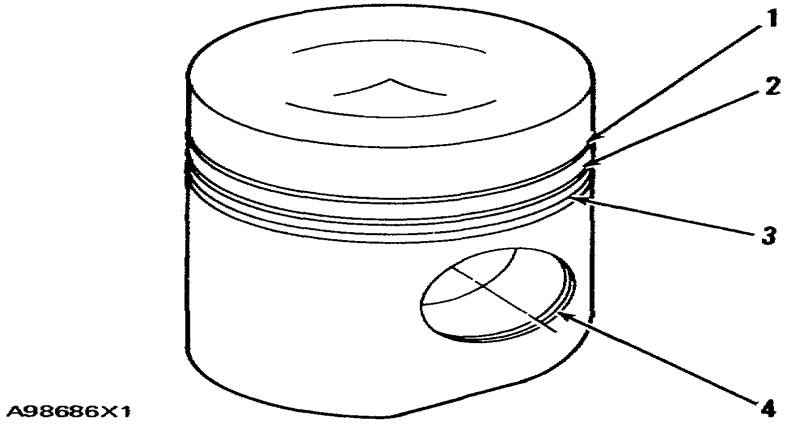
(1) 3H465 Plate

(6) 8B7548 Push-Puller Crossbar.



NOTE: FOR TORQUE VALUES NOT GIVEN, SEE THE FIRST35 PAGE OF SPECIFICATIONS FOR GENERAL TIGHTENING TORQUES

PISTONS AND RINGS



PISTONS AND PISTON RINGS				
	(1) TOP RING*	**(2) INTERMEDIATE RING***	**(3) OIL CONTROL RING**(with 17 oil slots)**	**(3) OIL CONTROL RING**(with 12 oil slots)**
Width of groove in piston for piston ring (new)	—	—	5.050 ± 0.013 mm (.1988 ± .0005 in)	5 050 ± 0.013 mm (.1988 ± .0005 in.)
Thickness of piston ring (new).	—	—	4.968 ±0.013 mm (.1956 ± 0005 in.)	4.954 ± 0 019 mm (.1950 ±0007 In)
Clearance between groove and piston ring (new).	—	—	0.082 ±0 013 mm (0032 ±.0005 In.)	0 064 to 0 128 mm (0025 to .0050 in.)
Clearance between ends of piston ring when installed in a cylinder liner with a bore size of 170 mm (6.694 in)	0.80 ± 0.20 mm (.031 ± .008 In,)	0 80 ± 0.20 mm (.031 ± 008 in.)	0 56 ±12 mm (.022 ±005 In.)	0 70 ± 0.19 mm (.028 ± 007 in)
Increase in clearance between ends of piston ring for each 0 03 mm in) increase in cylinder liner bore size	(.0010 08 mm (003 in)			

*Install piston ring with "UP" side toward top of piston.

NOTE: Top Ring (1) has the mark "UP-1." Intermediate Ring (2) has the mark "UP-2."

**Install Oil Control Ring (3) with the gap in the spring 180° away from the gap in the ring. White portion of spring must be visible at the ring end gap.

(4) Bore in piston for pin ..... 69.983 + .008 mm (2.7552 + .0003 in.)

Clearance between pin and bore in piston ..... 0.008 to 0.034 mm (.0003 to .0013 in.)

Pin diameter ..... 69.962 ±.005 mm (2.7544 ±.0002 in.)

CONNECTING RODS

(1) Distance between center of bearings..... 380.00 mm (14.961 in.)

(2) Distance that locating pin extends from rod cap ..... 4.0 ± 0.5 mm (.16 ±.02 in.)

(3) Bore in connecting rod for bearing with bolts tightened to specifications (6) ..... 143.028 ± 0.015 mm (5.6310 ± .0006 in.)

(4) Take the connecting rod bearing measurements on the centerline of the connecting rod bores.

Bore in bearing for crankshaft..... ..... 135.133 to 135.194 mm (5.3202 to 5.3226 in.)

Clearance between bearing and crankshaft (new)..... 0.107 to 0.218 mm (.0042 to .0086 in.)

(5) Side of connecting rod with chamfer.

(6) Tighten connecting rod bolts as follows:

NOTE: Bolts A and B are on the same end of the rod cap that has bearing tabs and location pin (7).

a. Before assembly, put Fel-Pro C100 Lubricant (if not available, use 2P2506 Thread Lubricant) on the bolt threads and all surfaces that make contact between the bolt and the cap.

b. Tighten bolts A and B to ..... 90 ± 5 N•m (65 ± 4 lb. ft.)

c. Tighten bolts C and D to ..... 90 ± 5 N•m (65 ±4 lb. ft.)

d. Tighten bolts A and B again to..... 90 ±5 N•m (65 ± 4 lb. ft.)

e. Tighten bolts C and D again to..... 90 ± 5 N•m (65 ± 4 lb. ft.)

f. Tighten each bolt more..... 90 ± 5°

(7) Location pin for correct installation of connecting rod caps.

(8) Bore in bearing for piston pin (new)..... 70.000 ± 0.008 mm (2.7559 ±.0003 in.)

Diameter of piston pin (new) .....69.962 ± 0.005 mm (2.7544 ±. 0002 in.)

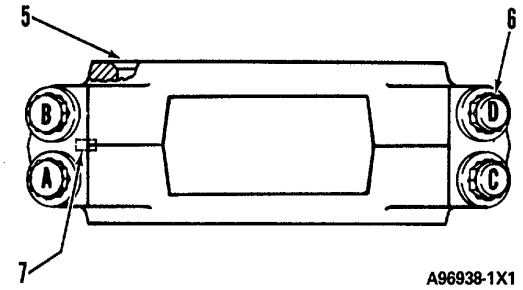
NOTE: Connecting rod must be heated for installation of piston pin bearing. Do not use a torch. Heat connecting rod to a temperature of 177 to 204° C (350 to 400° F)

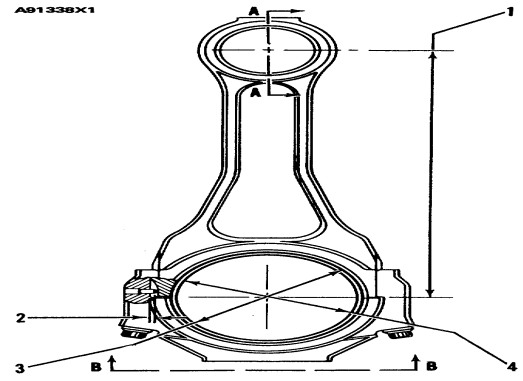
Side clearance between two connecting rods on same crankshaft pin (new):

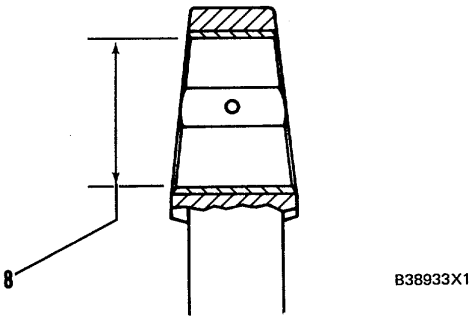
3508 ..... 0.900 ± 0.282 mm (.0354 ± .0111 in.)

3512 ..... 0.850 ± 0.232 mm (.0335 ± .0091 in.)

3516 ..... 0.850 ± 0.332 mm (.0335 ± .0131 in.)







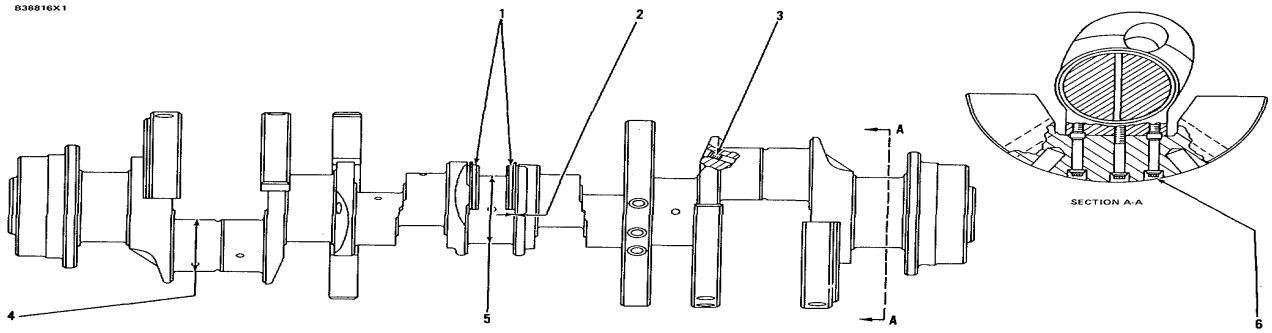
NOTE: FOR TORQUE VALUES NOT GIVEN, SEE THE FIRST PAGE OF SPECIFICATIONS FOR GENERAL TIGHTENING TORQUES

CONNECTING ROD AND MAIN BEARING JOURNALS

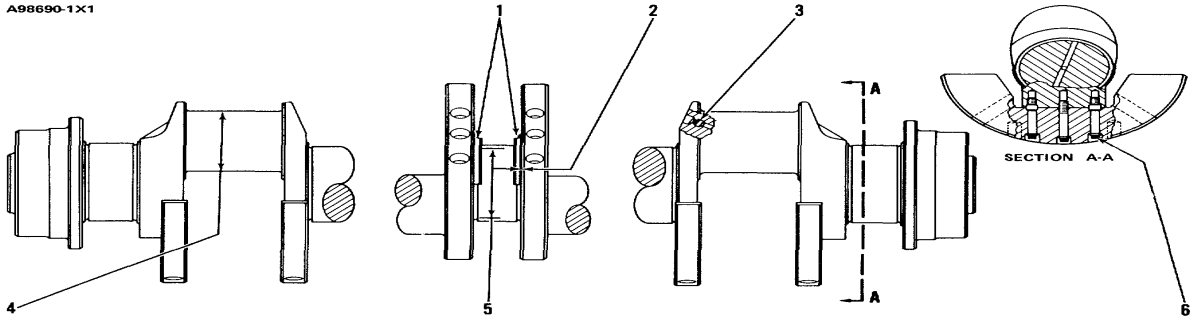
CONNECTING ROD BEARING JOURNALS			
	ORIGINAL SIZE JOURNAL	**0.63 mm (.025 in.) UNDERSIZE (SMALLER) JOURNAL**	**1.27 mm (.050 in.) UNDERSIZE (SMALLER) JOURNAL**
Diameter of crankshaft journal (bearing surface) for connecting rod	135 000 ± 0.025 mm (5.3150 ± 0010 in.)	134.370 ± 0.025 mm (5.2902 ± .0010 in.)	133.730 ± 0 025 mm (5.2650 ±.0010 in.)
Clearance between bearing and journal (new).	0.107 to 0.218 mm (.0042 to 0086 in.)		

MAIN BEARING JOURNALS			
	ORIGINAL SIZE JOURNAL	**0.63 mm (.025 in.) UNDERSIZE (SMALLER) JOURNAL**	**1.27 mm (.050 in.) UNERSIZE (SMALLER) JOURNAL**
Diameter of crankshaft journal (bearing surface) for main bearings.	160.000 ± 0.025 mm (6.2992 ± 0010 in.)	159.370 ± 0 025 mm (6.2744 ± .0010 in.)	158 730 ± 0 025 mm (6.2492 ± .0010 In.)
Clearance between bearing and journal (new)	0.122 to 0.241 mm (.0048 to .0095 in.)		

CRANKSHAFT



(3508)



(3512 & 3516)

(1) Thrust plates for center bearing only.

(2) End play for the crankshaft
(new) ..... 0.170 to 0.630 mm (.0067 to .0248 in.)

(3) Plugs.

Earlier:

Torque for 1/4 pipe thread
plugs ..... 25 N•m (20 lb. ft.) min

"Stake" (make a mark with a punch) the crankshaft to hold the pipe plugs tight.

Later:

Torque for straight thread
plugs ..... 50 ± 7 N•m (37 ± 5 lb. ft.)

(4) Make reference to Connecting Rod Bearing Journals.

(5) Make reference to Main Bearing Journals.

(6) Procedure to tighten counterweight bolts:

a. Before assembly, put Fel-Pro C100 Lubricant (if not available, use 2P2506 Thread Lubricant) on the bolt threads, shank, and underside of bolt head.

b. Tighten the bolts evenly to ..... 50 ±5 N•m (37 ± 4 lb. ft.)

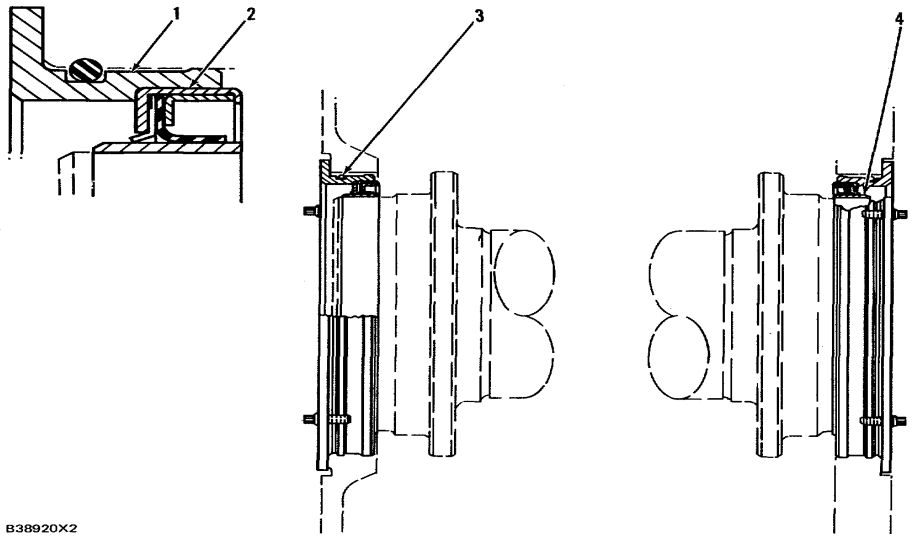
c. Tighten each bolt more ..... 120 ± 5°

NOTICE

Each counterweight has a number and must be installed in the same position as the correct number on the crankshaft mounting pad to prevent damage to the crankshaft when the engine is run.

NOTE: FOR TORQUE VALUES NOT GIVEN, SEE THE FIRST PAGE OF SPECIFICATIONS FOR GENERAL TIGHTENING TORQUES

CRANKSHAFT WEAR SLEEVES AND SEALS



(1) Adapter.

(2) Crankshaft seals:

Crankshaft seals must be installed with the lip of the seal toward the inside of the engine as shown. Make sure the correct seal is installed on each end of the crankshaft. For SAE Standard Rotation engines use 1W6974 Seal Group on the front and 1W6977 Seal Group on the rear. For SAE Opposite Rotation engines use 1W6977 Seal Group on the front and 1W6974 Seal Group on the rear.

(3) Put clean engine oil on the O-ring seals at assembly.

(4) Wear sleeve.

Removal:

a. Remove the seal adapters from each end of the engine and remove the seals from the adapters.

NOTE: Seals and wear sleeves can not be used again, after the seals and wear sleeves are separated.

b. Remove wear sleeves with 5P7409 Distorter and 6V3143 Distorter Adapter.

Installation:

a. **Do not** separate wear sleeves (4) from crankshaft seals (2). Once they are separated, they can not be used again.

NOTE: For complete procedure with illustrations, make reference to Disassembly and Assembly section of this Service Manual.

b. Install sleeve and seal assembly into adapter (1) with correct tools.

c. Clean the outer surface of the crankshaft and the inner surface of wear sleeve (4) with 6V1541 Quick Cure Primer.

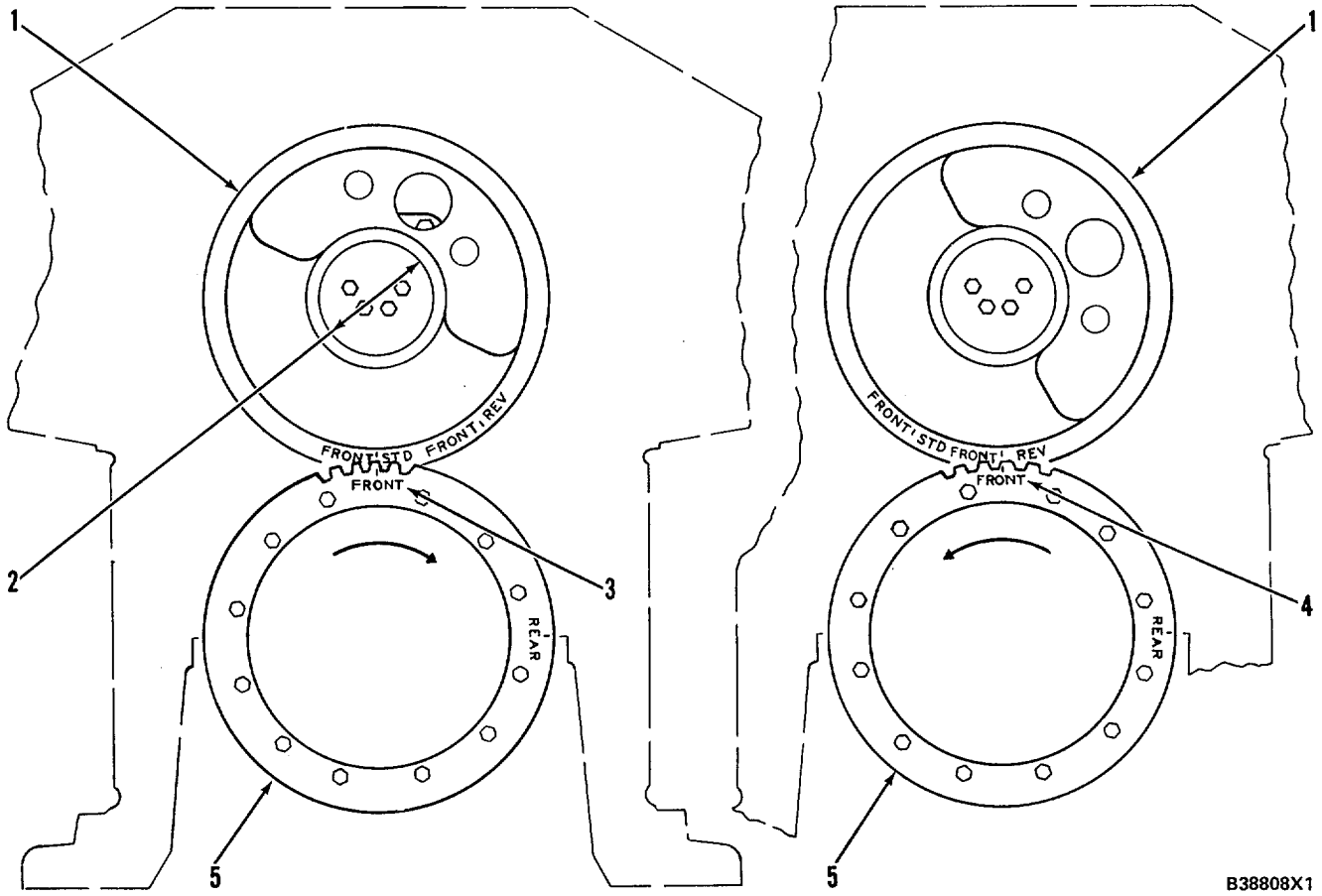
d. Carefully put a thin coat of 9S3265 Retaining Compound on the inner surface of wear sleeve (4) and on crankshaft surface.

e. Install adapter (1), seal (2) and wear sleeve (4) as a unit on the end of the crankshaft with the correct tools.

Tools Needed

6V4002	Forcing Bracket	(2)
6V4001	Forcing Ring	(1)
1B4330	Nut (5/16"-18 NC)	(4)
6V4003	Locator	(1)
2N5006	Bolt (1"-14 NF x 2 5 in. long)	(2)
	Guide Bolts (5/16"-18 NC x 4 in. long)	(2)
6V4977	Installer	(1)
9S8858	Nut	(1)

FRONT BALANCER GROUP
(3508)

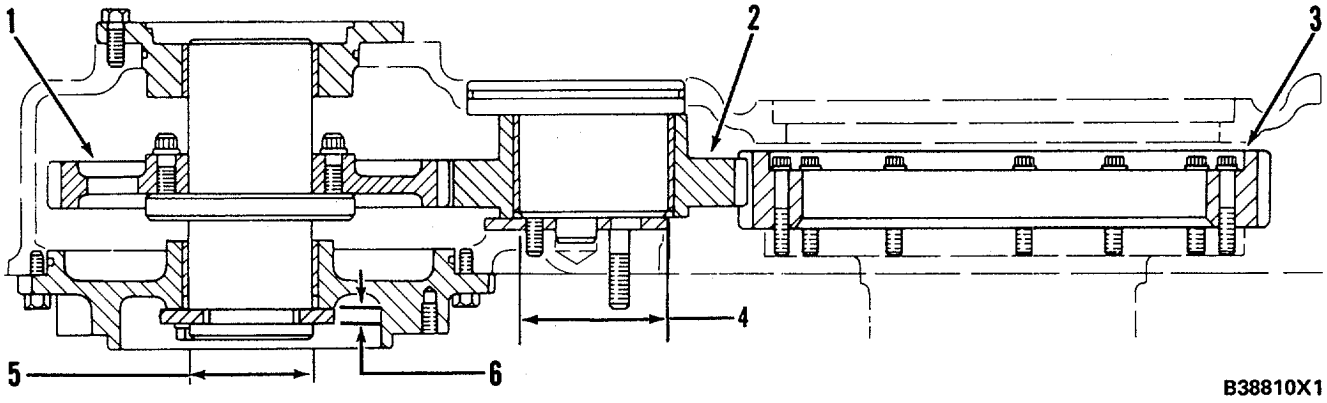


(1) Balancer gear.
(2) Diameter of shaft
(new) .....74 900 + 0 015 mm (2 9488 + .0006 in)
Bore in bearing (after
assembly).....75 000 + 0.053 mm (2 9528 + .0021 in)
Bearing joint must be in center of heavy section in gear at
assembly.
(3) Balancer gear marks must be in alignment with crankshaft gear marks as shown for SAE standard rotation engines
(4) Balancer gear marks must be in alignment with crankshaft gear marks as shown for SAE opposite rotation engines
(5) Crankshaft gear.

NOTE: FOR TORQUE VALUES NOT GIVEN, SEE THE FIRST PAGE OF SPECIFICATIONS FOR GENERAL TIGHTENING TORQUES

LOWER FRONT GEAR GROUP

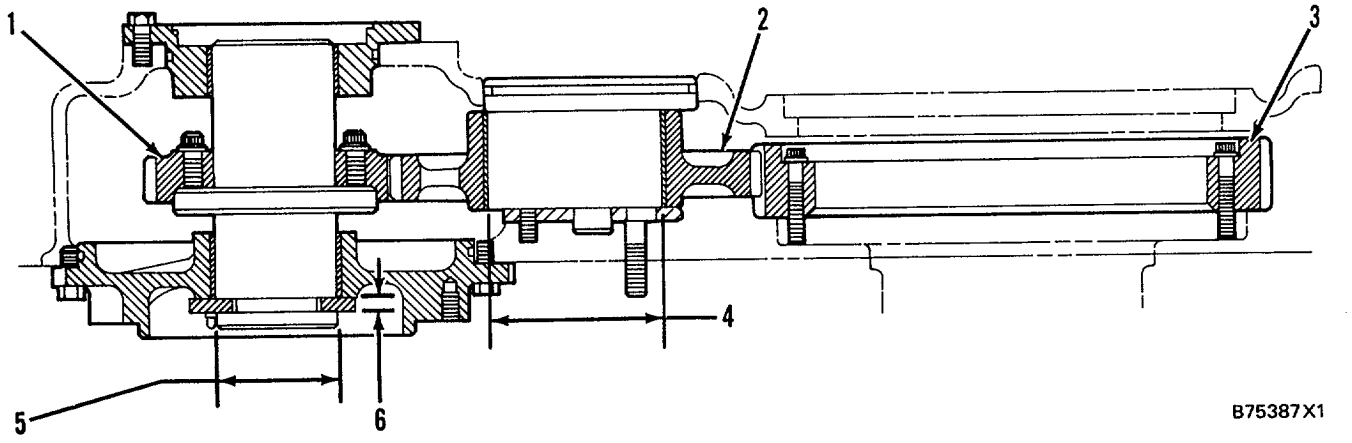
(8N7174)



(1) Drive gear for water and oil pumps.
(2) Idler gear.
(3) Crankshaft gear.
(4) Bore in bearing (after assembly) .....90.000 + 0.065 mm (3.5430 + .0026 in.)
Diameter of shaft (new) .....89.880 ± 0.020 mm (3.5386 ± .0008 in.)
(5) Bore in bearings (after assembly) .....75.000 + 0.055 mm (2.9528 ± .0022 in.)
Diameter of shaft (new) .....74.900 + 0.015 mm (2.9488 _ .0006 in.)
(6) Thickness of thrust washer (new) .....8.50 _ 0.05 mm (.335 _ .002 in.)
Width of groove in shaft (new) .....8.750 + 0.025 mm (.3445 + .0010 in.)
End play for shaft .....0.175 to 0.325 mm (.0069 to .0128 in.)

LOWER FRONT GEAR GROUP

(8N5620)

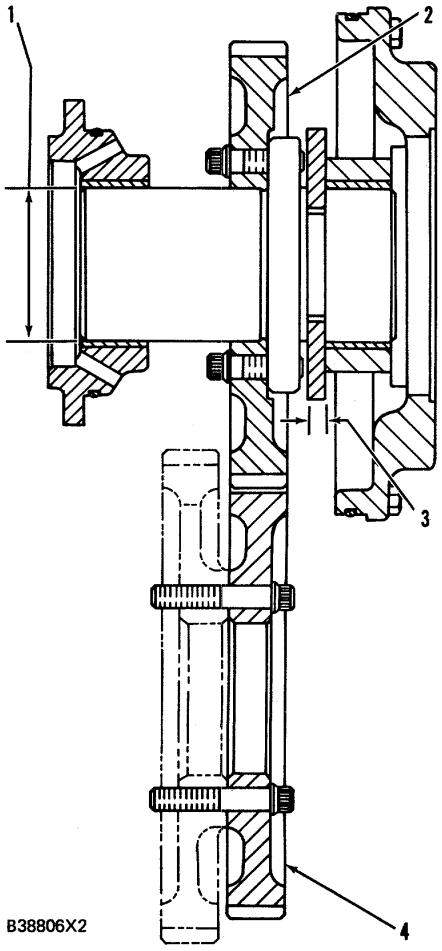


(1) Drive gear for water and oil pumps.
(2) Idler gear.
(3) Crankshaft gear.
(4) Bore in bearing (after assembly) .....106.000 _ 0.065 mm (4.1732 _ .0026 in.)
Diameter of shaft (new) .....105.880 ± 0.020 mm (4.1685 + .0008 in.)
(5) Bore in bearings (after assembly) .....75.000 _ 0.055 mm (2.9528 _ .0022 in.)
Diameter of shaft (new) .....74.900 + 0.015 mm (2.9488 + .0006 in.)
(6) Thickness of thrust washer (new) .....8.50 + 0.05 mm (.335 _ .002 in.)
Width of groove in shaft (new) .....8.750 _ 0.025 mm (.3445 + .0010 in.)
End play for shaft .....0.175 to 0.325 mm (.0069 to .0128 in.)

NOTE: FOR TORQUE VALUES NOT GIVEN, SEE THE FIRST PAGE OF SPECIFICATIONS FOR GENERAL TIGHTENING TORQUES

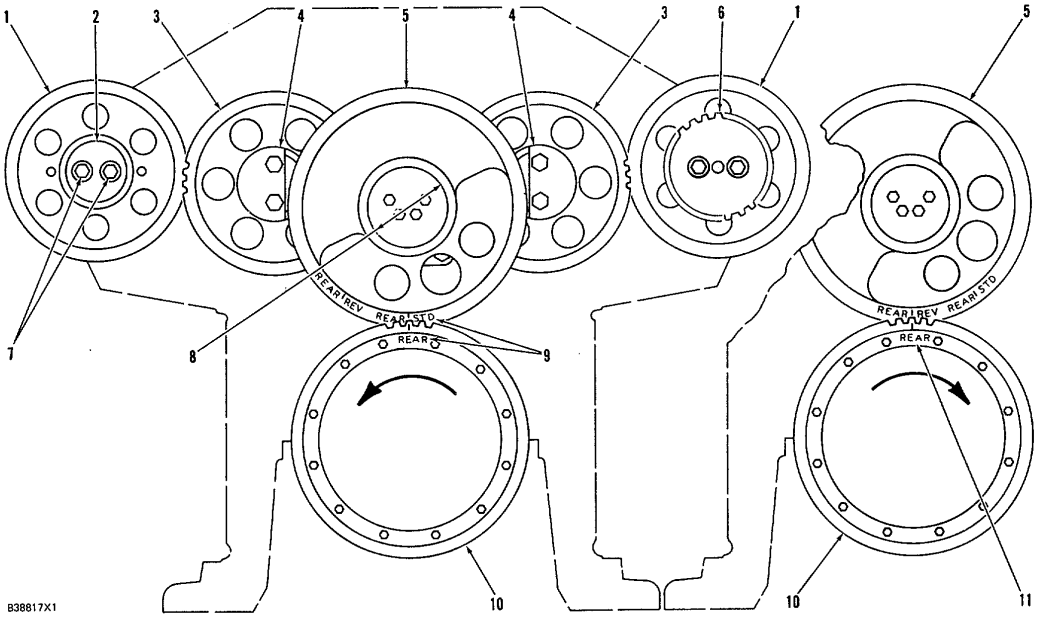
UPPER FRONT GEAR GROUP
(7N4871)

(1) Bore in the bearings (after assembly) .....75.000 + 0.055 mm (2.9528 _ .0022 in.)
Diameter of shaft .....74.900 _ 0.015 mm (2.9488 + .0006 in.)
(2) Drive gear on shaft for governor drive.
(3) Thickness of washer (new) .....8.50 ± 0.05 mm (.335 _ .002 in.)
Width of groove in shaft (new) .....8.750 _ 0.025 mm (.3445 + .0010 in.)
End play for the shaft .....0.175 to 0.325 mm (.0069 to .0128 in.)
(4) Gear fastened to water and oil pump drive.



2REAR GEAR GROUP

(3508)

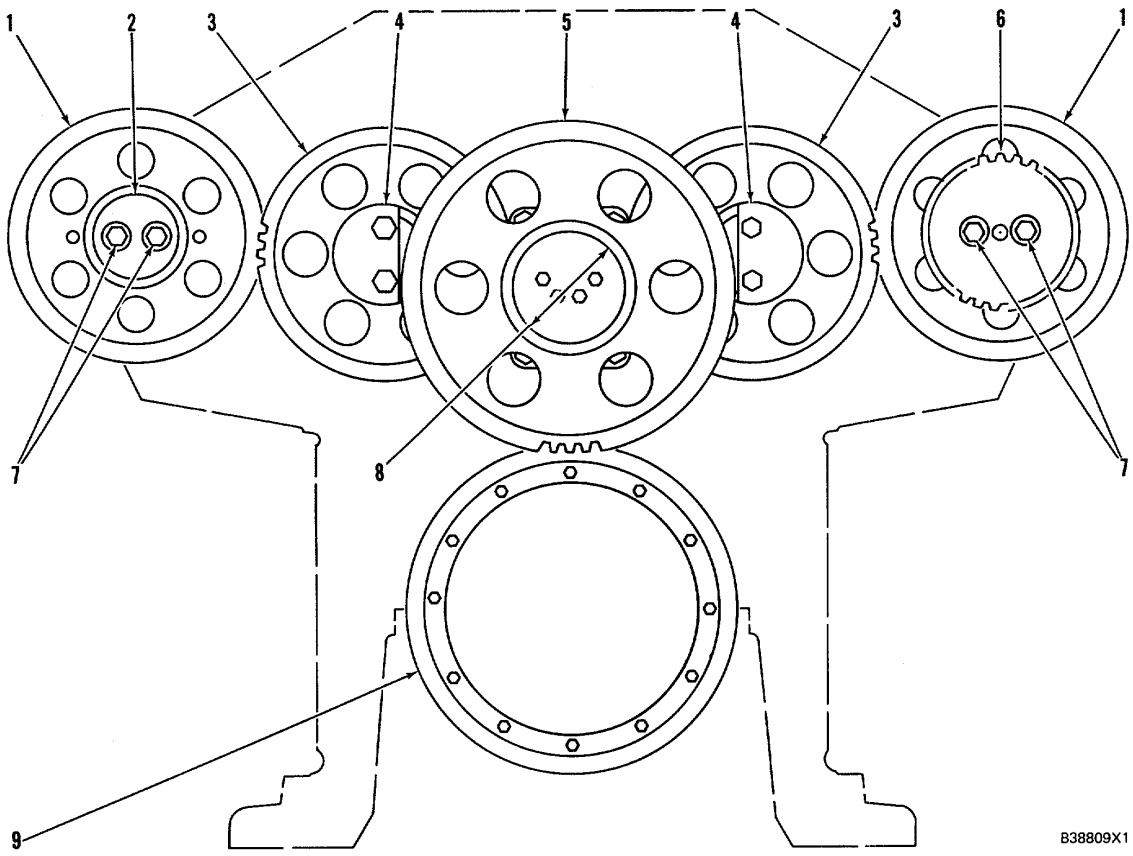


(1) Camshaft drive gears.
(2) Plate.
(3) Camshaft idler gears
(4) Diameter of shafts
(new) 74.900 + 0 015 mm (2.9488 + .0006 in.)
Bore in bearings (after assembly) .....75.000±0.055 mm (2.9528 + .0022 in.)
(5) Cluster idler gear (balancer gear).
(6) Gear for hydramechanical protective system drive.
(7) Bolts. tighten the bolts as follows:
a. Put camshaft drive gears (1) in position on the camshafts.
b. Use hand pressure to turn and hold camshaft drive gears
(1) in their normal direction of rotation. This removes all gear clearance (backlash) between camshaft drive gears (1) and camshaft idler gears (3).
c. Install plate (2) (on left side of engine) and/or drive gear (6) (on right side of engine) to hold camshaft drive gears (1) to each camshaft.
d. Tighten bolts (7) in steps to a torque of 100 + 15 N-m (75 ± 11 lb. ft.)
e. Hit the face of plate (2) or drive gear (6), then tighten the bolts to a torque of 100 + 15 N-m (75 + 11 lb. ft.)
f. Again hit the face of plate (2) or drive gear (6) and again tighten the bolts to a torque of .....100 $^{+}$ 15 N-m (75 $^{+}$ 11 lb. ft.)

NOTE: If necessary, repeat Step 7f until the bolts hold torque (can not be moved) to make sure the drive gears are in full contact with the taper on the camshafts.

(8) Diameter of shaft
(new) 74.900 ± 0 015 mm (2.9488 ± .0006 in.)
Bore in bearing (after assembly) .....75.000 ± 0 053 mm (2.9528 ± .0021 in.)
Bearing joint must be in center of heavy section in gear at assembly.
(9) Balancer gear marks must be in alignment with crankshaft gear marks as shown for SAE standard rotation engines
(10) Crankshaft gear.
(11) Balancer gear marks must be in alignment with crankshaft gear marks as shown for SAE opposite rotation engines

REAR GEAR GROUP
(3512 & 3516)



(1) Camshaft drive gears.
(2) Plate.
(3) Camshaft idler gears.
(4) Diameter of shafts
(new) 74.900 + 0.015 mm (2.9488 + .0006 in)
Bore in bearings (after assembly) .....75.000 0.055 mm (2.9528 + 0022 in.)
(5) Cluster idler gear.
(6) Gear for hydramechanical protective system drive.
(7) Bolts. Tighten the bolts as follows:
a. Put camshaft drive gears (1) in position on the camshafts.
b. Use hand pressure to turn and hold camshaft drive gears (1) in their normal direction of rotation. This removes all gear clearance (backlash) between camshaft drive gears (1) and camshaft idler gears (3).
c. Install plate (2) (on left side of engine) and/or drive gear (6) (on right side of engine) to hold camshaft drive gears (1) to each camshaft.
d. Tighten bolts (7) in steps to a torque of of 100 ±15 N-m (75 + 11 lb. ft.)
e. Hit the face of plate (2) or drive gear (6), then tighten the bolts to a torque of 100 **f** 15 N-m (75 ± 11 lb. ft.)
f. Again hit the face of plate (2) or drive gear (6) and again tighten the bolts to a torque of .....100 15 N-m (75 + 11 lb. ft.)

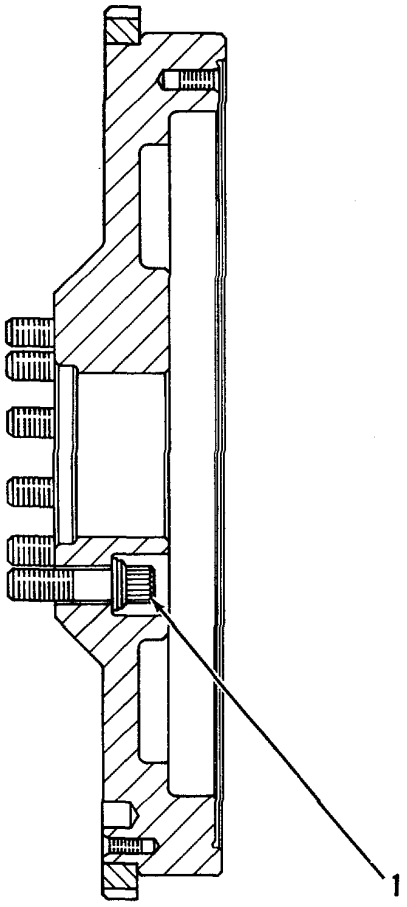
NOTE: If necessary, repeat Step 7f until the bolts hold torque (can not be moved) to make sure the drive gears are in full contact with the taper on the camshafts.

(8) Diameter of shaft
(new) 74.900 + 0.015 mm (2.9488 + 0006 in)
Bore in bearing (after assembly) ..... 75 000 + 0 053 mm (2 9528 t .0021 in)
(9) Crankshaft gear.

FLYWHEEL
(1N3770 & 7N7732)

Make reference to FLYWHEEL RUNOUT for the correct method of
flywheel inspection.

(1) Put 2P2506 Thread Lubricant on all the bolt threads that l
torque of .....1150 ± 60 N-m
(840 + 44 lb. ft.)
NOTE: When flywheel is installed, put dash mark on flywl nkshaft



B38800X2

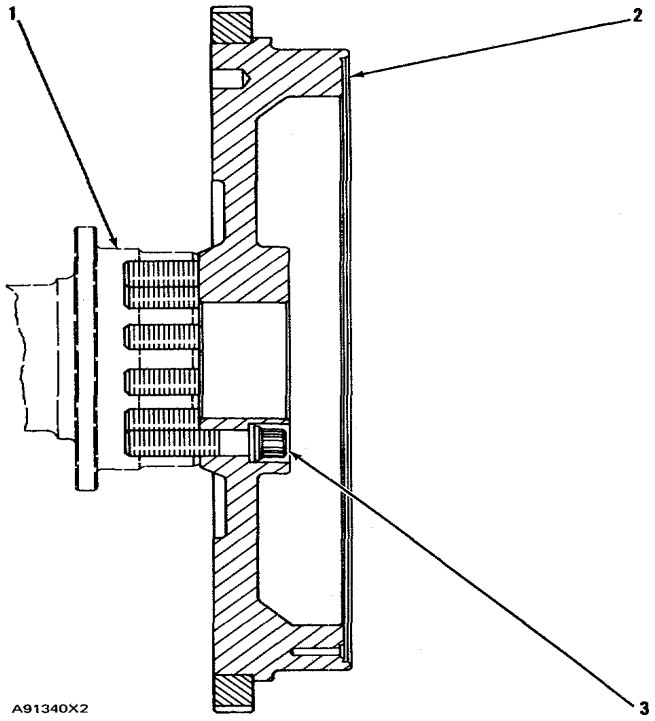
NOTE: FOR TORQUE VALUES NOT GIVEN, SEE THE FIRST PAGE OF SPECIFICATIONS FOR GENERAL TIGHTENING TORQUES

FLYWHEEL
(1N3565 & 7N5014)

Make reference to FLYWHEEL RUNOUT for the correct method of flywheel inspection.

(1) Crankshaft.
(2) Flywheel.
(3) Put 2P2506 Thread Lubricant on all the bolt threads that hold the flywheel to the crankshaft and tighten to a torque of .....1150 + 60 N-m (840 + 44 lb. ft.)

NOTE: When flywheel is installed, put dash mark on flywheel (near pilot bore) in alignment with dash mark on crankshaft.

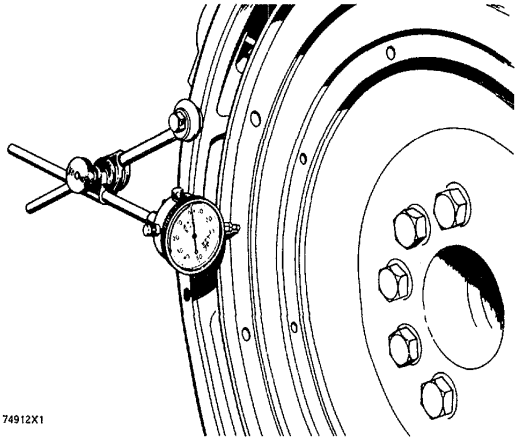


FLYWHEEL RUNOUT

Face Runout (axial eccentricity) of the Flywheel:

1 Install the dial indicator as shown Put a force on the
2 Set the dial indicator to read 0 0 mm (000 in)
3 Turn the flywheel and read the indicator every 90 P
4 The difference between the lower and higher measurements taken at all four points must not be more than 0 15 mm (006 in) which is the maximum permissible face runout (axial eccentricity of the flywheel)

ading

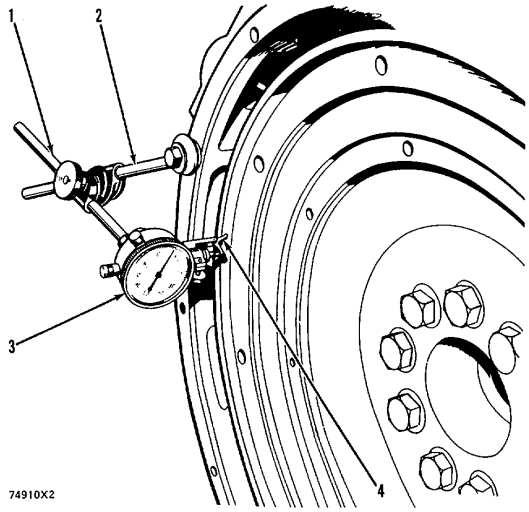


CHECKING FACE RUNOUT OF THE FLYWHEEL (TYPICAL EXAMPLE)

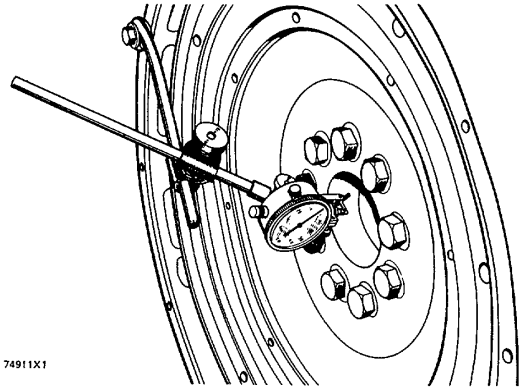
Flywheel Runout (Cont.)

Bore Runout (radial eccentricity) of the Flywheel:

1 Install the dial indicator (3) and make an adjustment of the universal attachment (4) so it makes contact as shown.
2. Set the dial indicator to read 0.0 mm (.00 in.)
3. Turn the flywheel and read the indicator every 90°
4. The difference between the lower and higher measurements taken at all four points must not be more than 0 15 mm (.006 in), which is the maximum permissible bore runout (radial eccentricity) of the flywheel.
5. Runout (eccentricity) of the bore for the pilot bearing for the flywheel clutch, must not exceed 0.13 mm (005 in)



CHECKING FLYWHEEL BORE

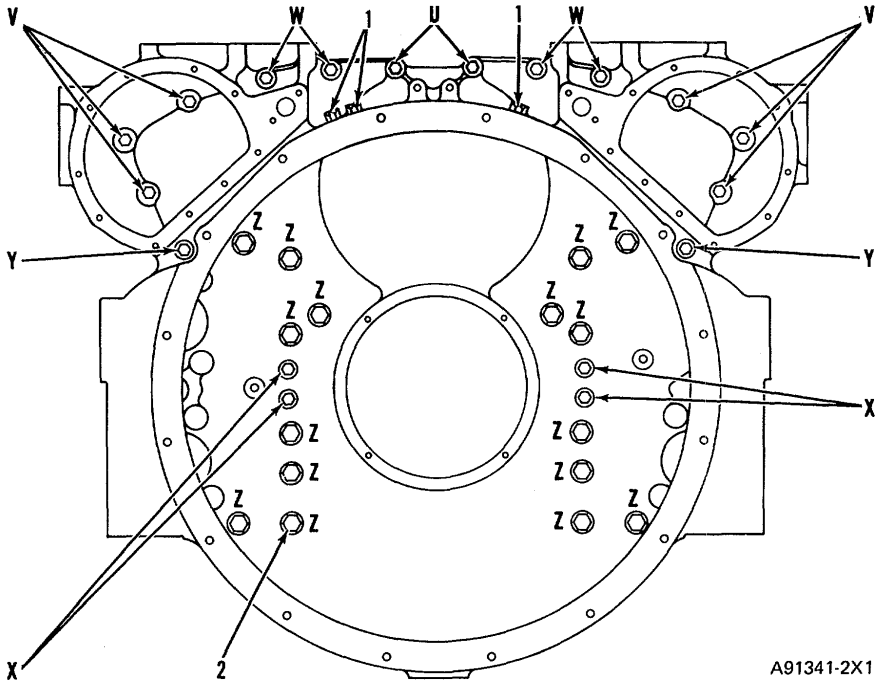


CHECKING FLYWHEEL CLUTCH PILOT BEARING BORE

NOTE: FOR TORQUE VALUES NOT GIVEN, SEE THE FIRST PAGE OF SPECIFICATIONS FOR GENERAL TIGHTENING TORQUES

FLYWHEEL HOUSING

(SAE "00")



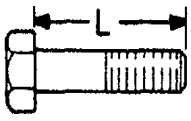
Make reference to FLYWHEEL HOUSING RUNOUT and FLY-WHEEL HOUSING BORE for the correct methods of flywheel housing inspection.

(1) Torque for plugs .....70 + 15 N-m (50 + 11 lb. ft.)

(2) Tighten the bolts that hold the flywheel housing to the engine block evenly See FLYWHEEL HOUSING BOLT INSTALLA-TION CHART for correct position

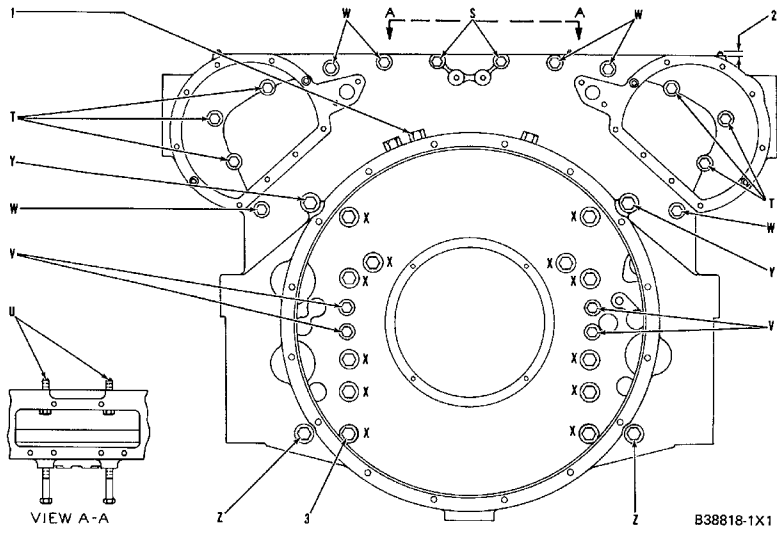
Torque for 1/2"-13 NC bolts .....100 ++ 14 N-m (75 + 10 lb ft)

Torque for 5/8"-11 NC bolts .....200 ±25 N-m (150 ± 20 lb ft)

FLYWHEEL HOUSING BOLT INSTALLATION CHART				
Dia.	Bolt Location	Part No.	Bolt Length "L"	
			mm	in.
1/2"	U	6M9613	228.6	9.00
	V	S1595	31.8	1.25
	W	1D4566	88.9	3.50
	X	8S9089	114.3	4.50
	Y	9S1374	203.2	8.00
5/8"	Z	1D4590	120.7	4.75

FLYWHEEL HOUSING

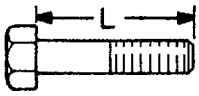
(SAE "0")



Make reference to FLYWHEEL HOUSING RUNOUT and FLY-WHEEL HOUSING BORE for the correct methods of flywheel housing inspection

(1) Torque for plugs .....70 + 15 N-m (50 + 11 lb. ft.)
(2) Install three dowels to a height of .....6.0 ± 0 5 mm (24 + .02 In.)
(3) Tighten the bolts that hold the flywheel housing to the engine block evenly See FLYWHEEL HOUSING BOLT INSTALLA-TION CHART for correct position
Torque for 1/2"-13 NC bolts .....100 + 14 N-m (75 + 10 lb ft.)
Torque for 5/8"-11 NC bolts .....200 + 25 N-m (150 + 20 lb ft.)

FLYWHEEL HOUSING BOLT INSTALLATION CHART



Dia.	Bolt Location	Part No.	Bolt Length "L" mm	Bolt Length "L" in.
1/2"	S	1A5822*	69.9	2.75
		L1329	76.2	3.00
	T	S1595	31.8	1.25
	U	2B947	57.2	2.25
	V	6F5282	133.4	5.25
	W	1D4574	152.4	6.00
5/8"	X	1D4593	139.7	5.50
	Y	1D4597	165.1	6.50
	Z	1D4602	241.3	9.50

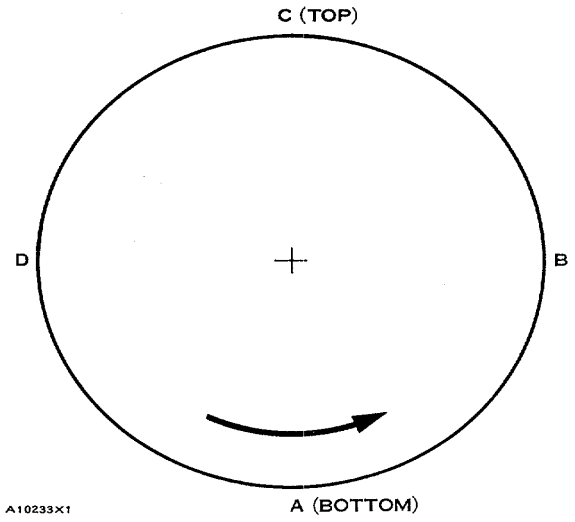
*NOTE: This bolt used on earlier engines.

NOTE: FOR TORQUE VALUES NOT GIVEN, SEE THE FIRST PAGE OF SPECIFICATIONS FOR GENERAL TIGHTENING TORQUES

FLYWHEEL HOUSING BORE

NOTE: Write the dial indicator measurements with their positive (+ and negative (-) notation (signs). This notation is necessary for making the calculations in the chart correctly.

1. Fasten the dial indicator to the flywheel so the anvil of the indi cator will touch the flywheel housing bore With the dial indi cator In position at (C), adjust the dial Indicator to "O" (zero)
   Push the crankshaft up against the top bearing. Write the, measurement for bearing clearance on line 1 In column (C)
2. Divide the measurement from Step 1 by 2. Write this number on line 1 in columns (B) & (D).
3. Turn the crankshaft to put the dial Indicator at (A) Adjust the, dial indicator to "O" (zero).
4. Turn the crankshaft counterclockwise to put the dial Indicator at (B) Write the measurement in the chart.
5. Turn the crankshaft counterclockwise to put the dial Indicator at (C) Write the measurement In the chart.
6. Turn the crankshaft counterclockwise to put the dial indicator at (D). Write the measurement in the chart.
7. Add fines I and II by columns.
8. Subtract the smaller number from the larger number in line II In columns (B) & (D) The result is the horizontal "eccentricity (out of round). Line Ill, column (C) is the vertical eccentricity



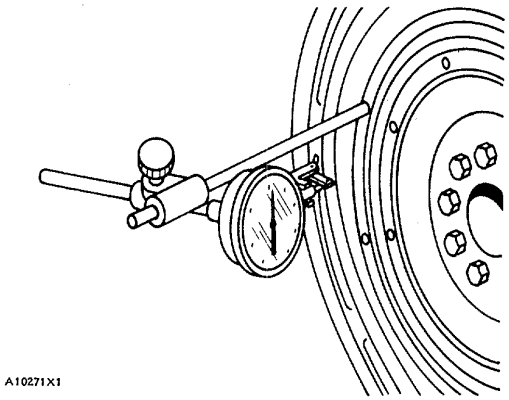


CHART FOR DIAL INDICATOR MEASUREMENTS

		Position of dial indicator			
	Line No.	A	B	C	D
Correction for bearing clearance	**I**	**0**			
Dial Indicator Reading	**II**	**0**			
Total of Line 1 & 2	**III**	**0**	**	*	**

* Total Vertical eccentricity (out of **round).**

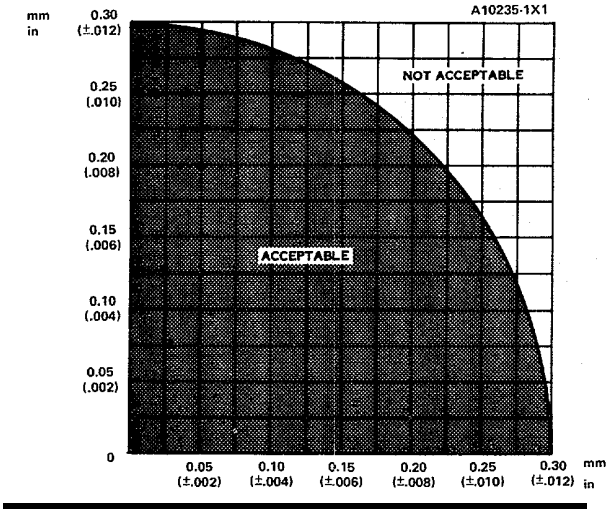
** Subtract the smaller No. **from the** larger No. The difference is

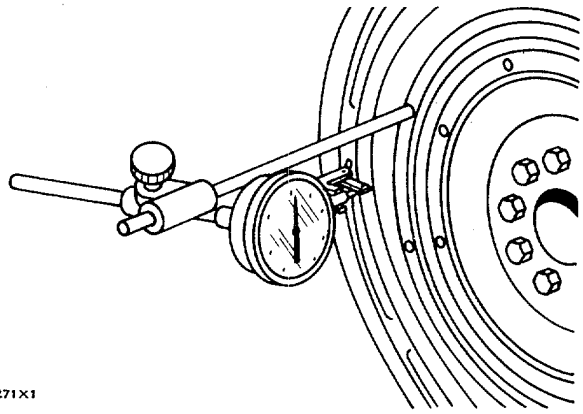
the total horizontal eccentricity.

A10234X1

9 On the graph for total eccentricity find the point of intersection of the lines for vertical eccentricity and horizontal eccentricity

10 If the point of intersection Is In the range marked "Acceptable" the bore is In alignment If the point of intersection is In the range marked "Not Acceptable" the flywheel housing must be changed.



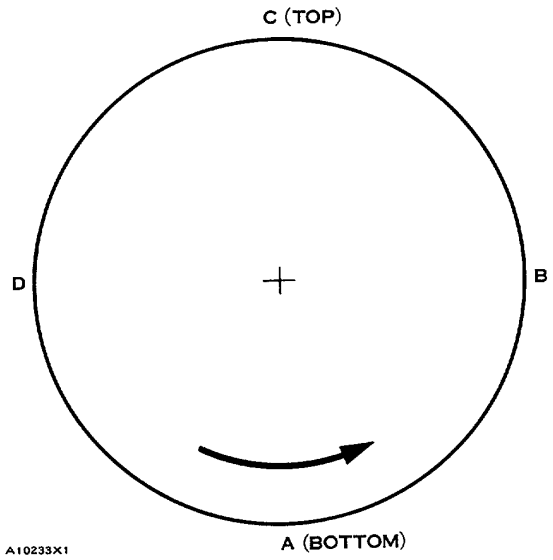


8S2328 DIAL INDICATOR GROUP INSTALLED (TYPICAL EXAMPLE)

FLYWHEEL HOUSING RUNOUT

Face Runout (axial eccentricity) of the Flywheel Housing:

1. Fasten a dial indicator to the crankshaft flange so the anvil of the Indicator will touch the face of the flywheel housing.
2. Put a force on the crankshaft toward the rear before reading the indicator at each point
3 With dial indicator set at 0 0 mm (.000 in.) at location (A), turn the crankshaft and read the indicator at locations (B), (C) and (D)
4. The difference between lower and higher measurements taken at all four points must not be more than 0.30 mm (.012 in.), which is the maximum permissible face runout (axial eccentricity) of the flywheel housing.



NOTE: FOR TORQUE VALUES NOT GIVEN, SEE THE FIRST PAGE OF SPECIFICATIONS FOR GENERAL TIGHTENING TORQUES

ALTERNATORS AND REGULATORS Deleted

Alternators and Regulators (Cont.) Deleted

NOTE: FOR TORQUE VALUES NOT GIVEN, SEE THE FIRST PAGE OF SPECIFICATIONS FOR GENERAL TIGHTENING TORQUES

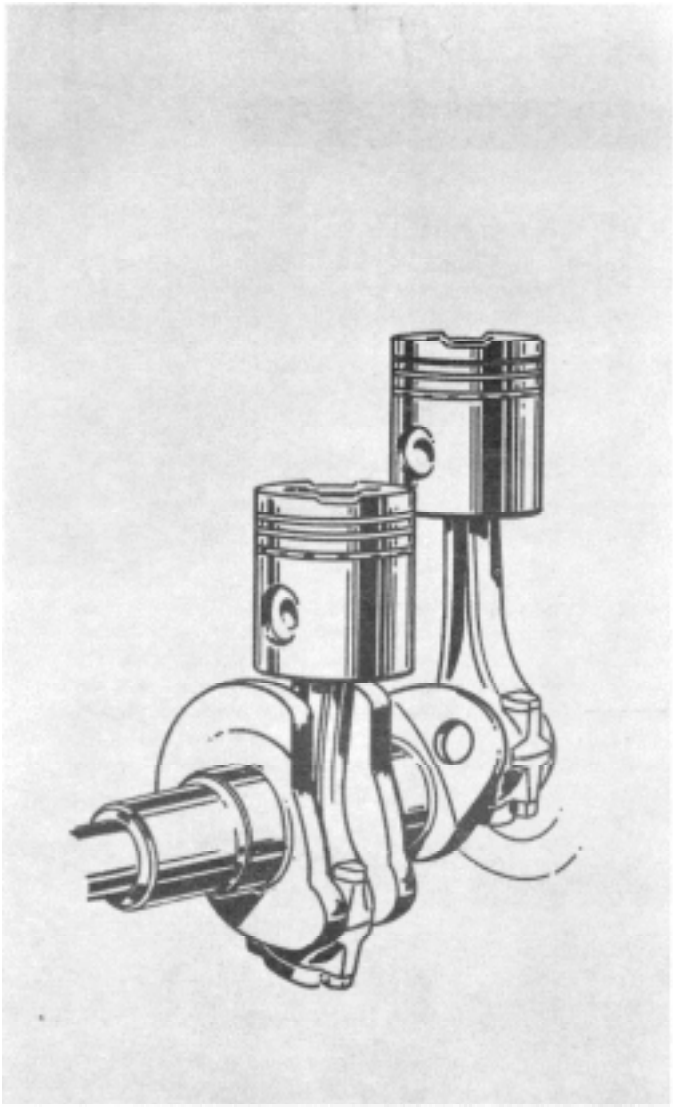
ELECTRIC STARTER MOTORS Deleted

STARTER SOLENOIDS Deleted

NOTE: FOR TORQUE VALUES NOT GIVEN, SEE THE FIRST PAGE OF SPECIFICATIONS FOR GENERAL TIGHTENING TORQUES

AIR STARTER MOTORS Deleted

PRESSURE REGULATING VALVE FOR AIR STARTER MOTOR Deleted



FORM NO. SENR2352-01

FOR USE IN SERVICE MANUAL'
3500 INDUSTRIAL ENGINES,
SENR2573

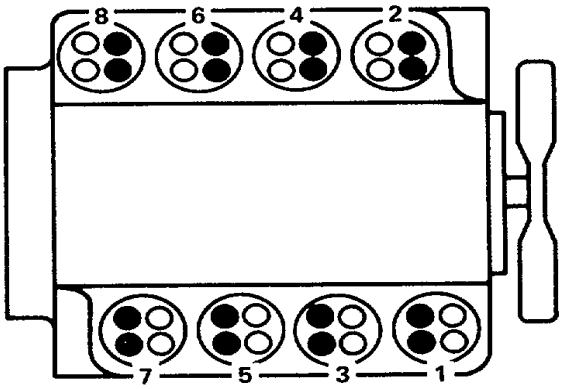
SYSTEMS OPERATION
TESTING AND ADJUSTING

3500 INDUSTRIAL ENGINES

49Y1-UP	**65Z1-UP**
95Y1-UP	**68Z1-UP**
27Z1-UP	**71Z1-UP**

ENGINE DESIGN

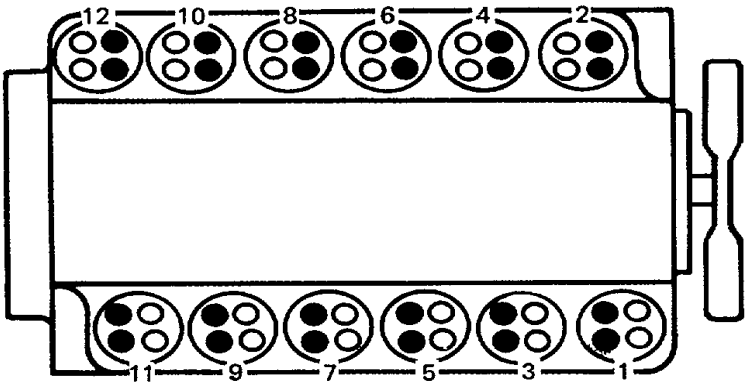
CYLINDER AND VALVE LOCATION



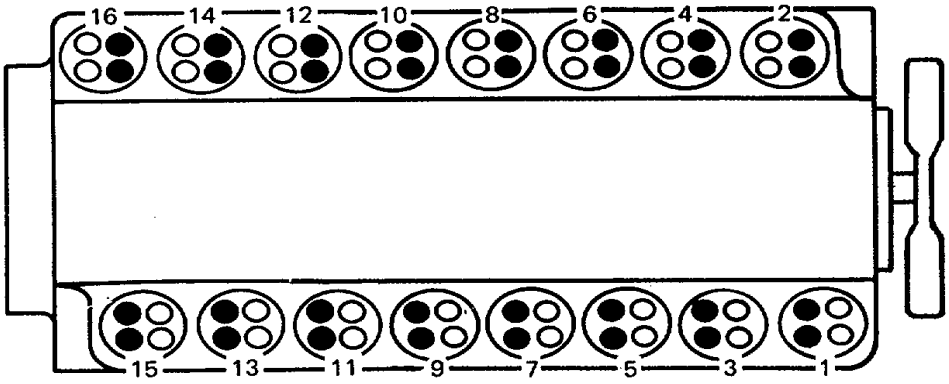
3508

○ INTAKE 0.38mm (.015 in.)

● EXHAUST 0.76mm (.030 in.)



3512



3516

B62374X1

ENGINE DESIGN

SPECIFICATIONS		ENGINE		
		3508	3512	3516
NUMBER AND ARRANGEMENT OF CYLINDERS		60° V-8	60° V-12	60° V-16
VALVES PER CYLINDER		4	4	4
DISPLACEMENT		34.5 LITER (2105 cu. in.)	51.8 LITER (3158 cu. in.)	69.1 LITER (4210 cu. in.)
BORE		170mm (6.7 in.)		
STROKE		190mm (7.5 in.)		
COMPRESSION RATIO		13:1		
TYPE OF COMBUSTION		Direct Injection		
VALVE SETTING	Intake	0.38mm (.015 in.)		
	Exhaust	0.76mm (.030 in.)		

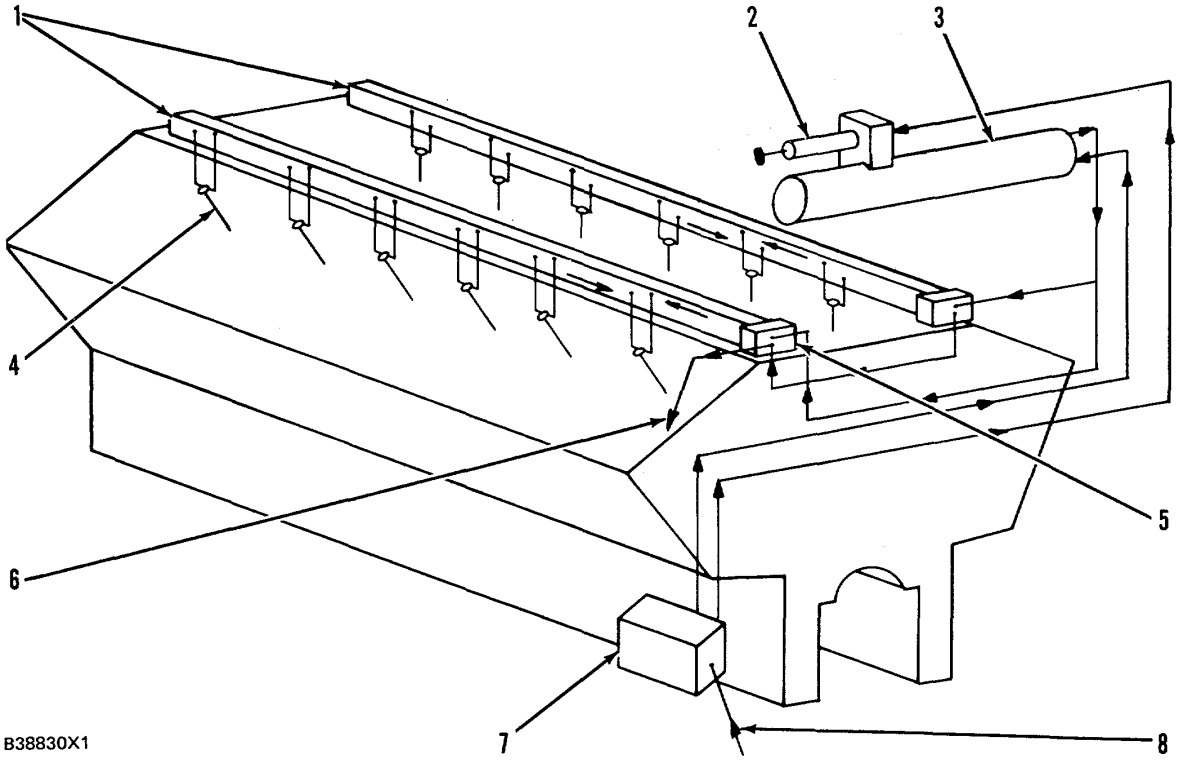
FIRING ORDER (INJECTION SEQUENCE)		
ENGINE	SAE STANDARD ROTATION*	SAE OPPOSITE ROTATION*
3508	1-2-7-3-4-5-6-8	1-8-7-2-6-5-4-3
3512	1-12-9-4-5-8-11-2-3-10-7-6	1-4-9-8-5-2-11-10-3-6-7-12
3516	1-2-5-6-3-4-9-10-15-16-11-12-13-14-7-8	1-6-5-4-3-10-9-16-15-12-11-14-13-8-7-2

* Direction of Rotation (as viewed from flywheel end):
SAE Standard Rotation----------Counterclockwise
SAE Opposite Rotation--------Clockwise

NOTE: Front end of engine is opposite the flywheel end. Left side and right side of engine are as seen from flywheel end, No. 1 cylinder is the front cylinder on the right side. 64No. 2 cylinder is the front cylinder on the left side.

FUEL SYSTEM

GENERAL



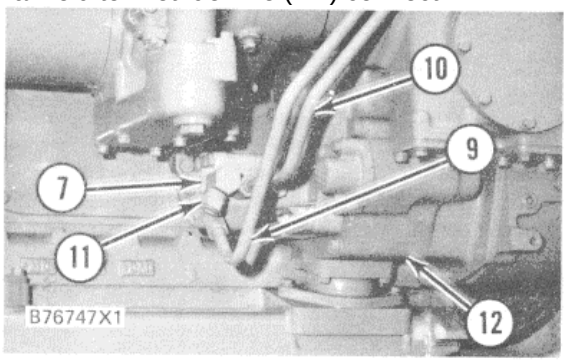
FUEL FLOW SCHEMATIC
(3512 Illustrated)

1. Fuel manifolds. 2. Fuel priming pump. 3. Fuel filter housing. 4. Fuel injectors. 5. Pressure regulating valve. 6. Fuel return to supply. 7. Fuel transfer pump. 8. Fuel from supply.

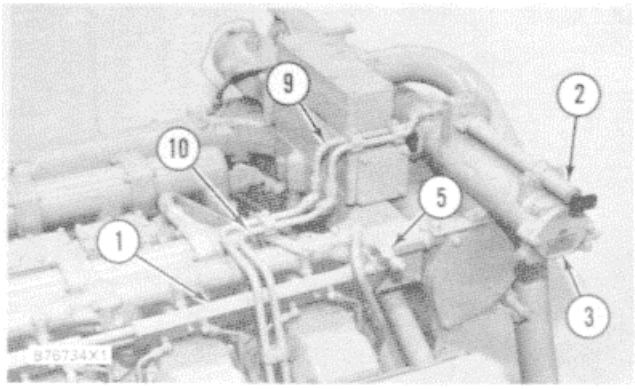
Fuel transfer pump (7) is located on the right side of the engine. The lower shaft of engine oil pump (12) drives the gear type transfer pump. Fuel from the supply tank is pulled through a primary fuel filter by the transfer pump and sent to the fuel filter housing.

The transfer pump has a check valve and a bypass valve. The check valve is located in the pump head assembly located behind where line (9) is connected. The check valve prevents fuel flow back through the transfer pump when priming pump (2) is used. The bypass valve is located behind a cap (plug) in the drive end of the pump. The bypass valve limits the maximum pressure of the fuel. It will open the outlet side of the pump to the pump inlet if the fuel pressure goes up to 860 kPa (125 psi). This helps prevent damage to fuel system components caused by too much pressure.

The transfer pump pushes fuel through fuel filter housing (3) to fuel manifolds ( ). The fuel manifolds have two sections. The fuel flows through the top section of the manifold to inlet fuel line (14) connect-



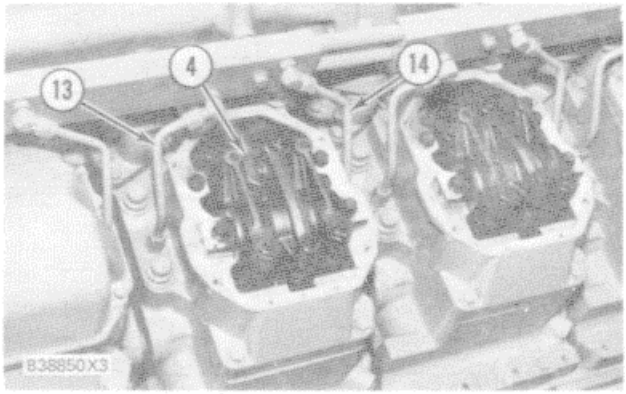
RIGHT SIDE OF ENGINE
7. Fuel transfer pump. 9. Fuel line to filter housing. 10. Fuel line to priming pump. 11. Elbow (fuel supply).
12. Engine oil pump.



RIGHT SIDE OF ENGINE

1. Fuel manifold (right hand). 2. Priming pump. 3. Fuel filter housing. 5. Pressure regulating valve. 9. Fuel line to filter housing (from transfer pump). 10. Fuel line to priming pump (from transfer pump).

ed to the right side of each cylinder head. On earlier engines, filter screens are located in the fittings where fuel goes into each cylinder head. On later engines, the filter screens are located in the ports of the unit injector. A drilled passage (15) in cylinder head (16) takes fuel to a circular (shape of a circle) chamber around the injector. The chamber is made by O-rings on the outside diameter of injector (4) and the injector bore in the cylinder head.



CYLINDER HEADS

3. Fuel injector. 13. Outlet fuel line. 14. Inlet fuel line.

Only part of the fuel in the chamber is used for injection. Approximately 4½/2 times as much fuel as needed for normal combustion flows through the chamber to a drilled passage in the left side of the cylinder head. This passage is connected by outlet fuel line (13) to the bottom section of the fuel manifold. This constant flow of fuel around the injectors helps to cool them.

The fuel flows back through the bottom section of each fuel manifold to pressure regulating valve (2), on the front of the right fuel manifold. The fuel flows through this valve and then back to the tank.

FUEL FLOW THRU INJECTOR

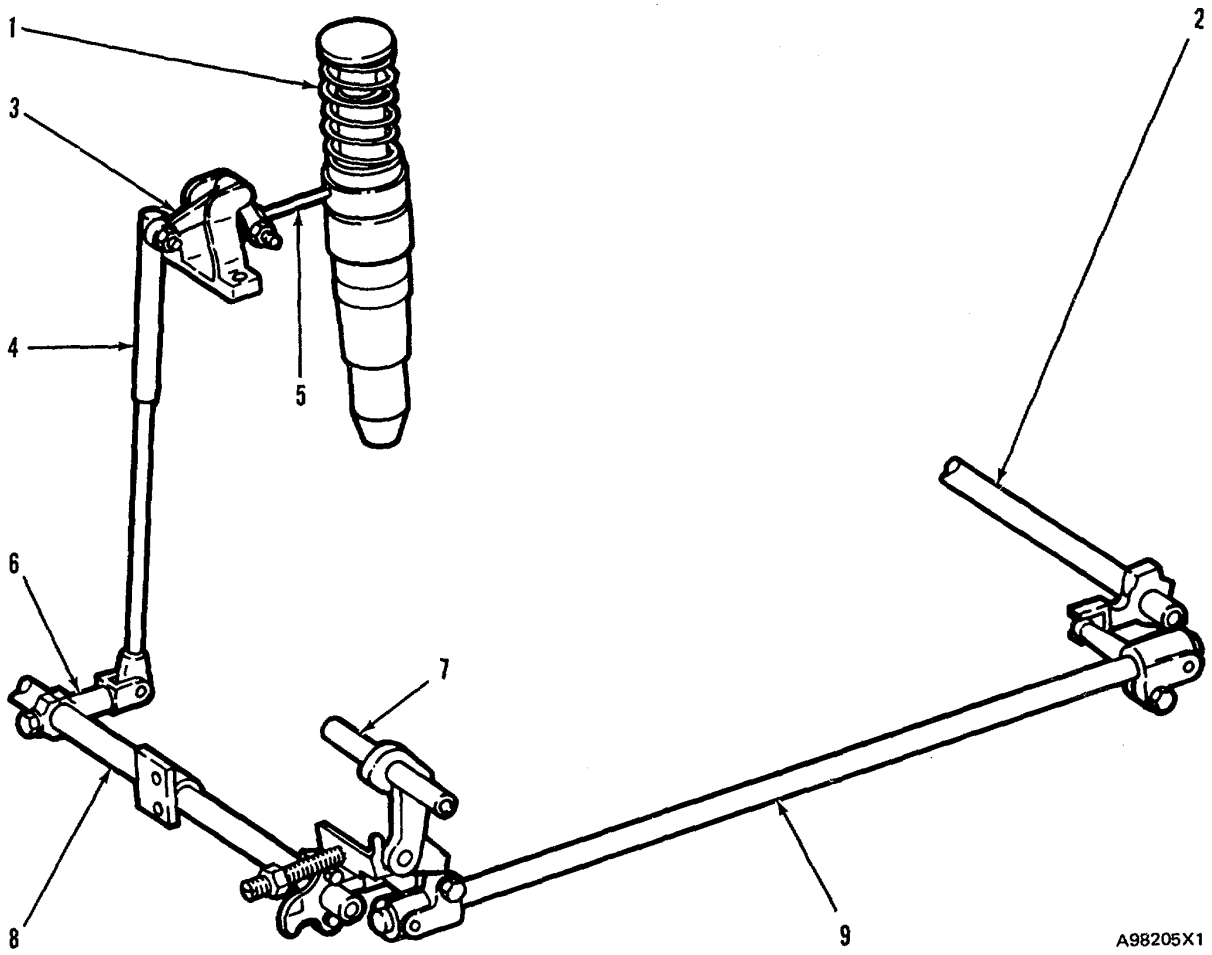
4. Injector. 13. Outlet fuel line. 14. Inlet fuel line. 15. Drilled passage. 16. Cylinder head. 17. Cylinder.

Check each engine installation for an excess fuel flow based on fuel consumed (used for combustion). Minimum flow is three times the amount of fuel consumed. Excess fuel is then returned to the fuel tank, not back to the pump inlet. This will make sure that any air in the system will be removed before the fuel is sent back to the injectors.

Pressure regulating valve (2) has a spring and plunger arrangement between the bottom section of the fuel manifolds and the line that returns fuel to the tank. This valve keeps the pressure of the fuel at 415 to 450 kPa (60 to 65 psi) in the cylinder heads and fuel manifolds. The valve also has resistance to fuel flow but little resistance to air. This helps re- move (bleed) air from the fuel injection system when the engine is in operation. The air is returned to the fuel tank and vented to the atmosphere.

A small orifice connects the inlet and outlet passages in the adapter (housing) of pressure regulating valve (2). The orifice is used as a syphon break when the fuel filters are changed. This keeps the fuel lines and manifolds from being drained and the use of fuel priming pump (4) is not normally needed. The fuel priming pump must be used when the lines are dry. For example: after an overhaul or other major fuel system work.

FUEL INJECTION CONTROL LINKAGE



FUEL INJECTOR CONTROL LINKAGE

1. Injector. 2. Control shaft (left side). 3. Bellcrank. 4. Control rod. 5. Rack. 6. Lever. 7. Governor shaft. 8. Control shaft (right side}. 9. Cross shaft.

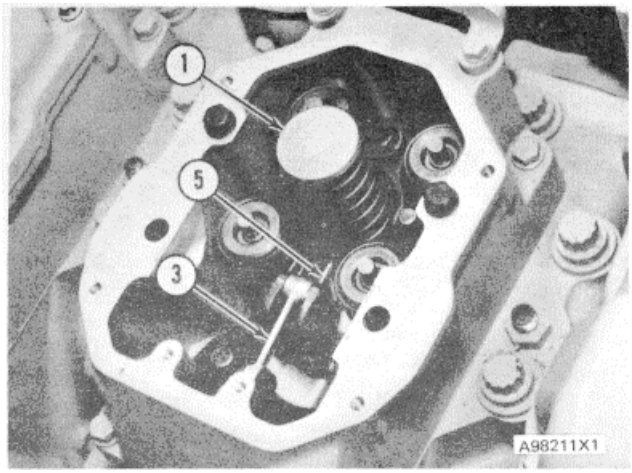
A fuel injector (1) is located in each cylinder head. The position of rack (5) controls the amount of fuel injected into-the cylinder. Pull the rack out of the injector for more fuel, push it in for less fuel.

Rack position is changed by bellcrank (3). The bellcrank is moved by control rod (4). The control rods have an adjustment screw on the top. The adjustment screw is used to synchronize the injectors. The control rods are spring loaded. If the rack of one injector sticks (will not move), it will still be possible for the governor to control the other racks so the engine can be shutdown. Each control rod on the right side of the engine is connected by a lever (6) to control shaft (8).

When the rotation of governor shaft (7) is clockwise, as seen from in front of the engine, the action of the governor linkage moves control shaft (8) counterclockwise. That is, in the fuel "ON" direction.

Right control shaft (8) and left *control* shaft (2) are connected by cross shaft (9). The linkage between the injectors on the left side of the engine and control shaft (2) is similar to the linkage on the right side.

Should the linkage become disconnected from the governor, the weight of the control linkage will move the fuel injector racks to the fuel "SHUTOFF" position, and the engine will stop.



CYLINDER HEAD
(Rocker Shaft Removed for Photo Illustration)
1. Injector. 3. Bellcrank. 5. Rack.

FUEL INJECTOR

The injector is held in position by clamp (3). Fuel is injected when rocker arm (2) pushes the top of the injector down. The movement of the rocker arm is controlled by the camshaft through lifter assembly (7) and push rod (4). The amount of fuel injected is controlled by rack (5). Movement of the rack causes rotation of a gear fastened to plunger (6). Rotation of the plunger changes the effective stroke (that part of the stroke during which fuel is actually injected) of the plunger.

Injection timing is a product of two factors; the angular location of camshaft (8) and the location of plunger (6). The angular location of the camshaft is controlled by the camshaft drive gears at the rear of the engine. The location of the plunger can be adjusted with screw (1).

Injection Cycle

When the plunger is at the top of its stroke, fuel flows from the fuel supply chamber, around the injector and through both the lower and upper ports of the barrel. As plunger (6) is moved down by rocker arm (2), fuel is pushed back into the supply chamber through the lower port. The fuel can now go up through a passage in the center of the plunger and out through the upper port of the barrel. As the lower port is closed by the end of plunger (6), fuel can still flow through the upper port until it is closed by the upper scroll on plunger (6). At this point, injection starts and the effective stroke begins. During the effective stroke, fuel is injected into the cylinder until the downward movement of plunger (6) causes the lower scroll to open the lower port and release the fuel pressure.

Fuel then goes through the center passage of plunger (6) and the lower port during the remainder of the downstroke. This sudden release of pressure as the lower port is opened causes the fuel to hit the spill deflector with a high force. The spill deflector gives protection to the injector housing (nut) from erosion (wear) because of the force of the released fuel. On the return (UP) stroke, the chamber inside the injector barrel is filled with fuel again.

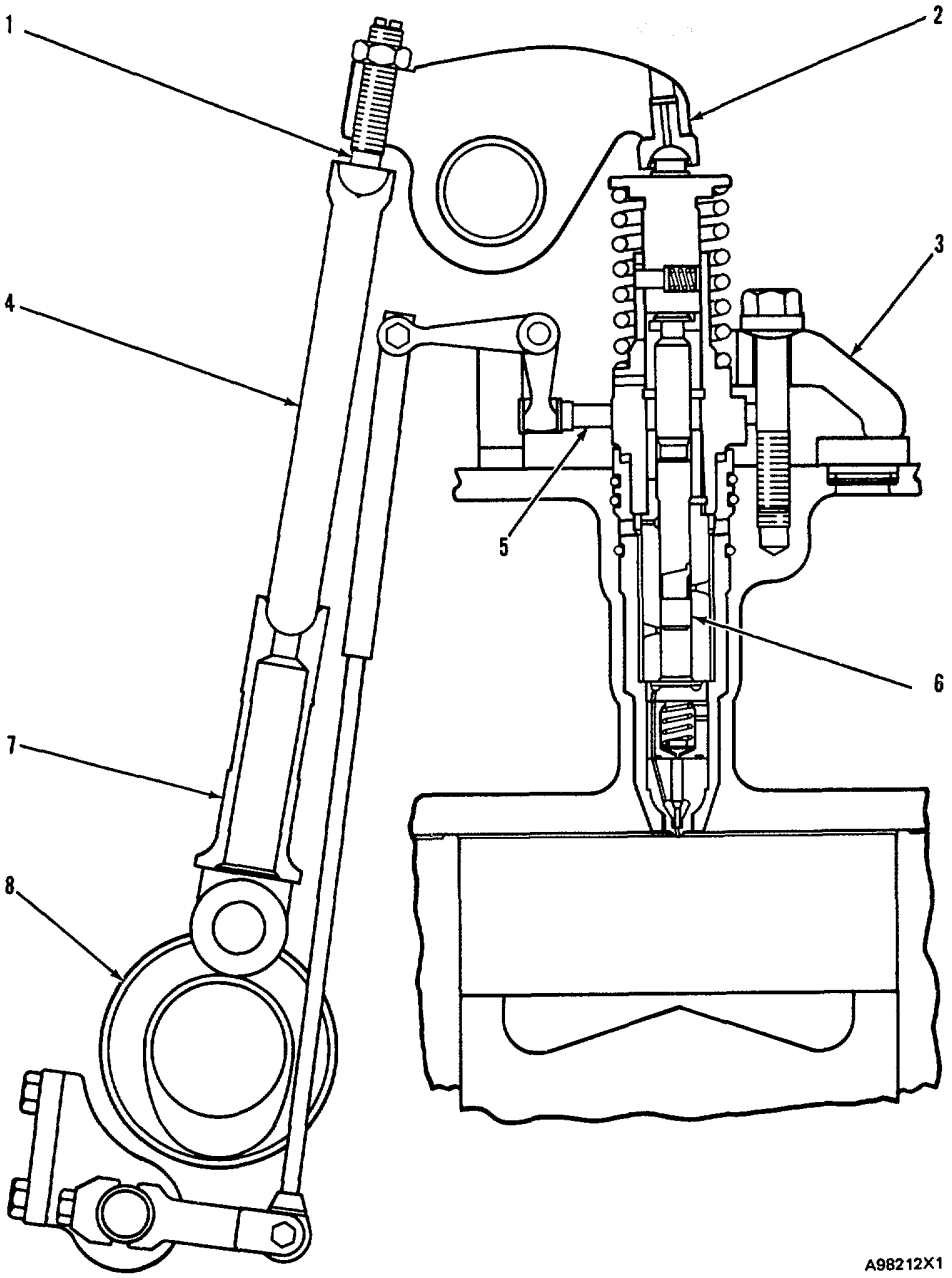
The plunger can be turned by rack (5) at the same time it is moved up and down by rocker arm (2). The upper section of the plunger has a flat side that fits in the gear, which is engaged with the rack. The plunger slides up and down in the gear, which also has a flat side on its inside diameter. The flat sides let the parts turn together. The rack is engaged with the gear.

When the rack moves, it turns the plunger through the gear. The rotation of plunger (6) controls injection timing and the fuel output of the injector. Rotation of the plunger changes the relation of the plunger scrolls to the ports in the barrel, and this increases or decreases the length of the effective stroke and the point at which injection takes place.

When rack (5) is moved all the way in against the injector body, no injection takes place during the downstroke of the plunger. This is the fuel "SHUT-OFF" position. A small amount of rack movement "OUT" from the injection body is used as a "NO FUEL" movement or "SHUTOFF" position for governing purposes. This "NO FUEL" distance starts at the "ALL-THE-WAY-IN" position of the rack, and ends when the lower scroll opens the lower port and the upper scroll closes the upper port. Movement of the rack "OUT" from this point in the fuel "ON" direction, gives an interval in the plunger stroke when both ports are closed by the plunger and injection takes place. As the rack is moved farther "OUT" in the fuel "ON" direction, the quantity of fuel during the injection stroke increases until a maximum is available at full rack movement.

The scrolls on plunger (6) are used to time the start of injection and set the amount of fuel per injection stroke. The scrolls can change the start of injection in relation to the engine piston position and the length of the effective stroke in relation to the different engine loads. The start of injection can be retarded (made later) with a decrease or increase in injector output according to the engine needs.

During the fuel injection stroke, fuel passes from the barrel chamber through a valve assembly. The valve assembly has a spring-loaded needle valve with a cone shaped end which operates against a seat. The angle of the valve is slightly larger than that of the



FUEL INJECTOR OPERATION

1. Screw. 2. Rocker arm. 3. Clamp. 4. Control rod. 5. Rack. 6. Plunger. 7. Litter assembly. 8. Camshaft.

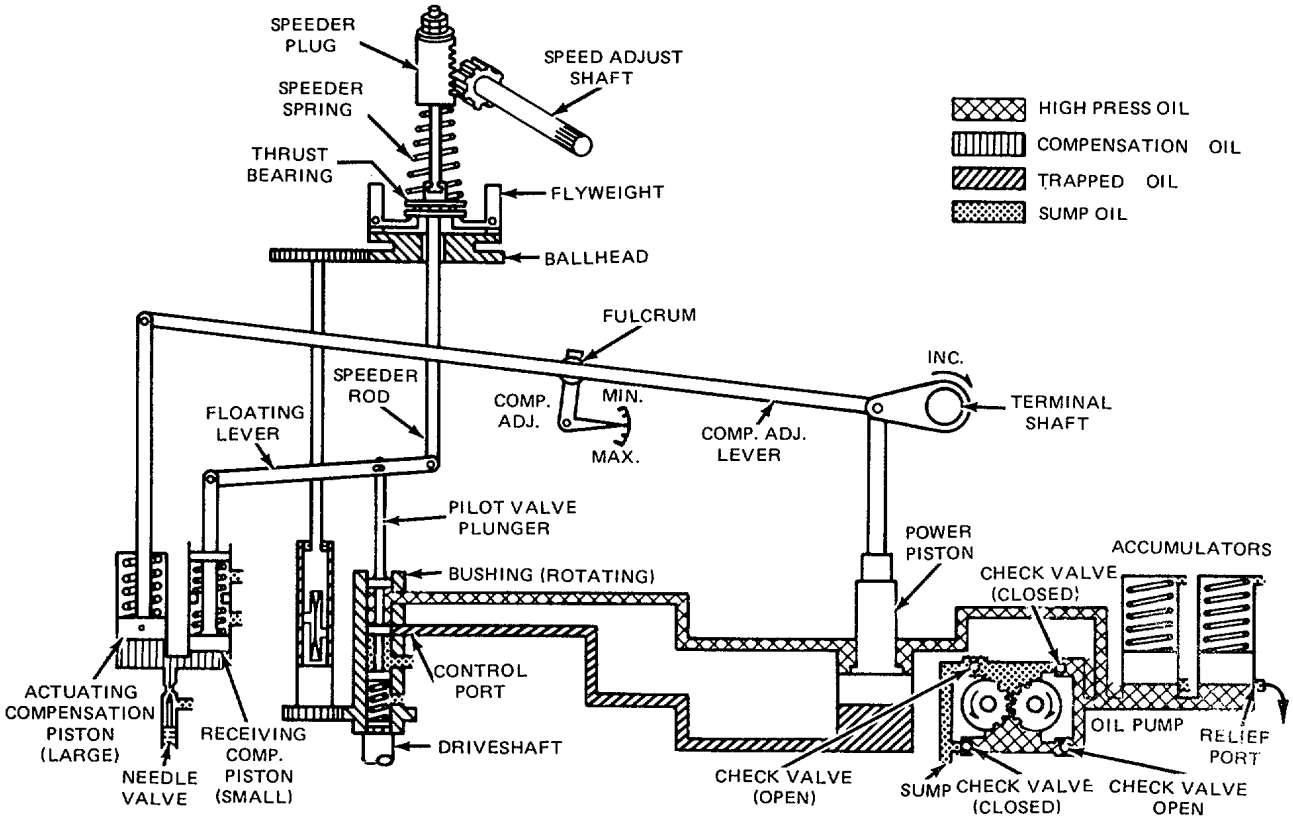
seat to give line contact. The valve opens at approximately 20 000 to 23 300 kPa (2800 to 3400 psi) and closes at approximately 10 300 kPa (1500 psi). The fuel flows from the chamber inside the barrel through drilled passages and grooves in the spring cage, and then through passages around the guide section of the valve to the valve chamber. Here the fuel pressure lifts the needle valve off its seat, and the fuel now flows through the spray tip and out the orifices into the combustion chamber.

A flat check valve is used above the needle valve to keep the high pressure combustion gases out of the injector. If the needle valve is held open by small foreign particles for a moment between injection cycles, combustion gases can come into the injector and cause damage. The injector operates with the flat check valve until the foreign particle has washed on through and normal operation takes place.

The spray tip of the injector extends a short distance below the cylinder head into the combustion chamber. The spray tip has several small orifices spaced evenly around the outside diameter. The tip sprays fuel into the combustion chamber. The top surface of the piston has a shaped (mexican hat-type) crater. The design of the piston causes rotation of the air as it comes through the valves into the combustion chamber, which improves the mixture of the fuel and air.

WOODWARD UG8 LEVER GOIVERNORS

A90202X1



SCHEMATIC OF UG8 LEVER GOVERNOR

The Woodward UG8L is the standard governor used on Industrial Engines. Standard location for the governor is on the right side of the front housing; with an attachment gear group it can be located on the left side.

The UG8 Lever Governor is a mechanical-hydraulic governor. A hydraulic activated power piston is used to turn the output terminal shaft of the governor. The terminal shaft is connected by linkage to the fuel control torsion shafts. The rotation of the fuel control torsion shafts controls rack movement at each fuel injector. Make reference to FUEL INJECTOR CONTROL LINKAGE. The governor oil pump and ballhead are driven by a bevel gear set in the governor drive housing. The bevel gear set is driven by the front gear group.

The oil pump gives pressure oil to operate the power piston. The drive gear of the oil pump has a bushing in which the pilot valve plunger moves up and down. The driven gear of the oil pump is also the drive for the ballhead.

An accumulator is used to keep a constant oil pressure of approximately 830 kPa (120 psi) to the top of the power piston and to the pilot valve.

The power piston is connected by a linkage system to one side of the output terminal shaft. There is oil pressure on both the top and bottom of the power piston. The bottom of the piston has a larger area than the top.

Less oil pressure is required on the bottom than on the top to keep the piston stationary. When the oil pressure is the same on the top and bottom of the piston, the piston will move up and cause the output terminal shaft to turn in the increase fuel direction. When oil pressure on the bottom of the piston is directed to the sump (drain), the piston will move down and cause the output terminal shaft to turn in the decrease fuel direction. Oil to or from the bottom of the power piston is controlled by the pilot valve.

The pilot valve has a plunger and bushing. The bushing is turned by the governor drive shaft. The rotation of the bushing helps reduce friction between

the bushing and plunger. The pilot valve plunger has a land that controls the oil flow through the ports in the bushing. When the pilot valve plunger is moved down, high pressure oil goes to the bottom of the power piston and the power piston will move up. When the pilot valve plunger is moved up, the oil on the bottom of the power piston is released to the sump and the power piston moves down. When the pilot valve plunger is in the center (balance) position, the oil port to the bottom of the power piston is closed and the power piston will not move. The pilot valve plunger is moved by the ballhead assembly.

The ballhead assembly has a ballhead, flyweights, speeder spring, thrust bearing, speeder plug and speeder rod. The ballhead assembly is driven by a gear and shaft from the driven gear of the oil pump. The speeder rod is fastened to the thrust bearing which is in contact with the flyweights. The speeder rod is connected to the pilot valve plunger by a lever. The speeder spring is held in position on the thrust bearing by the speeder plug.

As the ballhead turns, the flyweights move out due to centrifugal force. This will make the flyweight toes move up and cause compression of the speeder spring. When the force of the speeder spring and the force of the flyweights are equal the engine speed is constant. The speeder plug can be moved up or down manually to change the compression of the speeder spring which will change the speed of the engine.

The compensation system gives stability to engine speed changes. The compensation system has a needle valve and two pistons-an actuating piston and a receiving piston. The actuating piston is also con-nected to the output terminal shaft by the compensa- tion adjusting lever and linkage system. A fulcrum that is adjustable is on the lever. When the position of the fulcrum is changed, the amount of movement possible of the actuating piston is changed.

The receiving piston is connected to the pilot valve plunger and the speeder rod by a lever.

The needle valve makes a restriction to oil flow between the oil sump and the two pistons.

When the actuating piston moves down, the piston puts a force on the oil under the receiving piston and moves it up. When the receiving piston moves up it raises the pilot valve plunger to stop the flow of oil to the bottom of the power piston.

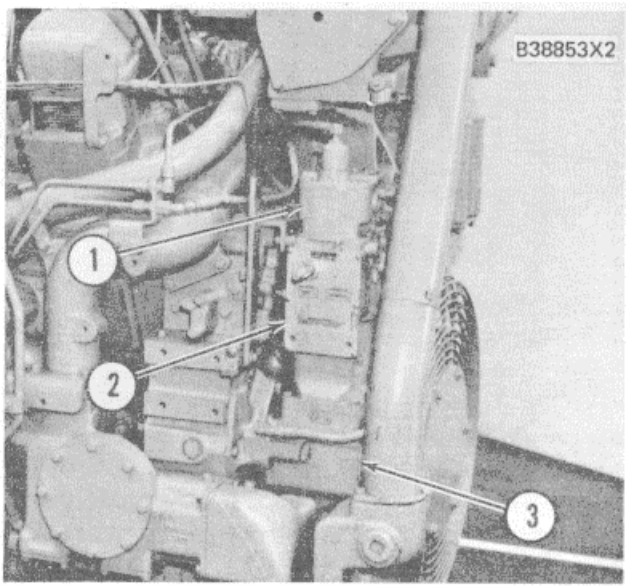
When the engine is in operation at a steady speed the land on the pilot control valve is in the center of the control port of the bushing. A decrease in load will cause an increase in engine speed. With an in- crease in engine speed the flyweights move out and raise the speeder rod and floating lever. This raises the pilot valve plunger and releases oil from the bottom of the power piston. As the power piston moves down, the output terminal shaft moves in the decrease fuel direction. When the output terminal shaft moves, the actuating compensation piston moves up and causes a suction on the oil under the receiving piston which moves down. The floating lever is pulled down by the receiving piston and the lever moves the pilot control valve down to close the control port. The output terminal shaft and power piston movement is stopped. As the engine speed returns to normal, the flyweights move in and the speeder rod moves down. When the oil pressure in the compensation system and the sump oil become the same through the needle valve, the receiving compensation piston moves up at the same rate as the speeder rod moves down. This action keeps the pilot valve plunger in position to close the port.

An increase in load will cause a decrease in engine speed. When engine speed decreases, the flyweights move in and lower the speeder rod and floating lever. This lowers the pilot valve plunger and lets pressure oil go under the power piston. The power piston moves up and turns the output terminal shaft in the increase fuel direction. When the output terminal shaft moves, the actuating compensation piston moves down and causes a pressure on the receiving piston which moves up. The floating lever is pushed up by the receiving piston and the lever moves the pilot valve plunger up to close the control port. The output terminal shaft and power piston movement is stopped.

A change to the speed setting of the governor will give the same governor movements as an increase or decrease in load.

A lever on the speed adjustment shaft is used to change the engine speed. The speed adjustment shaft moves the speeder plug up and down to change the force of the speeder spring.

This governor is also equipped with speed droop, however, it must be adjusted inside the governor.



UG8 LEVER GOVERNOR
1. Air-Fuel ratio control. 2. Governor. 3. Governor drive.

AIR FUEL RATIO CONTROL

The air fuel ratio control is installed on top of the basic UG8L Governor. The unit is made up of an inlet manifold pressure sensor, a hydraulic circuit and mechanical linkage that connects the unit to the governor. Pressure oil from the governor hydraulic system is used to operate the unit.

When engine speed or load is increased rapidly, it is possible for a standard (unlimited) governor to supply more fuel than can be burned with the amount of available air. Too much smoke and poor acceleration are the result. The fuel ratio control works to limit the movement of the governor terminal shaft in the increase fuel direction as a direct result of inlet manifold pressure. Thus, fuel which can be burned is limited to the air available for combustion as the engine speed is increased. This gives more complete combustion and keeps smoke to a minimum while acceleration is improved.

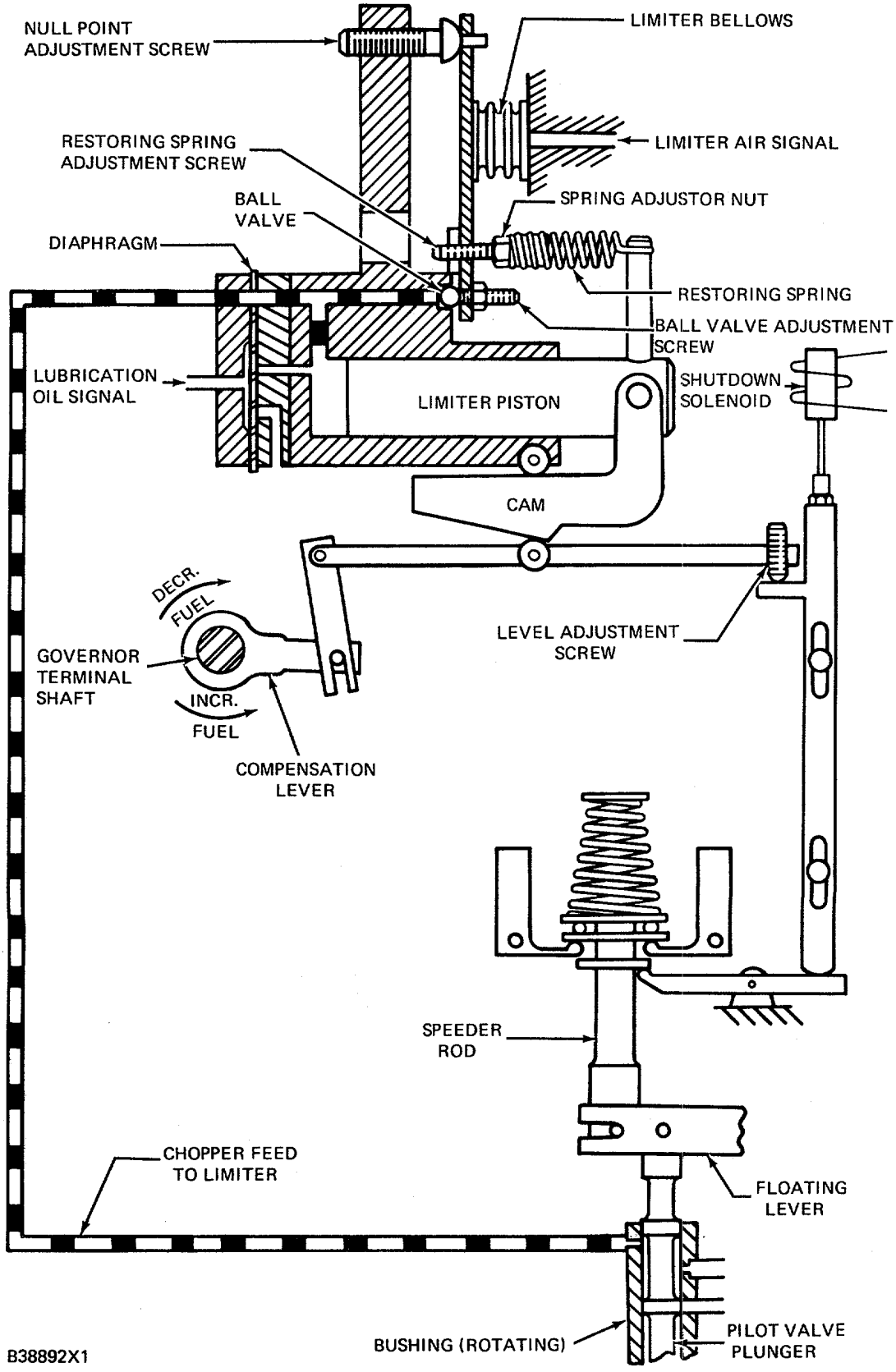
The air fuel ratio is also used for protection to limit the fuel as the result of any large, sudden restriction of air supply to the engine.

Governor accumulator oil pressure is changed to a restricted variable (pulsating) oil flow as small holes (ports) in the pilot valve bushing move past a passage in the controlet housing. In a constant speed opera- tion, the ball valve is not tight against its seat and lets oil flow back to the sump. The ball valve is held in position by the sensing bellows, which is connected to inlet manifold air pressure. The force used to hold the ball valve is proportional to the inlet manifold air pressure.

As inlet manifold air pressure increases, the ball valve makes contact with its seat and oil pressure increases to move the limiter piston to the right against the force of the restoring spring. This movement increases the tension on the restoring spring until the spring force is in balance with the sensing bellows force. The oil pressure now can push the ball valve off its seat and let a small amount of oil flow to the sump. This reduces the pressure behind the limiter piston and the piston stops movement. The piston position is proportional to inlet manifold air pressure.

The cam fastened to the limiter piston operates through linkage to limit the travel of the governor terminal shaft. The governor terminal shaft limits the fuel to the engine through the fuel control link- age. The terminal shaft can turn in the increase fuel direction until the pivot lever lifts the pilot valve above center. Oil pressure on the bottom of the power piston is now directed to the sump. The power piston moves down and causes the terminal shaft to turn in the decrease fuel direction.

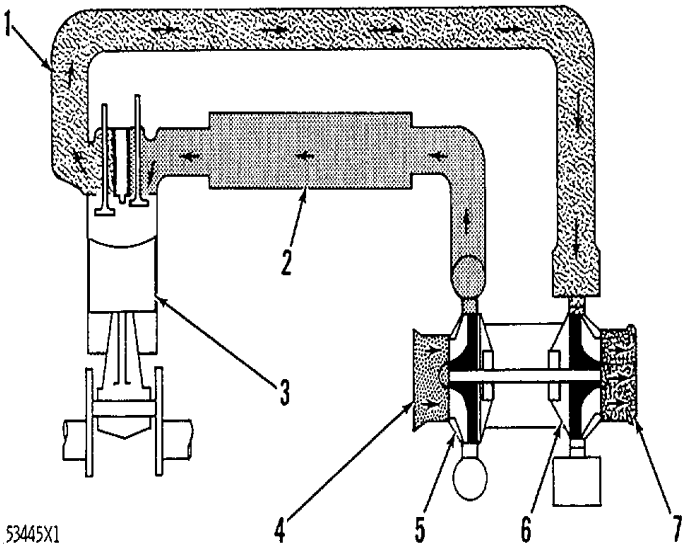
When the engine is stopped, the limiter piston is held to the left by the restoring spring. The fuel limit valve at this position is set high enough by the cam to give enough fuel for start up. At cranking speed, oil pressure behind the limiter piston goes by the diaphram to the sump. After the engine has started, engine lubrication oil pressure pushes the diaphram against its seat and closes the governor oil drain. Oil pressure now increases behind the limiter piston. The limiter piston moves out until the roller follower is on the operating slope of the cam. At this point the ball valve is moved off its seat, the oil can now flow to sump and the piston movement is stopped.



SCHEMATIC OF AIR FUEL RATIO CONTROL SYSTEM

AIR INLET AND EXHAUST SYSTEM

The components of the air inlet and exhaust system control the quality and amount of air avail- able for combustion. There is a separate turbocharger and exhaust manifold on each side of the engine. A common aftercooler is located between the cylinder heads in the center of the engine. The inlet manifold is a series of elbows that connect the aftercooler chamber to the inlet ports (passages) of the cylinder heads. Two camshafts, one in each side of the block, control the movement of the valve system components.



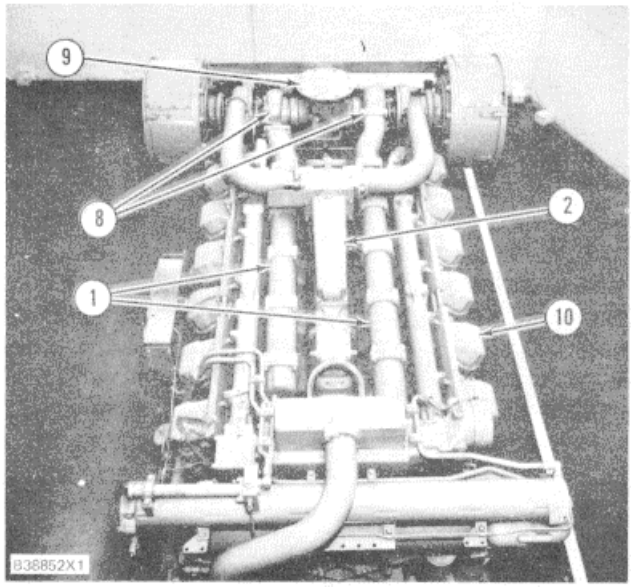
AIR INLET AND EXHAUST SYSTEM
1. Exhaust manifold. 2. Aftercooler. 3. Engine cylinder. 4. Air inlet. 5. Turbocharger compressor wheel. 6. Turbocharger turbine wheel. 7. Exhaust outlet.

Air flow is the same on both sides of the engine. Clean inlet air from the air cleaners is pulled through air inlet (4) by compressor wheel (5). The rotation of the compressor wheel causes compression of the air and forces it through a tube to aftercooler (2). The aftercooler lowers the temperature of the com- pressed air before it goes into the inlet chambers in each cylinder head. This cooled, compressed air fills the inlet chambers in the cylinder heads. Air flow from the inlet chamber into the cylinder is controlled by the intake valves.

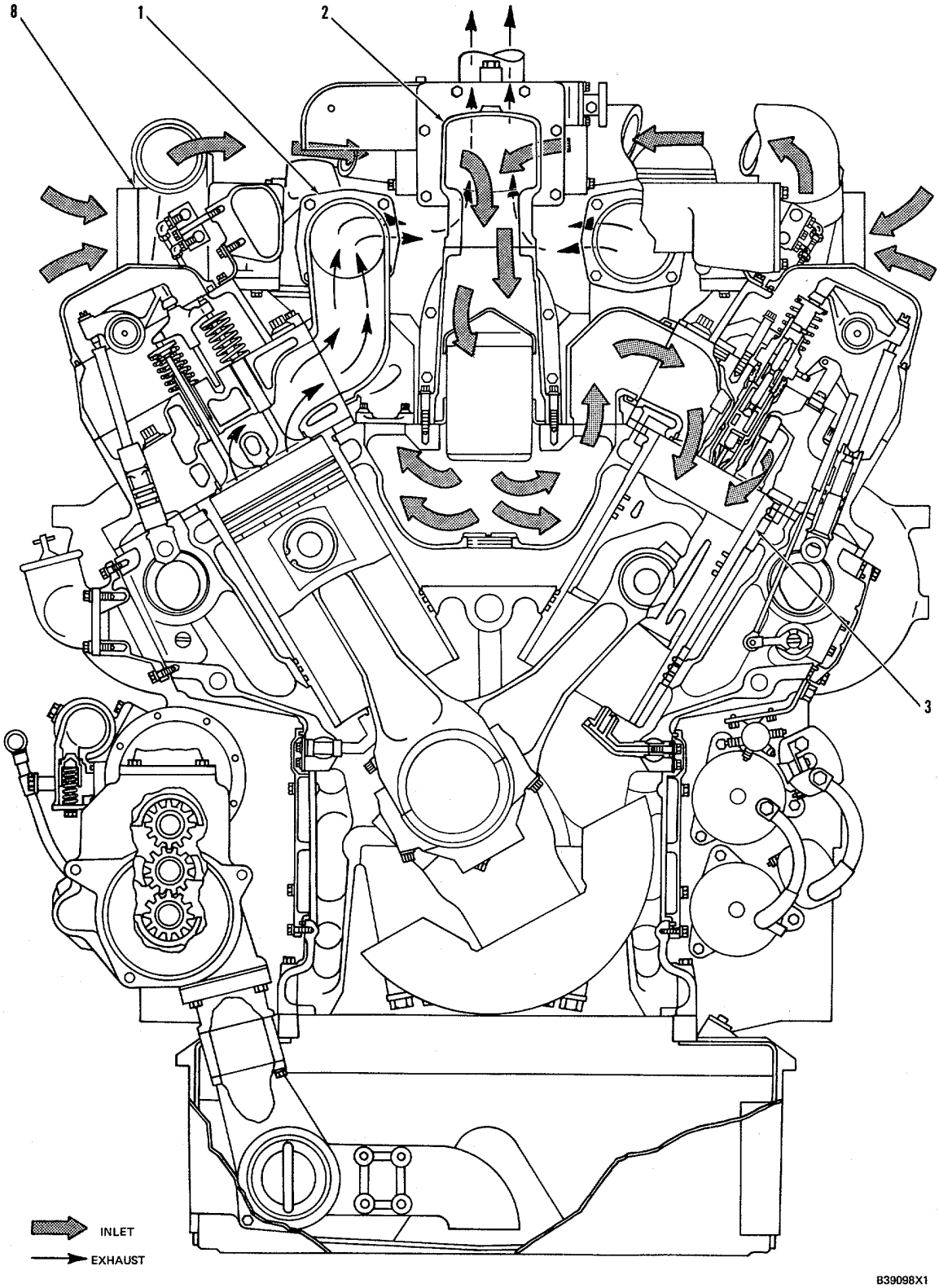
There are two intake and two exhaust valves for each cylinder. Make reference to Valve System Components. The intake valves open when the piston moves down on the inlet stroke. Cooled, compressed air from the inlet chamber is pulled into the cylinder.

The intake valves close and the piston starts to move up on the compression stroke. When the piston is near the top of the compression stroke, fuel is injected into the cylinder. The fuel mixes with the air and combustion starts. The force of combustion pushes the piston down on the power stroke. When the piston moves up again it is on the exhaust stroke. The exhaust valves open and the exhaust gases are pushed through the exhaust port into exhaust manifold (I). After the piston makes the exhaust stroke, the exhaust valves close and the cycle (inlet, compression, power, exhaust) starts again.

Exhaust gases from the exhaust manifold go into the turbine side of the turbocharger (8) and cause turbine wheel (6) to turn. The turbine wheel is con- nected to the shaft that drives compressor wheel (5). The exhaust gases then go out the exhaust outlet (7) through exhaust elbow (9).



AIR SYSTEM COMPONENTS
(3512 Engine Shown)
1. Exhaust manifolds. 2. Aftercooler. 8. Turbochargers. 9. Exhaust elbow. 10. Cylinder head.



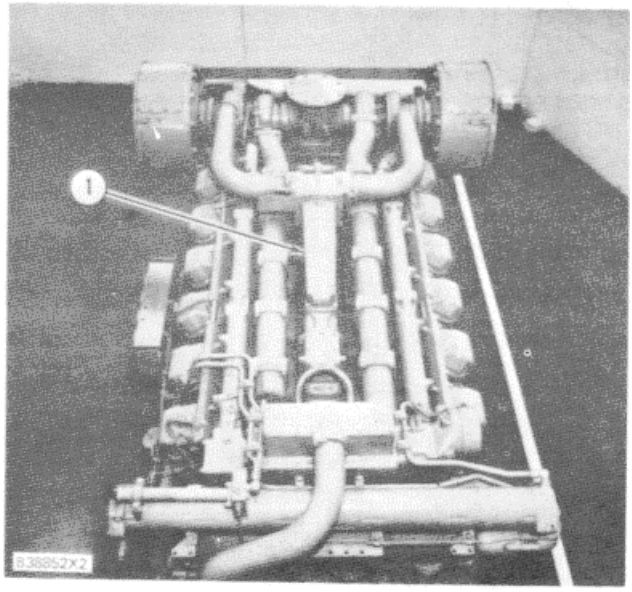
AIR FLOW SCHEMATIC
1. Exhaust manifold. 2. Aftercooler. 3. Cylinder. 8. Turbocharger.

AFTERCOOLER

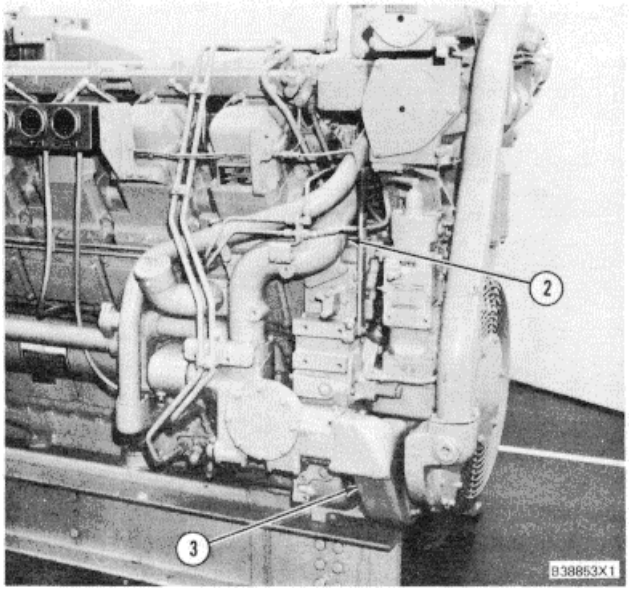
The aftercooler is located at the center of the vee, and has a coolant charged core assembly. The 3516 can have two core assemblies. Coolant from water pump (3) flows through pipe (2) into the aftercooler. It then flows through the core assembly (assemblies) and back out of the aftercooler through a different pipe into the rear of the cylinder block.

There is a connector (tube) that connects the bottom rear of each core assembly to the cylinder block. This is used to drain the core assembly (assemblies) when the coolant is drained from the engine.

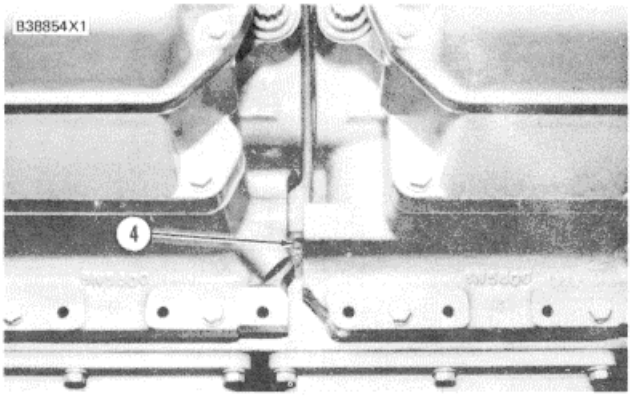
Inlet air from the compressor side of the turbo-chargers flows into the aftercooler through pipes. This air then passes through the fins of the core assembly (assemblies) which lowers the temperature. The cooler air goes out the bottom of the after-cooler into the air chamber, and then up through the elbows to the inlet ports (passages) in the cylinder heads.



TOP OF ENGINE
1. Aftercooler housing.



RIGHT FRONT OF ENGINE
2. Pipe. 3. Water pump.

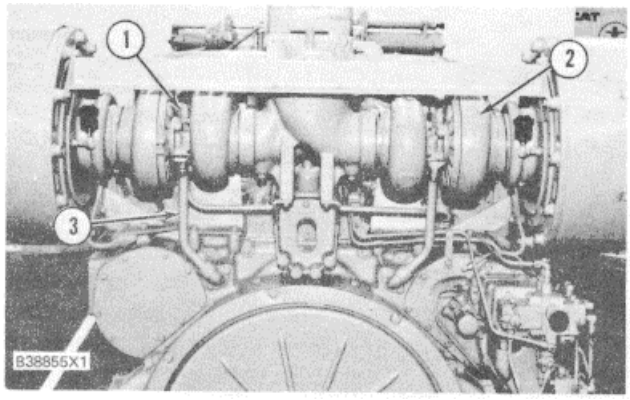


AFTERCOOLER AIR CHAMBER DRAIN
4. Drain plug.

One drain plug is located between the No. 1 and No. 3 cylinder heads, and another plug is located between the last two cylinder heads on the left side of the engine. These plugs can be removed to check for water or coolant in the aftercooler air chamber.

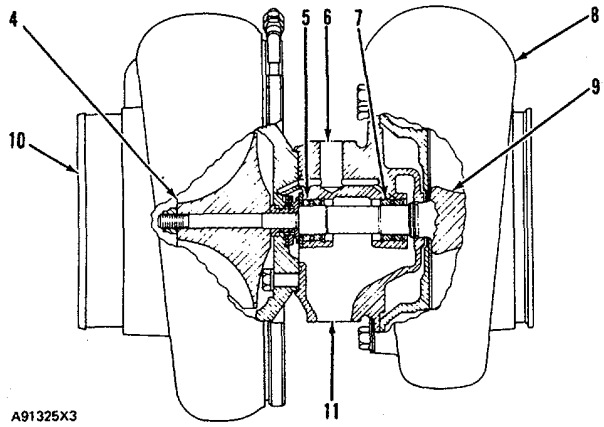
TURBOCHARGERS

There are two turbochargers, on the rear of the engine. The turbine side of the turbochargers is fastened to the exhaust manifolds. The compressor side of the turbocharger is connected to the aftercooler.



TURBOCHARGERS
1. Turbocharger. 2. Oil drain line. 3. Oil supply line.

The exhaust gases go into turbine housing (8) and push the blades of turbine wheel (9). This causes the turbine wheel and compressor wheel to turn at up to 70,000 rpm.



TURBOCHARGER
(3512 Shown)
4. Compressor wheel. 5. Bearing. 6. Oil Inlet. 7. Bearing. 8. Turbine housing. 9. Turbine wheel. 10. Air in-let. 11. Oil outlet.

Clean air from the air cleaners is pulled through the compressor housing air inlet (10) by rotation of compressor wheel (4). The action of the compressor wheel blades causes a compression of the inlet air. This compression gives the engine more power because it makes it possible for the engine to burn additional fuel with greater efficiency.

Maximum rpm of the turbocharger is controlled by the fuel setting, the high idle rpm setting and the height above sea level at which the engine is operated.

NOTICE

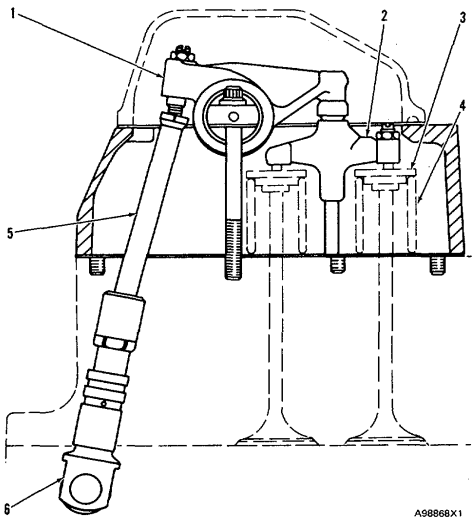
If the high idle rpm or the fuel setting is higher than given in the Fuel Setting And Related Information Fiche (for the height above sea level at which the engine is operated), there can be damage to engine or turbocharger parts. Damage will result when increased heat and/or friction due to the higher engine output goes beyond the engine cooling and lubrication systems abilities. A mechanic that has the proper training is the only one to make the adjustment of fuel setting and high idle rpm setting.

The bearings (5 and 7) in the turbocharger use engine oil under pressure for lubrication. The oil comes in through oil inlet port (6) and goes through passages in the center section for lubrication of the bearings. Then the oil goes out oil outlet port (11) and back to the oil pan.

VALVE SYSTEM COMPONENTS

The valve system components control the flow of inlet air and exhaust gases into and out of the cylinders during engine operation.

The crankshaft gear drives the camshaft gears through idlers. Both camshafts must be timed to the crankshaft to get the correct relation between piston and valve movement.



VALVE SYSTEM COMPONENTS
1. Rocker arm. 2. Bridge. 3. Rotocoil. 4. Valve spring. 5. Push rod. 6. Lifter.

The camshafts have three cam lobes for each cylinder. Two lobes operate the valves and one operates the fuel injector.

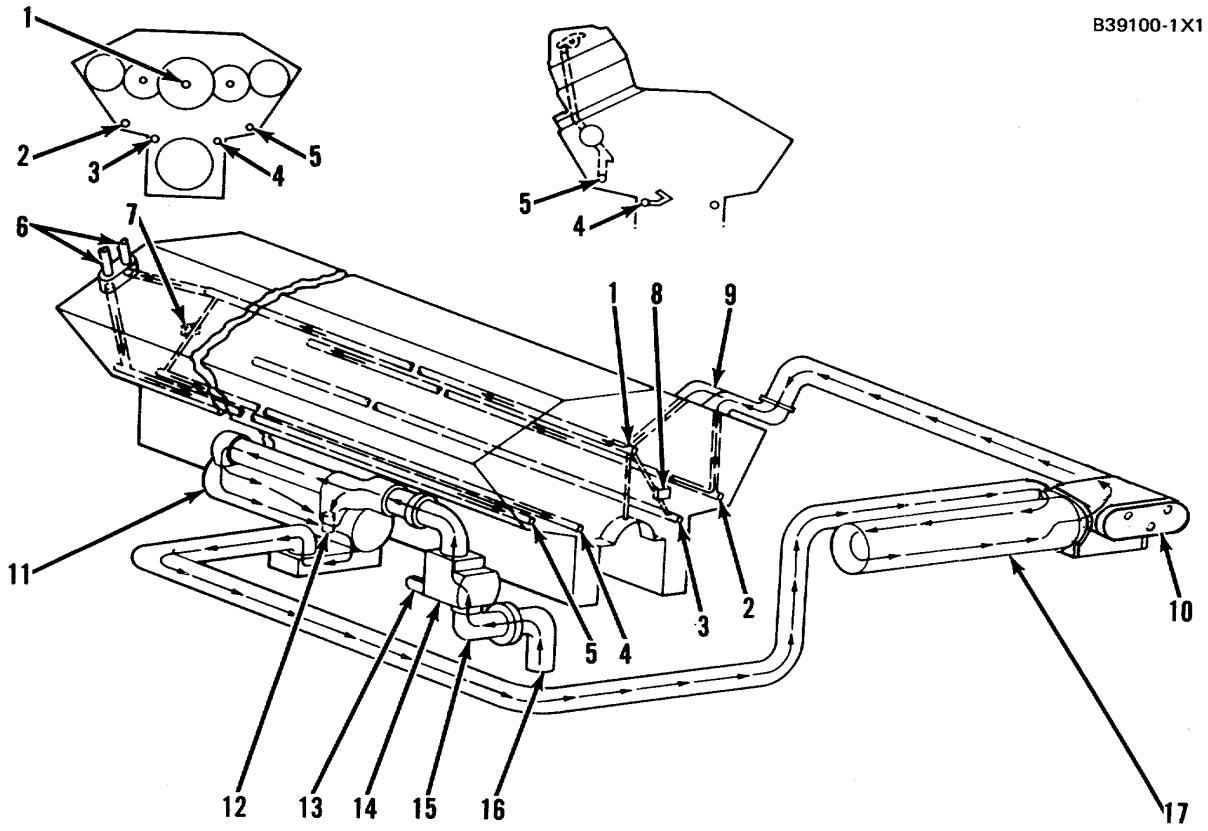
As each camshaft turns the lobes on the camshaft cause lifters (6) to go up and down. This movement makes push rods (5) move the rocker arms (1). Movement of the rocker arms makes the bridges (2) move up and down on dowels in the cylinder head. The bridges let one rocker arm open and close two valves (intake or exhaust). There are two intake and two exhaust valves for each cylinder.

Rotocoils (3) cause the valves to turn while the engine is running. The rotation of the valves keeps the deposit of carbon on the valves to a minimum and gives the valves longer service life.

Valve springs (4) cause the valves to close when the lifters move down.

LUBRICATION SYSTEM

B39100-1X1



LUBRICATION SYSTEM SCHEMATIC

1. Main oil gallery. 2. Left camshaft oil gallery. 3. Piston cooling jet oil gallery. 4. Piston cooling jet oil gallery. 5. Right camshaft oil gallery. 6. Turbocharger oil supply. 7. Sequence valve. 8. Sequence valve. 9. Elbow. 10. Oil filter bypass valve. 11. Oil cooler. 12. Oil cooler bypass valve. 13. Oil pump relief valve. 14. Engine oil pump. 15. Elbow. 16. Suction bell. 17. Oil filter housing.

This system uses an oil pump (14) with three pump gears that are driven by the front gear train. Oil is pulled from the pan through suction bell (16) and elbow (15) by the oil pump. The suction bell has a screen to clean the oil.

The oil pump pushes oil through oil cooler (11) and the oil filters to oil galleries (I and 2) in the block. The fin and tube type oil cooler lowers the temperature of the oil before the oil is sent on to the filters.

Bypass valve (12) lets oil flow directly to the filters if the oil cooler becomes plugged or if the oil becomes thick enough (cold start) to increase the oil pressure differential (cooler inlet to outlet) by an amount of 180 ± 20 kPa (26 ± 3 psi).

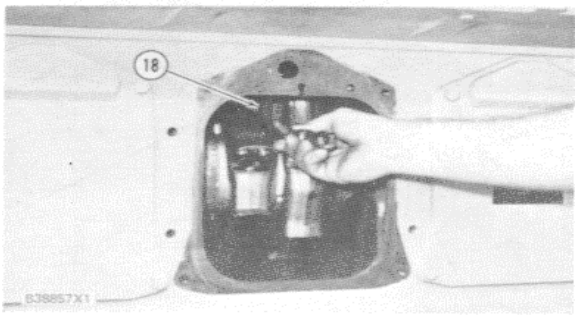
Cartridge type filters are located in oil filter housing (17) at the front of the engine. A single bypass valve is located in the oil filter housing.

Clean oil from the filters goes into the block through elbow (9). Part of the oil goes to left camshaft oil gallery (2), and the remainder goes to main oil gallery ( ).

The camshaft oil galleries are connected to each camshaft bearing by a drilled hole. The oil goes around each camshaft journal, through the cylinder head and rocker arm housing, to the rocker arm shaft. A drilled hole connects the bores for the valve lifters to the oil hole for the rocker arm shaft. The valve lifters get lubrication each time they go to the top of their stroke.

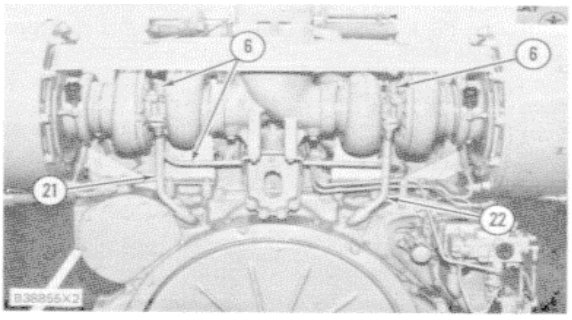
Main oil gallery (1) is connected to the main bearings by drilled holes. Drilled holes in the crankshaft connect the main bearing oil supply to the rod bearings. Oil from the rear of the main oil gallery goes to the rear of right camshaft gallery (5).

Sequence valves (7 and 8) let oil from main oil gallery (1) go to piston cooling jet oil galleries (3 and 4). The sequence valves open at 140 kPa (20 psi). The sequence valves will not let oil into the piston cooling jet oil galleries until there is pressure in the main oil gallery. This decreases the amount of time necessary for pressure build-up when the engine is started. It also helps hold pressure at idle speed.



PISTON COOLING AND LUBRICATION
18. Cooling jet.

There is a piston cooling jet (18) below each piston. Each cooling jet has two openings. One opening is directed at a passage in the bottom of the piston. This passage takes oil to a manifold behind the ring band of the piston. A slot (groove) is in the side of both piston pin bores and connects them with the manifold behind the ring band. The other opening is directed at the center of the piston. This helps cool the piston and gives lubrication to the piston pin.

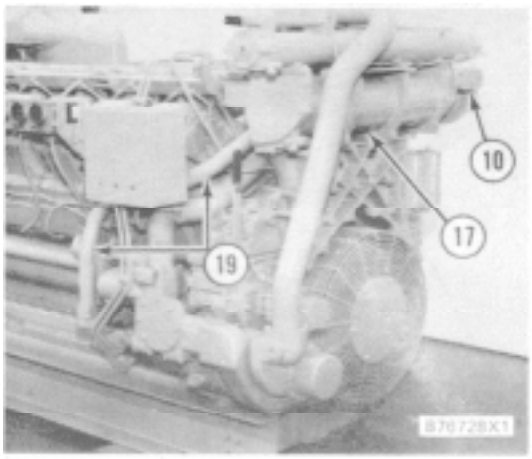


TURBOCHARGERS
(3516 Shown)
6. Oil supply lines. 21. Oil drain for left turbocharger. 22. Oil drain for right turbocharger.

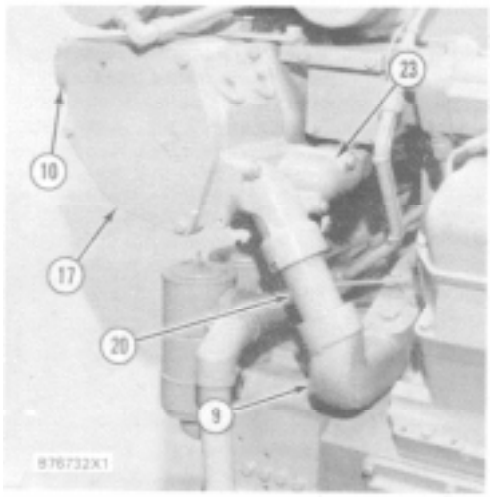
Oil lines (6) send oil to the turbochargers. The turbocharger drain lines (21 and 22) are connected to the flywheel housing on each side of the engine.

Oil is sent to the front and rear gear groups through drilled passages in the front and rear housings and cylinder block faces. These passages are connected to camshaft oil galleries (2 and 5).

After the oil for lubrication has done its work, it goes back to the engine oil pan.

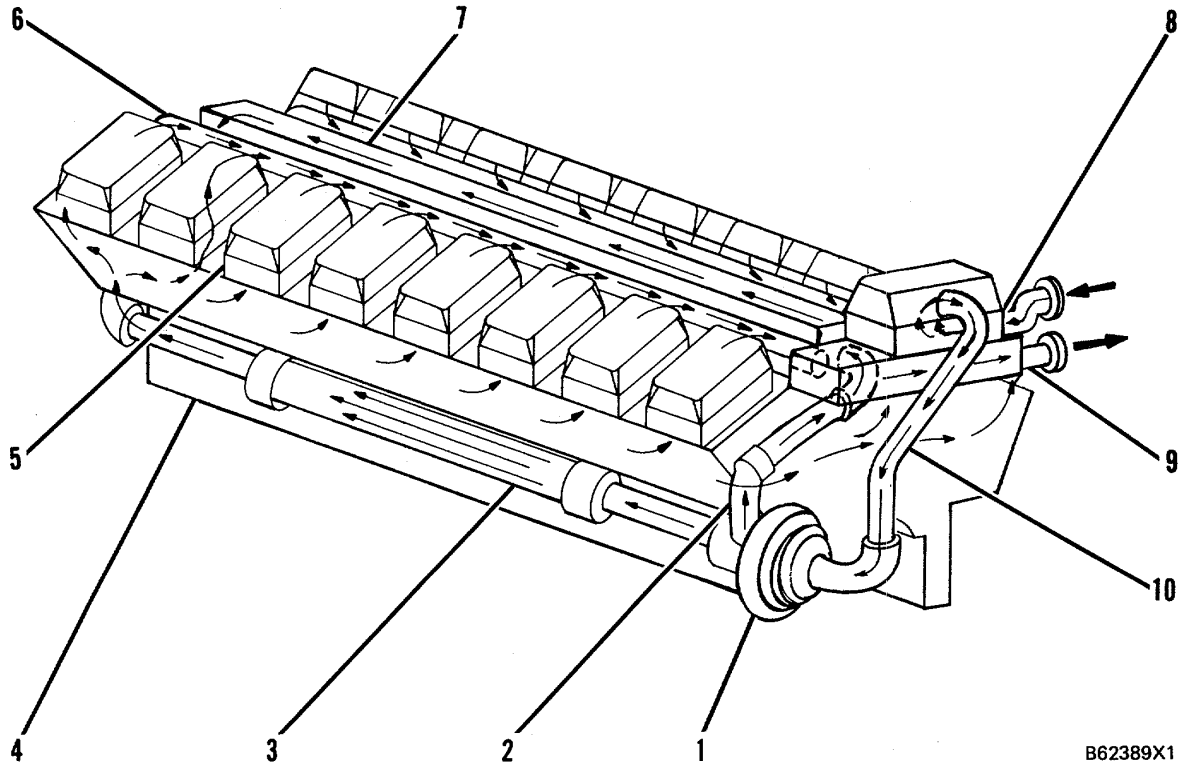


RIGHT FRONT SIDE OF ENGINE
10. Oil filter bypass valve. 17. Oil filter housing. 19. Oil line to filter housing.



LEFT FRONT OF ENGINE
9. Elbow. 10. Oil filter bypass valve. 17. Oil filter housing. 20. Oil outlet line from oil filter housing. 23. Filter oil supply from oil pump.

COOLING SYSTEM



SCHEMATIC OF COOLING SYSTEM
(3516 SHOWN)
1. Water pump. 2. Tube (to aftercooler). 3. Oil cooler. 4. Block. 5. Cylinder head. 6. Water manifold. 7. Aftercooler. 8. Regulator housing. 9. Tube (to radiator or heat exchanger). 10. Bypass tube.

Coolant goes in water pump (I) through an elbow that connects to the radiator or heat exchanger. The coolant flow is divided at the outlet of the water pump. Part of the coolant flow is sent to the aftercooler, while most of the coolant is sent through the oil cooler.

NOTE: There is one opening on the pump outlet so that a remote pump can be connected to the system. The remote pump can be used if there is a failure of the pump on the engine.

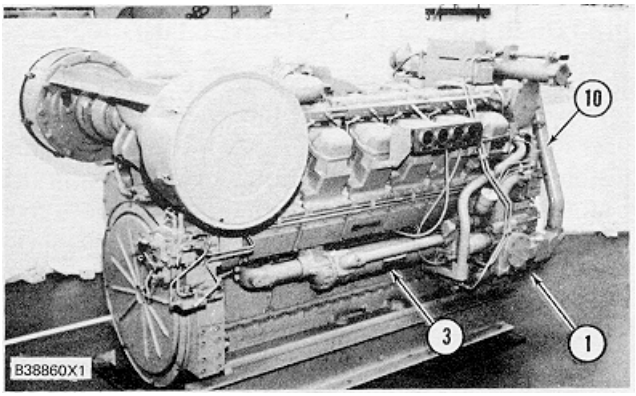
Coolant sent to the aftercooler goes through the aftercooler core, and then is sent through an elbow into a passage in the block near the center of the vee at the rear of the block. The coolant sent to the oil cooler goes through the oil cooler and flows into the water jacket of the block at the right rear cylinder. The cooler coolant mixes with the hotter coolant and goes to both sides of the block through distribution manifolds connected to the water jacket of all the cylinders. The main distribution manifold is located just above the main bearing oil gallery.

The coolant flows up through the water jackets and around the cylinder liners from the bottom to the top. Near the top of the cylinder liners, where the temperature is the hottest, the water jacket is made smaller. This shelf (smaller area) causes the coolant to flow faster for better liner cooling. Coolant from the top of the liners goes into the cylinder head which sends the coolant around the parts where the temperature is the hottest. Coolant then goes to the top of the cylinder head and out through an elbow, one at each cylinder head, into water manifolds (6) at each bank of cylinders. Coolant goes through the manifolds to the temperature regulator (thermostat) housing.

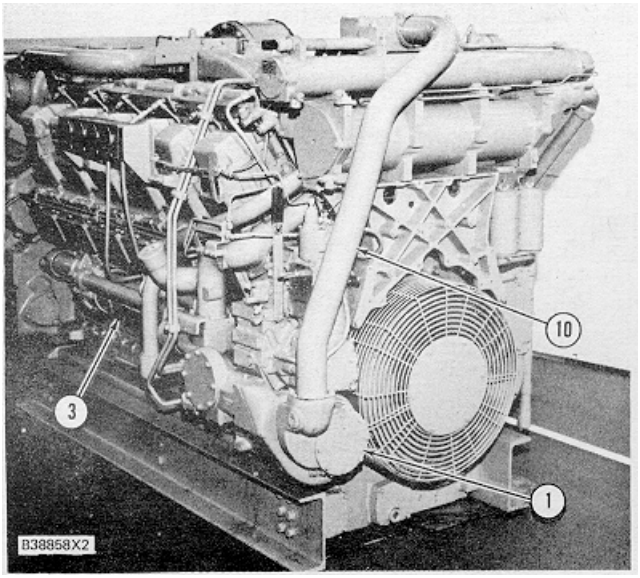
Regulator housing (8) has an upper and lower flow section, and uses four temperature regulators. The sensing bulbs of the four temperature regulators are in the coolant in the lower section of the housing. Before the regulators open, cold coolant is sent through the lower section of the housing and through the bypass line back to the inlet of the water pump. As the temperature of the coolant increases

enough to make the regulators start to open, coolant flow in the bypass line is stopped and coolant is sent through the outlets to the radiator or heat exchanger.

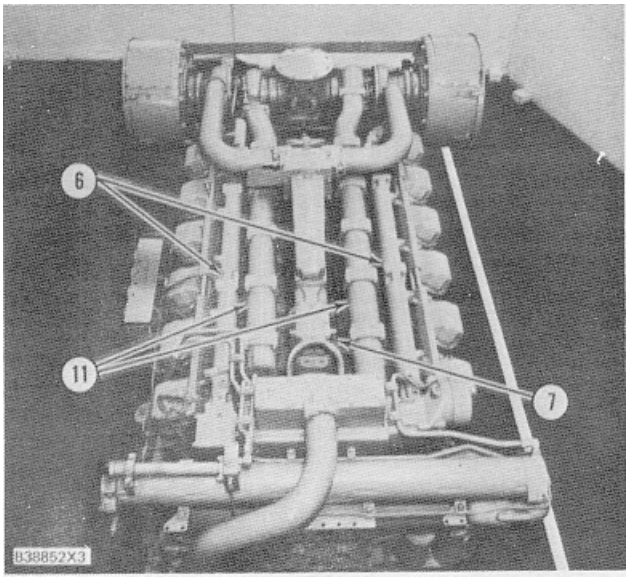
Total system coolant capacity will depend on the size of the heat exchanger. Use a coolant mixture of 50 percent pure water and 50 percent permanent antifreeze, then add a concentration of 3 to 6 percent corrosion inhibitor.



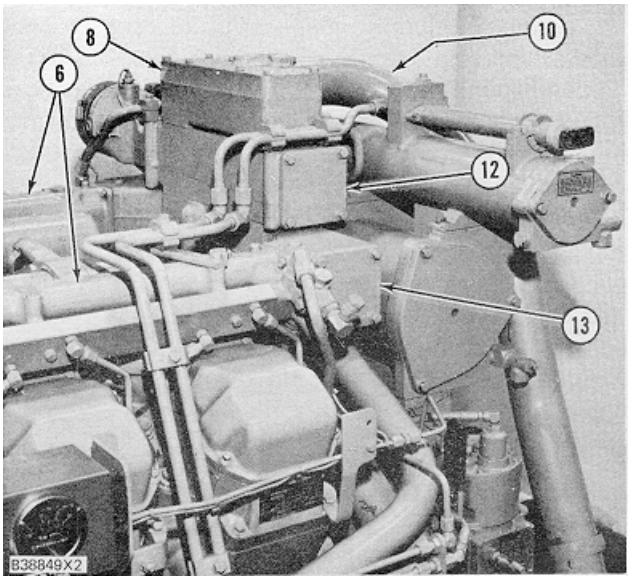
RIGHT SIDE OF ENGINE
1. Water pump. 3. Oil cooler. 10. Bypass tube.



FRONT OF ENGINE
1. Water pump. 3. Oil cooler. 10. Bypass tube.



TOP OF ENGINE
6. Water manifolds. 7. Aftercooler. 11. Exhaust manifolds.



WATER TEMPERATURE REGULATOR HOUSINGS
6. Water manifolds. 8. Regulator housing. 10. Bypass tube. 12. Regulator housing. 13. Housing.

BASIC BLOCK

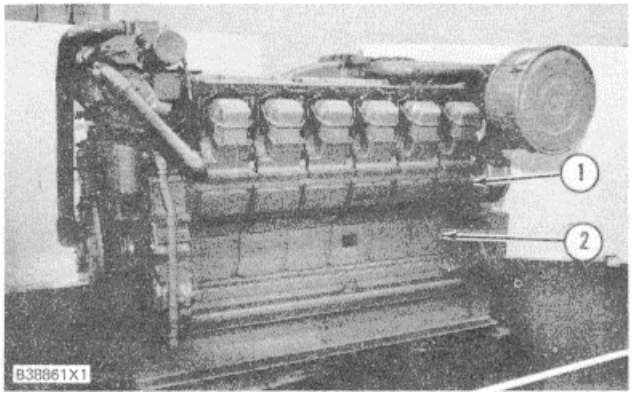
CYLINDER BLOCK, LINERS AND HEADS

The cylinders in the left side of the block make an angle of 600 with the cylinders in the right side of the block. The main bearing caps are fastened to the block with four bolts per cap.

The cylinder liners can be removed for replacement. The top surface of the block is the seat for the cylinder liner flange. Engine coolant flows around the liners to keep them cool. Three O-ring seals around the bottom of the liner make a seal between the liner and the cylinder block. A filler band goes under the liner flange and makes a seal between the top of the liner and the cylinder block.

The engine has a separate cylinder head for each cylinder. Four valves (two intake and two exhaust), controlled by a push rod valve system, are used for each cylinder. Valve guides without shoulders are pressed into the cylinder heads. The opening for the fuel injector is located between the four valves. A third lobe on the camshaft moves the push rod system that operates the fuel injector. Fuel is injected directly into the cylinder.

There is an aluminum spacer plate between each cylinder head and the block. Coolant goes out of the block through the spacer plate and into the head through eight openings in each cylinder head face. Water seals are used in each opening to prevent coolant leakage. Gaskets seal the oil drain passages between the head, spacer plate and block.



LEFT SIDE OF 3512 ENGINE
1. Covers for camshafts and fuel control linkage Inspection. 2. Covers for crankshaft main and rod bearing inspection.

Covers (1) allow access to the camshafts, valve lifters and fuel control shaft.

Covers (2) allow access to the crankshaft connecting rods, main bearings and piston cooling jets. With covers removed, all the openings can be used for inspection and service.

PISTONS, RINGS AND CONNECTING RODS

The aluminum pistons have an iron band for the top two rings. This helps reduce wear on the compression ring grooves. A chamber is cast into the piston just behind the top ring grooves. Oil from the piston cooling jets flows through this chamber to cool the piston and improve ring life. The pistons have three rings; two compression rings and one oil ring. All the rings are located above the piston pin bore. The oil ring is a standard (conventional) type. Oil returns to the crankcase through holes in the oil ring groove. The top two rings are the KEYSTONE type, which are tapered. The action of the ring in the piston groove, which is also tapered, helps prevent seizure of the rings caused by too much carbon deposit.

The connecting rod has a taper on the pin bore end. This gives the rod and piston more strength in the areas with the most load. Four bolts set at a small angle hold the rod cap to the rod. This design keeps the rod width to a minimum, so that a larger rod bearing can be used and the rod can still be removed through the liner.

CRANKSHAFT

The crankshaft changes the combustion forces in the cylinder into usable rotating torque which powers the machine. A vibration damper of the fluid type is used at the front of the crankshaft to reduce torsional vibrations (twist on the crankshaft) that can cause damage to the engine.

The crankshaft is symmetrical. This makes it possible to turn the crankshaft end for end when opposite engine rotation is desired.

The crankshaft drives a group of gears on the front and rear of the engine. The gear group on the front of the engine drives the oil pump, water pump, fuel transfer pump, governor and two accessory drives. The gear group on the rear of the engine drives the camshafts.

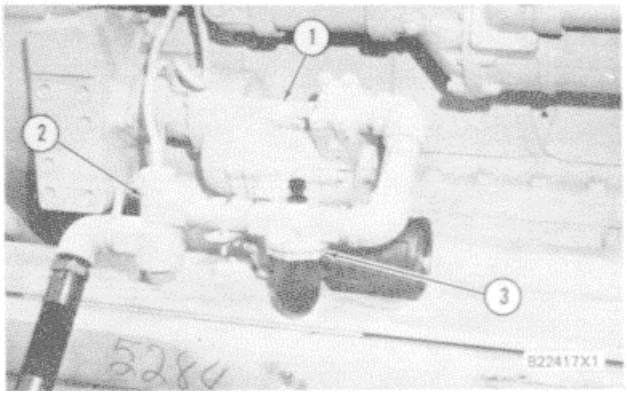
Lip seals and wear sleeves are used at both ends of the crankshaft for easy replacement and a reduction of maintenance cost. Pressure oil is supplied to all main bearings through drilled holes in the webs of the cylinder block. The oil then flows through drilled holes in the crankshaft to provide oil to the connecting rod bearings. The crankshaft is held in place by five main bearings on the 3508, seven main bearings on the 3512, and nine main bearings on the 3516. A thrust plate at either side of the center main bearing controls the end play of the crankshaft.

CAMSHAFTS

The engine has a camshaft or camshaft group for each side of engine, driven at the rear of the engine. Five bearings for the 3508, seven bearings for the 3512, and nine bearings on the 3516 support each camshaft or camshaft group. The 3512 and 3516 each use two camshafts per side that are doweled and bolted together to make a camshaft group. As the camshaft turns, each lobe moves a lifter assembly. There are three lifter assemblies for each cylinder. Each outside lifter assembly moves a push rod and two valves (either intake or exhaust). The center lifter assembly moves a push rod that operates the fuel injector. The camshafts must be in time with the crankshaft. The relation of the cam lobes to the crankshaft position cause the valves and fuel injectors in each cylinder to operate at the correct time.

AIR STARTING SYSTEM

The air starting motor is used to turn the engine flywheel fast enough to get the engine running.



TYPICAL AIR STARTING SYSTEM
1. Air starting motor. 2. Relay valve. 3. Oiler.

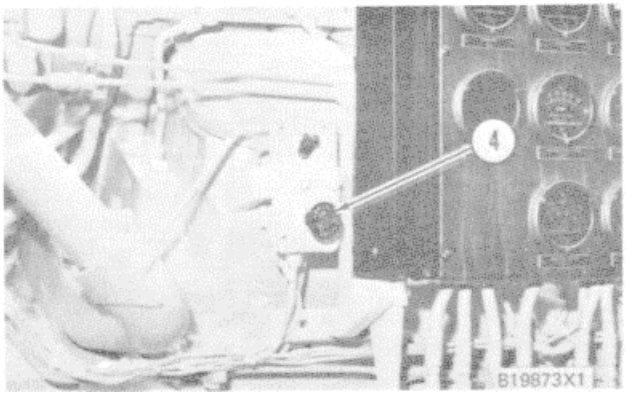
The air starting motor can be mounted on either side of the engine. Air is normally contained in a storage tank and the volume of the tank will determine the length of time the engine flywheel can be turned. The storage tank must hold this volume of air at 1720 kPa (250 psi) when filled.

For engines which do not have heavy loads when starting, the regulator setting is approximately 690 kPa (100 psi). This setting gives a good relationship between cranking speeds fast enough for easy starting and the length of time the air starting motor can turn the engine flywheel before the air supply is gone.

If the engine has a heavy load which can not be disconnected during starting, the setting of the air pressure regulating valve needs to be higher in order to get high enough speed for easy starting.

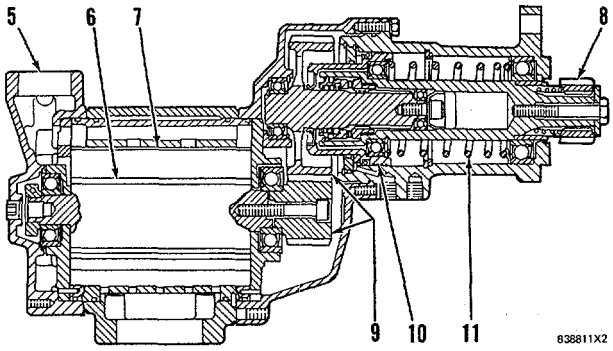
The air consumption is directly related to speed; the air pressure is related to the effort necessary to turn the engine flywheel. The setting of the air pressure regulator can be up to 1030 kPa (150 psi), if necessary, to get the correct cranking speed for a heavily loaded engine. With the correct setting, the air starting motor can turn the heavily loaded engine as fast and as long as it can turn a lightly loaded engine.

Other air supplies can be used if they have the correct pressure and volume. For good life of the air starting motor, the supply should be free of dirt and water. A lubricator with SAE 10 nondetergent oil [for temperatures above 0°C (32°F)], or diesel fuel [for temperatures below 0°C (32°F)] should be used with the starting system. The maximum pressure for use in the air starting motor is 1030 kPa (150 psi). Higher pressures can cause safety problems.



TYPICAL AIR START INSTALLATION
4. Air start control valve.

The air from the supply goes to relay valve (2). The starter control valve (4) is connected to the line before the relay valve (2). The flow of air is stopped by the relay valve (2) until starter control valve (4) is activated. The air from starter control valve (4) goes to piston (10) behind pinion (8) for the starter. The air pressure on piston (10) puts spring (11) in compression and puts pinion (8) in engagement with the flywheel gear. When the pinion is in engagement, air can go out through another line to relay valve (2). The air activates relay valve (2) which opens the supply line to the air starting motor.



AIR STARTING MOTOR
5. Air inlet. 6. Vanes. 7. Rotor. 8. Pinion. 9. Gears. 10 Piston. 11. Piston spring.

The flow of air goes through the oiler (3) where it picks up lubrication oil for the air starting motor.

The air with lubrication oil goes into the air motor through air inlet (5). The pressure of the air pushes against vanes (6) in rotor (7), and then exhausts through the outlet at bottom of air motor. This turns the rotor which is connected by gears (9) and a drive shaft to starter pinion (8) which turns the engine flywheel.

When the engine starts running the flywheel will start to turn faster than starter pinion (8). Pinion (8) retracts under this condition. This prevents damage to the motor, pinion (8) or flywheel gear.

When starter control valve (4) is released, the air pressure and flow to piston (10) behind starter pinion (8) is stopped, piston spring (11) retracts pinion (8). Relay valve (2) stops the flow of air to the air starting motor.

ELECTRICAL SYSTEM

The electrical system has three separate circuits: the charging circuit, the starting circuit and the low amperage circuit. Some of the electrical system components are used in more than one circuit. The battery (batteries), circuit breaker, ammeter, cables and wires from the battery are all common in each of the circuits.

The charging circuit is in operation when the engine is running. An alternator makes electricity for the charging circuit. A voltage regulator in the circuit controls the electrical output to keep the battery at full charge.

The starting circuit is in operation only when the start switch is activated.

The low amperage circuit and the charging circuit are both connected to the same side of the ammeter. The starting circuit connects to the opposite side of the ammeter.

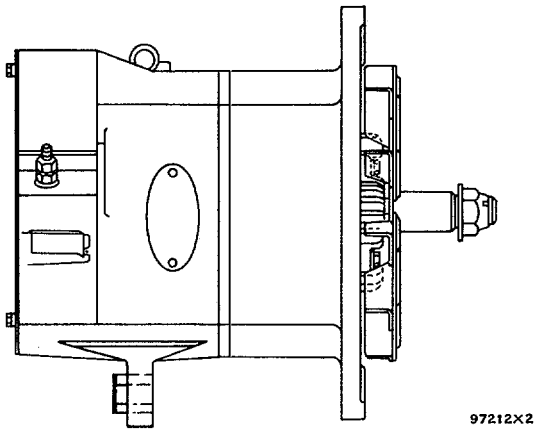
CHARGING SYSTEM COMPONENTS

Alternator

The alternator is driven by V-type belts from the crankshaft pulley. This alternator is a three phase, self-rectifying charging unit, and the regulator is part of the alternator.

This alternator design has no need for slip rings or brushes, and the only part that has movement is the rotor assembly. All conductors that carry current are stationary. The conductors are: the field winding, stator windings, six rectifying diodes, and the regulator circuit components.

The rotor assembly has many magnetic poles like fingers with air space between each opposite pole. The poles have residual magnetism (like permanent magnets) that produce a small amount of magnetlike lines of force (magnetic field) between the poles. As the rotor assembly begins to turn between the field winding and the stator windings, a small amount of alternating current (AC) is produced in the stator windings from the small magnetic lines of force made by the residual magnetism of the poles. This AC current is changed to direct current (DC) when it passes through the diodes of the recitifer bridge. Most of this current goes to charge the battery and to supply the low amperage circuit, and the remainder is sent on to the field windings. The DC current flow through the field windings (wires around an iron core) now increases the strength of the magnetic lines of force. These stronger lines of force now increase the amount of AC current produced in the stator windings. The increased speed of the rotor assembly also increases the current and voltage output of the alternator.



ALTERNATOR

The voltage regulator is a solid state (transistor, stationary parts) electronic switch. It feels the voltage in the system, and switches on and off many times a second to control the field current (DC current to the field windings) to the alternator. The output voltage from the alternator will now supply the needs of the battery and the other components in the electrical system.

NOTICE

Never operate the alternator without the battery in the circuit. Making or breaking an alternator connection with heavy load on the circuit can cause damage to the regulator.

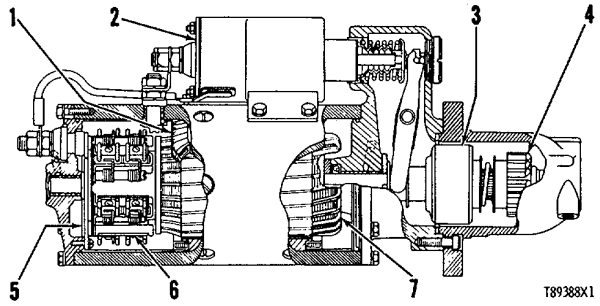
STARTER SYSTEM COMPONENTS

Starter Motor

The starter motor is used to turn the engine flywheel fast enough to gel the engine running.

The starter motor has a solenoid. When the start switch is activated, electricity will flow through the windings of the solenoid. The solenoid core will now move to push the starter pinion, by a mechanical

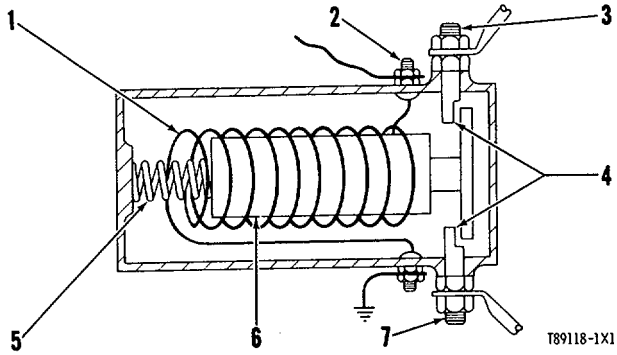
linkage to engage with the ring gear on the flywheel of the engine. The starter pinion will engage with the ring gear before the electric contacts in the solenoid close the circuit between the battery and the starter motor. When the circuit between the battery and the starter motor is complete, the pinion will turn the engine flywheel. A clutch gives protection for the starter motor so that the engine, when it starts to run, can not turn the starter motor too fast. When the start switch is releasd, the starter pinion will move away from the flywheel ring gear.



STARTER MOTOR
1. Field. 2. Solenoid. 3. Clutch. 4. Pinion. 5. Commutator. 6. Brush assembly. 7. Armature.

Starter Solenoid

A solenoid is a magnetic switch that causes low current to close a high current circuit. The solenoid has an electromagnet with a core (6) which moves.



SCHEMATIC OF A SOLENOID
1. Coil. 2. Switch terminal. 3. Battery terminal. 4. Contacts. 5. Spring. 6. Core. 7. Component terminal.

There are contacts (4) on the end of core (6). The contacts are held in the open position by spring (5) that pushes core (6) from the magnetic center of coil (1). Low current will energize coil (I) and make a magnetic field. The magnetic field pulls core (6) to the center of coil (I) and the contacts close.

OTHER COMPONENTS

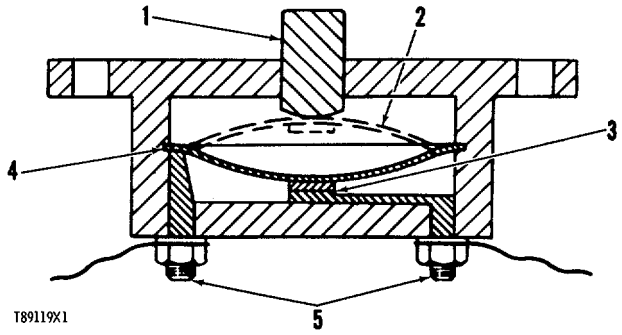
Circuit Breaker

The circuit breaker is a switch that opens the battery circuit if the current in the electrical system goes higher than the rating of the circuit breaker.

A heat activated metal disc with a contact point completes the electric circuit through the circuit breaker. If the current in the electrical system gets too high, it causes the metal disc to get hot. This heat causes a distortion of metal disc which opens the contacts and breaks the circuit. A circuit breaker that is open can be reset after it cools. Push the reset button to close the contacts and reset the circuit breaker.

NOTICE

Find and correct the problem that causes the circuit breaker to open. This will help prevent damage to the circuit components from too much current.



CIRCUIT BREAKER SCHEMATIC
1. Reset button. 2. Disc in open position. 3. Contacts. 4. Disc. 5. Battery circuit terminals.

Water Temperature Contactor Switch

The contactor switch for water temperature is installed in the regulator housing. No adjustment to the temperature range of the contactor can be made. The element feels the temperature of the coolant and then operates the micro switch in the contactor when the coolant temperature is too high. The element must be in contact with the coolant to operate correctly. If the reason for the engine being too hot is caused by low coolant level or no coolant, the contactor switch will not operate.

The contactor switch is normally connected to an alarm system in the marine application. When the temperature of the coolant lowers again to the operating range, the contactor switch opens automatically.



WATER TEMPERATURE CONTACTOR SWITCH

Troubleshooting can be difficult. On the following pages there is a list of possible problems. To make a repair to a problem, make reference to the cause and correction.

This list of problems, causes, and corrections, will only give an indication of where a possible problem can be, and what repairs are needed. Normally, more or other repair work is needed beyond the recommendations in the list.

Remember that a problem is not normally caused only by one part, but by the relation of one part with other parts. This list can not give all possible problems and corrections. The serviceman must find the problem and its source, then make the necessary repairs.

TROUBLESHOOTING INDEX

Item	Problem
1.	Engine Crankshaft Will Not Turn When Start Switch Is On.
2a.	Engine Will Not Start. Governor Terminal Shaft Does Not Move.
2b.	Engine Will Not Start. Governor Terminal Shaft Moves.
3.	Engine Overspeeds On Start.
4.	Engine Speed Does Not Have Stability.
5a.	Engine High Idle Speed Too Low.
5b.	Engine Loses High Idle After Start Up.
6.	Engine Can Not Be Shut Down Through Governor.
7.	Engine Misfiring or Running Rough.
8.	Engine Stall at Low rpm.
9.	Not Enough Power.
10.	Too Much Vibration.
11.	Loud Combustion Noise.
12.	Valve Train Noise (Clicking).
13.	Oil In Cooling System.
14.	Mechanical Noise (Knock) In Engine.
15.	Fuel Consumption Too High
16.	Loud Valve Train Noise.
17.	Too Much Valve Lash.
18.	Valve Rotocoil or Spring Lock is Free.
19.	Oil at the Exhaust.
20.	Little or No Valve Clearance.
21.	Engine Has Early Wear.
22.	Coolant in Lubrication Oil.
23.	Too Much Black or Gray Smoke.
24.	Too Much White or Blue Smoke.
25.	Engine Has Low Oil Pressure.
26.	Engine Uses Too Much Lubrication Oil.
27.	Engine Coolant Is Too Hot.
28.	Starter Motor Does Not Turn.
29.	Alternator Gives No Charge.
30.	Alternator Charge Rate Is Low or Not Regular.
31.	Alternator Charge Too High.
32.	Alternator Has Noise.
33.	Exhaust Temperature Too High.
34.	Air Starting Motor Turns Slowly or Has A Loss of Power.
35.	Air Starting Motor Pinion Does Not Engage With The Flywheel.
36.	Air Starting Motor Runs, Pinion Engages But Does Not Turn The Flywheel.
37.	Air Starting Motor Pinion Does Not Engage Correctly With The Flywheel.
38.	Protective Systems (See Troubleshooting section of); SENR3078 - Hydramechanical SENR2985 - Electrical SENR2984 - Electrical With Reversal Protection

1. ENGINE CRANKSHAFT WILL NOT TURN WHEN START SWITCH IS ON

Cause:	**Correction:**
Battery has Low Output	Check condition of battery. Charge battery or make replacement as necessary.
Wiring or Switches Have Defect	Make repairs or replacements as necessary.
Problem with Engine Protective System	Make reference to ELECTRIC PROTECTIVE SYSTEM, in Form SENR2984 or Form SENR2985.
Starter Motor Solenoid Has A Defect	Install a new solenoid.
Starter Motor Has a Defect	Make repair or replacement of starter motor.
Oil Pressure Switch For Prelubrication Pump Has A Defect	Make a replacement of defective switch.
Prelubrication Oil Pump Has A Defect	Repair or replace pump components as needed.
Inside Problem Prevents Engine Crankshaft From Turning	If the crankshaft can not be turned after disconnecting the driven equipment, remove the fuel injectors and check for fluid in the cylinders while turning the crankshaft. If fluid in the cylinders is not the problem, the engine must be disassembled to check for other inside problems. Some of these inside problems are bearing seizure, piston seizure, or valves making contact with the pistons.

2a. ENGINE WILL NOT START - GOVERNOR TERMINAL SHAFT DOES NOT MOVE FUEL CONTROL LINKAGE

Cause:	**Correction:**
Low Oil Level In Governor	Check gauge and add correct amount of clean oil to WOODWARD UG-8 GOVERNORS. Check for plugged oil supply passages to CATERPILLAR 3161 GOVERNORS.
Too Much Binding In Control Linkage	Engine can start cold, but with hot oil governor does not develop enough pump pressure to move linkage. Check linkage effort and correct.
Speed Control Shaft Setting Too Low (Low Idle Not set Correctly)	Move control shaft toward high idle while cranking engine. Terminal shaft on properly operating governor will move fuel control linkage to the "FUEL ON" position.
Solenoid Stuck In Shut Off Position	On UG8L remove top cover assembly and make sure shut down strap is up. Crank engine to start. Repair or make a replacement of faulty solenoid.
Problem with Engine Protective System	Make reference to ELECTRIC PROTECTIVE SYSTEM, in Form SENR2984 or Form SENR2985.
Solenoid Energized in Shutoff Position During Cranking	Disconnect wiring harness to stop signal. Correct by troubleshooting wiring to solenoid.
Low Oil Pressure In Governor	The governor oil pump relief valve may be stuck open or leaking. Correct by governor disassembly and cleaning.

2b. ENGINE WILL NOT START - GOVERNOR TERMINAL SHAFT OPENS AT LEAST HALF WAY OR MORE AT CRANKING AS OBSERVED BY OUTBOARD SHAFT ROTATION

Cause:	**Correction:**
Slow Cranking Speed	Battery has low output, make reference to Item 29.
No Fuel To Injectors	Check fuel tank and fill. "Prime" (remove the air and/or low quality fuel from the fuel system). Install new fuel filters if necessary. Blocked or broken fuel lines should be cleaned or replaced. Check the fuel transfer pump for damage or wear and make replacements as needed. Control lever, on governor terminal shaft, not connected to the fuel control linkage such as improper assembly during overhaul. Make sure governor linkage is correctly engaged. During cranking, the air-fuel ratio control will restrict injector rack to approximately 7 to 9 mm (.28 to .35 in.) which is below the fuel setting as set by the engine fuel setting screw. Once the lube oil pressure signal reaches the air-fuel ratio control from the engine, the rack will be further restricted to approximately 0 mm (0 in.). The engine must be running and generating boost pressure before the air-fuel ratio control allows more injector rack travel. A worn or damaged start-up override valve in the hydramechanical protective system can also hold the governor in the shutoff position. On later engines, after a fault condition, the start-up override valve must be used to release the hydraulic pressure on the fuel shutoff actuator before the engine can be started again. Make a replacement and make sure the governor and control linkage move.
Bad Quality Fuel	Remove fuel from the tank. Install new fuel filters and put a good grade of clean fuel in the fuel tank.
Fuel Pressure is Low.	At starting rpm, the minimum fuel pressure from fuel transfer pump must be 20 kPa (3 psi). If fuel pressure is less than 20 kPa (3 psi) change the fuel filters. Look for air in the fuel system. If fuel pressure is still low, check the fuel bypass valve and the fuel transfer pump for correct operation.
Wrong Fuel Injection Timing	Make adjustment to timing.

3. ENGINE OVERSPEEDS ON START

Cause:	Correction:
Fuel Control Linkage	Improper assembly after overhaul, linkage not free, bound up in "FUEL ON" position, governor control lever not connected with stop lever of fuel control linkage. Make repairs or replacements as needed.
High Idle Setting Incorrect	Start engine in mid speed position and make an adjustment of the high idle setting.
Compensation Needle Valve Adjustment	Make an adjustment of the compensation needle valve to get stable governor operation.
Incorrect Governor Oil Used	Oil viscosity is too high for ambient temperature starting conditions. Change oil to correct weight as recommended for the engine. In extreme low ambient temperatures DEXRON ATF can be used in UG-8 Governors only.
Dirty Governor Oil (Woodward UG-8)	Oil is sludged slowing governor response. Oil should be changed before it gets too thick. Drain and flush with diesel fuel and add new oil.
Governor Not Engaged In Drive Coupling	Make sure governor is driven by the engine. If necessary, remove and install governor to make sure it is engaged correctly with the governor drive. Also, check for worn or damaged drive components in the governor and engine.

4. ENGINE SPEED DOES NOT HAVE STABILITY.

Cause:	Correction:
Air In Oil (Foam) in Governor Especially on Initial Start With New Oil.	Open compensation needle valve and let governor oscillate for several minutes until air is vented from governor. Reset needle valve to approximately ½ to 3/4 open. Also make sure the correct grade of oil is used as recommended for the engine.
Low Oil Level	Add oil to correct level in WOODWARD UG-8 GOVERNORS. Check for leaks, especially at drive shaft. Check for plugged oil supply passages for CATERPILLAR 3161 GOVERNORS.
Compensation Adjustments Incorrect	Needle valve should be approximately 1/2 to ¾ open.
Negative Speed Regulation (Engine Speeds Up With Load Addition)	On governors with Isochronous droop setting, correct droop setting on governor.
Linkage Is Binding, Or Worn With Flat Spots and High Clearances.	Inspect and repair or replace linkage as needed.

(Cont. next page)

4. ENGINE SPEED DOES NOT HAVE STABILITY. (Cont.)

Cause:	**Correction:**
Rough Governor Drive	Worn splines and/ or high gear clearances can cause rough governor drive. Inspect and replace parts as needed. Governor can also be out of alignment with drive. Loosen governor and adjust as needed for correct alignment with drive.
Engine Misfiring	Make reference to Item 7.
Dirty Oil in Governor (Woodward UG-8)	Oil is decomposed and sludged slowing governor response. Replace with new oil after flushing with diesel fuel. High operating temperatures may require heavier viscosity oils.
Pneumatic (Air) Speed Setting Adjustment Wrong	If engine is equipped with pneumatic speed setting, improper adjustment or excessive play in the governor linkage can be a problem. Inspect and correct.
Power Piston Sticking	Governors on engines that have not been run for long periods may develop rust in areas of the compensation pistons, etc. causing instability. Oil varnish also causes parts to stick. Correct by governor disassembly and cleaning.
Governor Worn	Repair or replace governor.
Low Governor Oil Pressure	Check correct oil level. Oil pump relief valve does not seat. Replace valve. Oil pump worn. Replace parts.

5a. ENGINE HIGH IDLE SPEED TOO LOW

Cause:	**Correction:**
Speed Setting Shaft Not Against High Idle Stop	Check speed control linkage and/or pneumatic controls for restrictions. Make repairs or replacement as needed.
Incorrect Adjustment of High Idle	Governor speed setting shaft is against high idle stop and high idle is too low. Make adjustment to correct high idle. Also, check to make sure engine fuel setting is correct.
Speed Droop Adjustment Incorrect	Internal adjustable speed droop is set at the factory. Make adjustment if necessary.

5b. ENGINE LOSES HIGH IDLE AFTER START UP

Cause:	**Correction:**
Normal RPM Loss	Loss of approximately 20 rpm can be expected from average cold start to operating temperature. A shift of 6 to 8 rpm can be expected on the UG8D. A continuous steady speed loss suggests a slipping motor clutch. Adjust motor clutch to 0.51 to 0.62 N ·m (4.5 to 5.5 lb. in.).
High Idle Adjustment Incorrect	Make sure governor and engine fuel settings are correct. Make an adjustment of the high idle as needed.

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6. ENGINE CANNOT BE SHUT DOWN THROUGH GOVERNOR.

Cause:	**Correction:**
Bad Shut Down Solenoid	Solenoid with a fault, shorted or broken wires, or stuck in open position. Inspect and replace as needed.
Wires Not Connected Correctly	Shut down signal not connected with correct polarity to solenoid A positive (+), B negative (-) to 2 pin connector.
Hydraulic/ Pneumatic Shutoff Signal Too Low	The signal must be 172 to 276 kPa (25 to 40 psi). The bellows may also be damaged. Measure signal pressures, inspect parts and make repairs or replacements as needed.
Governor Not Correctly Installed	Make sure control lever on governor terminal shaft is engaged correctly with the stop lever of the engine fuel control linkage.
Governor Needs Repair	Disassemble, clean and inspect governor for worn and damaged parts. Make a replacement of parts as needed.

7. ENGINE MISFIRING OR RUNNING ROUGH

Cause:	**Correction:**
Fuel Pressure is Low	Make sure there is fuel in the fuel tank. Look for leaks or bad bends in the fuel line between fuel tank and fuel transfer pump. Look for air in the fuel system, sticking, binding or defective fuel bypass valve. Check fuel pressure. The outlet pressure of the fuel transfer pump must be a minimum of 415 kPa (60 psi) at full load speed. The pressure in both fuel manifolds must be 415 to 450 kPa (60 to 65 psi). If fuel pressure is lower than the above pressure, install new filters. If fuel pressure is still low, check the fuel transfer pump and fuel pressure regulator valve in the fuel manifold.
Air in Fuel System	Find the air leak in the fuel system and correct it. If air is in the fuel system it will generally get in on the suction side of the fuel transfer pump.
Leak or Break in Fuel Line Between Fuel Manifold	Install a new fuel line.
and Cylinder Head Defect in Fuel Injector(s)	Temperature of an exhaust manifold port, when the engine runs at low idle speed, can be an indication of the condition of a fuel injector. Low temperature at an exhaust manifold port is an indication of no fuel to the cylinder. This can possibly be an indication of an injector with a defect. Extra high temperature at an exhaust manifold port can be an indication of too much fuel to the cylinder, also caused by an injector with a defect.
Wrong Valve Clearance	Make adjustment according to Subject, VALVE CLEARANCE.
Wrong Fuel Injection Timing	Make adjustment to timing.
Bent or Broken Push Rod	Replacement of push rod is necessary.
Fuel Has "Cloud Point" Higher Than Atmospheric Temperature ("Cloud Point" = Temperature Which Makes Wax Form In Fuel).	Drain the fuel tank, lines and fuel manifolds. Change the fuel filter. Fill the tank with fuel which has the correct "cloud point" and remove the air from the system with the priming pump. In some installations it can be necessary to use fuel heaters to insure proper fuel flow and to prevent filter blockage from fuel wax. The fuel temperature at which flow is reduced and filter blockage occurs is usually dependent upon the amount of wax in the fuel or its cloud point.

8. ENGINE STALL AT LOW RPM

Cause:	Correction:
Fuel Pressure is Low	Make sure there is fuel in the fuel tank. Look for leaks or bad bends in the fuel line between fuel tank and fuel transfer pump. Look for air in the fuel system, sticking, binding or defective fuel bypass valve. Check fuel pressure. The outlet pressure of the fuel transfer pump must be a minimum of 415 kPa (60 psi) at full load speed. The pressure in both fuel manifolds must be 415 to 450 kPa (60 to 65 psi). If fuel pressure is lower than the above pressure, install new filters. If fuel pressure is still low, check the fuel transfer pump and fuel pressure regulator valve in the fuel manifold.
Idle rpm Too Low	Make adjustment to governor so idle rpm is the same as given in the FUEL SETTING AND RELATED INFORMATION FICHE.
Engine Accessories	Check engine accessories for damage and correct adjustment. If necessary, disconnect the accessories and test the engine.
Defect in Fuel Injector(s)	Make Reference to Item 7.

9. NOT ENOUGH POWER

Cause:	Correction:
Dirty Fuel Filters	Install new fuel filters.
Bad Quality Fuel or Water in Fuel	Remove the fuel from the fuel tank. Install new fuel filters. Put a good grade of clean fuel in the fuel tank.
Fuel Temperature is High	Excess fuel flow temperature should be 65.6 to 82.2°C (160 to 180°F). If excess fuel flow temperature exceeds 82.2°C (180°F), the use of a fuel cooler is recommended to prevent excessive engine power loss and to maintain an acceptable injector life.
Fuel Pressure is Low	Make sure there is fuel in the fuel tank. Look for leaks or bad bends in the fuel line between fuel tank and fuel transfer pump. Look for air in the fuel system, sticking, binding or defective fuel bypass valve. Check fuel pressure. The outlet pressure of the fuel transfer pump must be a minimum of 415 kPa (60 psi) at full load speed. The pressure in both fuel manifolds must be 415 to 450 kPa (60 to 65 psi). If fuel pressure is lower than the above pressure, install new filters. If fuel pressure is still low, check the fuel transfer pump and fuel pressure regulator valve in the fuel manifold. (Cont. next page)

9. NOT ENOUGH POWER (Cont.)

Cause:	**Correction:**
Defect in Fuel Injector	Make Reference to Item 7.
Leaks in Air Inlet System	Check the pressure in the air intake manifold. Look for restrictions in the air cleaner.
Governor And Fuel Control Linkage	Make sure governor is moving fuel control linkage against fuel setting screw. Make adjustment to get full travel of linkage. Install new parts for those that have damage or defects. If control linkage is not against stop and engine runs below rated speed under load: (a) Check high idle and adjust if necessary. (b) Air-fuel ratio control may be restricting control linkage travel and should be adjusted if necessary.
Wrong Valve Clearance	Make adjustment according to Subject, VALVE CLEARANCE.
Wrong Fuel Injection Timing	Make adjustment to timing. See Subject, FUEL TIMING.
Fuel Setting Incorrect	Make an adjustment of the fuel setting. See FUEL SETTING AND RELATED INFORMATION FICHE for the correct fuel setting. Also see Subject, FUEL SETTING for the correct procedure.
Defect in Aftercooler	Check temperature of inlet and outlet water supply. Remove any external or internal restrictions.
Turbocharger Has Carbon Deposits or Other Causes of Friction.	Make inspection and repair of turbocharger as necessary.

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10. TOO MUCH VIBRATION

Cause:	**Correction:**
Vibration Damper Loose	Check vibration damper for damage. Tighten bolts. If vibration damper bolt holes have damage or wear, replace with new parts.
Vibration Damper Has A Defect	Install a new vibration damper
Engine Supports Are Loose, Wrong or Have A Defect	Tighten all mounting bolts. Install new components if necessary.
Driven Equipment Is Not In Alignment Or Is Out of Balance	Check alignment and balance, correct if needed.
Misfiring or Running Rough	Make Reference to Item 7.

11. LOUD COMBUSTION NOISE (SOUND)

Cause:	Correction:
Bad Quality Fuel	Remove the fuel from the fuel tank. Install new fuel filters. Put a good grade of clean fuel in the fuel tank.
Wrong Fuel Injection Timing	Make adjustment to timing. See Subject, FUEL TIMING.
Defect in Fuel Injector(s)	Make Reference to Item 7.

12. VALVE TRAIN NOISE (CLICKING)

Cause:	Correction:
Damage to Valve Spring(s), Locks, or Broken or Worn Valve Lifter	Install new parts where necessary. Broken locks can cause the valve to get into the cylinder. This will cause much damage.
Not Enough Lubrication	Check lubrication in valve compartment. There must be a strong flow of oil at engine high rpm, but only a small flow of oil at low rpm. Oil passages must be clean, especially those that send oil to the cylinder head.
Too Much Valve Clearance	Make adjustment according to the Subject, VALVE CLEARANCE.
Damage to Valve(s)	Make a replacement of the valve(s) and make an adjustment as necessary.

13. OIL IN COOLING SYSTEM

Cause:	Correction:
Defect In Core of Engine Oil Cooler	Install a new engine oil cooler.
Failure of Cylinder Head Gasket or Water Seals	Check cylinder liner projection. Install a new cylinder head gasket and new water seals in the spacer plate. Tighten the bolts that hold the cylinder head according to the Specifications.

14. MECHANICAL NOISE (KNOCK) IN ENGINE

Cause:	Correction:
Failure of Bearing For Connecting Rod	Inspect the bearings for the connecting rods and the bearing surfaces (journals) on the crankshaft. Install new parts where necessary.
Damaged Gears	Install new parts where necessary.
Damaged Crankshaft	Make replacement of the crankshaft.
Defect in Attachment	Repair or install new components.

15. FUEL CONSUMPTION TOO HIGH

Cause:	Correction:
Fuel System Leaks	Tighten or make replacement of parts at points of leakage.
Fuel and Combustion Noise (Knock)	Make Reference to Item 7 and Item 9.
Wrong Fuel Injection Timing	Make adjustment to timing.
Defect in Fuel Injector(s)	Make Reference to Item 7.

16. LOUD VALVE TRAIN NOISE

Cause:	Correction:
Damage to Valve Spring(s)	Make replacement of parts with damage.
Damage to Camshaft	Make replacement of parts with damage. Clean engine thoroughly. If replacement of camshaft is made, new valve lifters are also necessary.
Damage to Valve Lifter	Clean engine thoroughly. Make a replacement of the damaged valve lifters. Inspect camshaft lobes for damage. Look for valves that do not move freely. Make an adjustment to valve clearance according to the Subject, VALVE CLEARANCE.

17. TOO MUCH VALVE LASH

Cause:	Correction:
Not Enough Lubrication	Check lubrication in valve compartment. There must be a strong flow of oil at engine high rpm, but only a small flow at low rpm. Oil passages must be clean, especially those sending oil to the cylinder head.
Rocker Arm Worn at Face That Makes Contact With Bridge	If there is too much wear, install new parts or rocker arms. Make adjustment of valve clearance according to Subject, VALVE CLEARANCE.
Bridges for Valves Worn	Make an adjustment or replacement as necessary.
End of Valve Stem Worn	If there is too much wear, install new valves. Make adjustment to valve clearance according to Subject, VALVE CLEARANCE.
Worn Push Rods	If there is too much wear, install new push rods. Make adjustment of valve clearance according to Subject, VALVE CLEARANCE.
Broken or Worn Valve Lifters	Install new valve lifters. Check camshaft for wear. Check for free movement of valves or bent valve stem. Clean engine thoroughly. Make adjustment of valve clearance according to Subject, VALVE CLEARANCE

(Cont. next page)

17. TOO MUCH VALVE LASH (Cont.)

Cause:	Correction:
Worn Cams on Camshaft	Check valve clearance. Check for free movement of valves or bent valve stems. Install a new camshaft. Install new valve lifters. Make adjustment of valve clearance according to Subject, VALVE CLEARANCE.

18. VALVE ROTOCOIL OR SPRING LOCK IS FREE

Cause:	Correction:
Broken Locks	Broken locks can cause the valve to slide into the cylinder. This will cause much damage.
Broken Valve Spring(s)	Install new valve spring(s)
Broken Valve	Replace valve and other damaged parts.

19. OIL AT THE EXHAUST

Cause:	Correction:
Too Much Oil in the Valve Compartment	Be sure that the dowel is installed in the left bolt hole of the rocker shaft.
Worn Valve Guides	Reconditioning of the cylinder head is needed.
Worn Piston Rings	Inspect and install new parts as needed.

20. LITTLE OR NO VALVE CLEARANCE

Cause:	Correction:
Worn Valve Seat or Face of Valve	Reconditioning of cylinder head is needed. Make adjustment of valve clearance according to the Subject, VALVE CLEARANCE.

21. ENGINE HAS EARLY WEAR

Cause:	Correction:
Dirt in Lubrication Oil	Remove dirty lubrication oil. Install new oil filters. Put clean oil in the engine. Check oil filter bypass valve for a weak or broken spring.
Air Inlet Leaks	Inspect all gaskets and connections. Make repairs if leaks are found.
Fuel Leakage Into Lubrication Oil	This will cause high fuel consumption and low engine oil pressure. Make repairs if leaks are found. Install new parts where needed.

22. COOLANT IN LUBRICATION OIL

Cause:	Correction:
Failure of Oil Cooler Core	Install a new core for the oil cooler. Drain crankcase and refill with clean lubricant. Install new oil filter element.
Failure of Cylinder Head Gasket or Water Seals	Check cylinder liner projection. Install a new cylinder head gasket and new water seals in the spacer plate. Tighten the bolts that hold the cylinder head according to the Specifications.
Crack or Defect in Cylinder Head	Install a new cylinder head.
Crack or Defect in Cylinder Block	Install a new cylinder block.
Failure of Liner Seals	Replace seals.

23. TOO MUCH BLACK OR GRAY SMOKE

Cause:	Correction:
Not Enough Air For Combustion	Check air cleaner for restrictions.
Bad Fuel Injectors	Install new fuel injectors.
Wrong Fuel Injection Timing	Make adjustment to timing. See Subject, FUEL TIMING.

24. TOO MUCH WHITE OR BLUE SMOKE

Cause:	Correction:
Too Much Lubrication Oil in Engine	Remove extra oil. Find where extra oil comes from. Put correct amount of oil in engine.
Engine Misfires or Runs Rough	Make Reference to Item 7.
Wrong Fuel Injection Timing	Make adjustment to timing. See Subject, FUEL TIMING.
Worn Valve Guides	Reconditioning of cylinder head is needed.
Worn Piston Rings	Install new piston rings.
Failure of Turbocharger Oil Seal	Check inlet manifold for oil and repair turbocharger if necessary.

25. ENGINE HAS LOW OIL PRESSURE

Cause:	Correction:
Dirty Oil Filters or Oil Cooler	Check the operation of bypass valve for the filter. Install new oil filters if needed. Clean or install new oil cooler core. Remove dirty oil from engine. Put clean oil in engine.
Diesel Fuel in Lubrication Oil	Find the place where diesel fuel gets into the lubrication oil. Make repairs as needed. Remove the lubrication oil that has diesel fuel in it. Install new oil filters. Put clean oil in the engine.
Too Much Clearance Between Rocker Arm Shaft and Rocker Arms	Check lubrication in valve compartments. Install new parts as necessary.
Oil Pump Suction Pipe Has A Defect	Replacement of pipe is needed.
Oil Pressure Relief Does Not Close	Clean valve and housing. Install new parts as necessary.
Oil Pump Has A Defect	Repair or replace oil pump.
Too Much Clearance Between Crankshaft and Crankshaft Bearings	Inspect the bearings and make replacement as necessary.
Too Much Clearance Between Camshaft and Camshaft Bearings	Install new camshaft and camshaft bearings if necessary.
Defect in Oil Pressure Gauge	Install new gauge.

26. ENGINE USES TOO MUCH LUBRICATION OIL

Cause:	Correction:
Too Much Lubrication Oil In Engine	Remove extra oil. Find where extra oil comes from. Put correct amount of oil in engine. Do not put too much oil in engine.
Oil Leaks	Find all oil leaks. Make repairs as needed. Check for dirty crankcase breather.
Oil Temperature is Too High	Check operation of oil cooler. Install new parts if necessary. Clean the core of the oil cooler.
Too Much Oil in the Valve Compartment	Be sure that the dowel is installed in the left bolt hole of the rocker shaft. The dowel is located between the rocker shaft and valve cover base.
Worn Valve Guides	Reconditioning of the cylinder head is needed.
Worn Piston Rings	Inspect and install new parts as needed.
Failure of Seal Rings in Turbocharger	Check inlet manifold for oil and make repairs to the turbocharger if necessary.

27. ENGINE COOLANT IS TOO HOT

Cause:	Correction:
Restriction To Flow of Coolant Through Radiator Core Tubes or Heat Exchanger	Clean and flush radiator or heat exchanger.
Restriction To Air Flow Through Radiator	Remove all restrictions of flow.
Low Fan Speed	Check for worn or loose fan belts.
Not Enough Coolant in System	Add coolant to cooling system. Check for leaks.
Pressure Cap Has A Defect	Check operation of pressure cap. Install a new pressure cap if necessary.
Combustion Gases in Coolant	Find out where gases get into the cooling system. Make repairs as needed.
Water Temperature Regulators (Thermostats) or Temperature Gauge Has A Defect	Check water temperature regulators for correct operation. Check temperature gauge operation. Install new parts as necessary.
Water Pump Has A Defect	Make repairs to the water pump as necessary.
Too Much Load On The System	Make a reduction to the load.
Wrong Fuel Injection Timing	Make adjustment to timing. See Subject, FUEL TIMING.

28. STARTER MOTOR DOES NOT TURN Deleted.

29. ALTERNATOR GIVES NO CHARGE Deleted.

33. EXHAUST TEMPERATURE IS TOO HIGH

Cause:	Correction:
Air Inlet System Has A Leak	Check pressure in the air intake manifold. Look for restrictions at the air cleaner. Correct any leaks.
Exhaust System Has A Leak	Find cause of exhaust leak. Make repairs as necessary.
Air Inlet or Exhaust System Has A Restriction	Remove restriction.
Wrong Fuel Injection Timing	Make an adjustment to the timing. See Subject, FUEL TIMING.

34. AIR STARTING MOTOR TURNS SLOWLY OR HAS A LOSS OF POWER

Cause:	Correction:
Low Supply Air Pressure	Make an increase to the air supply pressure.
Pressure Regulator Adjustment Not Correct	Make an adjustment to the air pressure regulator.
Oiler Not Working Correctly	Check the oiler, inlet hose, fitting and oil supply hose to make sure they are vacuum tight and free of leaks. Clean, make adjustment, tighten all fittings, fill oiler or make a replacement, if necessary.
Worn Motor Parts	Disassemble the motor and make an inspection of the parts. A guide for determining worn parts that cannot be used again is as follows: a. Install a set of new vanes if any vane is cracked, damaged or worn to the extent that its width is 32 mm (1.25 in.) at either end. b. Replace rotor bearings if any roughness or looseness is apparent in the bearings. c. Replace rotor if the body has deep scoring that cannot be removed with the use of emery cloth. d. Replace cylinder if there are any cracks or deep scoring. e. Clean up end plate scoring with emery cloth placed on a flat surface.
Air Leakage	Check the motor for worn seals. Plug the exhaust. Apply 205 kPa (30 psi) air to the inlet and put the unit in nonflammable fluid for 30 seconds. If bubbles appear, make a replacement of the motor seals.

FUEL SYSTEM

Either too much fuel or not enough fuel for combustion can be the cause of a problem in the fuel system.

Many times work is done on the fuel system when the problem is really with some other part of the engine. The source of the problem is difficult to find, especially when smoke comes from the exhaust. Smoke that comes from the exhaust can be caused by a bad fuel injector, but it can also be caused by one or more of the reasons that follow:

a. Not enough air for good combustion.
b. An overload at high altitude.
c. Oil leakage into combustion chamber.
d. Not enough compression.

FUEL SYSTEM INSPECTION

A problem with the components that send fuel to the engine can cause low fuel pressure. This can decrease engine performance.

1. Check the fuel level in the fuel tank. Look at the cap for the fuel tank to make sure the vent is not filled with dirt.

2. Check the fuel lines for fuel leakage. Be sure the fuel supply line does not have a restriction or a bad bend.

3. Install new fuel filters. Clean the primary fuel filter.

4. Inspect the fuel pressure relief valve in the fuel transfer pump to see that there is no restriction to good operation.

CHECKING ENGINE CYLINDERS SEPARATELY

Temperature of an exhaust manifold port, when the engine runs at low idle speed, can be an indication of the condition of a fuel injector. Low temperature at an exhaust manifold port is an indication of no fuel to the cylinder. This can possibly be an indication of an injector with a defect. Extra high temperature at an exhaust manifold port can be an indication of too much fuel to the cylinder, also caused by an injector with a defect.

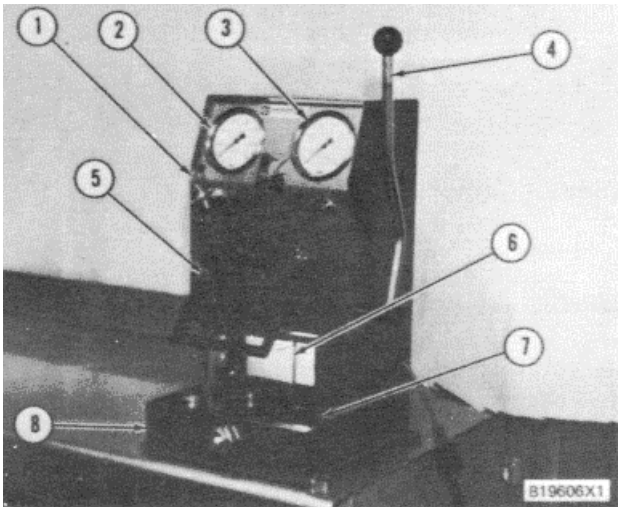
FUEL INJECTOR TESTING

Tools Needed:

6V4022 Injector Tester.
6V4172 Injector Sleeve.
6V6068 Calibration Fluid 19 liters (5 U.S. gal.)
-or-
6V6067 Calibration Fluid 208 liters (55 U.S. gal.)

NOTICE

Be sure to use clean SAE J967 Calibration Fluid when tests are made. Dirty test fluid will damage components of the fuel injectors. The temperature of the test fluid must be 18 to 24°C (65 to 75°F) for good test results.

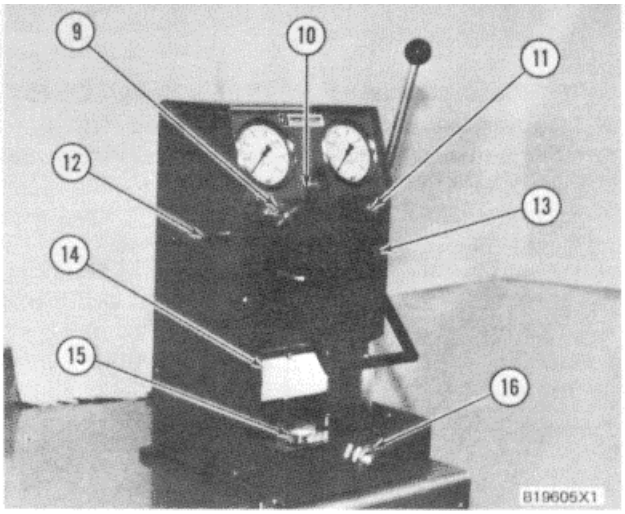


6V4022 INJECTOR TESTER

1. Sight tube. 2 Test pressure gauge. 3. Load cell pressure gauge. 4. Handle (to pump test fluid). 5. Injector holding block. 6. Spray shield. 7. Drain panel. 8. Base (reservoir).

⚠ WARNING

When fuel injectors are tested, be sure to wear eye protection. Test fluid comes from the orifices in the injector tip with high pressure. The test fluid can pierce (go thru) the skin and cause serious injury to the operator. Also, the 6V4022 Injector Tester must be used in an area that is well ventilated (good movement of air).



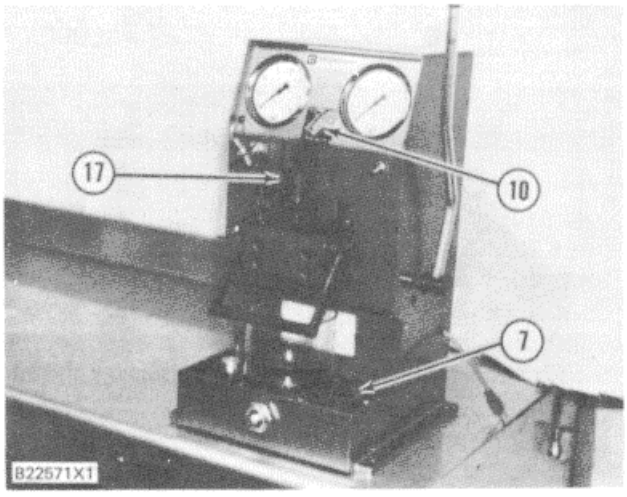
6V4022 INJECTOR TESTER

9. Test pressure valve. 10. Rocker arm. 11. Light switch. 12. Rocker arm control lever. 13. Clamp plate. 14. Light panel. 15. Drain cover. 16. Fluid level indicator.

The test procedures that follow will give an indication of injector condition. Do not use an injector in an engine unless all test results are within the test specifications.

Injector Tester Preparation

Before a new 6V4022 Injector Tester is put to use, some specific procedures must be followed to make sure the tester will operate correctly. Remove drain panel (7) to make sure that the test fluid reservoir is clean, and also that there is a clean filter element in its correct location. Use clean SAE J-967 Calibration Fluid to fill the supply reservoir to its correct level. This is the same type and quality of test fluid as that used in a Caterpillar Fuel Injection Test Bench. Be sure to put drain panel (7) back in position after the reservoir is filled.

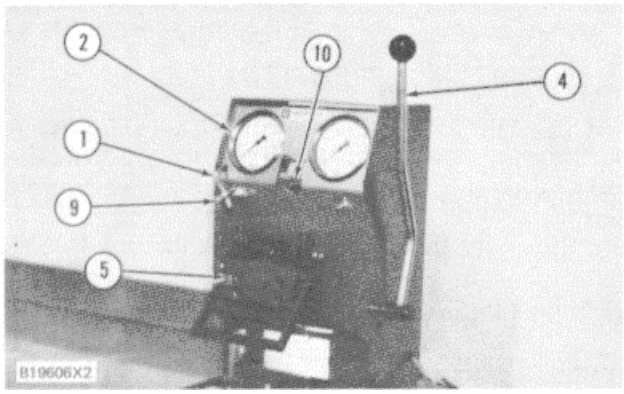


TESTER PREPARATION

7. Drain panel. 10. Rocker arm. 17. Test plug.

Install test plug (17) and check the adjustment of rocker arm (10). The roller on the rocker arm must just clear (be just above) the top of test plug (17) when the rocker arm is moved to either the extended or retracted position. If an adjustment is needed, see MAINTENANCE AND ADJUSTMENT PROCEDURES in Special Instruction, Form No. SEHS7788. While test plug (17) is still in position, check the tester for leaks. See LEAK TEST FOR INJECTOR TESTER in this section.

Operation Of The Tester

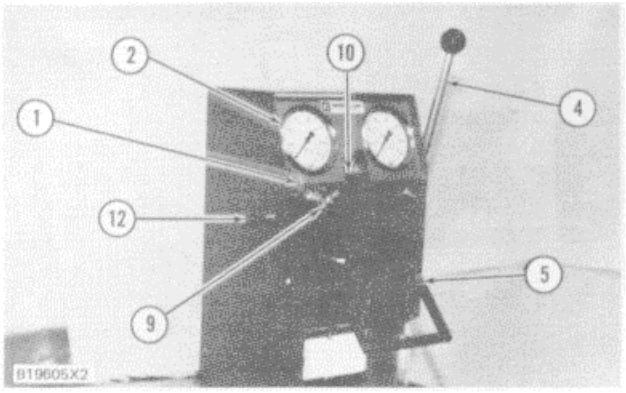


TESTER NOMENCLATURE

1. Sight tube. 2. Test pressure gauge. 4. Handle. 5. Injector holding block. 9. Test pressure valve. 10. Rocker arm.

Operation of handle (4) backward and forward pumps (sends) test fluid from the reservoir in the base of the tester, through the filter element (in the base), to an inlet check valve and an outlet check valve to test pressure gauge (2), then down to injector holding block (5). When an injector is in position in injector holding block (5), the test fluid fills the injector and the chamber around it, and is then sent to test pressure valve (9), through sight tube (1). It then returns to the reservoir in the base of the tester.

When test pressure valve (9) is in the "CLOSED" position, test fluid cannot go back to the reservoir c when handle (4) is operated. This causes high pressure in injector holding block (5), and in the injector. This high pressure is used to test the injector for external (outer) leakage and leakdown rate (amount of time for pressure drop between the specific pressure limits).



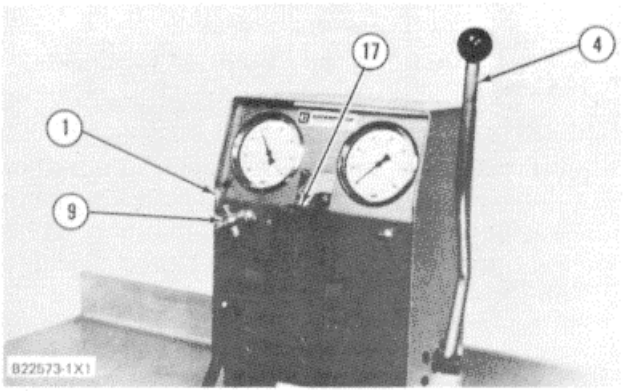
TESTER NOMENCLATURE

1. Sight tube. 2. Test pressure gauge. 4. Handle. 5. Injector holding block. 9. Test pressure valve. 10. Rocker arm. 12. Rocker arm control lever.

When test pressure valve (9) is in the "OPEN" position, the operation of handle (4) causes test fluid to be sent to the injector. Use control lever (12) to extend or retract rocker arm (10). The External Leakage Test, Tip Leakage Test and the Leakdown Rate Test must each be done with the rocker arm in the retracted position. The Valve Opening Pressure Test and the Orifice Inspection Test are each done with the rocker arm in the extended position.

Leak Test For Injector Tester

1. The 6V4022 Injector Tester must be checked with a leak test to make sure that there are no leaks within the tester. Do this test at regular intervals to be sure of good operation of the tester. This test can be done at any time, either before or after a test of an injector or a group of injectors.



LEAK TEST

1. Sight tube. 4. Handle. 9. Test pressure valve. 17. Test plug.

2. Install test plug (17) and then pump (operate) handle (4) to remove air from the system.

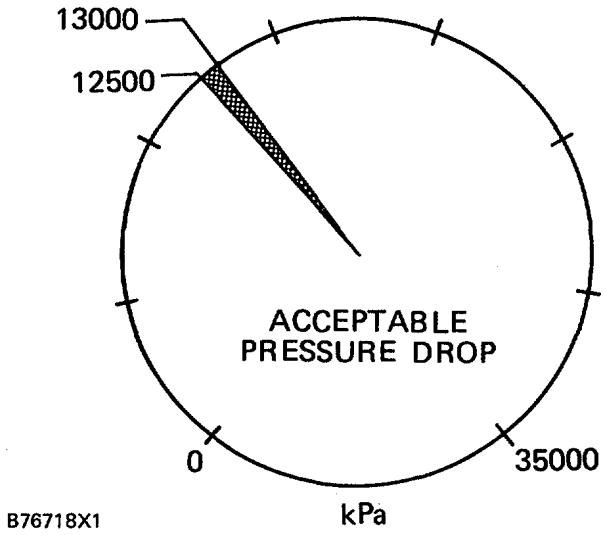
3. Turn test pressure valve (9) to the "CLOSED" position and use handle (4) to increase the pressure above 13 000 kPa on test pressure gauge (2). PRESSURE MUST NOT GO ABOVE 15 000 kPa.

4. When handle (4) is released, the pressure will always drop some amount. If the pressure has now dropped below the 13 000 kPa, move the handle just enough to maintain 13 000 kPa (or more) when handle is released.

5. If necessary, slightly open test pressure valve (9) to lower the pressure to the desired 13 000 kPa and close valve (9).

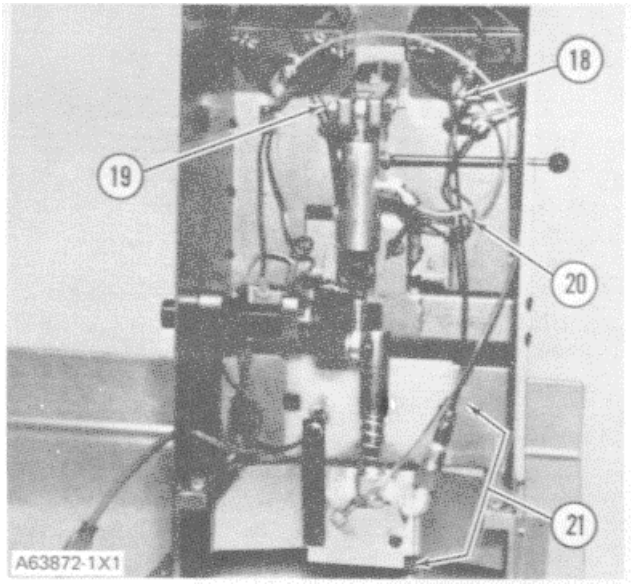
6. Pressure must not drop to 12 500 kPa in less than 7 minutes.

LEAK TEST SPECIFICATION FOR INJECTOR TESTER	
Maximum Pressure Drop	Minimum Time Interval
500 kPa	7 Minutes



TESTER LEAK TEST PRESSURE RANGE (7 MINUTES)

7. If the test shows too much leakage, find the leakage source and make the necessary repair. Check the seals on test plug (17). Test pressure valve (9) is also a possible leak source. This leakage can possibly be seen at sight tube (1).



CHECK BACK OF TESTER FOR LEAKS
18. Fittings. 19. Fluid line and fittings at both ends. 20. Fluid line and fittings at both ends. 21. Fittings.

8. Other possible locations or areas to check for a leak are shown in illustration. Check all fittings and fluid lines similar to those shown.

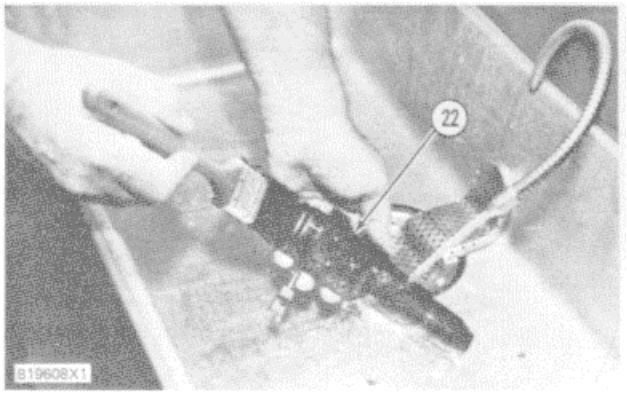
TEST SEQUENCE

To test fuel injectors, use the sequence that follows:

I. Injector Cleaning and Installation
II. Orifice Inspection
III. Valve Opening Pressure
IV. External Leakage
V. Tip Leakage
VI. Leakdown Rate

I. Injector Cleaning and Installation

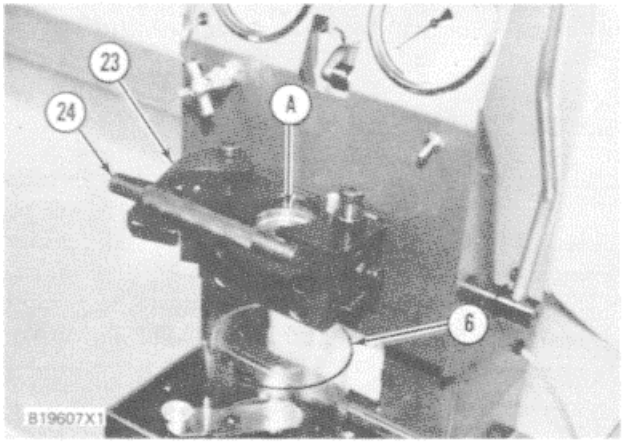
1. Clean the outer surface of the injector before it is tested. Install 6V4172 Injector Sleeve (22) on the injector, to cover the injector fuel ports. This will keep dirt and other foreign material out of the injector. Use clean solvent and a brush to clean the outside of the injector. After the outside of the injector is clean, let it become completely dry.



INJECTOR CLEANING
22. Injector sleeve.

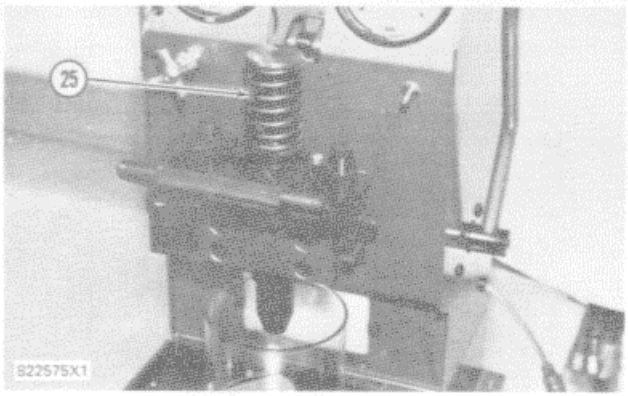
2. Remove sleeve (22) and drain all fuel from inside the injector.

NOTE: If each injector is cleaned before it is put on the tester, the test fluid in the tester will be kept clean, and can be used for a longer period of time. See MAINTENANCE AND ADJUSTMENT PROCEDURES in Special Instruction, Form No. SEHS7788 for more information on the test fluid.



CLAMP PLATE OPEN
A. Bore for injector. 6. Spray shield. 23. Clamp plate. 24. Clamp lever.

3. Lift clamp lever (24) just enough so it is above clamp plate (23). Move clamp plate (23) all the way out as shown. Make sure that bore (A), in the injector block, is clean. Put spray shield (6) on the drain panel.

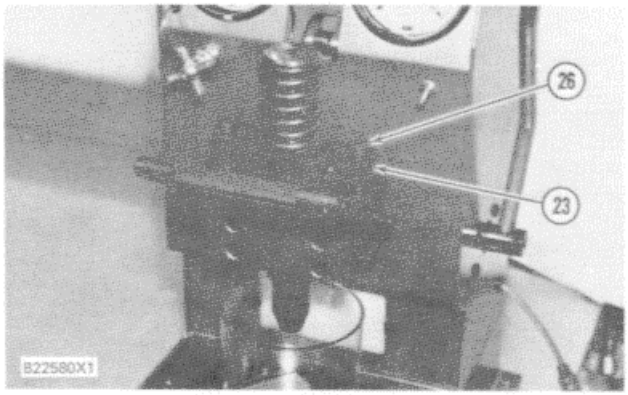


INJECTOR INSTALLED
25. Injector.

4. Inspect the seals on the injector and install replacement seals as necessary. To get a good test, the injector must have good seals. Put clean test fluid on the seals for lubrication, then install injector (25) in bore (A) of the injector block, with the dowels engaged as shown.

NOTE: Use only clean test fluid as a lubricant for the seals. Use of any other lubricant can make a mixture that will give test information that is not correct.

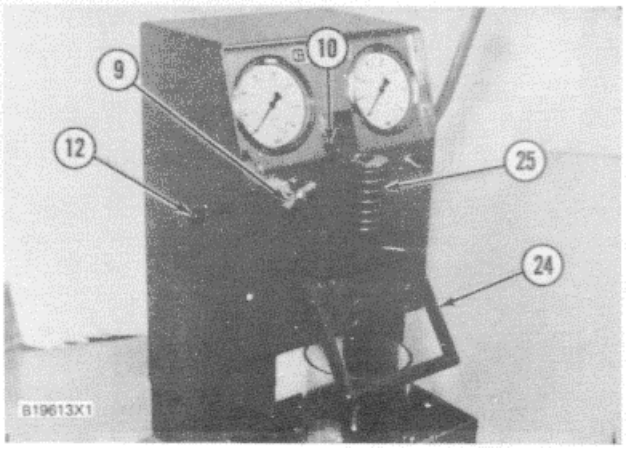
5. Turn clamp plate (23) so the slot is completely engaged with bolt (26).



CLAMP PLATE CLOSED
23. Clamp plate. 26. Bolt.

6. Push down fully on clamp lever (24) to pull injector (25) into the test position.

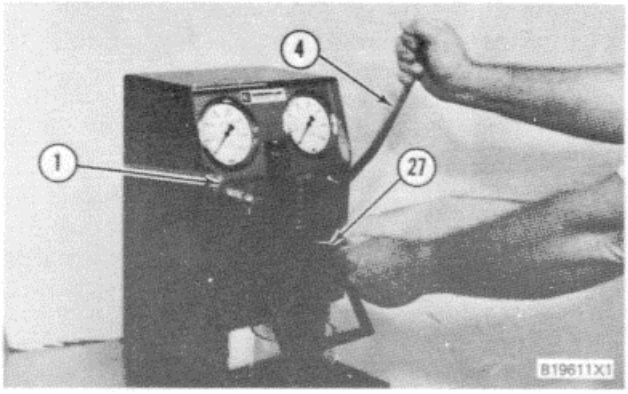
NOTE: Make sure clamp lever (24) is all the way down. High pressure caused by the test will put an upward force on injector (25).



INJECTOR IN TEST POSITION
9. Test pressure valve, 10. Rocker arm. 12. Rocker arm control lever. 24. Clamp lever. 25. Injector.

7. Open test pressure valve (9). Use control lever (12) to retract rocker arm (10).

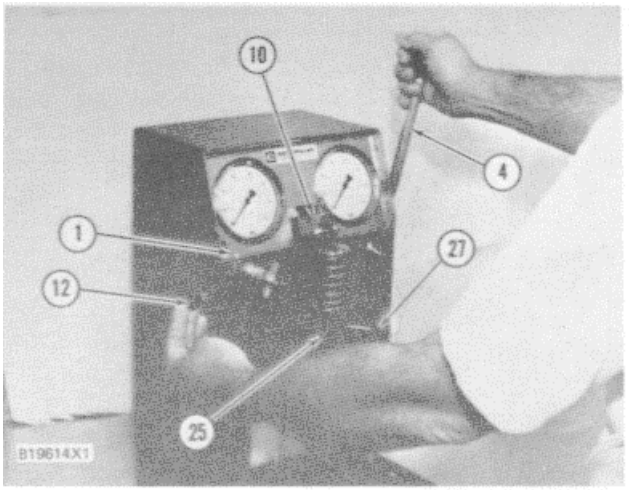
8. Pull rack (27) all the way out. Move handle (4) backward and forward to pump (push) the test fluid into and through the injector, until no air bubbles can be seen in sight tube (1).



AIR REMOVAL FROM TESTER
1. Sight tube. 4. Handle. 27. Injector rack.

9. When no more air bubbles can be seen in sight tube (l), release handle (4) to its original upright (released) position. Use control lever (12) to extend rocker arm (10) as shown.

10. With rocker arm (10) in the fully extended position, operate handle (4) for 10 to 12 strokes. This will activate injector (25) and remove any air that is inside the injector.



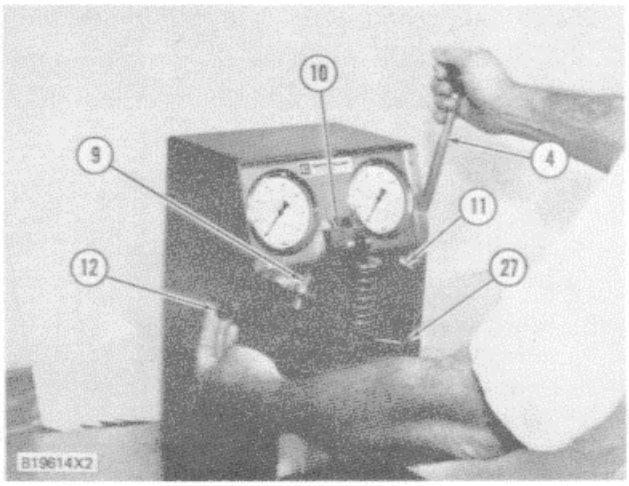
AIR REMOVAL FROM INJECTOR

1. Sight tube. 4. Handle. 10. Rocker arm. 12. Rocker arm control lever. 25. Injector. 27. Injector rack.

11. Release handle (4) and let it come back to the upright position. Move control lever (12) to retract rocker arm (10). Again use handle (4) to pump test fluid through the tester, for 10 or 12 strokes, and look for air bubbles at sight gauge (1). When no air bubbles can be seen at sight gauge (l), the injector is ready for the test procedure. If air bubbles are seen at sight gauge (1), do Steps 8 through 11 again until all air is removed from the tester system.

NOTE: Injector rack (27) must be pulled out all the way for all tests.

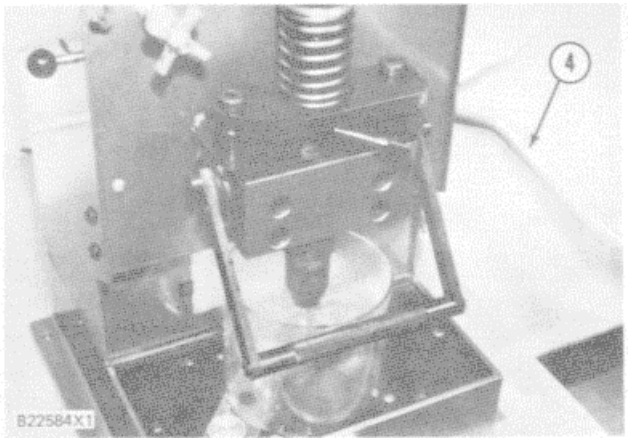
II. Orifice Inspection



INJECTOR IN POSITION FOR TEST

4. Handle. 9. Test pressure valve. 10. Rocker arm. 11. Light switch. 12. Rocker arm control lever. 27. Injector rack.

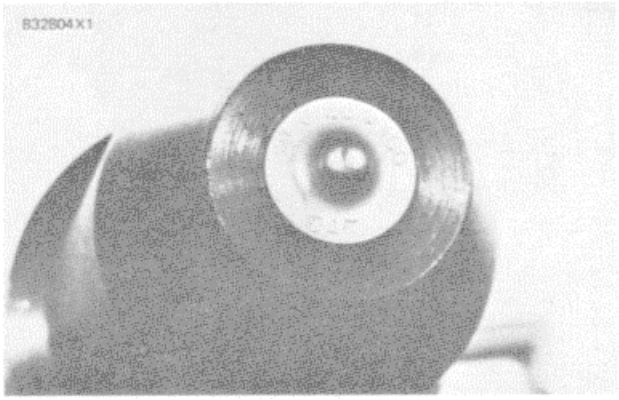
1. Handle (4) must be in an upright position as shown. Use control lever (12) to extend rocker arm (10), then pull injector rack (27) all the way out. Use switch (11) to turn on the panel light. Open test pressure valve (9) a minimum of one complete turn.



INJECTOR UNDER TEST

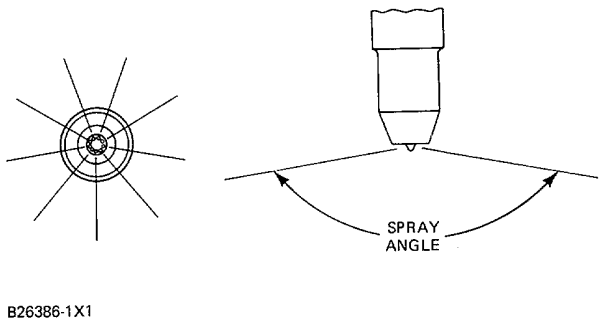
4. Handle.

2. The injector tip shown has nine orifices. Numbers on the tip of the injector will show: number of orifices, size of the orifices, and spray angle of orifices. An explanation of the 9-0.254-160 as shown in illustration is as follows: nine 0.254 mm orifices that have a 1600 spray angle. According to engine model and/or application, these numbers or specifications can be different from engine to engine.



INJECTOR TIP

3. Use handle (4) to pump the tester just fast enough to make sure orifices are not plugged.



CORRECT SPRAY ANGLE

4. If none of the orifices are plugged, rapidly pump handle (4) to make sure there is good flow of the test fluid at each orifice, and to make sure spray angle is correct.

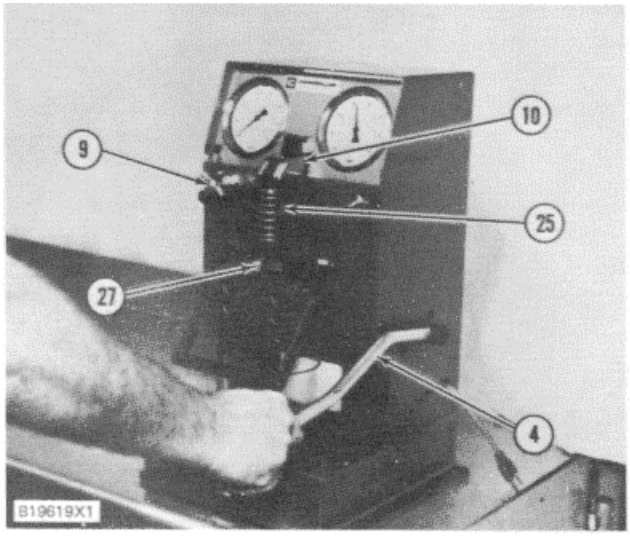
NOTE: If any orifices are plugged (closed), or if injector does not have a satisfactory spray angle, do not use the injector again.

III. Valve Opening Pressure (VOP)

The load cell and load cell gauge of the 6V4022 Tester are used to determine (find) the valve opening pressure of an injector. Valve opening pressure cannot be measured unless the injector is disassembled, but when the load cell and the load cell gauge of this tester are used, a measurement can be made of the force needed to depress (move down) the injector plunger. This force is in direct relation to the valve opening pressure. A conversion of these load cell gauge readings will give the valve opening pressure of an injector. All specifications for the valve opening pressure of an assembled injector will be given as load cell pressure readings. It will not be necessary to make any conversions or to have a special gauge. It must be remembered that the load cell gauge reading is a direct measurement of load cell pressure, and is not a direct measurement of valve opening pressure.

1. Make sure that all air has been removed from the tester and injector, and that test pressure valve (9) is OPEN a minimum of one complete turn. Pull injector rack (27) OUT all the way.

2. With rocker arm (10) extended, use handle (4) to pump the tester just fast enough to unseat (move off its seat) the needle valve inside injector (25). Test fluid will now move through the injector tip.

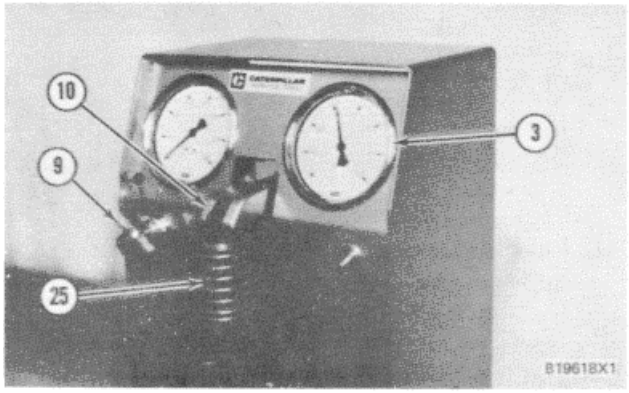


INJECTOR UNDER TEST
4. Handle. 9. Test pressure valve. 10. Rocker arm. 25. Injector. 27. Injector rack.

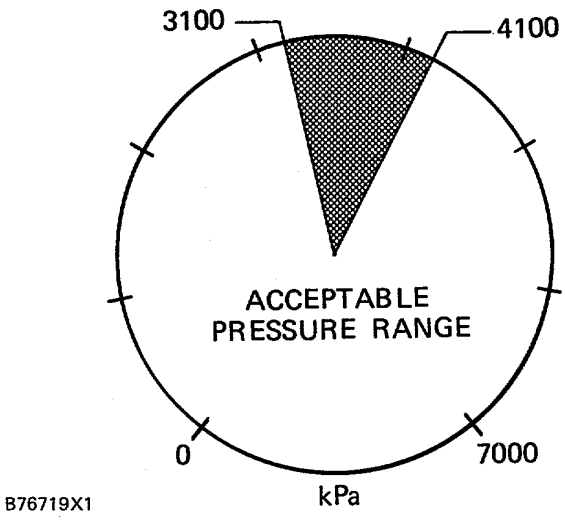
3. Look at load cell gauge (3). Slowly operate handle (4) to pump the tester and activate injector (25). During each stroke, the dial needle of load cell gauge (3) will go to a maximum pressure reading and then decrease.

NOTE: The highest gauge readings are made with a slow, steady movement of handle (4). Some extra practice (extra use of tester to learn better operating procedure) will show that a slow, steady movement of handle (4) will give the highest gauge readings.

4. Operate handle (4)just fast enough to cause test fluid to flow through the injector tip until the maximum reading on load cell gauge (3) is constant.



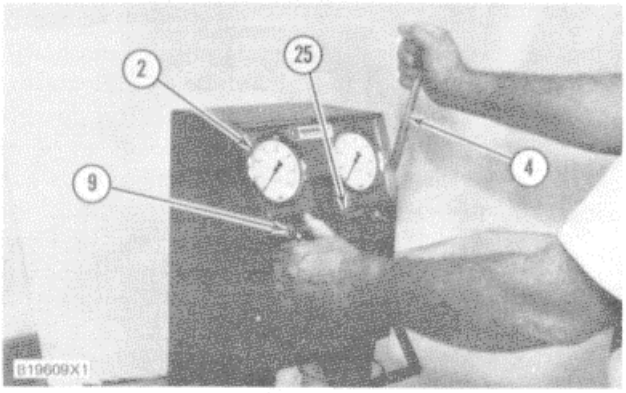
LOAD CELL PRESSURE INDICATION
3. Load cell pressure gauge. 9. Test pressure valve. 10. Rocker arm. 25. Injector.



LOAD CELL PRESSURE RANGE

5. The Load Cell Pressure for a new or used injector must be 3100 to 4100 kPa. If pressure is not within this pressure range, do not use the injector again.

IV. External Leakage



INJECTOR INSTALLED FOR TEST
2. Test pressure gauge. 4. Handle. 9. Test pressure valve. 25. Injector.

1. Remove all fluid from the injector holding block, injector body and injector tip with a clean cloth.

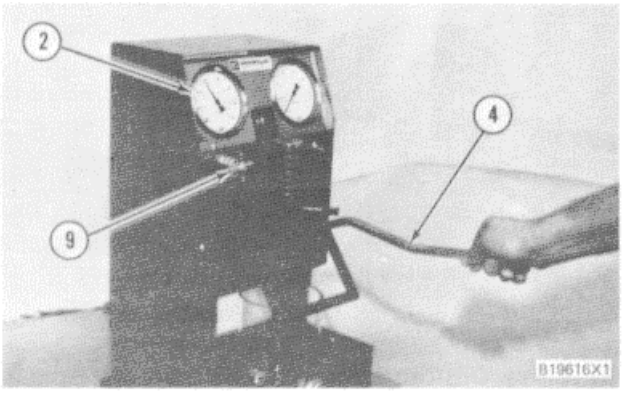
2. Close test pressure valve (9). Be sure the injector tip is completely dry.

NOTICE

Look at test pressure gauge (2) during the procedure in Step 3. High pressure can come rapidly, so be careful. PRESSURE MUST NOT GO ABOVE 14 000 kPa.

3. Pump the tester just fast enough to maintain a pressure between 10 000 and 14 000 kPa on gauge (2). With this amount of pressure on the injector, make a thorough visual inspection of the injector for any leakage.

4. There must be no leakage at the seals. If there is leakage, new seals must be installed. Make this repair before any other tests are started.



INJECTOR UNDER TEST
2. Test pressure gauge. 4. Handle. 9. Test pressure valve.

5. If there is leakage at any part of the injector (except at the rack hole or from the injector tip), do not use the injector again. A repair or replacement of the injector must be made.

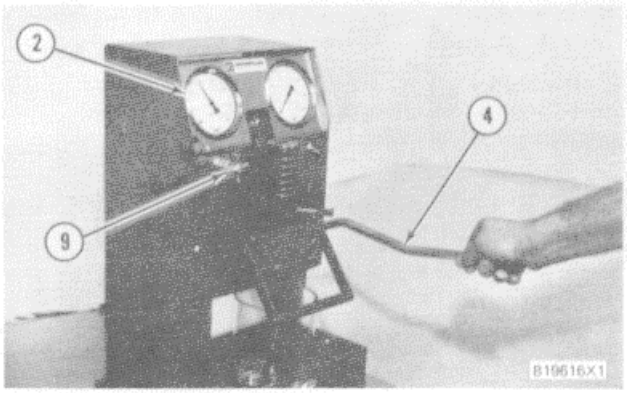
If there is leakage at the rack hole or from the injector tip, do the LEAKDOWN RATE TEST and the TIP LEAKAGE TEST (after EXTERNAL LEAKAGE TEST is complete) to see if the leakage is excessive.

NOTE: If there is to be a repair to the injector, see REPAIR OF UNIT INJECTORS in Special Instruction, Form No. SEHS8190.

V. Tip Leakage

1. Remove all fluid from the injector holding block, injector body and injector tip with a clean cloth.

2. Close test pressure valve (9). Be sure the injector tip is completely dry.



INJECTOR UNDER TEST

2. Test pressure gauge. 4. Handle. 9. Test pressure valve.

NOTICE

Look at test pressure gauge (2) during the procedure in Step 3. High pressure can come rapidly, so be careful. PRESSURE MUST NOT GO ABOVE 14 000 kPa.

3. Pump the tester just fast enough to maintain a pressure between 10 000 and 14 000 kPa on gauge (2). Use a stopwatch and make a visual inspection of the injector tip for 30 seconds.

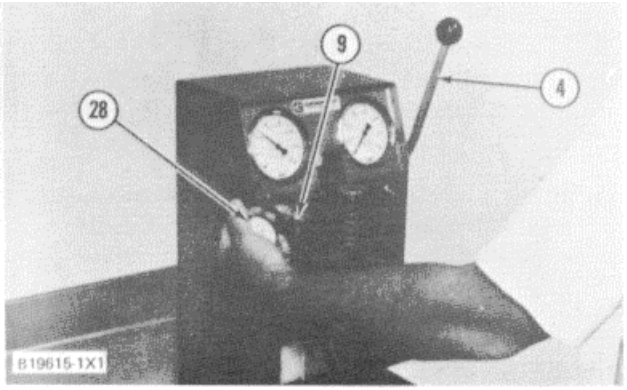
TIP LEAKAGE SPECIFICATION
No more than 15 drops can fall from the injector tip within 30 seconds.

NOTE: The test fluid must come from inside the injector through the tip orifice, not from any leakage above.

4. If more than 15 drops fall from the injector tip in 30 seconds, do not use the injector again. A repair or replacement of the injector must be made.

If there is to be a repair of the injector, see REPAIR OF UNIT INJECTORS in Special Instruction, Form No. SEHS8190.

VI. Leakdown Rate



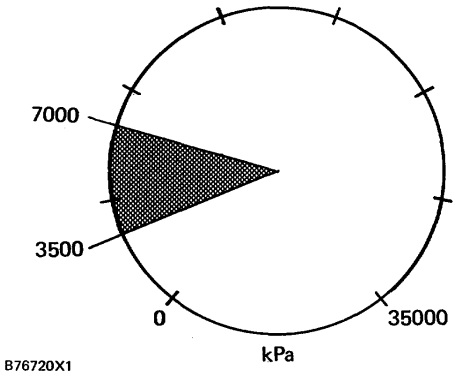
INJECTOR UNDER TEST

4. Handle. 9. Test pressure valve. 28. Stopwatch.

1. Test pressure valve (9) must be in the CLOSED position. Use handle (4) to slowly pump the tester and get a pressure of approximately 10 000 kPa. PRESSURE MUST NOT GO ABOVE 14 000 kPa.

2. Put handle (4) in the up (released) position. When pressure falls to 7000 kPa, activate stopwatch (28) and check the amount of time it takes for the pressure to drop to 3500 kPa.

LEAKDOWN RATE SPECIFICATION		
Injector Condition	Pressure Drop	Acceptable Time Interval
New or Rebuilt	3500 kPa	30 Seconds Minimum
Used	3500 kPa	20 Seconds Minimum



LEAKDOWN RATE PRESSURE RANGE

3. If leakdown time for the first test is one minute or more, the leakdown time is acceptable and no additional leakdown tests are necessary.

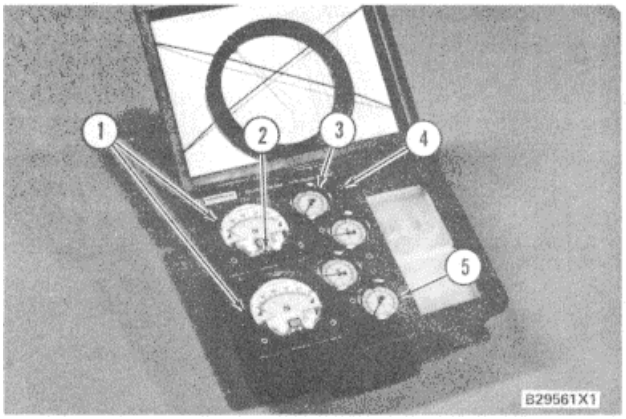
4. If leakdown time for the first test is less than one minute, it will be necessary to make three additional leakdown tests. Get an average of the results of the three additional tests.

5. If the average leakdown time of an injector is less than the time given in the specifications shown, do not use the injector. A repair or replacement of the injector must be made.

If there is to be a repair of the injector, see REPAIR OF UNIT INJECTORS in Special Instruction, Form No. SEHS8190.

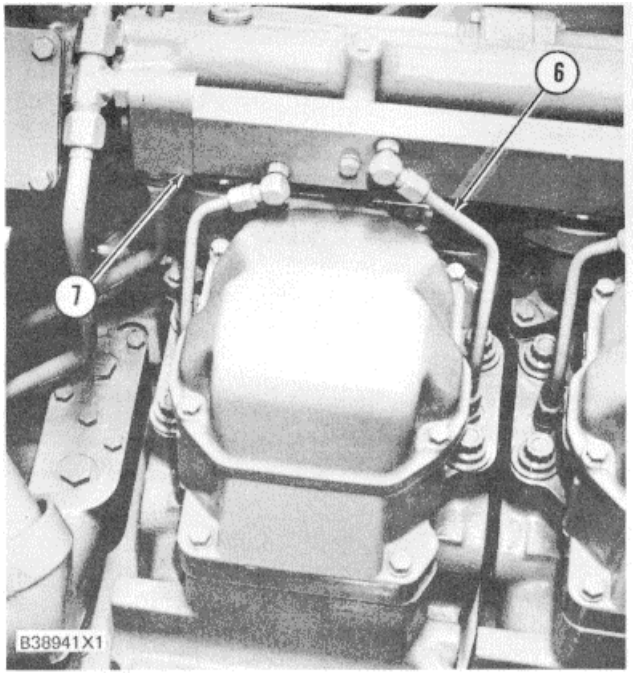
FUEL PRESSURE

The 6V3150 Engine Pressure Group can be used to check engine fuel pressures.



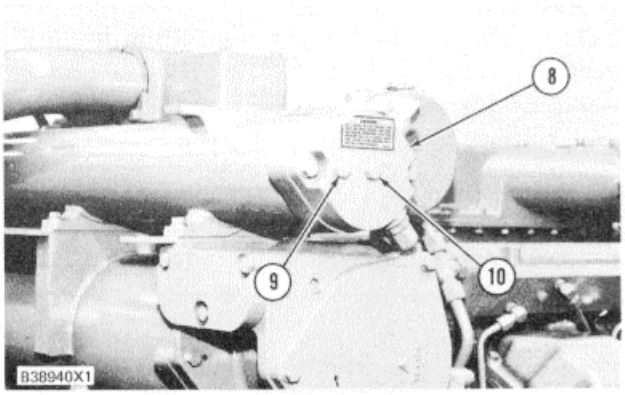
6V3150 ENGINE PRESSURE GROUP
1. Differential pressure gauges. 2. Zero adjustment screw. 3. Pressure gauge 0 to 1100 kPa (0 to 160 psi). 4. Pressure tap. 5. Pressure gauge 0 to 415 kPa (0 to 60 psi).

This tool group has a gauge to read pressure in the fuel manifolds. Special Instruction Form No. SEHS7851 is with the tool group and gives information for its use.



FUEL MANIFOLD AND LINES
6. Fuel supply line to cylinder head. 7, Fuel manifold.

The fuel pressure regulating valve keeps the pressure in fuel manifolds (7) between 415 and 450 kPa (60 to 65 psi). To check the fuel manifold pressure, disconnect one of the fuel lines (6) and install a tee between the line and manifold. Connect the 6V3150 Engine Pressure Group to the tee and operate the engine.



FUEL TRANSFER AND FILTER DIFFERENTIAL PRESSURES
8. Fuel filter housing. Plug. 10. Plug.

The outlet pressure of the fuel transfer pump can be checked at the location of plug (10) in filter housing (8).

Also the fuel filter differential can be checked at plugs (9) and (10) in filter housing (8).

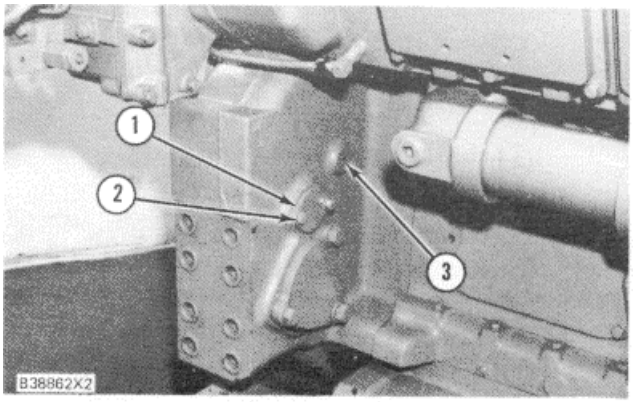
ENGINE ROTATION

SAE standard engine crankshaft rotation is counterclockwise as seen from the flywheel end of the engine.

FINDING TOP CENTER POSITION FOR NO. 1 PISTON

Tools Needed:

9S9082 Engine Turning Tool.



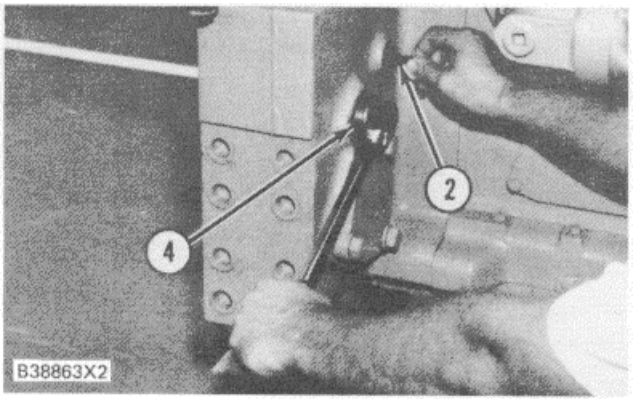
TIMING BOLT LOCATION
1. Cover. 2. Timing bolt. 3. Timing bolt hole In flywheel housing.

1. Remove cover (1) and the timing hole plug from the right front side of the flywheel housing. On some engines there is a cover and timing bolt hole located on the left side, also.

2. Put timing bolt (2) [long bolt that holds cover (1) on the flywheel housing] through the timing hole in the flywheel housing. Use the 9S9082 Engine Turning Tool (4) and 1/2" drive ratchet wrench to turn the engine flywheel in the direction of normal engine rotation until the timing bolt engages with the threaded hole in the flywheel.

NOTE: If the flywheel is turned beyond the point that the timing bolt engages in the threaded hole, the flywheel must be turned opposite normal engine rotation approximately 30 degrees. Then turn the flywheel in the direction of normal engine rotation until the timing bolt engages with the threaded hole. The reason for this procedure is to make sure the play is removed from the gears when the No. 1 piston is put on top center.

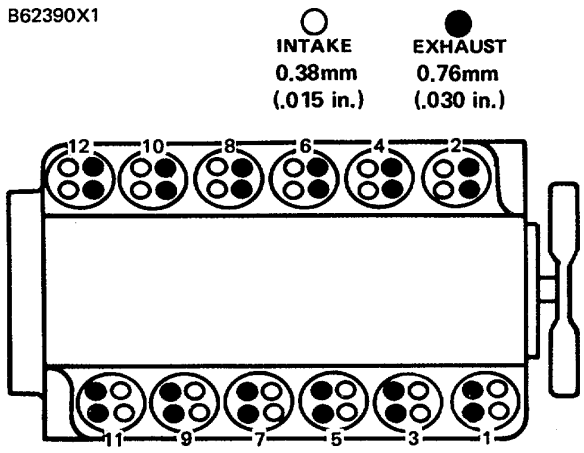
3. Remove the valve cover for the No. I cylinder head.



TIMING BOLT INSTALLATION
2. Timing bolt. 4. 9S9082 Engine Turning Tool.

4. The intake and exhaust valves for the No. 1 cylinder are fully closed if No. 1 piston is on the compression stroke and the rocker arms can be moved by hand. If the rocker arms can not be moved and the valves are slightly open, the No. 1 piston is on the exhaust stroke. Make reference to charts for CRANKSHAFT POSITIONS FOR INJECTOR TIMING AND VALVE CLEARANCE SETTING to find the correct cylinder(s) to be checked/adjusted for the stroke position of the crankshaft when the timing bolt has been installed in the flywheel.

NOTE: When the actual stroke position is identified, and the other stroke position is needed, it is necessary to remove the timing bolt from the flywheel and turn the flywheel 3600 in the direction of normal engine rotation.



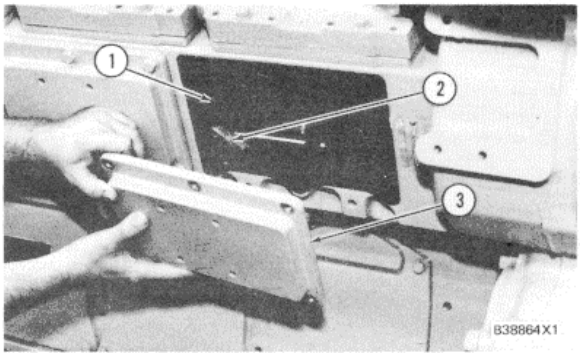
CYLINDER AND VALVE LOCATION
(3512 SHOWN)

CAMSHAFT TIMING

Timing Check

Tools Needed:
9S9082 Engine Turning Tool.

1. Remove rear camshaft cover (3) from both sides of the engine.

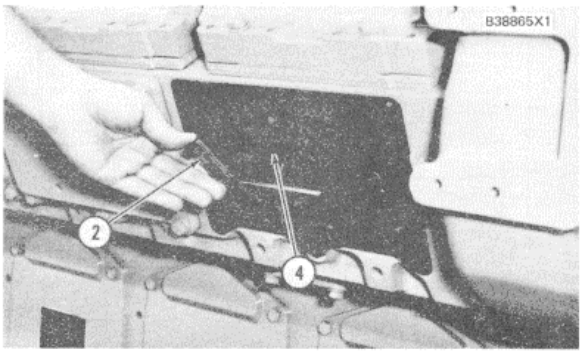


1. Timing hole. 2. Timing pin. 3. Cover.

2. Make reference to FINDING TOP CENTER POSITION FOR NO. I PISTON.

NOTE: Since both rear camshaft covers have to be removed to check the timing, it is not necessary to remove No. 1 valve cover to find the compression stroke when timing bolt is installed in flywheel.

3. With timing bolt installed in flywheel, look at rear of camshaft to see if timing groove (slot) is visible on the camshaft. If it is visible, No. 1 piston is on the compression stroke. If it is not visible, feel the backside of the camshaft for the groove. If the groove is at the back of the camshaft, the flywheel will have to be turned 3600 to put No. 1 piston on the compression stroke.



INSTALLATION OF TIMING PINS
2. Timing pin. 4. Camshaft (L.H.).

4. With timing bolt installed in flywheel with No. 1 piston now on compression stroke, remove timing pins (2) from their storage positions.

5. Install timing pins (2) through holes (1) in the engine block and into the groove (slot) in camshaft (4) on each side of the engine. For the engine to be timed correctly, the timing pins must fit into the groove of each camshaft.

6. If timing pins (2) do not engage in the grooves of both camshafts, the engine is not in time, and one or both camshafts must be adjusted.

7. Both camshafts are adjusted the same way. See TIMING ADJUSTMENT for the procedure to put the camshafts in time with the crankshaft.

NOTICE

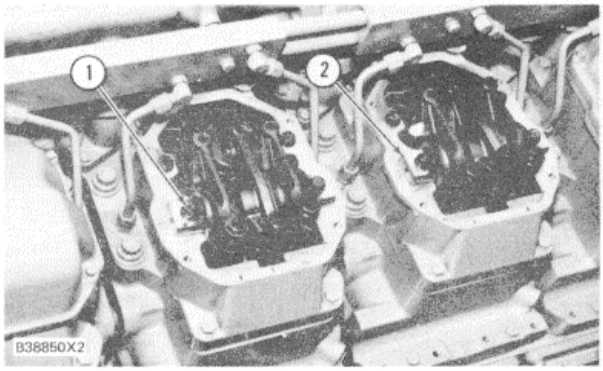
If a camshaft is out of time more than 18 degrees (approximately 1/2 the diameter of timing pin out of groove), the valves can make contact with the pistons. This will cause damage that will make engine repair necessary.

Timing Adjustment

Tools Needed:
9S9082 Engine Turning Tool.
6V3010 Puller Group.
9S9089 Two 1/2 - 13 NC Bolts 114.3 mm (4.50 in.) long.
5P1076 Two Washers (Hardened).

NOTE: Before any timing adjustments are made, the timing must be checked first to see if adjustment is necessary. See subject TIMING CHECK for this procedure.

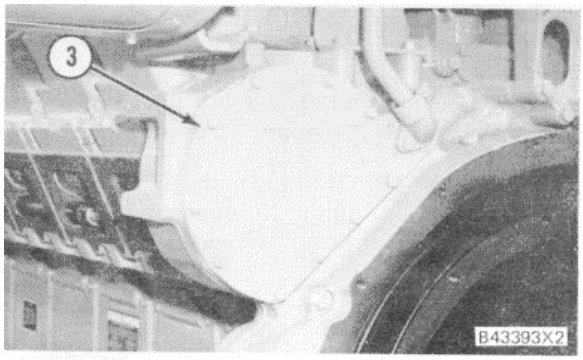
After TIMING CHECK procedure is complete, timing bolt will be engaged in flywheel with No. 1 piston at top center (TC) position.



LOOSEN ROCKER SHAFTS
1. Bolt. 2. Rocker shaft.

1. Remove all valve covers on the same side of the engine that camshaft needs adjustment. Now loosen bolts (1) [that hold all rocker shafts (2) to valve cover bases] until all rocker arms are free from the injectors and the valves.

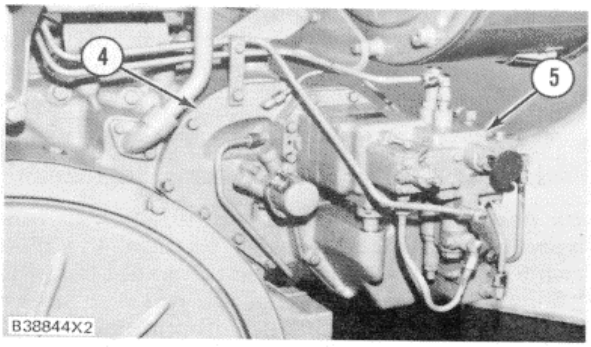
NOTE: The above procedure must be done before camshaft drive gear (7) is pulled off the camshaft taper.



REMOVE COVER (LH SIDE)
3. Cover.

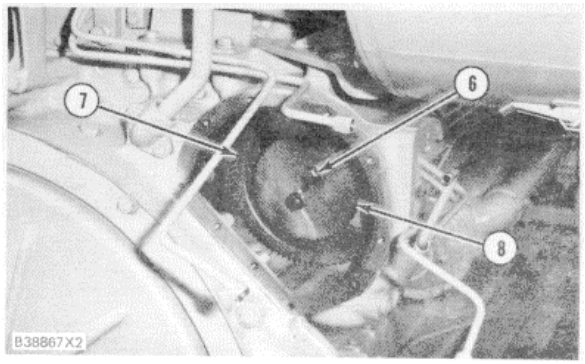
2. Remove camshaft drive gear cover (3) from the left side of the flywheel housing. Remove hydramechanical shutoff control group (5) and the shutoff drive (4) from the right side of the flywheel housing.

NOTE: See DISASSEMBLY AND ASSEMBLY install the hydramechanical protective system.



REMOVE HYDRAMECHANICAL PROTECTIVE *SYSTEM (RH SIDE)*
4. Hydramechanical shutoff drive. 5. Hydramechanical shutoff control group.

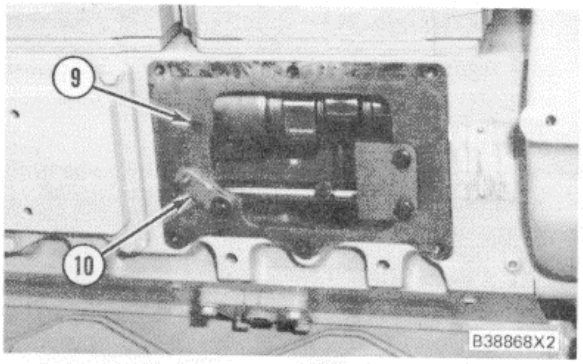
3. Remove bolts (6) and gear (8) from the right camshaft drive gear (7). Remove the bolts and plate from the left camshaft drive gear.



REMOVE CAMSHAFT DRIVE GEARS (RH SIDE)
6. Bolt. 7. Drive gear. 8. Accessory drive gear for hydramechanical protective system.

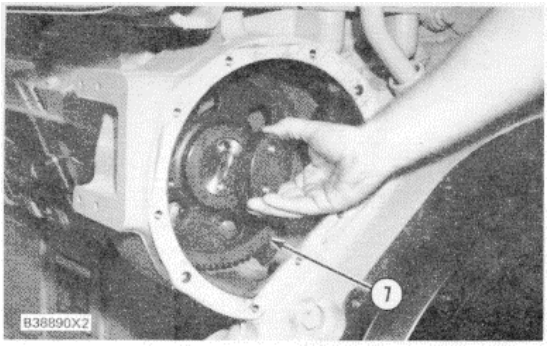
4. Install the 6V3010 Puller Group, two 9S9089 Bolts and two 5P1076 Washers. Loosen drive gears (7) from the taper on the camshafts. Remove the tooling and the gears.

5. Remove timing pin(s) (10) from the storage position (under the rear camshaft covers) on each side of the engine.



CAMSHAFT TIMING
9. Timing hole. 10, Timing pin.

6. Turn the camshafts until timing pins (10) can be installed through timing holes (9) and into the grooves (slots) in the camshafts.



INSTALL CAMSHAFT DRIVE GEARS
7. Drive Gear.

7. Install camshaft drive gears (7) as follows:

   a. Put camshaft drive gears (7) in position on the camshafts.

   b. Use hand pressure to turn and hold camshaft drive gears (7) in the direction of normal engine rotation. This removes all gear clearance (backlash) between camshaft drive gears (7) and the idler gear.

   c. Install the plate (on left side of engine) and drive gear (8) for the hydramechanical protective system (on right side of engine) to hold camshaft drive gears (7) to the camshaft.

   d. Tighten the bolts in steps to a torque of 100 ± 15 N ·m (75 ± 11 lb. ft.).

   e. Hit the face of the plate and drive gear and tighten the bolts to a torque of 100 ± 15 N ·m (75 ± 11 lb. ft.).

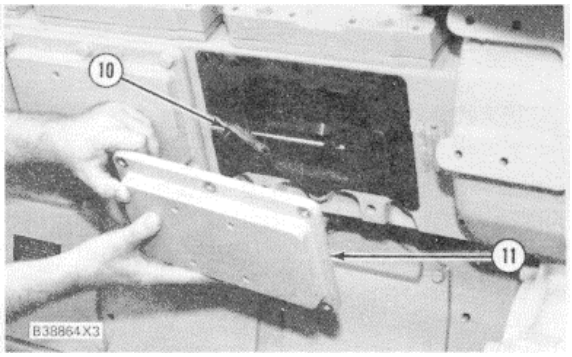
   f. Again hit the face of the plate and drive gear and again tighten the bolts to a torque of 100 ± 15 N ·m (75 ± 11 lb. ft.).

NOTE: If necessary, do Step 7f until the bolts hold torque (can not be moved) to make sure the drive gears are in full contact with the taper on the camshafts.

8. Install the gasket and cover on the left side of the flywheel housing.

9. Install the hydramechanical protective system on the right side of the flywheel housing.

10. Remove timing pins (10) from the camshafts. Remove the timing bolt from the flywheel housing. Install timing pins (10) in their storage positions. Install covers (11) over the camshafts and timing pins.



STORAGE POSITION FOR TIMING PINS
10. Timing pin. 11. Cover.

11. Install the 5M6213 Plug in the flywheel housing timing hole. Remove the engine turning pinion and install the cover and gasket.

12. Make sure the rocker arms are engaged correctly with the push rods and tighten the bolts to hold all of the rocker shafts in position.

13. Make adjustments to the valves and injector timing. See VALVE CLEARANCE SETTING and FUEL TIMING for the correct procedures.

START UP PROCEDURE

Use this procedure when an engine is started for the first time after work is done on the fuel system or governor.

1. Disconnect the air inlet system from the turbochargers.

2. Have a person in position near each turbocharger air inlet with a piece of steel plate large enough to completely cover the turbocharger air inlet.

⚠ WARNING

Be careful when plate is put against air inlet opening. Due to excessive suction, the plate can be pulled quickly against air inlet openings. To avoid crushed fingers, do not put fingers between plate and air inlet opening.

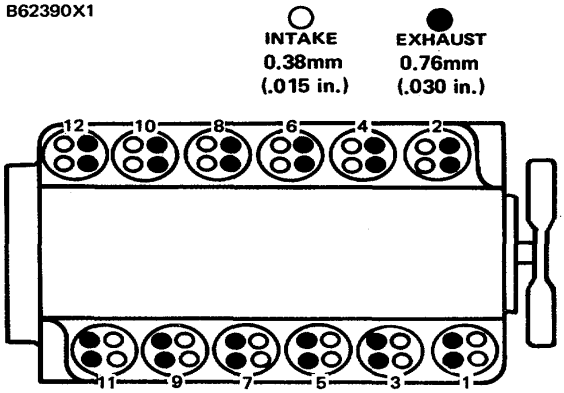
3. Start the engine. If the engine starts to run too fast or runs out of control, immediately put the steel plates against the turbocharger air inlets. This will stop the air supply to the engine, and the engine will stop.

CRANKSHAFT POSITIONS FOR FUEL TIMING AND VALVE CLEARANCE SETTING

STANDARD ROTATION (COUNTERCLOCKWISE) - as Viewed From Flywheel End				
ENGINE	CORRECT STROKE FOR NO.1 PISTON AT TOP CENTER POSITION*	CYLINDERS TO CHECK/ADJUST		
		VALVES		INJECTORS
		INTAKE	EXHAUST	
3508	COMPRESSION	1-2-6-8	1-2-3-7	3-4-5-7
	EXHAUST	3-5-4-7	4-5-6-8	1-2-6-8
3512	COMPRESSION	1-3-6-7-10-12	1-4-5-6-9-12	2-4-5-8-9-11
	EXHAUST	2-4-5-8-9-11	2-3-7-8-10-11	1-3-6-7-10-12
3516	COMPRESSION	1-2-5-7-8-12-13-14	1-2-3-4-5-6-8-9	3-4-6-9-10-11-15-16
	EXHAUST	3-4-6-9-10-11-15-16	7-10-11-12-13-14-15-16	1-2-5-7-8-12-13-14

REVERSE ROTATION (CLOCKWISE) - as Viewed From Flywheel End				
ENGINE	CORRECT STROKE FOR NO.1 PISTON AT TOP CENTER POSITION*	CYLINDERS TO CHECK/ADJUST		
		VALVES		INJECTORS
		INTAKE	EXHAUST	
3508	COMPRESSION	1-3-4-8	1-2-7-8	2-5-6-7
	EXHAUST	2-5-6-7	3-4-5-6	1-3-4-8
3512	COMPRESSION	1-3-4-6-7-12	1-4-5-8-9-12	2-5-8-9-10-11
	EXHAUST	2-5-8-9-10-11	2-3-6-7-10-11	1-3-4-6-7-12
3516	COMPRESSION	1-2-5-6-7-8-13-14	1-2-3-4-5-6-9-10	3-4-9-10-11-12-15-16
	EXHAUST	3-4-9-10-11-12-15-16	7-8-11-12-13-14-15-16	1-2-5-6-7-8-13-14

*Put No. 1 piston at top center (TC) position and make identification for the correct stroke. Make reference to FINDING TOP CENTER POSITION FOR NO. 1 PISTON. After top center position for a particular stroke is found and adjustments are made for the correct cylinders, remove the timing bolt and turn the flywheel 3600 in the direction of normal engine rotation. This will put No. 1 piston at top center (TC) position on the other stroke. Install the timing bolt in the flywheel and complete the adjustments for the cylinders that remain.



CYLINDER AND VALVE LOCATION (3512 SHOWN)121

FUEL TIMING

Tools Needed:

6V3139 Timing and Fuel Setting Tool Group.
8S3675 Contact Point, 3.0 mm (.12 in.) long.
6V3075 Dial Indicator (Metric).
6V3117 Set Gauge.
6V3118 Timing Fixture.
9S9082 Engine Turning Tool.

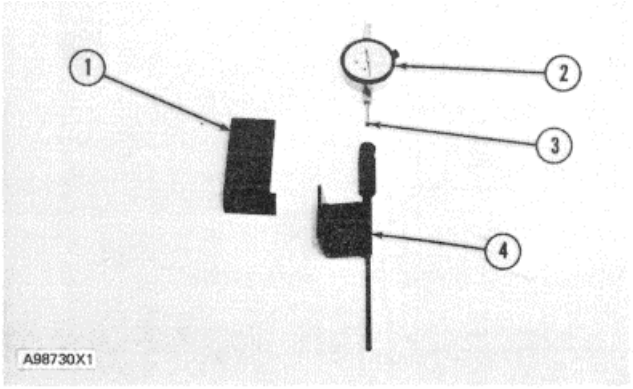
NOTICE

The camshafts must be correctly timed with the crankshaft before an adjustment of fuel timing is made. The timing pins must be removed from the camshafts before the crankshaft is turned or damage to the cylinder block will be the result.

1. See chart CRANKSHAFT POSITIONS FOR FUEL TIMING AND VALVE CLEARANCE SETTING and put the engine in time. With the two crankshaft positions given in the chart, all of the injectors can be checked or adjusted. This will make sure the pushrod lifters are off the lobes and on the base circles of the camshafts.

NOTE: See the Fuel Setting And Related Information Fiche for the correct fuel timing dimension to use.

Before a check or an adjustment of the fuel timing can be made, the tooling must be set to the correct dimension as follows:

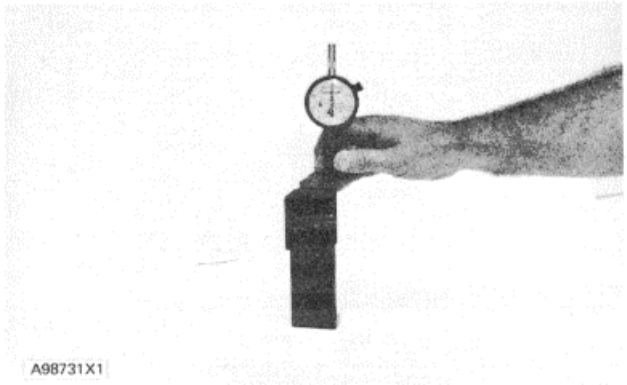


FUEL TIMING TOOLS

1. 6V3117 Set Gauge. 2. 6V3075 Dial Indicator (metric). 3. 8S3675 Contact Point, 3.0 mm (.12 in.) long. 4. 6V3118 Timing Fixture.

2. Install the 8S3675 Contact Point on the dial indicator stem.

3. Install 6V3075 Dial Indicator (2) in the collet of 6V3118 Timing Fixture (4).



ADJUSTMENT OF FUEL TIMING TOOLS

4. Put the dial indicator and timing fixture on 6V3117 Set Gauge (1) with the angle of the timing fixture on the top surface and the extension rod on the bottom step.

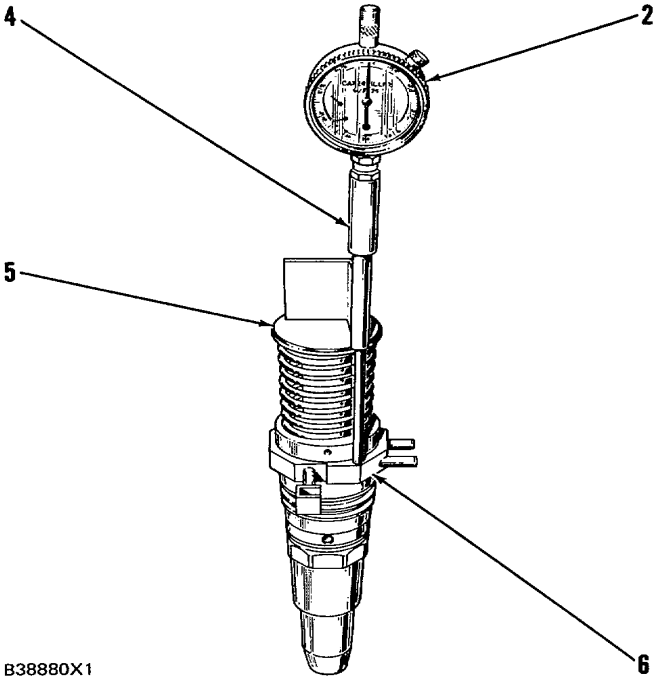
5. Move the dial indicator in the collet until the pointers indicate zero. Now move the dial indicator in the collet until the large pointer indicates setting shown in the DIAL INDICATOR SETTING CHART (if other than zero setting) and tighten the collet.

*DIAL INDICATOR SETTING CHART	
Fuel Timing Dimension mm	Dial Indicator Setting mm
88.28	+1.28
88.07	+1.07
87.85	+0.85
87.64	+0.64
87.43	+0.43
87.21	+0.21
87.00	0.00
86.79	--0.21
86.57	--0.43
86.36	--0.64
86.15	-0.84
85.93	-1.07
85.72	-1.28

*See Fuel Setting Information for the correct fuel timing dimension to use.

6. Make sure the top surfaces of injector follower (5) and shoulder (6) are clean and dry.

7. Put 6V3075 Dial Indicator (2) and 6V3118 Timing Fixture (4) in position on the injector to be checked. Make sure the angle of the timing fixture is on the top surface of follower (5) and the extension rod is on the top surface of injector shoulder (6) as shown in illustration.



FUEL TIMING TOOLS IN POSITION
2. 6V3075 Dial Indicator (metric). 4.6V3118 Timing Fixture. 5. Injector follower. 6. Shoulder on injector body.

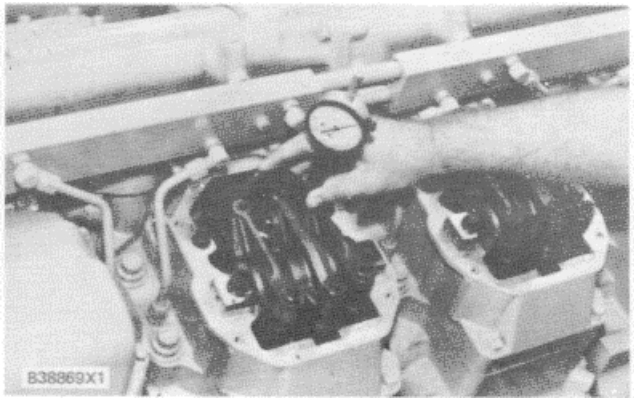
8. The dial indicator pointers must indicate 0.00 ± 0.20 mm.

9. If the dial indicator pointers indicate zero, or are within the tolerance given in Step 8, no adjustment is necessary. Proceed to Step 14.

10. If the dial indicator pointers do not indicate 0.00 ± 0.20 mm, do Steps 11 through 14.

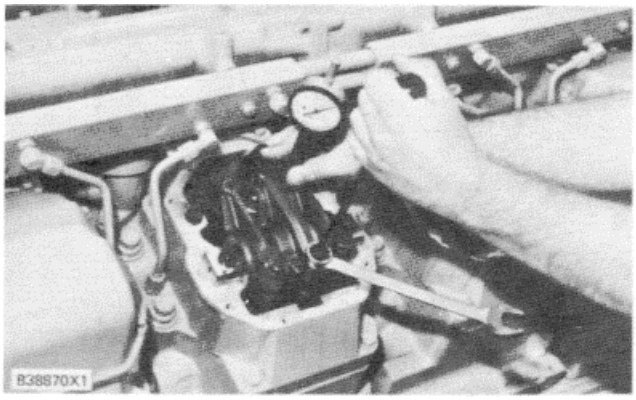
11. Loosen the push rod adjustment screw locknut for the injector to be adjusted.

12. Put 6V3075 Dial Indicator (2) and 6V3118 Timing Fixture (4) in position on the injector to be adjusted. Make sure that both edges of the angle of the timing fixture sets flat on the top surface of follower (5), and the extension rod is on the top surface of injector shoulder (6).



FUEL TIMING TOOLS IN POSITION

13. Turn the adjustment screw until zero is read on the dial indicator. Tighten the adjustment screw locknut to a torque of 70 ± 15 N-m (50 ±11 lb. ft.) and check adjustment again. If necessary, do this procedure again until the adjustment is correct.



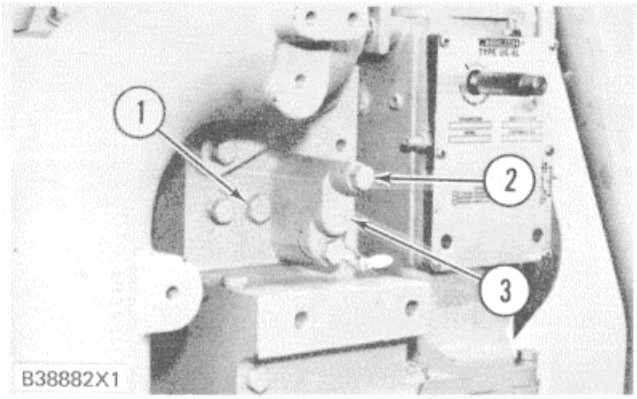
ADJUSTMENT OF FUEL TIMING

14. Remove the timing bolt from the flywheel when the fuel timing check is completed.

INJECTOR SYNCHRONIZATION

Tools Needed:
6V3119 Rack Synchronizing Gauge.

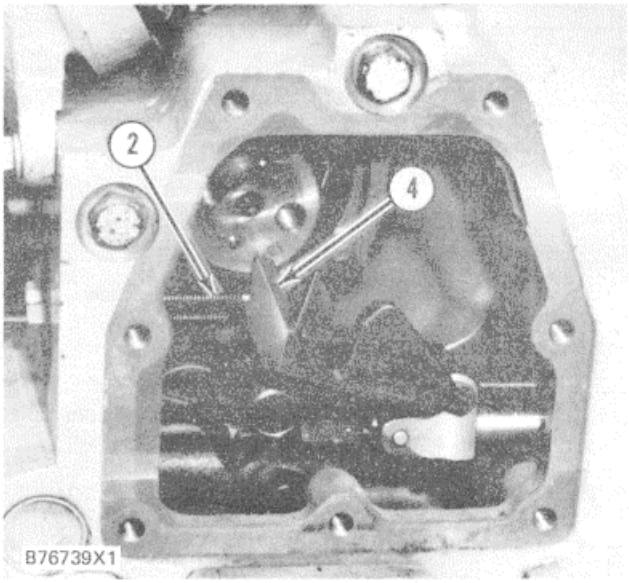
Injector synchronization is the setting of all injector racks to a reference position so each injector gives the same amount of fuel to each cylinder. This is done by setting each injector rack to the same position while the control linkage is in a fixed position (called the synchronizing position). The procedure for adjustment of injector synchronization is as follows:



LOCATION OF FUEL SETTING COVER AND SYNCHRONIZING PIN
1. Plug. 2. Synchronizing pin. 3. Cover.

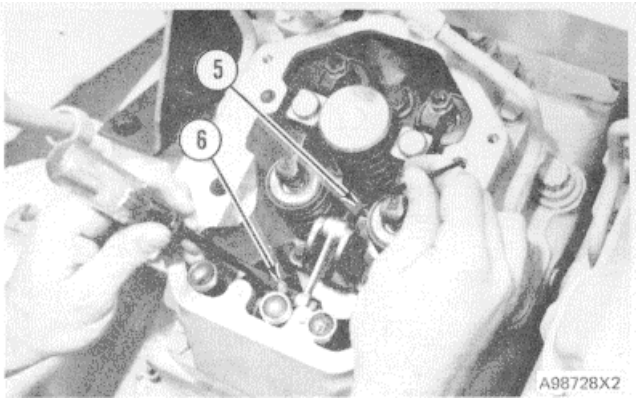
1. The top bolt that holds cover (3) in position is synchronizing pin (2). Remove synchronizing pin (2) and plug (1) from the front drive housing. DO NOT destroy seal or remove cover (3).

2. Remove the washer from synchronizing pin (2) and install it into the threaded hole where plug (1) was removed. Tighten synchronizing pin (2).



SYNCHRONIZING POSITION
(Governor Fastener Cover Removed Only For Illustration)

2. Synchronizing pin. 4. Fuel stop lever.



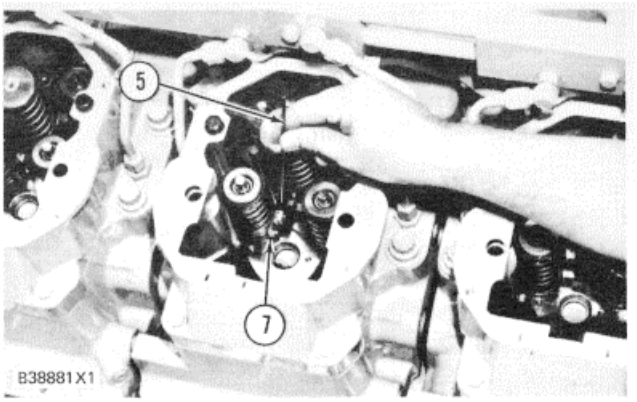
LOCATION FOR GAUGE AND CONTROL ROD ADJUSTMENT
(Rocker Shaft Removed for Illustration)

5. 6V3119 Rack Synchronizing Gauge [12.7 mm (.50 in.)]. 6. Control rod.

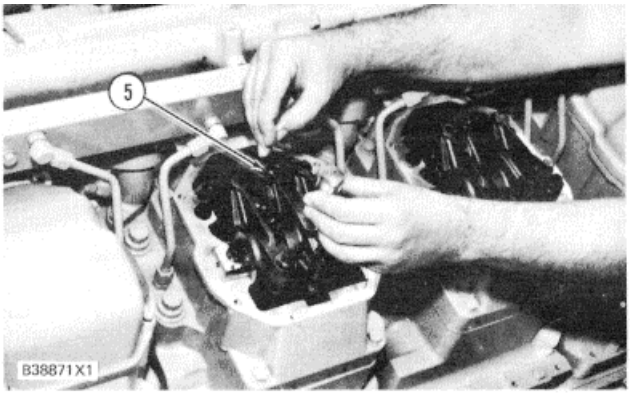
3. Turn the governor or actuator terminal shaft to the fuel "ON" position until the flat face of fuel stop lever (4) contacts synchronizing pin (2). This is the synchronizing position or zero reference point. Hold the control linkage in this position when the injectors are adjusted.

4. Remove the valve covers.

5. With the fuel stop lever against the synchronizing pin, put 6V3119 Rack Synchronizing Gauge (5) on the round part of the injector rack between the injector body and the end of the rack. Use a screwdriver and make an adjustment of control rod (6). Turn the screw on control rod (6) one "click" at a time until rack synchronizing gauge (5) just Fits between the injector body and the shoulder at the end of the rack. Remove the screwdriver from control rod (6) so no pressure is on the linkage while the setting is checked with rack synchronizing gauge(5). Any pressure on the linkage with the screwdriver will not give a correct indication when the setting is checked with the rack synchronizing gauge. To make sure the linkage is free and giving the correct setting, move (flip) the linkage and check the setting again. Put the box end of a 9/16" or 5/8" combination wrench over the nut and bolt that holds control rod (6) and the bellcrank together. Pull up on the control rod two or three times; then check the setting again.



GAUGE IN POSITION ON INJECTOR RACK (Rocker Shaft Removed for Illustration)
5. 6V3119 Rack Synchronizing Gauge [12.7 mm (.50 in.)]. 7. Fuel injector rack.



ADJUSTMENT OF FUEL CONTROL ROD
5. 6V3119 Rack Synchronizing Gauge.

6. Use rack synchronizing gauge (5) and, if necessary, make the adjustment to the other injectors, When all adjustments have been made, release the actuator terminal shaft.

7. Install the valve covers.

8. Make a check of the fuel setting and make adjustments if necessary. See FUEL SETTING AND RELATED INFORMATION FICHE for this procedure.

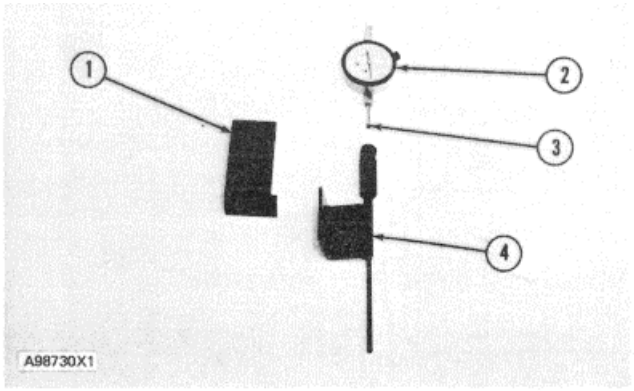
FUEL SETTING

Tools Needed:

6V3139 Timing and Fuel Setting Tool Group.
5P4814 Collet.
6V3075 Dial Indicator (metric).
5P7263 Contact Point, 76.2 mm (3.00 in.) long.
6V3119 Rack Synchronizing Gauge 12.7 mm (.50 in.).

Fuel Setting Check

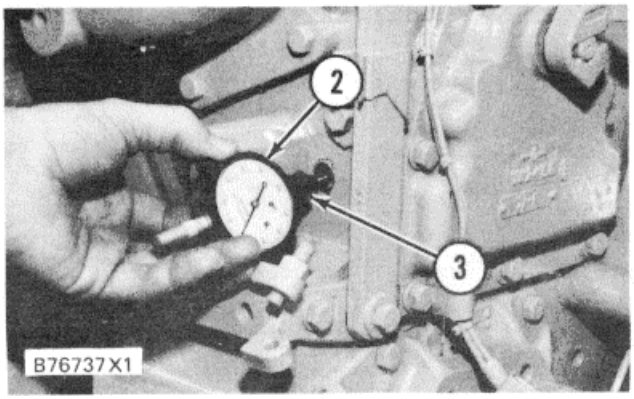
Fuel setting is the adjustment of the fuel setting screw to a specified position. The fuel setting screw limits the power output of the engine by setting the maximum travel of all the injector racks.



SYNCHRONIZATION AND FUEL SETTING TOOLS
1. 6V3119 Rack Synchronizing Gauge. 2. 6V3075 Dial Indicator (metric). 3. 5P4814 Collet. 4. 5P7263 Contact Point, 76.2 mm (3.00 in.) long.

Before the fuel setting is checked, the injectors must be correctly synchronized. See the subject INJECTOR SYNCHRONIZATION. After the injectors are synchronized correctly, leave the synchronizing pin in place for the procedure that follows.

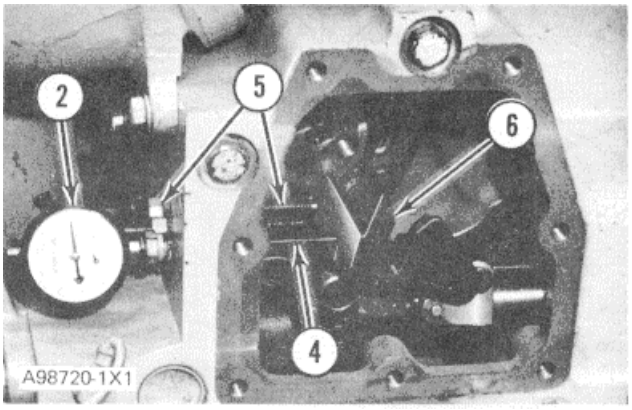
1. Put 6V3075 Dial Indicator (2) with 5P7263 Contact Point (4) in 5P4814 Collet (3). Remove the plug from the right side of fuel setting cover (8).



INSTALL DIAL INDICATOR

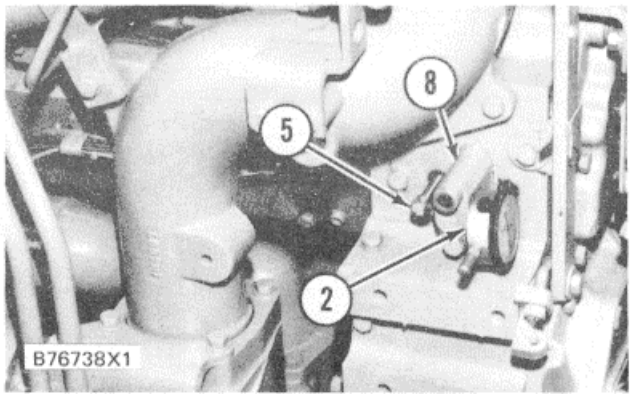
2. 6V3075 Dial Indicator with 5P7263 Contact Point attached. 3. 5P4814 Collet.

2. Move the governor or actuator terminal shaft in the fuel "ON" direction until the flat face of fuel stop lever (6) contacts synchronizing pin (5). Hold the linkage in this position.



DIAL INDICATOR IN POSITION
(Cover Removed Only for Photo Illustration)
2. 6V3075 Dial Indicator. 4. 5P7263 Contact Point, 76.2 mm (3.00 in.) long. 5. Synchronizing pin. 6. Fuel stop lever.

3. Install the dial indicator and collet (3) in the threaded hole as shown. When the contact point seats against fuel stop lever (6), slide the dial indicator in or out until the indicator reads zero. Now tighten collet (3) just enough to hold indicator at this position.



CHECKING FUEL SETTING
2. 6V3075 Dial Indicator (metric). 5. Synchronizing pin. 8. Fuel setting cover.

4. Turn synchronizing pin (5) back out a minimum of 25 mm (1 in.) (or remove it completely), and then slowly move the governor or actuator terminal shaft in the fuel "ON" direction until the flat face of the fuel stop lever is against the end of the fuel setting screw. With the linkage held in this position, the dial indicator reading will be the present fuel setting.

NOTE: See FUEL SETTING AND RELATED INFORMATION for the correct fuel setting.

5. If fuel setting is correct, remove the dial indicator and synchronizing pin (5). Install the two plugs, and install pin (5) back into cover (8).

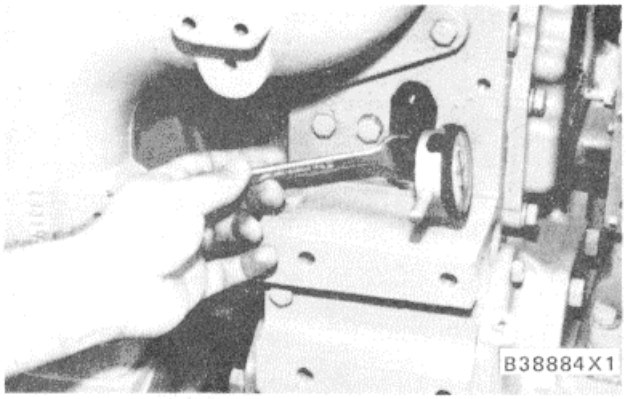
6. If fuel setting needs adjustment, go on to Fuel Setting Adjustment.

Fuel Setting Adjustment

NOTICE

A mechanic with governor and fuel setting training is the ONLY one to make adjustments to the engine fuel setting.

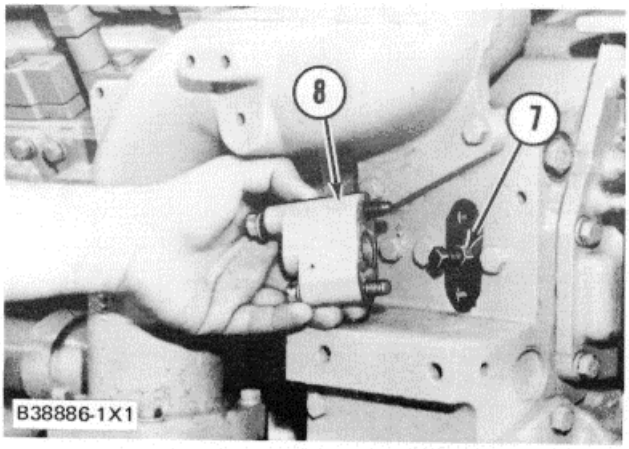
1. Cut the seal wire and remove fuel setting cover (8) and the gasket. Loosen locknut (7) and (with fuel stop lever still held against end of the fuel setting screw) turn the fuel setting screw in or out until the correct reading is on the dial indicator.



ADJUSTMENT OF THE FUEL SETTING SCREW

2. Now tighten locknut (7). Be sure that the fuel setting screw does not turn when the locknut (7) is tightened. Release the fuel linkage and again move linkage all the way in the fuel "ON" direction. Check the dial indicator reading again to be sure that fuel setting is still correct.

3. Remove the dial indicator and synchronizing pin (5), then install the two plugs. (5), then install the two plugs.



INSTALL COVER
7. Locknut. 8. Fuel setting cover.

4. Put fuel setting cover (8) and gasket in position over the fuel setting screw and install bolt and synchronizing pin (5) in cover. Install a new seal wire.

ENGINE SPEED MEASUREMENT



6V3121 MULTITACH GROUP

The 6V3 121 Multitach Group can measure engine speed from a tachometer drive on the engine. It also has the ability to measure engine speed from visual engine parts in rotation.

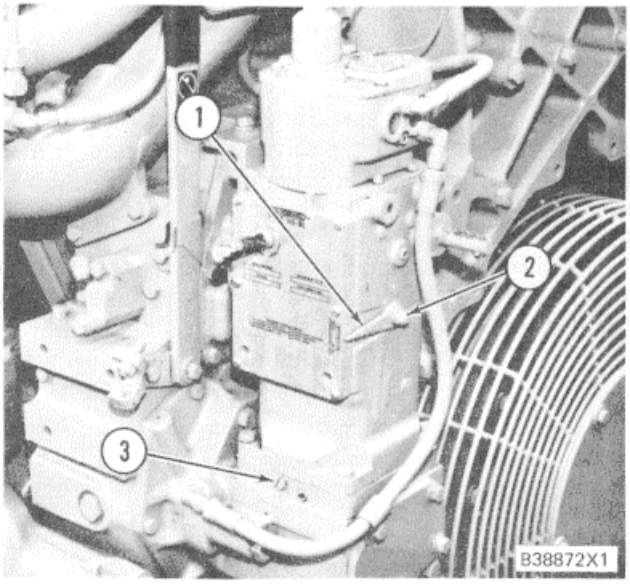
Special Instruction, Form No. SEHS7807 is with the 6V3121 Multitach Group and gives instructions for the test procedure.

WOODWARD UG8 LEVER GOVERNOR

COMPENSATING ADJUSTMENT

Although the governor may appear to be operating satisfactorily at no load, high overspeeds and underspeeds after load changes and slow return to normal speed are the results of incorrect compensation adjustments.

After the temperature of the engine and the oil in the governor have reached normal operating values, make compensation adjustments with the engine running at no load conditions.



UG8 LEVER GOVERNOR
1. Compensation pointer. 2. Nut. 3. Plug.

1. Loosen nut (2) that holds compensation pointer (1) and move the pointer up as far as it will go. Tighten the nut.

2. Remove plug (3) from the base of the governor to get access to the needle valve.

3. Use a screwdriver and turn the needle valve three to five turns in a counterclockwise (open) direction. Make sure the screwdriver engages with the shallow slot of the compensating needle valve and not in the deep slot that is at right angles to the shallow screwdriver slot.

4. Let the engine surge for approximately 30 seconds to help remove air from the governor oil passages.

5. Loosen nut (2) that holds compensation pointer (1) and move the pointer down as far as it will go. Tighten the nut.

6. Slowly turn the needle valve in a clockwise direction until the engine surge just stops.

7. Now check the number of turns the needle valve is open. To find the number of turns the needle valve is open, close the valve completely and make a note of the number of turns needed to close the valve.

8. Open the needle valve to the same position at which the engine did not surge (Step 6).

9. Move the governor linkage to change the engine speed. If the engine does not surge, and the needle valve is 1/2 to 3/4 of a turn open, the governor adjustment is correct. Install plug (3) in the base. If the needle valve is more than 3/4 of a turn open, do the steps that follow.

10. Loosen nut (2) and move compensation pointer (1) up two marks on the pointer scale.

11. Turn the needle valve three to five turns in a counterclockwise direction.

12. Let the engine surge for approximately 30 seconds to help remove air from the governor oil passages.

13. Slowly turn the needle valve in a clockwise direction until the engine surge just stops.

14. Now check the number of turns the needle valve is open. To find the number of turns the needle valve is open, close the valve completely and make a note of the number of turns needed to close the valve.

15. Open the needle valve to the same position at which the engine did not surge (Step 13).

16. Move the governor linkage to change the engine speed. If the engine does not surge, and the needle valve is 1/2 to 3/4 of a turn open, the governor adjustment is correct. Install plug (3) in the base. If the needle valve is more than 3/4 of a turn open, do Steps 10 thru 16 again.

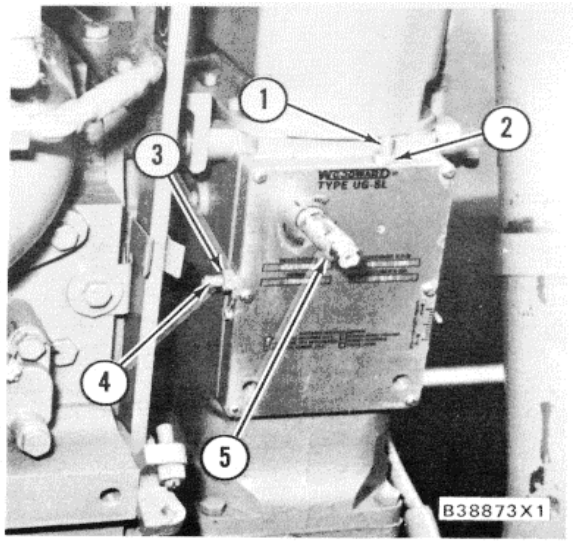
A needle valve that is opened less than 1/2 turn will cause a slow return of the engine to normal speed after a load change.

If the compensation pointer is too far toward the maximum position, the engine speed change will be too great when the load changes.

LOW AND HIGH IDLE SPEED ADJUSTMENT

Connect a tachometer with good accuracy to the engine. Make reference to MEASURING ENGINE SPEED.

1. Start the engine and run to get the engine to the normal temperature of operation.



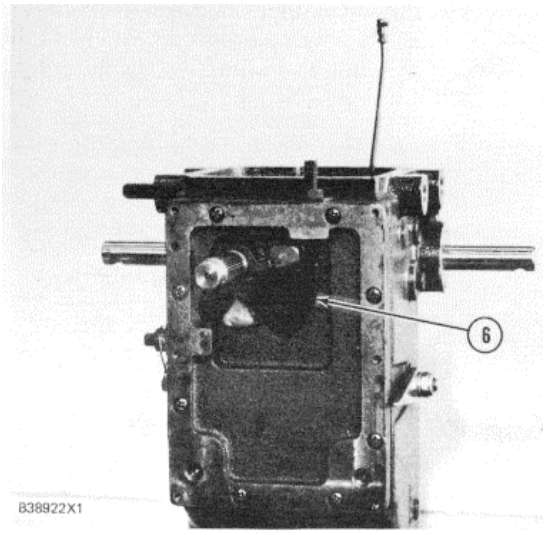
LOW AND HIGH IDLE ADJUSTMENT
1. Low idle adjustment screw. 2. Locknut. 3. Locknut. 4. High idle adjustment screw. 5. Governor speed adjustment shaft.

2. Move the governor speed adjusting shaft (5) to run the engine at high idle speed. Loosen locknut (3) and turn high idle adjustment screw (4). Turn adjustment screw (4) clockwise to decrease engine speed and counterclockwise to increase engine speed.

3. After the high idle speed has been adjusted, tighten the locknut and check high idle speed again.

NOTE: Make reference to the Fuel Setting Information Fiche for the correct low and high idle speed.

4. Move the governor speed adjusting shaft (5) to run the engine at low idle speed. Loosen locknut (2) and turn low idle adjustment screw (I). Turn adjustment screw (I) clockwise to increase low idle speed and counterclockwise to decrease low idle speed.



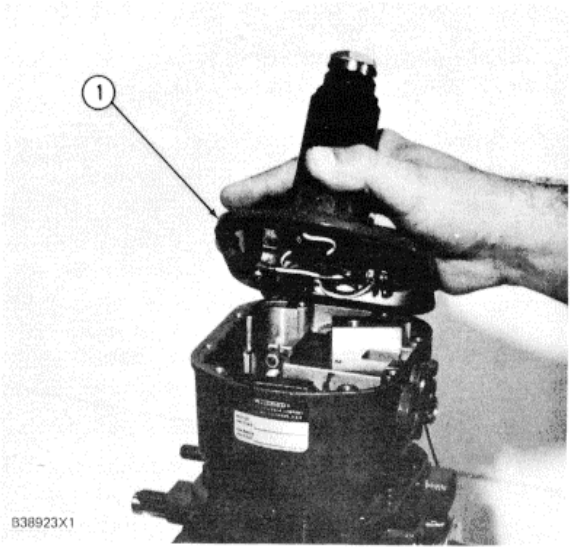
LOW AND HIGH IDLE STOP LEVER
6. Low and high idle stop lever.

SPEED DROOP ADJUSTMENT

Adjustment for Zero Droop

Tools Needed:
8S2328 Dial Indicator Group.
5P7264 Indicator Contact Point Group.

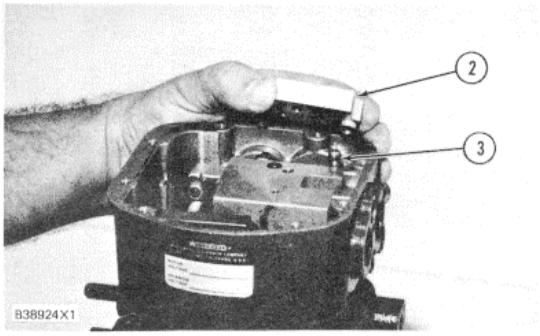
1. Disconnect the engine oil pressure and air inlet pressure lines for the air fuel ratio control housing.



COVER AND SHUT-OFF SOLENOID
1. Cover assembly.

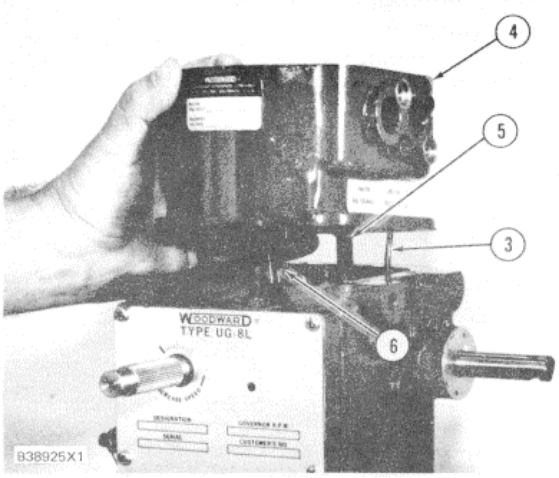
2. Remove the oil level gauge from cover assembly (1).

3. Remove the screws that hold cover assembly ( ) in position. Remove cover assembly (I) and the shut-off actuator as a unit from the governor.



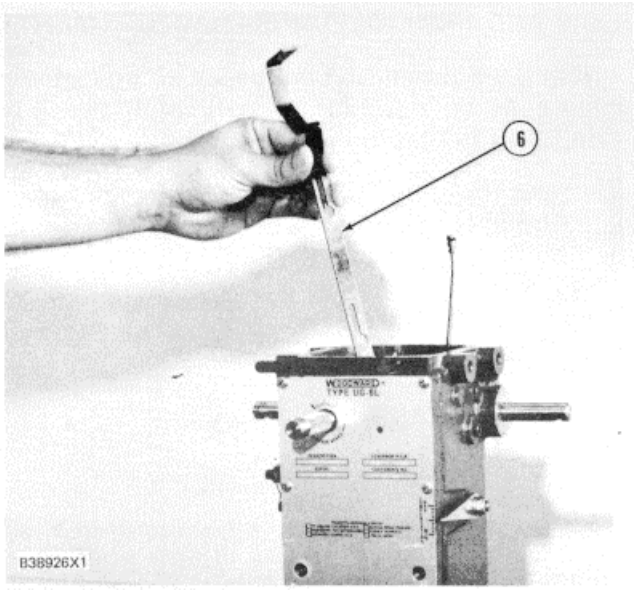
OIL PRESSURE LINE TO AIR FUEL RATIO CONTROL
2. Junction block. 3. Oil pressure line (from rotating bushing).

4. Remove the screw and pull junction block (2) from oil pressure line (3).



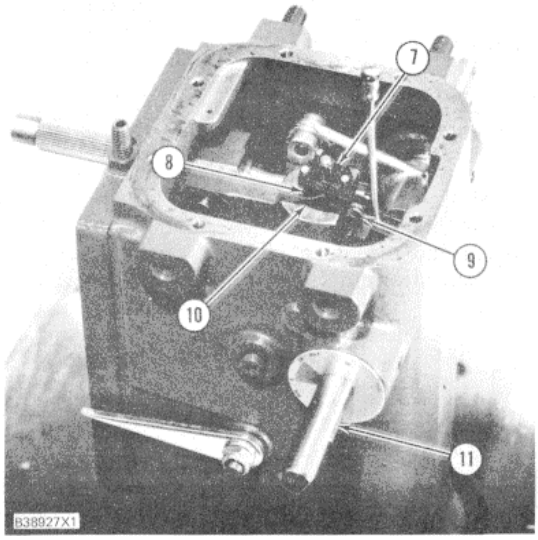
REMOVAL OF AIR FUEL RATIO CONTROL
3. Oil pressure line. 4. Air fuel ratio control housing. 5. Lever. 6. Shut-off strap.

5. Remove the eight bolts that hold air fuel ratio control housing (4) to the governor housing. Lift the unit until lever (5) is disconnected from the compensation lever. Turn and lift the unit to move the air fuel ratio control around and off shut-off strap (6). Be careful not to damage pressure line (3) when the air fuel ratio control is removed.



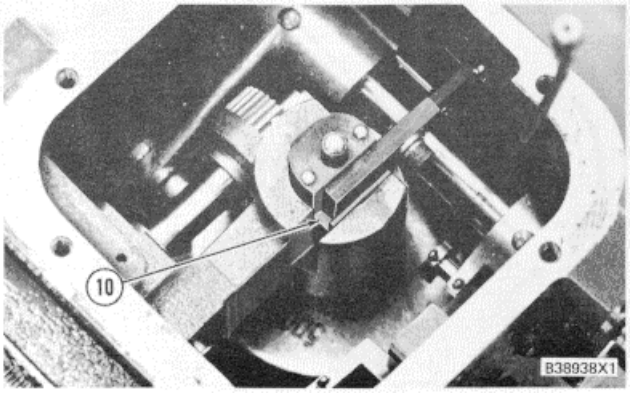
GOVERNOR SHUT-OFF STRAP
6. Shut-off strap.

6. Move shut-off strap (6) off the pins in the governor housing and remove it.



DROOP ADJUSTMENT
7. Speeder plug. 8. Droop cam. 9. Screw. 10. Bracket. 11. Terminal shaft.

7. Install the 3S3269 Contact Point, 25.4 mm(1.00 in.) long on the dial indicator. Put the dial indicator in position on the governor with the contact point on bracket (10) of speeder plug (7). Adjust the dial of the indicator to zero.



DROOP ADJUSTMENT
10. Bracket.

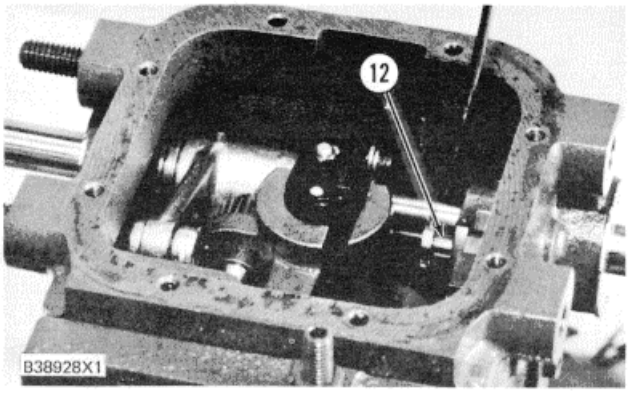
8. Move governor terminal shaft (11) from the maximum position to the minimum position. The dial indicator must read 0.00 to 0.05 mm (.000 to .002 in.) for zero droop.

9. If the droop adjustment is not correct, loosen screw (9) and move droop cam (8). Tighten screw (9). Move droop cam (8) toward speeder plug (7) to increase droop, and away from the speeder plug to decrease droop.

10. Check the speed droop adjustment again with the dial indicator.

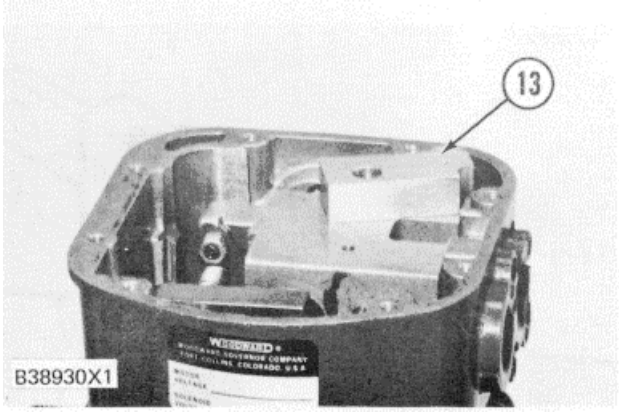
11. Install the shut-off strap in the governor.

12. Install the air fuel ratio control over the shut-off strap. Make sure lever (5) is engaged correctly with compensation lever (12) and install the screws to hold the unit to the governor.

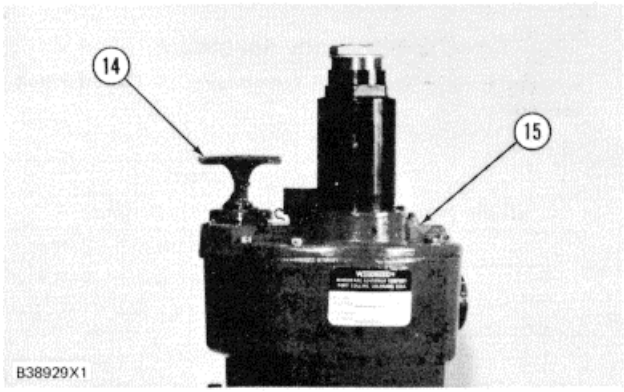


GOVERNOR ASSEMBLY
12. Compensation lever.

13. Make sure the O-ring seals are installed on the oil pressure line and into the air fuel ratio control. Install junction block (13).



AIR FUEL RATIO CONTROL OIL LINE
13. Junction block.



GOVERNOR COVER ASSEMBLY
14. Oil level gauge. 15. Cover assembly.

14. Install the shut-off actuator and cover assembly (15) on the air fuel ratio control housing. Install oil level gauge (14) in the cover assembly.

15. Connect the engine oil pressure and air inlet pressure lines to the air fuel ratio control housing.

Adjustment for Positive Droop

1. Remove the air fuel ratio control from the governor. See Steps I thru 6 in Adjustment for Zero Droop.

2. Connect a tachometer with good accuracy to the engine. Make reference to MEASURING ENGINE SPEED.

3. Loosen screw (9) and move droop cam (8) on droop lever (16) to get distance (A) for the droop percentage needed. See SPEED DROOP CHART to get the dimension needed.

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SPEED DROOP ASSEMBLY
8. Droop cam. 9. Screw. 16. Droop lever. A. Speed droop setting.

SPEED DROOP CHART	
Droop Percentage	**Distance A**
3	8.33 mm (.328 In.)
5	6.76 mm (.266 in.)
10	3 58 mm (.141 in)

NOTE: Dimension (A) is an approximate dimension. The final adjustments must be determined with the engine running.

4. Install the air fuel ratio control on the governor. See Steps 12 thru 16 in the Adjustment for Zero Droop. Start the engine and run to get the engine to the normal temperature of operation.

5. Put a load on the engine to get maximum full load. Make a note of the full load rpm.

6. Remove all load from the engine and make a note of the no load high idle rpm.

7. Find the difference of the no load high idle rpm and the full load rpm. Divide the difference by the full load rpm and multiply times 100. The result is the percent of speed droop.

$$\frac{\text{No load high idle speed full load rpm}}{\text{Full load rpm}} \times 100 = \%\ \text{of speed droop}$$

8. If the speed droop is not correct, stop the engine and move droop cam (8) toward speeder plug (7) to increase speed droop, or move away from the speeder plug to decrease speed droop.

9. Do Steps I thru 8 to check the speed droop and adjust again if needed.

AIR FUEL RATIO CONTROL

The UG8 Lever governors are equipped with an air fuel ratio control. Most adjustments are made at the factory or when the unit is rebuilt and there is a test bench available to make the adjustments. The following adjustment can be used to control acceleration smoke and engine response.

Adjustment

NOTE: Engine must be shutdown before making this adjustment to keep dirt and foreign material out of the governor.

1. Remove the cover assembly and shut-off actuator as a unit from the top of the governor.

2. Turn adjusting screw (I) clockwise to reduce smoke or counterclockwise to increase engine response.

3. Turn the adjusting screw 1/2 turn or less in the desired direction.

4. Replace the top cover assembly and shut-off actuator on the governor.

5. Start the engine and check the acceleration smoke and engine response to see if further adjustment is necessary. If necessary repeat Steps I, 2 and 3.

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LOCATION OF ADJUSTMENT SCREW
1. Adjusting screw.

AIR INLET AND EXHAUST SYSTEM

RESTRICTION OF AIR INLET AND EXHAUST

There will be a reduction of horsepower and efficiency of the engine if there is a restriction in the air inlet or exhaust system.

Air flow through the air cleaner must not have a restriction (negative pressure difference measurement between atmospheric air and air that has gone through air cleaner) of more than 762 mm (30 in.) of water.

Back pressure from the exhaust (pressure difference measurement between exhaust at outlet elbow and atmospheric air) must not be more than 686 mm (27 in.) of water.

MEASUREMENT OF PRESSURE IN INLET MANIFOLD

The efficiency of an engine can be checked by making a comparison of the pressure in the inlet manifold with the information given in the FUEL SETTING AND RELATED INFORMATION FICHE. This test is used when there is a decrease of horsepower from the engine, yet there is no real sign of a problem with the engine.

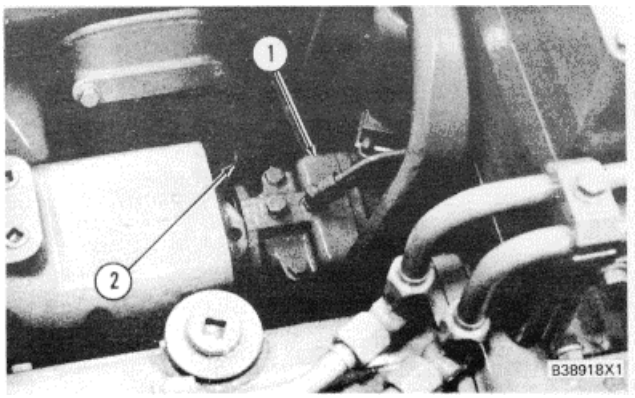
The correct pressure for the inlet manifold is given in the FUEL SETTING AND RELATED INFORMATION FICHE. Development of this information is done with these conditions:

a. 737 mm (29 in.) of mercury barometric pressure (dry).

b. 29° C (850 F) outside air temperature.

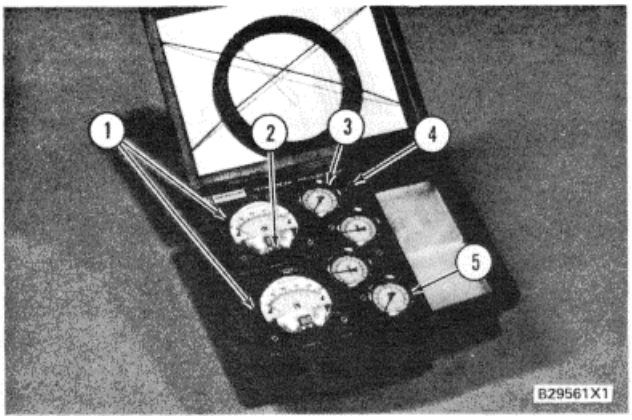
c. 35 API rated fuel.

On a turbocharged aftercooled engine, a change in fuel rating will also change horsepower and the pressure in the inlet manifold. If the fuel is rated above 35 API, pressure in the inlet manifold can be less than given in the FUEL SETTING AND RELATED INFORMATION FICHE. If the fuel is rated below 35 API, the pressure in the inlet manifold can be more than given in the FUEL SETTING AND RELATED INFORMATION FICHE. BE SURE THAT THE AIR INLET AND EXHAUST DO NOT HAVE A RESTRICTION WHEN MAKING A CHECK OF PRESSURE IN THE INLET MANIFOLD.



PRESSURE TEST LOCATION
1. Inlet water elbow to aftercooler. 2. Elbow or plug for aftercooler air chamber pressure.

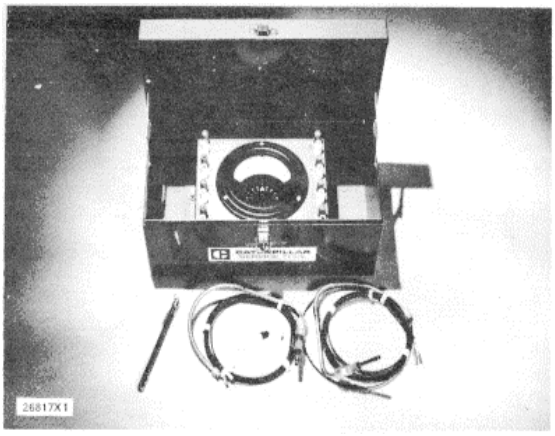
Use the 6V3150 Engine Pressure Group to check the pressure in the inlet manifold.



6V3150 ENGINE PRESSURE GROUP
1. Differential pressure gauges. 2. Zero adjustment screw. 3. Pressure gauge 0 to 100 kPa (0 to 160 psi). 4. Pressure tap. 5. Pressure gauge 0 to 415 kPa (O to 60 psi).

This tool group has a gauge to read pressure in the inlet manifold. Special Instruction, Form No. SEHS7851 is with the tool group and gives instructions for its use.

EXHAUST TEMPERATURE



1P3060 PYROMETER GROUP

Use the IP3060 Pyrometer Group to check exhaust temperature. Special Instruction, Form No. SMHS7179 is with the tool group and gives instructions for the test procedure.

CRANKCASE (CRANKSHAFT COMPARTMENT) PRESSURE

Pistons or rings that have damage can be the cause of too much pressure in the crankcase. This condition will cause the engine to run rough. There will also be more than the normal amount of fumes coming from the crankcase breather. This crankcase pressure can also cause the element for the crankcase breather to have a restriction in a very short time. It can also be the cause of oil leakage at gaskets and seals that would not normally have leakage.

COMPRESSION

An engine that runs rough can have a leak at the valves, or have valves that need adjustment. Removal of the head and inspection of the valves and valve seats is necessary to find those small defects that do not normally cause a problem. Repair of these problems is normally done when reconditioning the engine.

CYLINDER HEADS

The cylinder heads have valve seat inserts, valve guides and bridge dowels that can be removed when they are worn or have damage. Replacement of these components can be made with the tools that follow.

Valves

Valve removal and installation is easier with use of the IP3527 Valve Spring Compressor Assembly.

Valve Seat Inserts

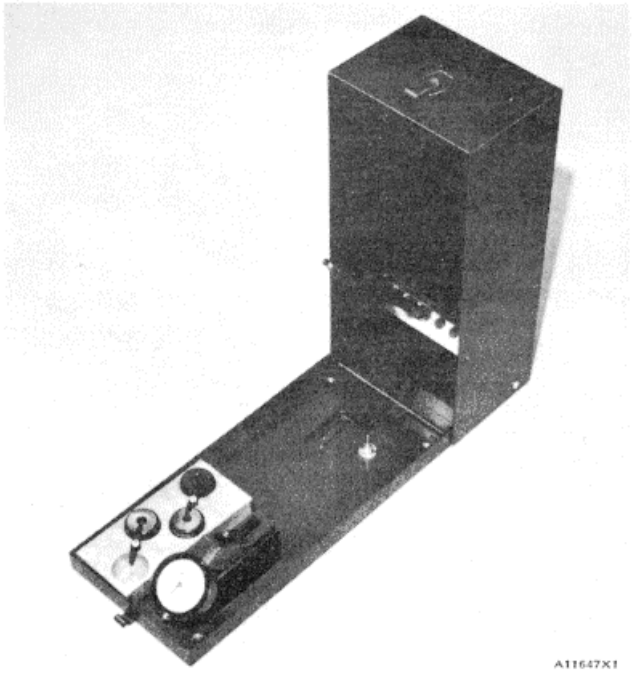
To remove and install valve seat inserts, use the 6V4805 Valve Seat Extractor Group. For installation, lower the temperature of the insert before it is installed in the head.

Valve Guides

Tools needed to remove and install valve guides are the 5P1729 Bushing and 7M3975 Driver. The counterbore in the driver bushing installs the guide to the correct height. Use a I P7451 Valve Guide Honing Group to make a finished bore in the valve guide after installation of the guide in the head. Special Instruction, Form No. SMHS7526 gives an explanation for this procedure. Grind the valves after the new valve guides are installed.

Checking Valve Guide Bores

Use the 5P3536 Valve Guide Gauge Group to check the bore of the valve guides. Special Instruction, Form No. GMG02562 gives complete and detailed instructions for use of the 5P3536 Valve Guide Gauge Group.



SP3536 VALVE GUIDE GAUGE GROUP

Bridge Dowels

Use a 5P944 Dowel Puller Group with a 5P942 Extractor to remove the bridge dowels. Install a new bridge dowel with a 6V4009 Dowel Driver. This dowel driver installs the bridge dowel to the correct height.

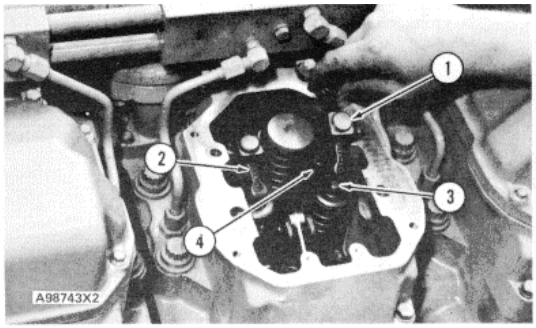
BRIDGE ADJUSTMENT

When the cylinder head is disassembled, keep the bridges with their respective valves. To make an adjustment to the bridges, use the procedure that follows:

NOTE: The only time bridge adjustment is necessary is when a valve has been replaced, ground, or cylinder head has been reconditioned. Valves must be fully closed when adjustment is made. To find when valves are fully closed, see subject FINDING TOP CENTER POSITION FOR NO. 1 PISTON and chart CRANKSHAFT POSITIONS FOR INJECTOR TIMING AND VALVE CLEARANCE SETTING.

1. Put engine oil on bridge dowel (4) in the cylinder head and in the bore in bridge (2).

2. Install bridge (2) with adjustment screw (5) toward the exhaust manifold.

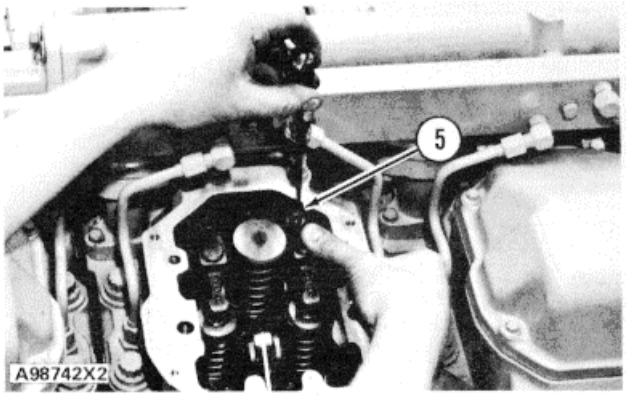


BRIDGE INSTALLATION
1. Top contact surface. 2. Bridge. 3. Valve stem. 4. Bridge dowel.

3. Loosen the locknut for adjustment screw (5) and loosen the adjustment screw several turns.

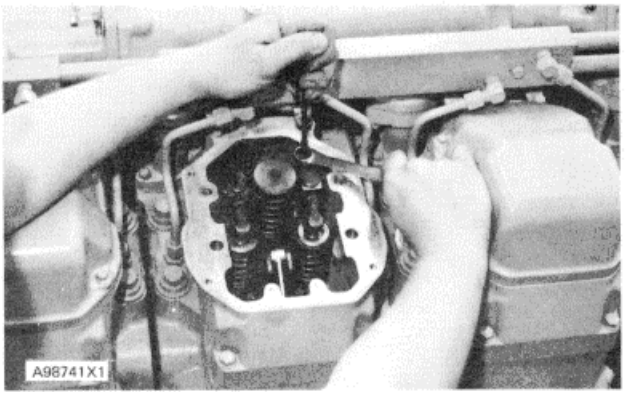
4. Put a force of 5 to 45 N (I to 10 lb.) by hand straight down on top contact surface (I) of bridge (2).

5. Turn adjustment screw (5) clockwise until it just makes contact with valve stem (3). Then turn the adjustment screw 20 to 300 more in a clockwise direction to make the bridge straight on the dowel, and to make compensation for the clearance in the threads of the adjustment screw.



BRIDGE ADJUSTMENT
5. Adjustment screw.

6. Hold adjustment screw (5) in this position and tighten the locknut to 30 ± 4 N ·m (22 ± 3 lb. ft.).



TIGHTEN LOCKNUT

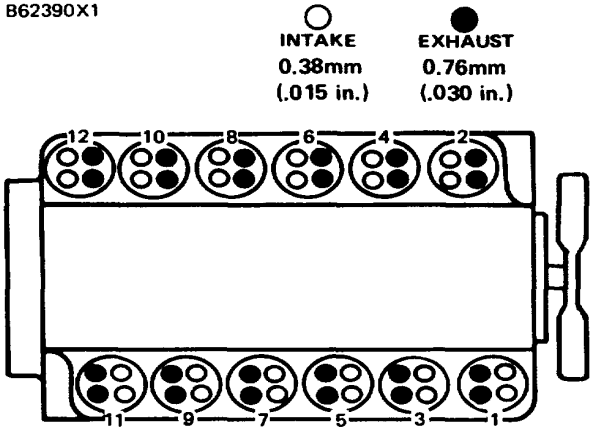
7. Put engine oil on top contact surface (I) where the rocker arm makes contact with the bridge.

CRANKSHAFT POSITIONS FOR FUEL TIMING AND VALVE CLEARANCE SETTING

STANDARD ROTATION (COUNTERCLOCKWISE) as Viewed From Flywheel End				
ENGINE	CORRECT STROKE FOR NO. PISTON AT TOP CENTER POSITION*	CYLINDERS TO CHECK/ADJUST		
		VALVES		INJECTORS
		INTAKE	EXHAUST	
3508	COMPRESSION	1-2-6-8	1-2-3-7	3-4-5-7
	EXHAUST	3-5-4-7	4-5-6-8	1-2-6-8
3512	COMPRESSION	1-3-6-7-10-12	1-4-5-6-9-12	2-4-5-8-9-11
	EXHAUST	2-4-5-8-9-11	2-3-7-8-10-11	1-3-6-7-10-12
3516	COMPRESSION	1-2-5-7-8-12-13-14	1-2-3-4-5-6-8-9	3-4-6-9-10-11-15-16
	EXHAUST	3-4-6-9-10-11-15-16	7-10-11-12-13-14-15-16	1-2-5-7-8-12-13-14

REVERSE ROTATION (CLOCKWISE) - as Viewed From Flywheel End				
ENGINE	CORRECT STROKE FOR NO.1 PISTON AT TOP CENTER POSITION*	CYLINDERS TO CHECK/ADJUST		
		VALVES		INJECTORS
		INTAKE	EXHAUST	
3508	COMPRESSION	1-3-4-8	1-2-7-8	2-5-6-7
	EXHAUST	2-5-6-7	3-4-5-6	1-3-4-8
3512	COMPRESSION	1-3-4-6-7-12	1-4-5-8-9-12	2-5-8-9-10-11
	EXHAUST	2-5-8-9-10-11	2-3-6-7-10-11	1-3-4-6-7-12
3516	COMPRESSION	1-2-5-6-7-8-13-14	1-2-3-4-5-6-9-10	3-4-9-10-11-12-15-16
	EXHAUST	3-4-9-10-11-12-15-16	7-8-11-12-13-14-15-16	1-2-5-6-7-8-13-14

*Put No. 1 piston at top center (TC) position and make identification for the correct stroke. Make reference to FINDING TOP CENTER POSITION FOR NO. 1 PISTON. After top center position for a particular stroke is found and adjustments are made for the correct cylinders, re- move the timing bolt and turn the flywheel 360° in the direction of normal engine rotation. This will put No. 1 piston at top center (TC) position on the other stroke. Install the timing bolt in the flywheel and complete the adjustments of the cylinders that remain.



CYLINDER AND VALVE LOCATION (3512 SHOWN)

VALVE CLEARANCE

Valve clearance (lash) is measured between the rocker arm and the bridge for the valves. All clearance measurements and adjustments must be made with the engine stopped, and with the valves FULLY CLOSED.

Valve Clearance Check

When the valve clearance is checked, adjustment is NOT NECESSARY if the measurement is in the range given in the chart for VALVE CLEARANCE CHECK: ENGINE STOPPED. However, it is the recommendation of Caterpillar that the valve clearance setting is to be made at the initial (first) 1000 service hours of operation, and every 3000 service hours thereafter.

VALVE CLEARANCE: ENGINE STOPPED	
VALVES	ACCEPTABLE CLEARANCE RANGE
Intake	0.30 to 0.46 mm (.012 to .018 in.)
Exhaust	0.68 to 0.84 mm (.027 to .033 in.)

If the measurement is not within this range, or if the service meter indication is at the specified interval, adjustment is necessary. See the subject VALVE CLEARANCE ADJUSTMENT.

Valve Clearance Adjustment

NOTICE

Due to normal changes (break-in effects) of new or rebuilt engines, the recommended first interval for valve clearance setting is at 1000 service hours of engine operation.

Use the procedure that follows for adjustment of the valves:

1. Put No. 1 piston at top center (TC) position. Make reference to FINDING TOP CENTER POSITION FOR NO. 1 PISTON.

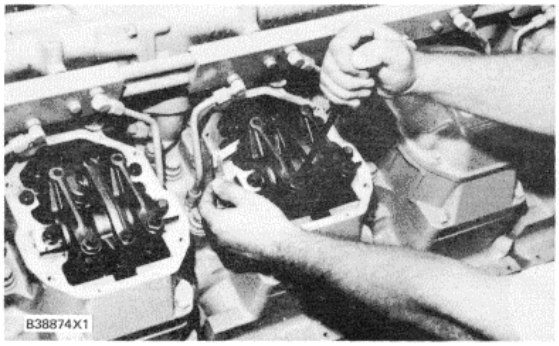
2. With No. 1 piston at top center position of the correct stroke, adjustment can be made to the valves as shown in the chart CRANKSHAFT POSITIONS FOR FUEL TIMING AND VALVE CLEARANCE SETTING.

NOTE: Before any actual adjustments are made, tap (hit lightly) each rocker arm (at top of adjustment screw) with a soft hammer to be sure that the lifter roller is seated against the camshaft base circle.

3. Loosen the locknut for the push rod adjustment screw. If there is not enough clearance for feeler gauge between rocker arm and bridge contact surface, turn the adjustment screw counterclockwise to increase the valve clearance.

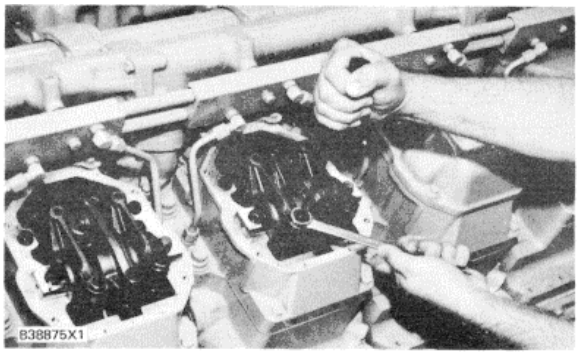
VALVE CLEARANCE SETTING: ENGINE STOPPED	
VALVES	GUAGE DIMENSION
Intake	0.28 mm (.015 in.)
Exhaust	0.76 mm (.030 in.)

4. Put a feeler gauge of the correct dimension between the rocker arm and bridge contact surface. Turn the adjustment screw clockwise until the valve clearance is set to the specifications in the chart VALVE CLEARANCE SETTING: ENGINE STOPPED.



VALVE CLEARANCE ADJUSTMENT

5. After each adjustment, tighten the nut for the adjustment screw to a torque of 70 + 15 N-m (50 + 11 lb. ft.) and check the adjustment again.



TIGHTEN ADJUSTMENT SCREW LOCKNUT

6. Remove the timing bolt and turn the flywheel 3600 in the direction of engine rotation. This will put No. 1 piston at top center (TC) position on the opposite stroke. Install the timing bolt in the flywheel.

7. With No. I piston at top center position of the opposite stroke, adjustment can be made to the remainder of the valves as shown in the chart CRANKSHAFT POSITIONS FOR FUEL TIMING AND VALVE CLEARANCE SETTING.

8. Repeat Steps 3, 4 and 5 for these valve adjustments.

9. Remove the timing bolt from the flywheel when all valve clearances have been adjusted.

LUBRICATION SYSTEM

One of the problems in the list that follows will generally be an indication of a problem in the lubrication system for the engine.

TOO MUCH OIL CONSUMPTION

OIL PRESSURE IS LOW

OIL PRESSURE IS HIGH

TOO MUCH BEARING WEAR

INCREASED OIL TEMPERATURE

TOO MUCH OIL CONSUMPTION

Oil Leakage on Outside of Engine

Check for leakage at the seals at each end of the crankshaft. Look for leakage at the oil pan gasket and all lubrication system connections. Check to see if oil comes out of the crankcase breather. This can be caused by combustion gas leakage around the pistons. A dirty crankcase breather will cause high pressure in the crankcase, and this will cause gasket and seal leakage.

Oil Leakage Into Combustion Area of Cylinders

Oil leakage into the combustion area of the cylinders can be the cause of blue smoke. There are four possible ways for oil leakage into the combustion area of the cylinders:

1. Oil leakage between worn valve guides and valve stems.

2. Worn or damaged piston rings, or dirty oil return holes in the piston.

3. Compression ring and/or intermediate ring not installed correctly.

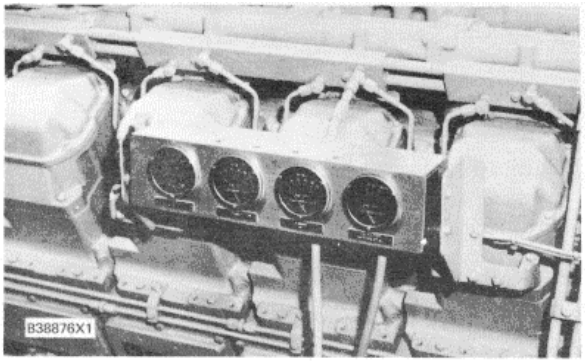
4. Oil leakage past the seal rings in the impeller end of the turbocharger shaft.

Too much oil consumption can also be the result if oil with the wrong viscosity is used. Oil with a thin viscosity can be caused by fuel leakage into the crankcase, or by increased engine temperature.

MEASURING ENGINE OIL PRESSURE

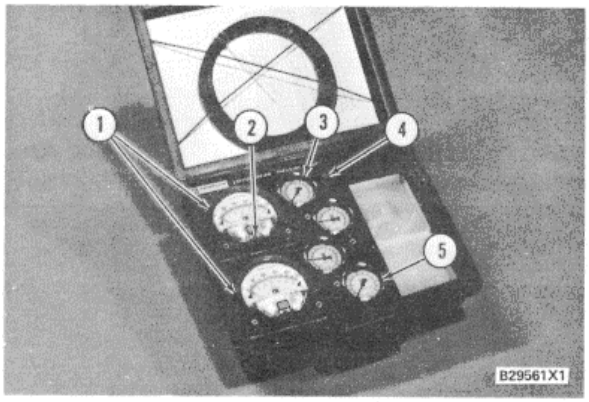
Tools Needed:

6V3150 Engine Pressure Group or
5P6225 Hydraulic Test Box.



INSTRUMENT PANEL

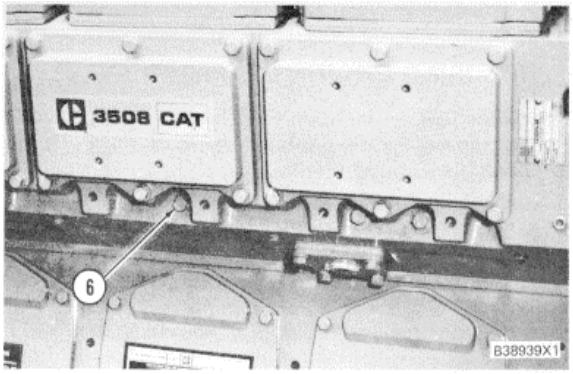
An oil pressure gauge that has a defect can give an indication of low or high oil pressure.



6V3150 ENGINE PRESSURE GROUP

1. Differential pressure gauges. 2. Zero adjustment screw. 3. Pressure gauge 0 to 1100 kPa (0 to 160 psi). 4. Pressure tap. 5. Pressure gauge 0 to 415 kPa (0 to 60 psi).

The 6V3150 Engine Pressure Group can be used to measure the pressure in the system. This tool group has a gauge to read pressure in the oil manifold. Special Instruction Form No. SEHS7851 is with the tool group and gives instruction for its use.



OIL GALLERY PLUG
6. Plug.

⚠ WARNING

Work carefully around an engine that is running. Engine parts that are hot, or parts that are moving, can cause personal injury.

Oil pressure to the camshaft and main bearings should be checked on each side of the cylinder block at oil gallery plug (6). With the engine at operating temperature, minimum oil pressure at full load rpm should be approximately 280 kPa (40 psi), and minimum oil pressure at low idle rpm should be approximately 140 kPa (20 psi).

OIL PRESSURE IS LOW

Crankcase Oil Level

Check the level of the oil in the crankcase. Add oil if needed. It is possible for the oil level to be too far below the oil pump supply tube. This will cause the oil pump not to have the ability to supply enough lubrication to the engine components.

Oil Pump Does Not Work Correctly

The inlet screen of the supply tube for the oil pump can have a restriction. This will cause cavitation (low pressure bubbles suddenly made in liquids by mechanical forces) and a loss of oil pressure. Air leakage in the supply side of the oil pump will also cause cavitation and loss of oil pressure. If the bypass valve for the oil pump is held in the open (unseated) position, the lubrication system can not get to maximum pressure. Oil pump gears that have too much wear will cause a reduction in oil pressure.

Oil Filter Bypass Valve

If the bypass valve for the oil filters is held in the open position (unseated) because the oil filters have a restriction, a reduction in oil pressure can result. To correct this problem, remove and clean the bypass valve and bypass valve bore. Install new Caterpillar oil filters to be sure that no more debris makes the bypass valve stay open.

Too Much Clearance at Engine Bearings or Open Lubrication System (Broken or Disconnected Oil Line or Passage)

Components that are worn and have too much bearing clearance can cause oil pressure to be low. Low oil pressure can also be caused by an oil line or oil passage that is open, broken or disconnected.

Piston Cooling Jets

When engine is operated, cooling jets direct oil toward the bottom of the piston to lower piston and ring temperatures. If a jet is broken, plugged or installed wrong, seizure of the piston will be caused in a very short time.

OIL PRESSURE IS HIGH

Oil pressure will be high if the bypass valve for the oil pump can not move from the closed position.

TOO MUCH BEARING WEAR

When some components of the engine show bearing wear in a short time, the cause can be a restriction in an oil passage.

If the gauge for oil pressure shows enough oil pressure, but a component is worn because it can not get enough lubrication, look at the passage for oil supply to the component. A restriction in a supply passage will not let enough lubrication get to a component, and this will cause early wear.

INCREASED OIL TEMPERATURE

Look for a restriction in the oil passages of the oil cooler. If the oil cooler has a restriction, the oil temperature will be higher than normal when the engine is operated. The oil pressure of the engine will not get low just because the oil cooler has a restriction.

Also check the oil cooler bypass valve to see if it is held in the open position (unseated). This condition will let the oil through the valve instead of the oil cooler, and oil temperature will increase.

COOLING SYSTEM

This engine has a pressure type cooling system. A pressure type cooling system gives two advantages. The first advantage is that the cooling system can have safe operation at a temperature that is higher than the normal boiling (steam) point of water. The second advantage is that this type system prevents cavitation (low pressure bubbles suddenly made in liquids by mechanical forces) in the water pump. With this type system, it is more difficult for an air or steam pocket to be made in the cooling system.

VISUAL INSPECTION OF THE COOLING SYSTEM

The cause for increased engine temperature is generally because regular inspections of the cooling system were not made. Make a visual inspection of the cooling system before a test is made with test equipment.

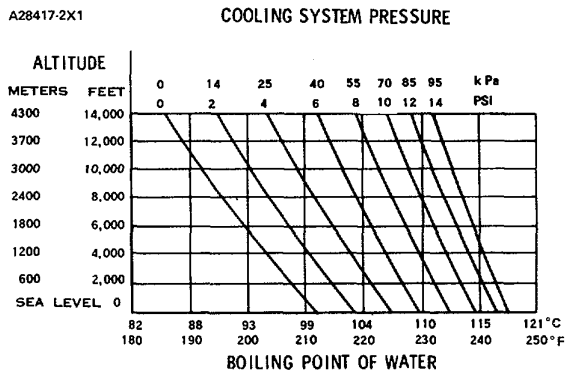
⚠ WARNING

DO NOT loosen the filler cap or pressure cap on a hot engine. Steam or hot coolant can cause severe burns.

1. After the engine is cool, loosen the pressure cap and turn it to the first stop to let pressure out of the cooling system. Then remove the pressure cap.
2. Check coolant level in the cooling system.
3. Look for leaks in the system.
4. Look for bent radiator fins. Be sure that air flow through the radiator does not have a restriction.
5. Inspect the drive belts for the fan.
6. Check for damage to the fan blades.
7. Look for air or combustion gas in the cooling system.
8. Inspect the filler cap and the surface that seals the cap. This surface must be clean and the seal must not be damaged.

TESTING THE COOLING SYSTEM

Remember that temperature and pressure work together. When a diagnosis is made of a cooling system problem, temperature and pressure must both be checked. Cooling system pressure will have an effect on cooling system temperatures. For an example, look at the chart to see the effect of pressure and height above sea level on the boiling (steam) point of water.



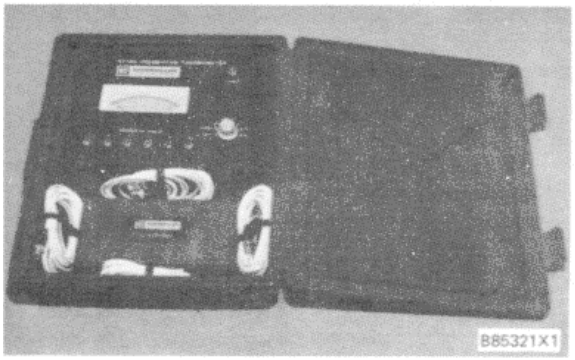
Tests Tools for Cooling System

Tools Needed:

8T470 Thermistor Thermometer Group.
9S7373 Air Meter Group.
6V3121 Multitach Group.
9S8140 Cooling System Pressurizing Pump Group.

⚠ WARNING

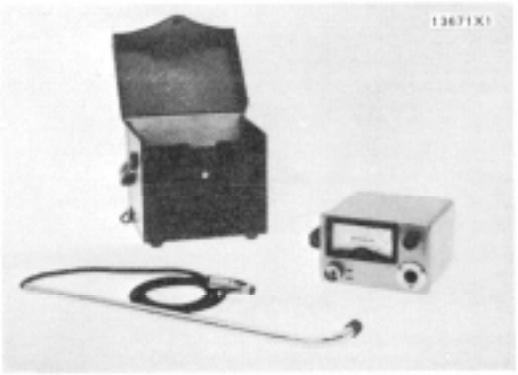
Work carefully around an engine that is running. Engine parts that are hot, or parts that are moving, can cause personal injury.



8T470 THERMISTOR THERMOMETER GROUP

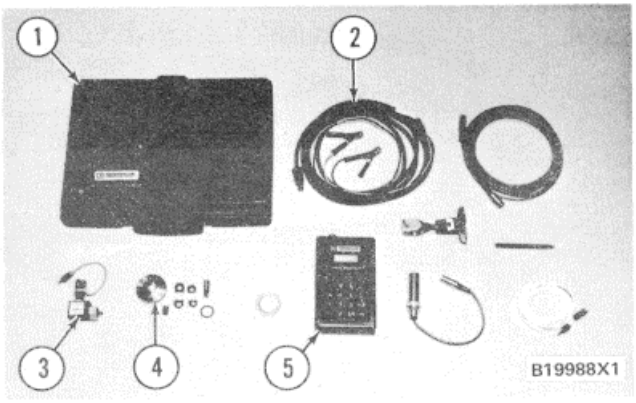
The 8T470 Thermistor Thermometer Group is used in the diagnosis of overheating (engine hotter than normal) or overcooling (engine cooler than normal) problems. This group can be used to check temperatures in several different parts of the cooling system. The testing procedure is in Special Instruction Form No. SEHS8446.

The 9S7373 Air Meter Group is used to check the air flow through the radiator core. The test procedure is in Special Instruction Form No. SMHS7063.



9S7373 AIR METER GROUP

The 6V3121 Multitach Group can be used to check the fan speed. Special Instruction Form No. SEHS7807 is with this group and gives instructions for the procedure.



6V3121 MULTITACH GROUP

1. Carrying case. 2. Power cable. 3. Tachometer generator. 4. Tachometer drive group. 5. Multitach.

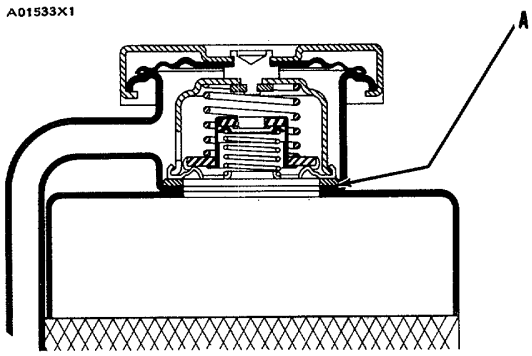
Pressure Cap Test

Tools Needed:

9S8140 Cooling System Pressurizing Pump Group

⚠ WARNING

DO NOT loosen the filler cap or pressure cap on a hot engine. Steam or hot coolant can cause severe burns.

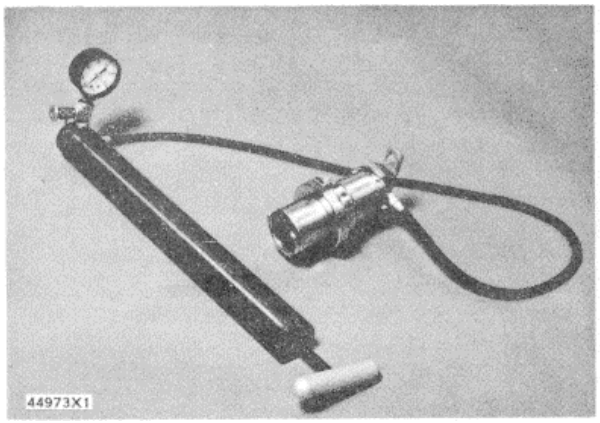


TYPICAL SCHEMATIC OF PRESSURE CAP A.
A. Sealing surface of cap and radiator.

1. After the engine is cool, loosen the pressure cap to the first stop and let the pressure out of the cooling system. Then remove the pressure cap.

One cause for a pressure loss in the cooling system can be a bad seal on the pressure cap of the system. Inspect the pressure cap carefully. Look for damage to the seal or to the surface that seals. Any foreign material or deposits on the cap, valve, seal, or surface that seals must be removed.

2. Put the pressure cap on the 9S8140 Cooling System Pressurizing Pump Group.



9S8140 COOLING SYSTEM PRESSURIZING PUMP GROUP

3. Look at the gauge for the exact pressure that makes the pressure cap open.

4. Make a comparison of the reading on the gauge with the correct pressure at which the pressure cap must open.

NOTE: The correct pressure that makes the pressure cap open is on the pressure cap and is also in the SPECIFICATIONS.

5. If the pressure cap is bad, install a new pressure cap.

Radiator and Cooling System Leak Tests (Systems That Use Pressure Cap)

Tools Needed:

9S8140 Cooling System Pressurizing Pump Group.

To test the radiator and cooling system for leaks, use the procedure that follows:

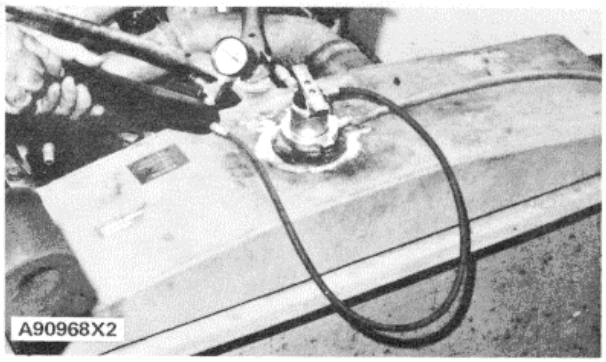
⚠ WARNING

DO NOT loosen the filler cap or pressure cap on a hot engine. Steam or hot coolant can cause severe burns.

1. After the engine is cool, loosen the pressure cap to the first stop and let the pressure out of the cooling system. Then remove the pressure cap.

2. Make sure the coolant is over the top of the radiator core.

3. Put the 9S8140 Cooling System Pressurizing Pump Group on the radiator.



9S8140 PRESSURIZING PUMP GROUP INSTALLED ON RADIATOR THAT USES PRESSURE CAP (TYPICAL EXAMPLE)

4. Get the pressure reading on the gauge to 20 kPa (3 psi) more than the pressure on the pressure cap.

5. Check the radiator for outside leakage.

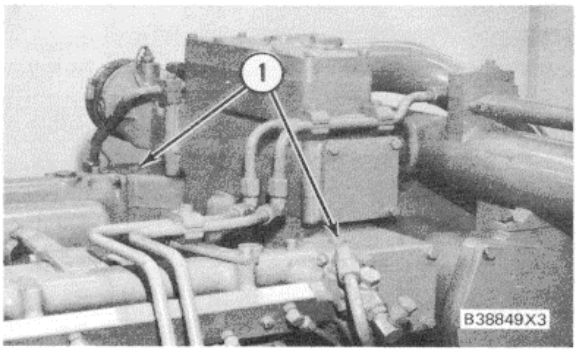
6. Check all connections and hoses of the cooling system for outside leakage.

7. If you do not see any outside leakage and the pressure reading on the gauge is still the same after 5 minutes, the radiator and cooling system does not have leakage. If the reading on the gauge goes down and you do not see any outside leakage, there is leakage on the inside of the cooling system. Make repairs as necessary.

Water Temperature Gauge Test

Tools Needed:

8T470 Thermistor Thermometer Group or 2F7112 Thermometer and 6B5072 Bushing



TEST LOCATION

1. Plug (one on each side of engine).

Check the accuracy of the water temperature gauge if either of the conditions that follow are found: 1. The gauge reads normal, but the engine is too hot and a loss of coolant is found.

2. The gauge shows that the engine is hot, but no loss of coolant can be found.

Remove plug (1) [1/2 Std. Pipe Thread] and install the 8T470 Thermistor Thermometer Group or the 2F7112 Thermometer and 6B5072 Bushing. A temperature gauge of known accuracy can also be used to make this check.

⚠ WARNING

Work carefully around an engine that is running. Engine parts that are hot, or parts that are moving, can cause personal injury.

Start the engine and run it until the temperature reaches the desired range according to the test thermometer. If necessary, put a cover over part of the radiator or cause a restriction of the coolant flow. The reading on the gauge for water temperature should agree with test thermometer within the tolerance range of the gauge. Make reference to SPECIFICATIONS or ATTACHMENT SPECIFICATIONS in this manual to find correct range for a specific gauge.

Water Temperature Regulator Test.

1. Remove the regulator from the engine.
2. Heat water in a pan until the temperature is 920C (1970F). Move the water around in the pan to make it all the same temperature.
3. Hang the regulator in the pan of water. The regulator must be below the surface of the water and it must be away from the sides and bottom of the pan.
4. Keep the water at the correct temperature for 10 minutes.
5. After ten minutes, remove the regulator and immediately measure the distance the regulator has opened. The distance must be a minimum of 9.53 mm (.375 in.).
6. If the distance is less than 9.53 mm (.375 in.), make a replacement of the regulator.

V-BELT TENSION CHART

BELT SIZE	WIDTH BELT TOP		WIDTH TOP OF PULLEY GROOVE		BELT TENSION "INITIAL" GAUGE READING		BELT TENSION "USED"** GAUGE READING		BORROUGHS GAUGE NUMBERS	
	mm	in.	mm	in.	N	lb.	N	lb.	OLD GAUGE NO.	NEW GAUGE NO.
3/8	10.72	.422	9.65	.380	445 + 22	100 + 5	400 + 22	90 + 5	BT-33-73F	BT-33-95
1/2	13.89	.547	12.70	.500	534 + 22	120 + 5	400 + 44	90 + 10	BT-33-96-4-16	BT-33-95
5V	15.88	.625	15.24	.600	534 + 22	120 + 5	400 + 44	90 + 10	BT-33-72-4-15	BT-33-72C
11/16	17.48	.688	15.88	.625	534 + 22	120 + 5	400 + 44	90 + 10	BT-33-72-4-15	BT-33-72C
3/4	19.05	.750	17.53	.690	534 + 22	120 + 5	400 + 44	90 ± 10	BT-33-72-4-15	BT-33-72C
15/16	23.83	.938	22.30	.878	534 + 22	120 + 5	400 + 44	90 + 10	BT-33-72-4-15	BT-33-72C

MEASURE TENSION OF BELT FARTHEST FROM THE ENGINE

*"INITIAL" BELT TENSION is for a new belt.

**"USED" BELT TENSION is for a belt which has more than 30 minutes of operation at rated speed of engine. A10232-1X1

BASIC BLOCK

CONNECTING ROD BEARINGS

The connecting rod bearings fit tightly in the bore in the rod. If bearing joints or backs are worn (fretted), check bore size. This can be an indication of wear because of a loose fit.

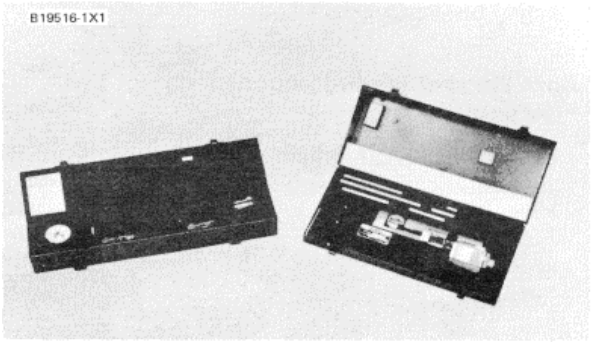
Connecting rod bearings are available with 0.63 mm (.025 in.) and 1.27 mm (.050 in.) smaller inside diameter than the original size bearings. These bearings are for crankshafts that have been ground (made smaller than original size).

MAIN BEARINGS

Main bearings are available with a larger outside diameter than the original size bearings. These bearings are for cylinder blocks that have had the bore for the main bearings "bored" (made larger than the original size). The size available is 0.63 mm (.025 in.) larger outside diameter than the original size bearings.

CYLINDER BLOCK

The bore in the block for main bearings can be checked with the main bearing caps installed without bearings. Tighten the nuts that hold the caps to the torque shown in the SPECIFICATIONS section. Alignment error in the bores must not be more than 0.08 mm (.003 in.). Special Instruction, Form No. SMHS7606 gives instructions for the use of 1P4000 Line Boring Tool Group for alignment of the main bearing bores. The 1P3537 Dial Bore Gauge Group can be used to check the size of the bores. Special Instruction, Form No. GMG00981 is with the group.



1P3537 DIAL BORE GAUGE GROUP

PROJECTION OF CYLINDER LINERS

Tools Needed:

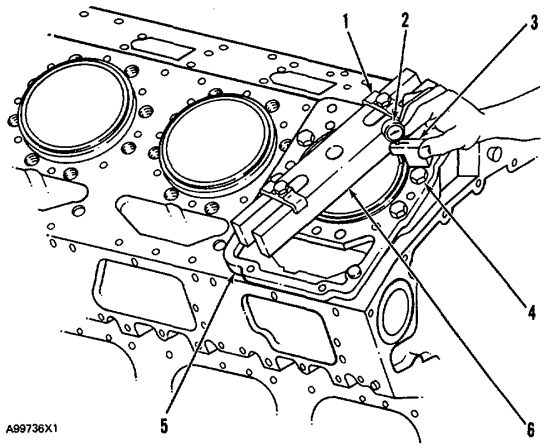
8B7548 Puller Assembly (Crossbar).
Two 2H465 Plates.
Two 8F6123 3/4"-16NF Bolts, 140 mm (5.5 In.) long.
Four Washers (3/4"-Copper).
Four S1575 3/4"-16NF Bolts, 76 mm (3.0 in.) long.
8T455 Liner Projection Tool Group.

Check liner projection above the spacer plate as follows:

1. Make sure the top surface of the cylinder block, the liner bores, spacer plates and liner flanges are clean and dry.

2. Install a new gasket and spacer plate (5) on the cylinder block.

3. Install the cylinder liners in the cylinder block without seals or bands.



MEASURING LINER HEIGHT PROJECTION

1. 3H465 Plate. 2. Dial indicator. 3. 1P2402 Gauge Body. 4. S1575 Bolt. 5. Spacer plate. 6. 8B7548 Puller Assembly (Crossbar).

4. Hold the spacer plate and liner in position as follows:
   a. Install four bolts (4) and washers around each cylinder liner as shown. Tighten the bolts evenly to a torque of 95 N-m (70 lb. ft.).

   b. Install crossbar (6), plates (1) and the two 8F6123 Bolts. Be sure the crossbar is in position at the center of the liner and the liner surface is clean. Tighten the bolts evenly to a torque of 70 N-m (50 lb. ft.).

c. Check the distance from the bottom edge of crossbar (6) to the top edge of the spacer plate. The distance on each end of the crossbar must be the same.

5. Use 8T455 Liner Projection Tool Group to measure liner projection.

6. To zero dial indicator (2), use the back of 1 P5507 Gauge with dial indicator (2) mounted in 1P2402 Gauge Body (3).

7. Liner projection must be 0.059 to 0.199 mm (.0023 to .0078 in.). Make the measurement to the outer flange of the liner, not the inner ring. The maximum difference between high and low measurements made at four places around each liner is 0.05 mm (.002 in.).

NOTE: If liner projection changes from point to point around the liner, turn the liner to a new position within the bore. If still not within specifications, move liner to a different bore.

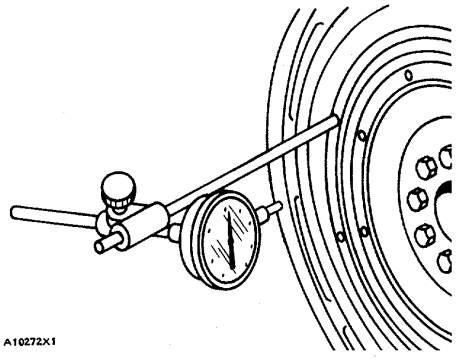
NOTE: When liner projection is correct, put a temporary mark on the liner and spacer plate so when the seals and band are installed, the liner can be installed in the correct position.

FLYWHEEL AND FLYWHEEL HOUSING

Tools Needed:

8S2328 Dial Indicator Group.

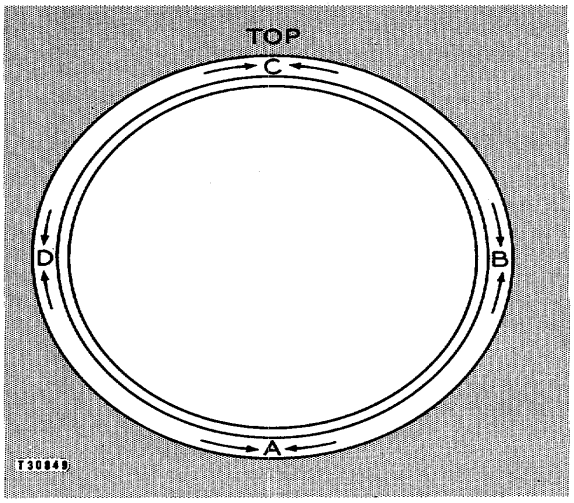
Face Run Out (axial eccentricity) of the Flywheel Housing



8S2328 DIAL INDICATOR GROUP INSTALLED

1. Fasten a dial indicator to the crankshaft flange so the anvil of the indicator will touch the face of the flywheel housing.

2. Put a force on the crankshaft toward the rear before the indicator is read at each point.



CHECKING FACE RUNOUT OF THE FLYWHEEL HOUSING
A. Bottom. B. Right side. C. Top. D. Left side.

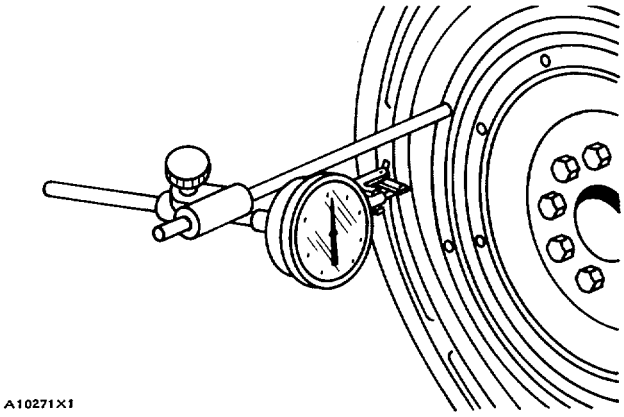
3. With dial indicator set at "O" (zero) at location (A), turn the crankshaft and read the indicator at locations (B), (C) and (D).

4. The difference between lower and higher measurements taken at all four points must not be more than 0.30 mm (.012 in.), which is the maximum permissible face run out (axial eccentricity) of the flywheel housing.

Bore Runout (radial eccentricity) of the Flywheel Housing

1. Fasten the dial indicator as shown so the anvil of the indicator will touch the bore of the flywheel housing.

2. With the dial indicator in position at (C), adjust the dial indicator to "O" (zero). Push the crankshaft up against the top of the bearing. Write the measurement for bearing clearance on line 1 in column (C) in the CHART FOR DIAL INDICATOR MEASUREMENTS.



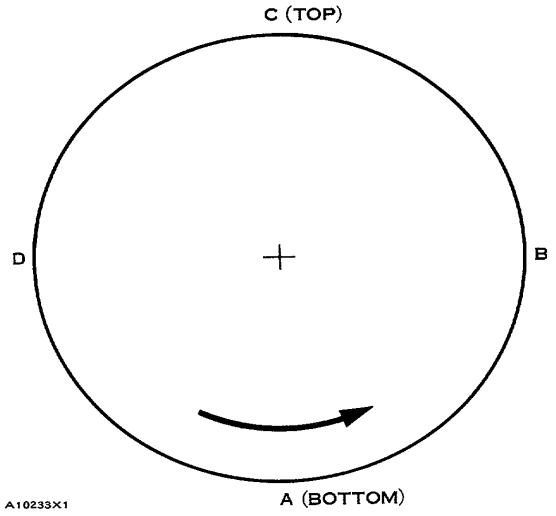
8S2328 DIAL INDICATOR GROUP INSTALLED

NOTE: Write the dial indicator measurements with their positive (+) and negative (-) notation (signs). This notation is necessary for making the calculations in the chart correctly.

3. Divide the measurement from Step 2 by 2. Write this number on line 1 in columns (B) & (D).

4. Turn the crankshaft to put the dial indicator at (A). Adjust the dial indicator to "O" (zero).

5. Turn the crankshaft counterclockwise to put the dial indicator at (B). Write the measurements in the chart.



CHECKING BORE RUNOUT OF THE FLYWHEEL HOUSING

6. Turn the crankshaft counterclockwise to put the dial indicator at (C). Write the measurement in the chart.

7. Turn the crankshaft counterclockwise to put the dial indicator at (D). Write the measurement in the chart.

CHART FOR DIAL INDICATOR MEASUREMENTS

	Position of dial indicator				
	Line No.	A	B	C	D
Correction for bearing clearance	I	0			
Dial Indicator Reading	II	0			
Total of Line 1 & 2	III	0	••	•	••

*Total Vertical eccentricity (out of round).

**Subtract the smaller No. from the larger No. The difference is the total horizontal eccentricity.

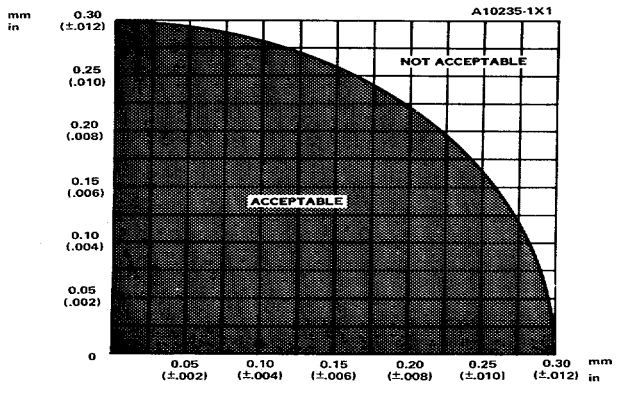
A10234X5

8. Add lines I & II by columns.

9. Subtract the smaller number from the larger number in line III in columns (B) & (D). The result is the horizontal eccentricity (out of round). Line III, column (C) is the vertical eccentricity.

10. On the graph for total eccentricity, find the point of intersection of the lines for vertical eccentricity and horizontal eccentricity.

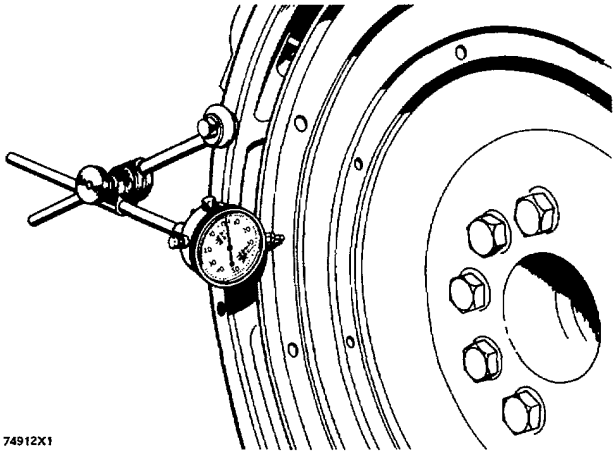
11. If the point of intersection is in the range marked "Acceptable", the bore is in alignment. If the point of intersection is in the range marked "Not Acceptable", the flywheel housing must be changed.



GRAPH FOR TOTAL ECCENTRICITY

Face Runout (axial eccentricity) of the Flywheel

1. Install the dial indicator as shown. Always put a force on the crankshaft in the same direction before the indicator is read so the crankshaft end clearance (movement) is always removed.



CHECKING FACE RUNOUT OF THE FLYWHEEL

2. Set the dial indicator to read "0" (zero).

3. Turn the flywheel and read the indicator every 90°.

4. The difference between the lower and higher measurements taken at all four points must not be more than 0.15 mm (.006 in.), which is the maximum permissible face runout (axial eccentricity) of the flywheel.

Bore Runout (radial eccentricity) of the Flywheel

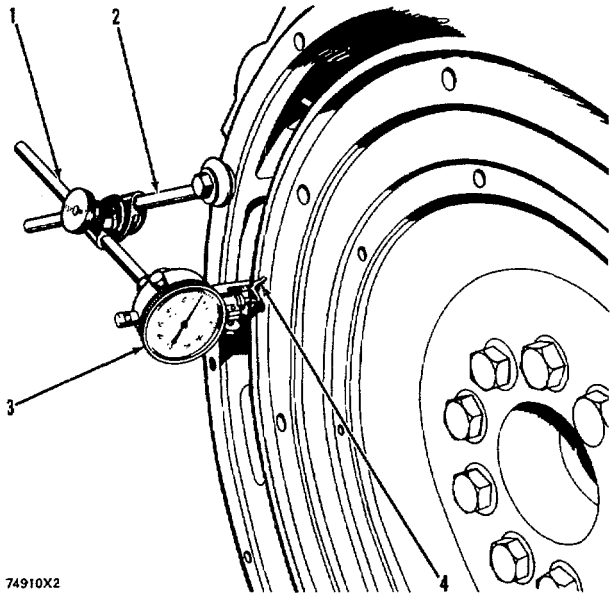
1. Install the dial indicator (3) and make an adjustment of the universal attachment (4) so it makes contact as shown.

2. Set the dial indicator to read "0" (zero).

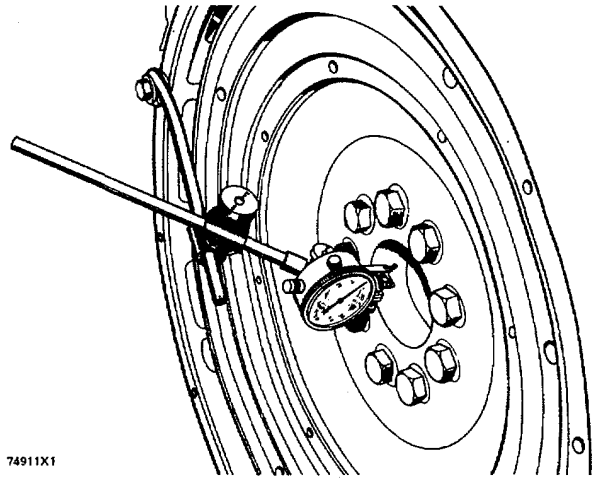
3. Turn the flywheel and read the indicator every 90°.

4. The difference between the lower and higher measurements taken at all four points must not be more than 0.15 mm (.006 in.), which is the maximum permissible bore runout (radial eccentricity) of the flywheel.

5. Runout (eccentricity) of the bore for the pilot bearing for the flywheel clutch, must not exceed 0.13 mm (.005 in.).



CHECKING BORE RUNOUT OF THE FLYWHEEL 1. 7H1945 Holding Rod. 2. 7H1645 Holding Rod. 3. 7H1942 Indicator. 4. 7H1940 Universal Attachment.



CHECKING FLYWHEEL CLUTCH PILOT BEARING BORE

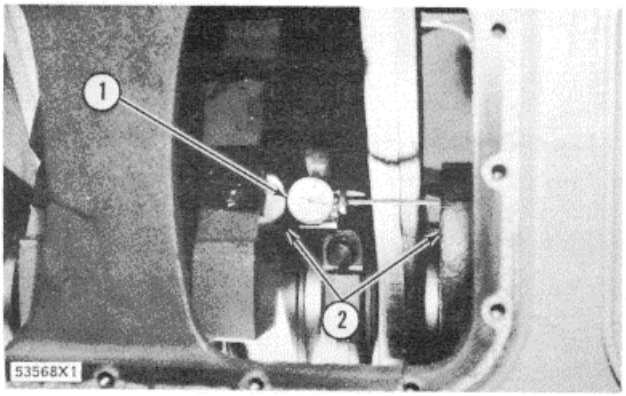
CHECKING CRANKSHAFT DEFLECTION (BEND)

The crankshaft can be deflected (bent) because the installation of the engine was not correct. If the engine mounting rails are not fastened correctly to the foundation mounting rails, the cylinder block can twist or bend and cause the crankshaft to deflect. This deflection can cause crankshaft and bearing failure.

The crankshaft deflection must be checked after the final installation of the engine. The check must be made with the engine cold and also with the engine at the temperature of normal operation. The procedure that follows can be used to check crankshaft deflection with the engine either cold or warm.

1. Remove an inspection cover from the cylinder block that will give access to the connecting rod journal of the crankshaft nearest to the center of the engine.

2. Turn the crankshaft in the direction of normal rotation until the center of the counterweights just go beyond the connecting rod.



MEASURING DEFLECTION OF THE CRANKSHAFT (TYPICAL EXAMPLE)
1. Dial gauge. 2. Mounting face.

3. Install a Starrett Crankshaft Distortion Dial Gauge No. 696 with Starrett No. 696B Balancer Attachment between the counterweights as shown. Put dial gauge (1) within 6.4 mm (.25 in.) of counterweight mounting surface (2). Turn the dial of the indicator to get alignment of the zero and the pointer. Turn the indicator on its end points until the pointer of the indicator will not move from zero.

4. 4. Turn the crankshaft in the direction of normal rotation until the indicator almost makes contact with the connecting rod on the other side of the crankshaft.

NOTE: Do not let the indicator make contact with the connecting rod.

5. The dial indicator reading must not change more than 0.03 mm (.001 in.) for the approximately 300 degrees of crankshaft rotation. Now turn the crankshaft in the opposite direction to the starting position. The dial indicator must now read zero. If the dial indicator does not read zero, do the procedure again.

If the dial indicator reads more than 0.03 mm (.001 in.), the cylinder block is bent. Loosen the bolts that hold the engine mounting rails to the foundation mounting rails and adjust the shims to make the engine straight again. Also check to see if the engine mounting bolts have enough clearance to let the engine have expansion as it gets hot.

VIBRATION DAMPER

Damage to or failure of the damper will increase vibrations and result in damage of the crankshaft.

If the damper is bent or damaged, or if the bolt holes in the damper are loose fitting, replace the damper. Replacement of the damper is also needed at the time of crankshaft failure (if a torsional type).

ELECTRICAL SYSTEM

TEST TOOLS FOR ELECTRICAL SYSTEM

Tools Needed:

6V4930 Battery Load Tester.
8T900 AC/DC Clamp-On Ammeter.
6V7070 Heavy-Duty Digital Multimeter or
6V7800 Regular-Duty Digital Multimeter.

Most of the tests of the electrical system can be done on the engine. The wiring insulation must be in good condition, the wire and cable connections must be clean and tight, and the battery must be fully charged. If the on-engine test shows a defect in a component, remove the component for more testing.

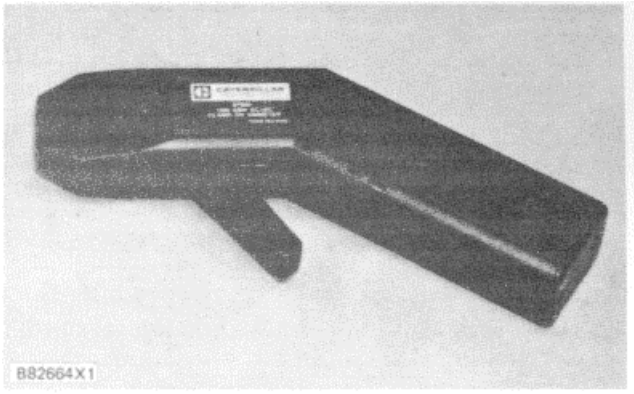
The service manual TESTING AND ADJUSTING ELECTRICAL COMPONENTS, Form No. REG00636 has complete specifications and procedures for the components of the starting circuit and the charging circuit.



6V4930 BATTERY LOAD TESTER

The 6V4930 Battery Load Tester is a portable unit in a metal case for use under field conditions and high temperatures. It can be used to load test all 6, 8 an 12V batteries. This tester has two heavy-duty load cables that can easily be fastened to the battery terminals, and a load adjustment knob on the front panel permits a current range up to a maximum of 700 amperes. The tester also has a thermometer to show when the safe operating temperature limit of the unit has been reached.

NOTE: Make reference to Special Instruction Form No. SEHS8268 for more complete information for use of the 6V4930 Battery Load Tester.

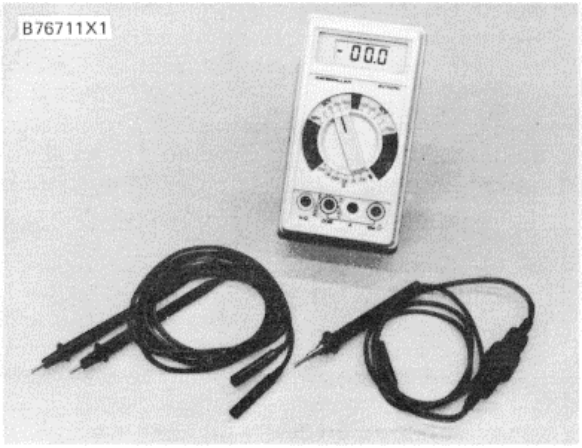


8T900 AC/DC CLAMP-ON AMMETER

The 8T900 AC/DC Clamp-On Ammeter is a completely portable, self-contained instrument that allows electrical current measurements to be made without breaking the circuit or disturbing the insulation on conductors. A digital display is located on the ammeter for reading current directly in a range from 1 to 1200 amperes. If an optional 6V6014 Cable is connected between this ammeter and one of the digital multimeters, current readings of less than 1 ammeter can then be read directly from the display of the multimeter.

A lever is used to open the jaws over the conductor [up to a diameter of 19 mm (.75 in.)], and the spring loaded jaws are then closed around the conductor for current measurement. A trigger switch that can be locked in the ON or OFF position is used to turn on the ammeter. When the turn-on trigger is re- leased, the last current reading is held on the display for 5 seconds. This allows accurate measurements to be taken in limited access areas where the digital display is not visible to the operator. A zero control is provided for DC operation, and power for the ammeter is supplied by batteries located inside the handle.

NOTE: Make reference to Special Instruction Form No. SEHS8420 for more complete information for use of the 8T900 Clamp-On Ammeter.



6V7070 HEAVY-DUTY DIGITAL MULTIMETER

The 6V7070 Heavy-Duty Digital Multimeter is a completely portable, hand held instrument with a digital display. This multimeter is built with extra protection against damage in field applications, and is equipped with seven functions and 29 ranges. The 6V7070 Multimeter has an instant ohms indicator that permits continuity checks for fast circuit inspection. It also can be used for troubleshooting small value capacitors.

The 6V7800 Regular-Duty Digital Multimeter (a low cost option to the Heavy-Duty Multimeter) is also available; however, the 6V7800 Multimeter does not have the O1A range or the instant ohms feature of the 6V7070 Multimeter.

NOTE: Make reference to Special Instruction Form No. SEHS7734 for more complete information for use of the 6V7070 and 6V7800 Multimeters.

BATTERY

⚠ WARNING

Never disconnect any charging unit circuit or battery circuit cable from battery when the charging unit is operated. A spark can cause an explosion from the flammable vapor mixture of hydrogen and oxygen that is released from the electrolyte through the battery outlets. Injury to personnel can be the result.

The battery circuit is an electrical load on the charging unit. The load is variable because of the condition of the charge in the battery. Damage to the charging unit will result if the connections (either positive or negative) between the battery and charging unit are broken while the charging unit is in operation. This is because the battery load is lost and there is an increase in charging voltage. High voltage will damage, not only the charging unit, but also the regulator and other electrical components.

Load test a battery that does not hold a charge when in use. To do this, put a resistance across the main connections (terminals) of the battery. For a 6, 8 or 12V battery, use a test load of three times the ampere/hour rating (the maximum test load on any battery is 500 amperes). Let the test load remove the charge (discharge) of the battery for 15 seconds and with the test load still applied, test the battery voltage. A 6V battery in good condition will show 4.5V; and 8V battery will show 6V; a 12V battery will show 9V. Each cell of a battery in good condition must show 1.6V on either a 6, 8 or 12V battery.

CHARGING SYSTEM

The condition of charge in the battery at each regular inspection will show if the charging system operates correctly. An adjustment is necessary when the battery is constantly in a low condition of charge or a large amount of water is needed (more than one ounce of water per cell per week or per every 50 service hours).

When it is possible, make a test of the charging unit and voltage regulator on the engine, and use wiring and components that are a permanent part of the system. Off-engine (bench) testing will give a test of the charging unit and voltage regulator operation. This testing will give an indication of needed repair. After repairs are made, again make a test to give proof that the units are repaired to their original condition of operation.

Before the start of on-engine testing, the charging system and battery must be checked as shown in the Steps that follow:

1. Battery must be at least 75% (1.240 Sp. Gr.) fully charged and held tightly in place. The Battery holder must not put too much stress on the battery.

2. Cables between the battery, starter and engine ground must be the correct size. Wires and cables must be free of corrosion and have cable support clamps to prevent stress on battery connections (terminals).

3. Leads, junctions, switches and panel instruments that have direct relation to the charging circuit must give correct circuit control.

4. Inspect the drive components for the charging unit to be sure they are free of grease and oil and have the ability to operate the charging unit.

Alternator Regulator Adjustment (Delco-Remy)

When an alternator is charging the battery too much or not enough, an adjustment can be made to the output voltage of some alternators. Make reference to the SPECIFICATIONS section to find all testing specifications for the alternators and regulators.

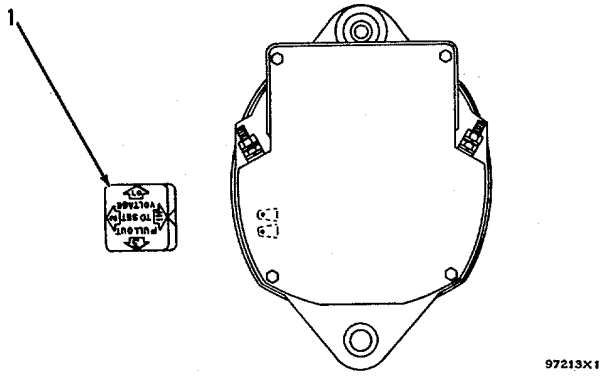
Delco-Remy 24V 60A (4N3986 Alternator)

No adjustment of voltage output can be made on this alternator. If the voltage and ampere output is not correct, the alternator must be repaired or replaced.

Delco-Remy 32V 60A (4N3987 Alternator)

To make an adjustment to the voltage output, pull out voltage adjustment cap (1). Turn the cap 90° and install it again into the alternator. The voltage adjustment cap has four positions: HI, LO, and two positions between the high and the low setting.

The 4N3987 Alternator can be adjusted for either 30 or 32 volts. A replacement alternator shipped from the factory will be adjusted for 32V (16 battery cells) systems. Where the alternator is to be used in a 30V (15 battery cells) system, pull out voltage adjustment cap (1) and change from the HI position to position 3.



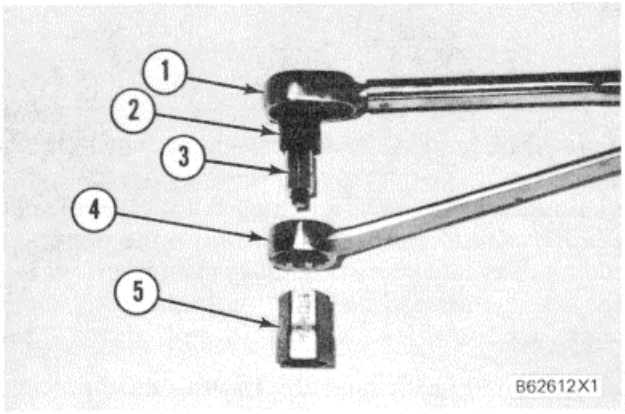
CAP TYPE REGULATOR ADJUSTMENT

1. Voltage adjustment cap.

No adjustment can be made to change the rate of charge on these alternator regulators. If the rate of charge (ampere output) is within 10 amperes of rated output (marked on the alternator frame) the regulator is good. An over or under charged battery condition can be corrected sometimes by an adjustment to the voltage. If rate of charge is not correct, a replacement of the regulator is necessary.

Alternator Pulley Nut Tightening (Delco-Remy)

Tighten nut that holds the pulley to a torque of 100 ± 10 N ·m (75 Z± 5 lb. ft.) with the tools shown.



TOOLS TO TIGHTEN ALTERNATOR PULLEY NUT 1. 5P7425 Torque Wrench. 2. 8S1588 Adapter (1/2" female to 3/8" male). 3. FT1697 Socket. 4. 8H8517 Combination Wrench (1 1/8"). 5. FT1696 Wrench.

STARTING SYSTEM

Use the multimeter in the DCV range to find starting system components which do not function.

Move the start control switch to activate the starter solenoid. Starter solenoid operation can be heard as the pinion of the starter motor is engaged with the ring gear on the engine flywheel.

If the solenoid for the starter motor will not operate, it is possible that the current from the battery did not get to the solenoid. Fasten one lead of the multimeter to the connection (terminal) for the battery cable on the solenoid. Put the other lead to a good ground. A zero reading is an indication that there is a broken circuit from the battery. More testing is necessary when there is a voltage reading on the multimeter.

The solenoid operation also closes the electric circuit to the motor. Connect one lead of the multimeter to the solenoid connection (terminal) that is fastened to the motor. Put the other lead to a good ground. Activate the starter solenoid and look at the multimeter. A reading of battery voltage shows the problem is in the motor. The motor must be removed for further testing. A zero reading on the multimeter shows that the solenoid contacts do not close. This is an indication of the need for repair to the solenoid or an adjustment to be made to the starter pinion clearance.

Make a test with one multimeter lead fastened to the connection (terminal) for the small wire at the solenoid and the other lead to the ground. Look at the multimeter and activate the starter solenoid. A voltage reading shows that the problem is in the solenoid. A zero reading is an indication that the problem is in the start switch or the wires for the start switch.

Fasten one multimeter lead to the start switch at the connection (terminal) for the wire from the battery. Fasten the other lead to a good ground. A zero reading indicates a broken circuit from the battery. Make a check of the circuit breaker and wiring. If there is a voltage reading, the problem is in the start switch or in the wires for the start switch.

A starter motor that operates too slow can have an overload because of too much friction in the engine being started. Slow operation of the starter motor can also be caused by a short circuit, loose connections and/or dirt in the motor.

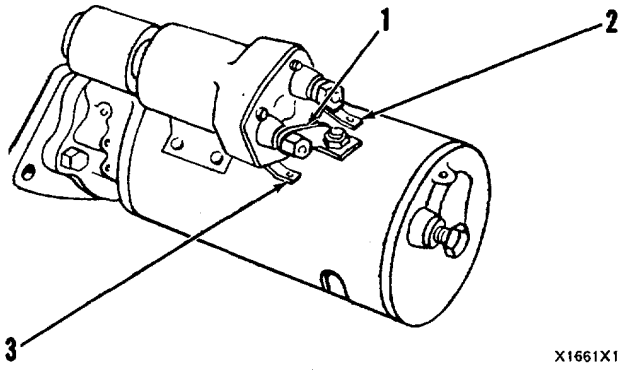
Pinion Clearance Adjustment

When -the solenoid is installed, make an adjustment of the pinion clearance. The adjustment can be made with the starter motor removed.

1. Install the solenoid without connector (1) from the MOTOR connections (terminal) on solenoid to the motor.

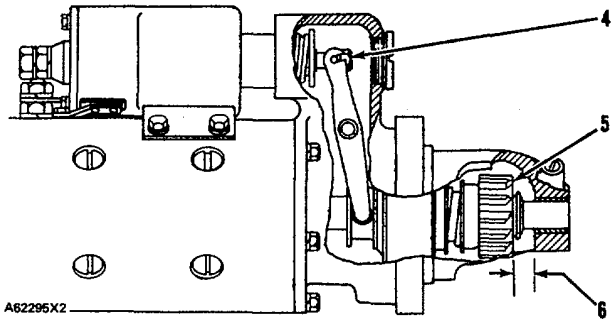
2. Connect a battery, of the same voltage as the solenoid, to the terminal (2), marked SW.

3. Connect the other side of the battery to ground terminal (3).



CONNECTION FOR CHECKING PINION CLEARANCE
1. Connector from MOTOR terminal on solenoid to motor. 2. SW terminal. 3. Ground terminal.

4. Connect for a moment, a wire from the solenoid connection (terminal) marked MOTOR to the ground connection (terminal). The pinion will shift to crank position and will stay there until the battery is disconnected.



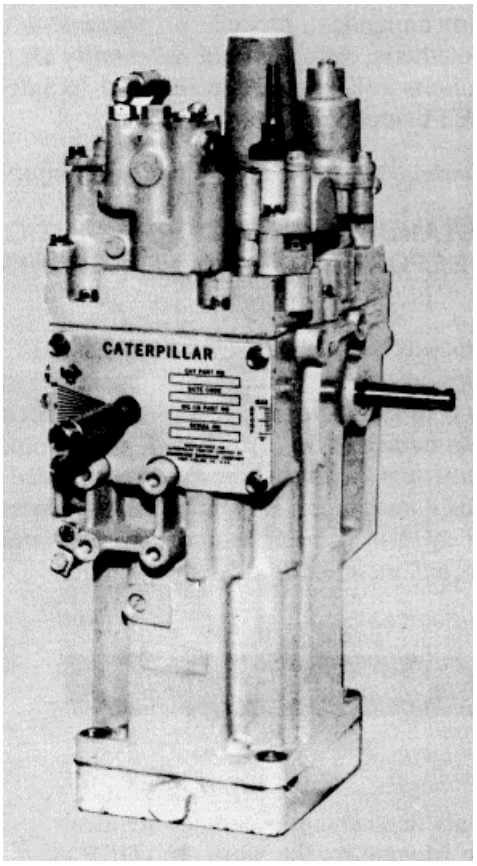
PINION CLEARANCE ADJUSTMENT
4. Shaft nut. 5. Pinion. 6. Pinion clearance.

5. Push the pinion toward the commutator end to remove free movement.

6. Pinion clearance (6) must be 8.4 to 9.9 mm (.33 to .39 in.).

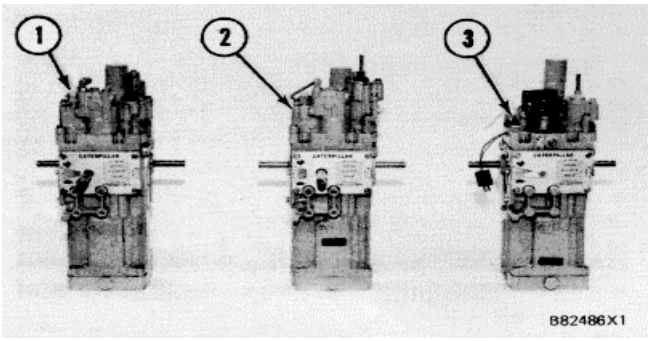
7. To adjust pinion clearance, remove plug and turn nut (4).

FORM NO. SENR3028



SERVICE MANUAL
CATERPILLAR
3161 GOVERNOR

GOVERNOR TYPES

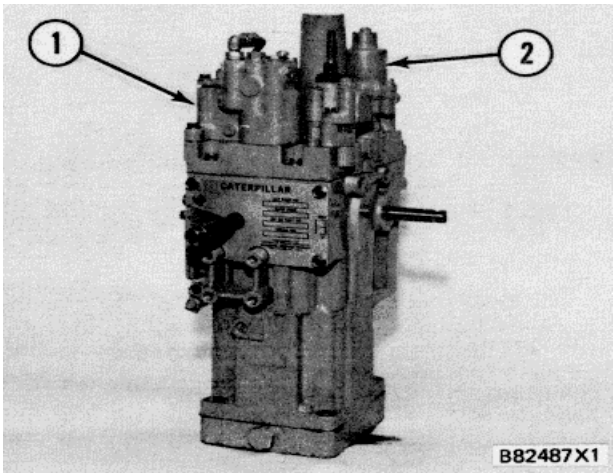


3161 GOVERNORS
1. 3161 Standard Governor. 2. 3161 Governor with Torque Rise. 3. 3161 Generator Set Governor.

The 3161 Standard Governor (1), the 3161 Governor with Torque Rise (2) and the 3161 Generator Set Governor (3) are the three arrangements of this governor that are available.

A mechanical head cover, a pneumatic head cover and a speed adjusting motor head cover are the three top covers available for use with any of the 3161 governors. These top covers make each governor adaptable for use with optional controls. The optional controls can be factory installed or added to a governor already in service without any

3161 STANDARD GOVERNOR



3161 STANDARD GOVERNOR
1. Pneumatic speed setting control. 2. Air fuel ratio control.

The 3161 Standard Governor is the base governor.

The 3161 Standard Governor is equipped with:

A pneumatic speed setting control (I) or manual mechanical speed control.

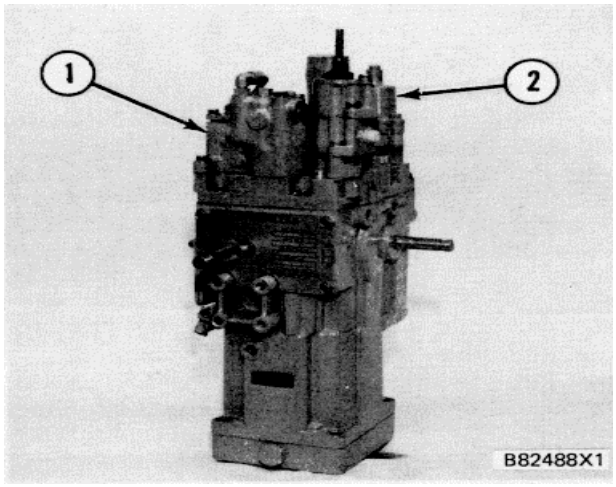
An air fuel ratio control (2).

The optional controls for this governor are:

1. Manual mechanical speed control (or pneumatic speed setting control).
2. Manual shutdown.
3. Pressure (pneumatic or hydraulic) shutdown.
4. Electric "energize to shutdown" solenoid.
5. Electric "energize to run" solenoid.
6. Pneumatic mid-speed control.

The shutdown controls (manual, pneumatic and electric) can be used separately or together as needed.

3161 GOVERNOR WITH TORQUE RISE



3161 GOVERNOR WITH TORQUE RISE
1. Pneumatic speed setting control. 2. Air fuel ratio control.

The 3161 Governor with Torque Rise is a standard base governor with the torque rise components installed.

This governor is used with engine arrangements that require a specific torque rise application. The torque rise control can be adjusted and gives similar engine output to that given by the torque spring and spacer arrangement used in other Caterpillar governors.

The 3161 Governor with Torque Rise comes with:

A pneumatic speed setting control (1) or a manual mechanical speed control;

An air fuel ratio control (2); and

A torque rise control (internal not shown).

The optional controls for this governor are:

1. Pneumatic speed setting control (not to be used with a manual mechanical speed control).

2 Manual shutdown.

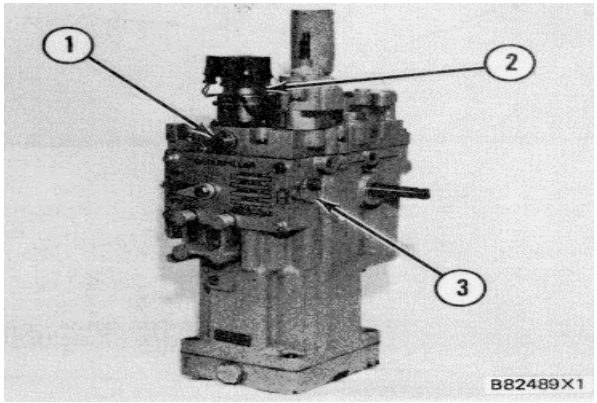
3. Pressure (pneumatic or hydraulic) shutdown.

4. Electric "energize to shutdown" solenoid.

5. Electric "energize to run" solenoid.

The shutdown controls (manual, pneumatic and electric) can be used separately or together as needed.

3161 GENERATOR SET GOVERNOR



3161 GENERATOR SET GOVERNOR
1. Manual speed setting control. 2. Speed adjusting motor
head. 3. External droop adjustment.

The 3161 Generator Set Governor is a special arrangement of the base governor and is primarily for use on electric set engine arrangements.

An electric set engine equipped with a 3161 Generator Set-Governor can be paralleled with other generator set engines governed by a 3161, 2301, a hydramechanical governor, or with an infinite bus.

The 3161 Generator Set Governor comes with:

A manual speed setting control (1).

A speed adjusting motor head [24-32 volts DC] (2).

An external droop adjustment (3).

The optional controls for this governor are:

1 Manual shutdown.

2. Pressure (pneumatic or hydraulic) shutdown.

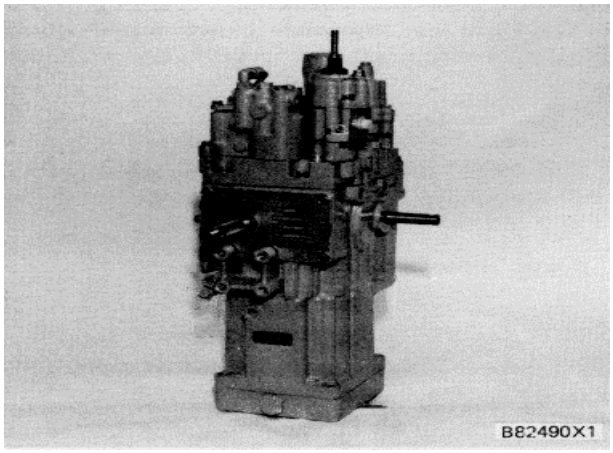
3 Electric "energize to shutdown" solenoid.

4. Electric "energize to run" solenoid.

5. Utility power converter (115-230 volts AC) for speed adjusting motor (24-32 volts DC).

The shutdown controls (manual, pneumatic and electric) can be used separately or together' as needed.

BASIC GOVERNOR



3161 STANDARD GOVERNOR

The 3161 Governor is a mechanical-hydraulic governor that senses (feels) engine speed and is connected to the engine fuel system by mechanical linkage. The governor controls the rate of fuel injected into each of the engine cylinders as needed to adjust for engine loads.

Droop and compensation can be adjusted on the governor as needed for stability of engines with different rates of engine speed changes.

The 3161 Governor has a maximum of 8 N•m (6 lb. ft.) of torque output over the full 42 degrees of terminal (output) shaft rotation in both the fuel ON and OFF directions. Because the governor terminal shafts are moved in both directions by hydraulic pressure, no return spring is used on the outside of the governor. A 1.4 N•m (1 lb. ft.) spring inside the governor moves the terminal shafts to the full shutoff position when the governor is not in operation.

The recommended travel (rotation) of the terminal shafts is approximately 30 degrees from low idle to full load. This gives extra travel at each end for the governor to make a complete shutdown and gives maximum fuel when needed.

The 3161 Governor is connected to the engine lubrication oil system. The oil supply (under pressure) is sent to the governor through an orifice and internal passages. The governor keeps the correct oil level and drains excess oil back into the engine, this gives a constant flow of oil through the governor.

After removal or overhaul, the governor must be filled with approximately 1.8 liters (2. U.S. qt.) of clean engine oil before engine startup. The oil fill plug on all 3161 Governors is located on the top cover.

GOVERNOR COMPONENTS

Gerotor Oil Pump

The gerotor oil pump is located in the base of the governor. The inner rotor of the pump is driven by a pin in the drive shaft, and carries the outer rotor around in mesh, this pushes oil to the accumulator piston.

Accumulator

A single accumulator, that consists of a piston and spring, acts as a relief valve for the oil pump and supplies a reservoir of high pressure oil for rapid power piston movement. Oil is sent to the accumulator by the governor pump, with an increase in pressure as the accumulator spring is put under compression. When the pressure gets to a set point, oil is returned to sump through relief ports in the piston wall.

Power Piston

The power piston is fastened to the output shaft by a link and lever assembly. The power piston has a large area on the bottom and a small area on top (differential piston). A small pressure increase on the large area of the piston will move the piston up, this causes the output shaft to turn in the "increase" direction. The piston can move down only when oil under the piston is released to sump. Oil to or from the bottom of the power piston is controlled by the ballhead pilot valve and ballhead pilot valve bushing.

Pilot Valve System

The pilot valve system is made of two components, the ballhead pilot valve (rotating) bushing, and the ballhead pilot valve plunger. The bushing is turned relative to the pilot valve plunger to reduce friction between the two parts. The control land of the pilot valve plunger controls the flow of oil through the control ports of the ballhead bushing.

When the pilot valve plunger is lowered, oil under high pressure moves through the control port of the bushing, to the bottom side of the power piston, and the piston moves up. When the pilot valve plunger is raised, the oil from the bottom of the power piston is released to sump, and the higher oil pressure on top of the piston moves the piston down. When the engine is running at a steady state, the control land of the pilot valve plunger covers the ports in the ballhead bushing and the power piston does not move. The movement of the pilot valve plunger is controlled by the ballhead assembly.

Ballhead Assembly

The ballhead system has a ballhead, flyweights, speeder spring, thrust bearing, and speeder plug. The ballhead, as part of the pilot valve bushing, is turned by the drive coupling and drive shaft.

As the ballhead turns, the centrifugal force causes the flyweights to pivot outward. At the same time, the force of the speeder spring pushes the thrust bearing down on the flyweight toes against the centrifugal force of the flyweights. When the speeder plug is pushed down this increases the downward pressure on the speeder spring, and the governor speed setting is increased. The engine then runs at a higher speed and puts a higher centrifugal force on the flyweights to equal the speeder spring force and put the system back in balance.

Speeder spring force or speed setting is controlled through the speed setting shaft.

Compensation System

The compensation system has a needle valve and a buffer piston with two springs. This system can be adjusted to give the desired rate of governor control and engine speed stability. Since the governor makes an adjustment rapidly to a change in engine load or speed setting, the engine can go into a "hunt" condition (temporary increase and decrease in engine speed) if too much adjustment is made. The purpose of the compensation system is to prevent overcorrection to the engine load or speed setting change. The system uses a pressure differential that is applied across the compensation land of the pilot valve plunger to give a stable governor control.

Speed Droop

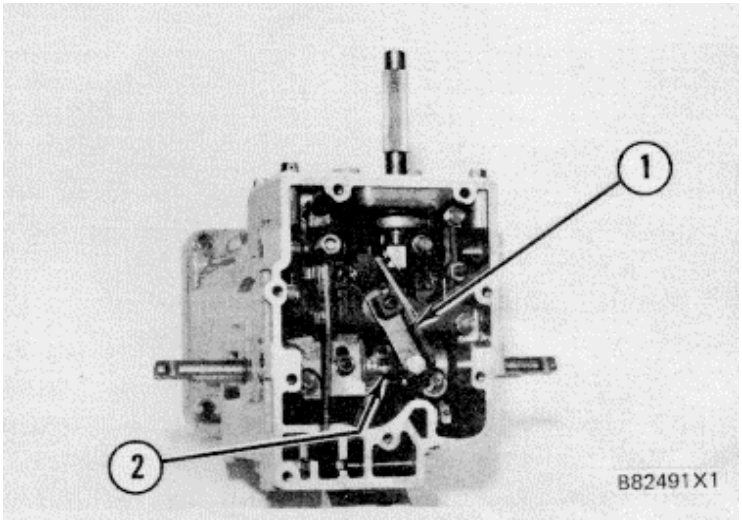
The 3161 Governor is an isochronous governor with the ability to operate with droop by the adjustment of an internal droop pivot pin. The governor may be used with droop to allow for load division between two or more engines connected to a single shaft, or for operating in parallel.

The speed droop of a governor is the percent that the engine speed drops between high idle and full load.

The 3161 Standard and Torque Rise Governors are designed to operate with a 2 to 8 percent droop and have an internal droop pivot pin adjustment.

The 3161 Generator Set Governor is designed to operate with a 0 to 4 percent droop. It has an external adjustment lever connected to the internal droop pivot pin. This permits droop adjustments to be on the outside of the governor housing.

Torque Rise Control



TORQUE RISE COMPONENTS
1. Torque control lever. 2. Cam.

The torque rise control consists of a cam that makes the governor give more fuel to the engine under lug conditions.

Different percentages of torque rise can be selected by changing the cam to a programmed rate of rise. This change can be made on or off the engine. Cam selection and high idle settings must be based on factory recommendations.

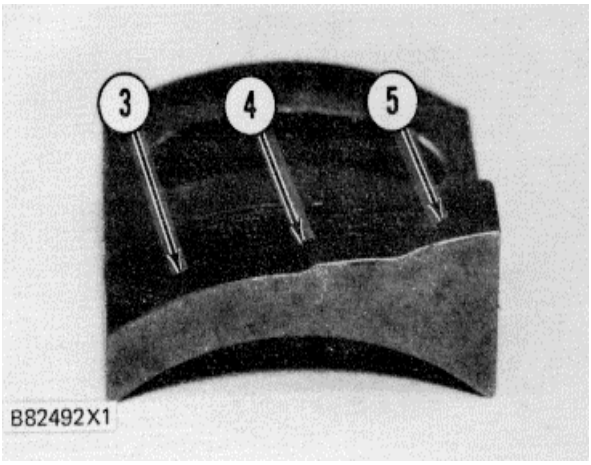
The torque rise control is factory installed. It is not practical to install it in the field.

The torque rise cam has three distinct profiles: the base circle area (3); the approach ramp area (4); and the cam lift area (5).

The "base circle area" is a radius that does not lift the cam follower. The cam follower must be positioned on the base circle area when the dial indicator is zeroed, for a check or adjustment of the torque rise setting.

The "approach ramp area" is the "transition area" from the base circle to the cam lift area.

The "cam lift area" is the area on the cam that lifts the cam follower and torque rise pilot valve lever, which allows additional fuel for torque rise greater than the natural torque rise of the engine.



TORQUE RISE CAM
3. Base circle area. 4. Approach ramp area. 5. Cam lift area.

During the torque rise cam adjustment the set point of the terminal shaft is positioned by the synchronizing pin at the full load fuel setting. The cam is moved to position the cam follower on the start of the cam lift area at a specified point that will lift the cam follower 1.00 ± 0.05 mm above the base circle. This removes the free travel (clearances) from the governor and fuel control linkages so the torque rise will occur at the correct engine speed.

Limit/Shutdown Pilot Valve

Shutdown of the engine is done with the limit/ shutdown pilot valve. With the engine running on speed, the ballhead pilot valve is in the centered position. When the limit/shutdown pilot valve is lowered, pressure oil above the control land of the ballhead pilot valve is drained back to the pump area. As engine speed begins to slow, ballhead flyweights move in, lowering the ballhead pilot valve plunger. Oil under the power piston is then drained to the pump area. As the power piston moves down, the output shaft is turned in the decrease direction, and the engine is shut down.

OPERATION OF THE 3161 GOVERNOR

Make reference to the 3161 Governor Schematic for use with the systems operations that follow. The schematic shows the governor pilot valve in the increase fuel position.

The 3161 Governor uses engine lubrication oil for its hydraulic system. The oil supply (under pressure) is sent to the governor through an orifice and internal passages. The oil goes from the suction side to the pressure side of the gerotor pump as the drive shaft is turned by the engine. An accumulator spring and piston keeps the pump pressure at approximately 690 kPa (100 psi). The accumulator piston moves up in its cylinder until the pump pressure is 690 kPa
(100 psi). At this time, ports in the piston are opened to control the pump pressure.

The pump pressure, as set by the accumulator, controls the work output of the governor. Pump pressure is also used for the auxiliary controls installed on the governor top cover.

Increase In Speed Setting

When the speed setting shaft is turned clockwise, the speed setting of the governor is increased. The high idle screw limits the high speed setting of the governor. As the speed setting shaft turns, the speed setting lever pushes down on the floating lever which is fastened to the speeder plug. The downward pressure on the speeder plug puts the speeder spring under compression. The speeder spring force then becomes greater than the centrifugal force of the ballhead flyweights, and the ballhead pilot valve plunger is moved down. This increases the governor speed setting.

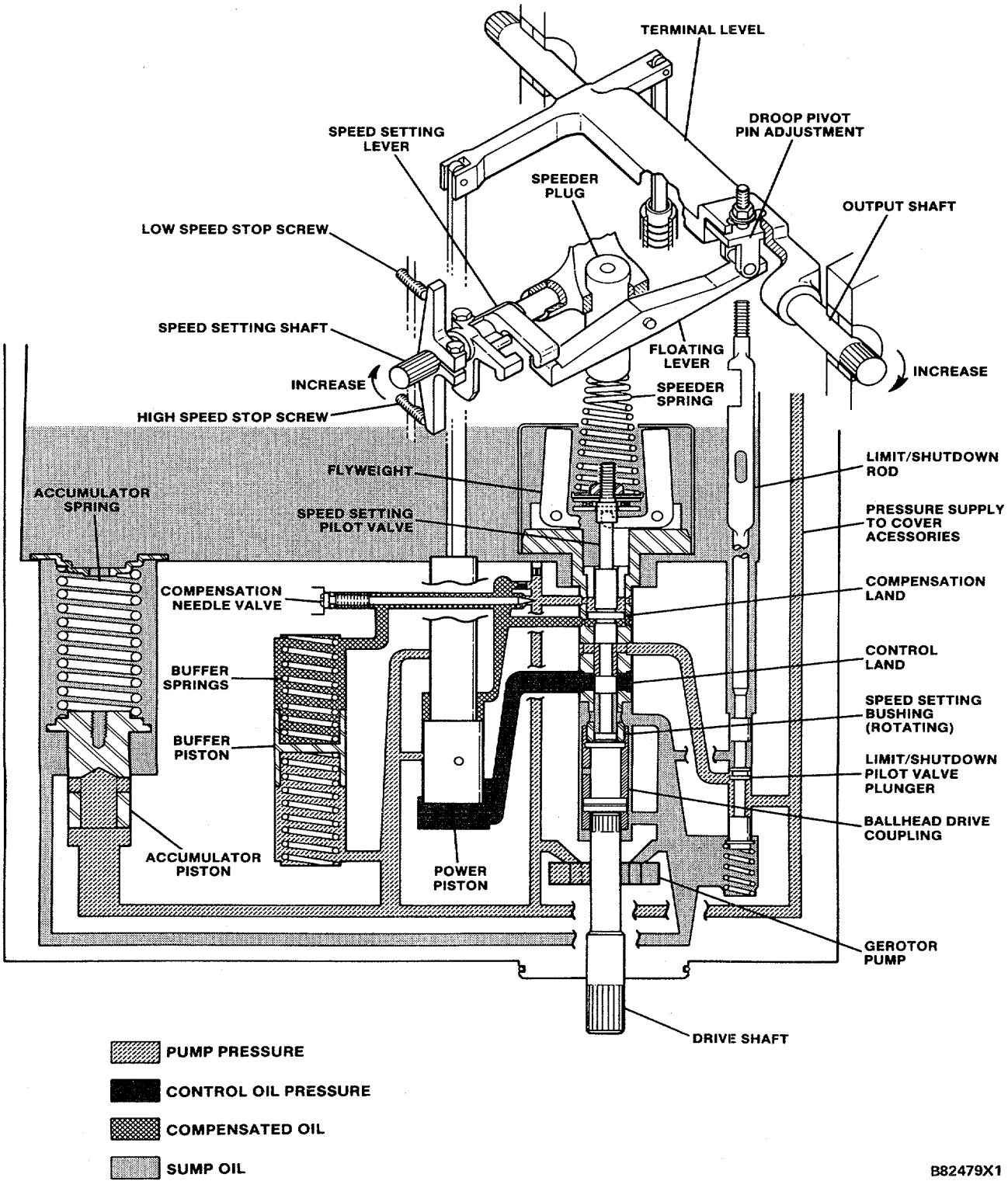
As the pilot valve plunger is moved down, pressure oil moves under the power piston and pushes the piston up. This moves the terminal lever up and the output shafts are turned in the "increase" fuel direction to increase the engine speed.

Before the engine gets to the new set speed, the compensation system starts to move the pilot valve plunger back to its center position and put the governor under stable control as follows.

The oil above the power piston is connected to the upper side of the buffer piston and lower side of the pilot valve compensation land. As the power piston moves up the oil pressure moves the buffer piston down and increases the compression of the lower buffer piston spring. The force of the spring works against the buffer piston movement and this results in a small increase in oil pressure on the upper side of the buffer piston. This higher pressure is directed to the lower side of the pilot valve compensation land and makes a force to push the pilot valve plunger up toward its center position. This stops the flow of pressure oil to the lower side of the power piston and movement of the piston is stopped.

As the pilot valve plunger is returned to its center position and the power piston movement is stopped, there is oil leakage through the needle valve orifice.

This lets the oil pressure above and below the pilot valve compensation land become equal and the pilot valve plunger movement is stopped and the engine speed is returned to a stable condition. As the pressure above and below the compensation land become equal, the buffer springs return the buffer piston to its center position.



SCHEMATIC OF THE 3161 GOVERNOR
16 2(Increased Fuel Position)

Decrease In Speed Setting

When the speed setting shaft is turned counterclockwise, the speed setting of the governor is decreased. The low idle screw limits the low speed setting of the governor. As the speed setting shaft is turned counterclockwise, the force of the speed setting lever on the floating lever is removed. This lowers the compression of the speeder spring. Centrifugal force from the ballhead flyweights lifts the pilot valve plunger to open the control port in the rotating bushing. Control oil under the power piston now drains to the sump and lets the power piston move down. The output shafts are turned in the "decrease" fuel direction and the engine speed is decreased.

Before the engine gets to the new set speed, the compensation system starts to move the pilot valve plunger back to its center position and put the governor under stable control as follows.

When the pilot valve plunger is lifted the oil under the power piston is released to drain back to the governor sump. Pump pressure oil on the bottom of the buffer piston now forces the buffer piston up. The oil above the buffer piston then puts a force on the top of the power piston to move the power piston down.

The movement of the buffer piston up increases the compression of the upper buffer piston spring. The force of the upper spring works against the buffer piston movement and this results in a small increase to the pump oil pressure on the lower side of the buffer piston and on the top surface of the pilot valve plunger compensation land. This small increase is greater than the pressure sent to the bottom surface of the compensation land. This pressure difference on the two sides of the compensation land makes a force (greater at the top) to push the pilot valve plunger back down to the center position.

When the output shaft has turned far enough to satisfy the new fuel setting, the force of the pressure difference on the compensation land puts the pilot valve plunger in its center position (even though the engine speed is not yet completely back to normal). The movement of the power piston, and the output shaft, is now stopped.

The continued decrease of engine speed to its steady-state setting, results in a continued increase in downward force of the speeder spring on the pilot valve plunger as the ballhead flyweights move in. At the same time, the pressure difference on each side of the buffer piston (and at top and bottom of the compensation land) is being released by the flow of oil through the needle valve orifice. This controlled discharge allows the buffer piston to return slowly to its normal, "centered" position. The speeder spring continues to push down on the pilot valve plunger until the spring force and ballhead flyweight force become equal. At the same time the controlled reduction of the pressure difference on the two sides of the compensation land occur exactly at the same rate (while the pilot valve plunger remains centered) until the engine is again at the on-engine speed condition at the new speed setting.

NOTE: An increase or decrease in engine load will give the similar governor movement as an increase or decrease in governor speed setting.

Shutdown

The limit/shutdown pilot valve is located in the pump oil pressure supply line to the ballhead pilot valve. When the engine shutdown system is activated, the limit/shutdown rod pushes the limit/ shutdown pilot valve plunger below the supply passage. This drains oil from the supply to the ballhead pilot valve plunger. Control oil from under the power piston now drains past the control land of the pilot valve plunger. The power piston then moves down and the output shaft is turned in the "decrease fuel" direction. As the engine speed decreases, the ballhead flyweights move in and this lowers the ballhead pilot valve. Oil from under the power piston is now drained to the governor sump at a faster rate. As the power piston continues to move down, the output shaft is turned to the shutdown position until the engine is stopped.

AUXILIARY CONTROLS

This section describes the Auxiliary Controls and attachments that are available for the 3161 Governor. These controls are installed and calibrated at the factory before shipment to the user. The shutdown controls can be added to a governor already in service without any further modification to the governor.

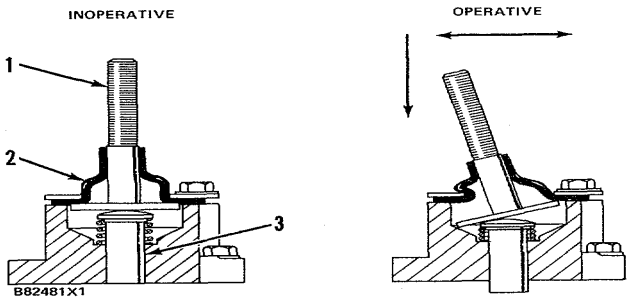
The controls that can be fastened to the governor top cover are:

1. Manual Shutdown
2. Mechanical Shutdown
3. Electric Shutdown
4. Pneumatic Speed Setting Control
5. Air Fuel Ratio Control

Other controls added to the governor include:

1. Speed Adjusting Motor Head
2. Manual Speed Setting Control
3. Manual Mechanical Speed Control
4. Pneumatic Mid Speed Control

MANUAL SHUTDOWN



MANUAL SHUTDOWN

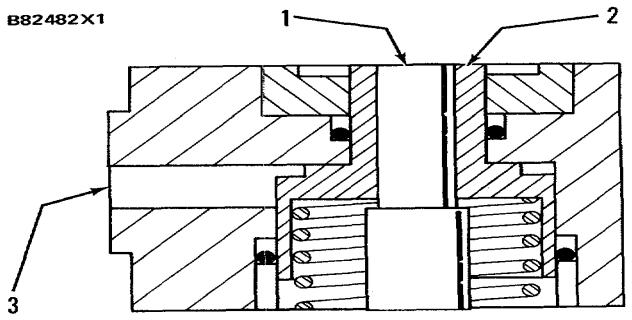
1. Threaded shutdown handle. 2. Boot. 3. Shutdown plunger.

The manual shutdown assembly is installed on the right front corner of the governor top cover.

To shutdown the engine, the threaded shutdown handle can be either pushed down or tilted in any one of the 360 degrees to make contact with the shutdown rod. As the shutdown handle is tilted, the flat disc of the shutdown handle lowers the shutdown/limit pilot valve, to let control oil drain and cause engine shutdown.

The manual shutdown can be used in addition to the pressure or electric shutdown controls.

PRESSURE SHUTDOWN



PRESSURE SHUTDOWN

1. Shutdown plunger. 2. Shutdown piston. 3. Shutdown control pressure passage.

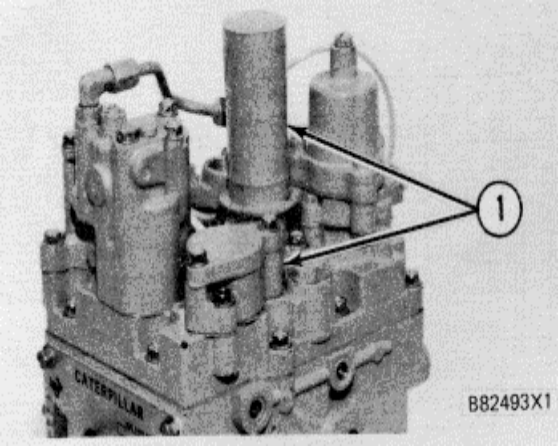
The pressure shutdown assembly is installed on the right front cover of the governor top cover.

This shutdown uses either pneumatic or hydraulic pressure at a minimum of 276 kPa (40 psi) to shutdown the engine. When the pressure (air or oil) is applied to the shutdown piston, the piston is moved down and makes contact with the shutdowns plunger. The plunger then pushes down on the shutdown rod and the shutdown/limit pilot valve. The pilot valve then lets control oil drain from under the power piston and causes engine shutdown. The shutdown will reset when pressure goes below 138 kPa (20 psi) and lower.

The pressure shutdown can be used in addition to the manual or electric shutdown controls. If this shutdown is added after the governor has been shipped from the factory, and is not used with any other shutdown, a small cover and gasket must be installed on top of the shutdown assembly.

ELECTRIC SHUTDOWN

The electric shutdown assembly (1) is installed on the right front corner of the governor top cover. This shutdown uses a 24 volt DC (energized-to-shutdown) solenoid that positions the shutdown lever and shutdown/limit pilot valve. When the solenoid is energized the plunger moves down. It lowers the shutdown rod and shutdown/limit pilot valve to let control oil drain from under the power piston and cause engine shutdown.



ELECTRIC SHUTDOWN
1. Electric shutdown assembly.

There is a diode used in the circuit for the electric solenoid because it is polarity sensitive. If the wires are connected the wrong way the solenoid will not operate.

The electric shutdown can be used by itself, or in addition to the manual and pressure shutdown controls. If this shutdown is added after the governor has been shipped from the factory, an adjustment must be made. See TESTING AND ADJUSTING section for the correct adjustment.

When the electric shutoff is used by itself, a small cover and gasket must be installed on top of the shutdown assembly.

PNEUMATIC SPEED SETTING CONTROL

The pneumatic speed setting control is installed on the left front corner of the governor top cover. Because of its design, it is not practical to add the pneumatic speed control on the 3161 Governor in the field.

System air pressure from a remote throttle and internal pressure oil from the governor operate the control to increase or decrease the speed at which the engine runs. This control has the ability to repeat constant speed settings over a large range of conditions.

The pneumatic speed setting control has a standard air pressure range of 70 to 415 k Pa (10 to 60 psi). Special applications of this control can use a pressure range of 35 to 380 kPa (5 to 55 psi) or 35 to 620 kPa (5 to 90 psi).

Increase Engine Speed

As control air pressure enters the speed setting bellows through the inlet port, expansion of the bellows takes place. The bellows pushes down on the speed setting lever to the left of the pivot. This lifts the right end of the speed setting lever against the feedback spring force to close the nozzle to drain.

Supply oil flows through an orifice to the lower side of the speed setting pilot valve plunger and then to drain through the nozzle. When oil flow from the nozzle is stopped by the speed setting lever, oil pressure increases and the speed setting pilot valve plunger moves up. This lets control oil go to the top of the speed setting piston. As the control oil pressure increases, the speed setting piston moves down to increase the governor speed setting through a rod and lever connected to the governor speed setting shaft.

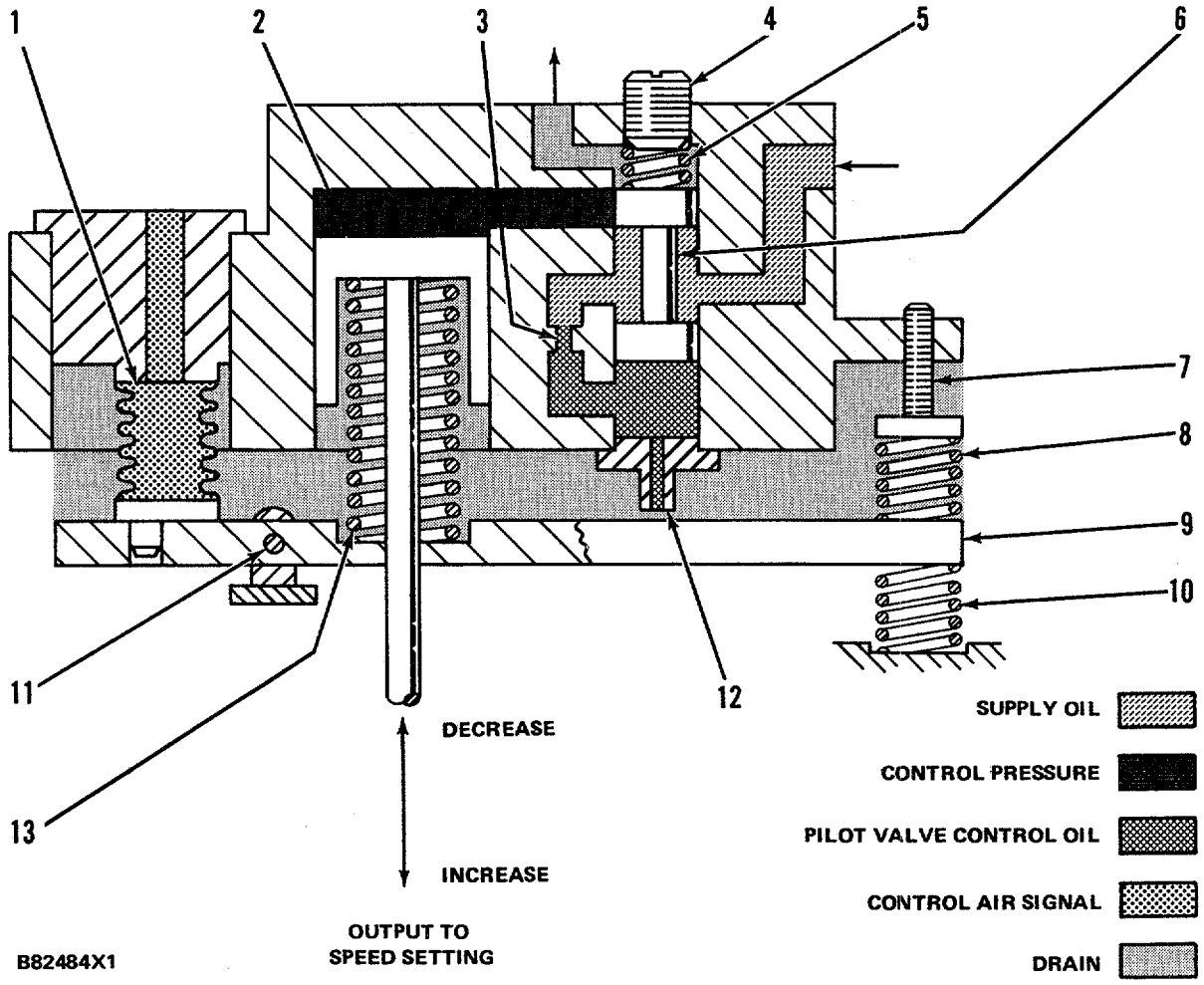
As the speed setting piston moves down, the feedback spring is put under compression and pushes the speed setting lever away from the nozzle. Control oil can now go to drain and the pilot valve loading spring pushes the pilot valve plunger down to stop oil flow to the top of the speed setting piston. This results in the speed setting piston stopped in a new position that is proportional to the air pressure supplied to the speed setting bellows.

Decrease Engine Speed

When the control air pressure is lowered, the speed setting bellows moves back toward its original position. The feedback spring now pushes the speed setting lever away from the nozzle and control oil goes to drain through the nozzle.

As control oil pressure goes to drain, the oil pressure below the speed setting pilot valve plunger is decreased and the pilot valve loading spring moves the plunger down. This lets control oil above the speed setting piston go to drain and the feedback spring pushes the piston up. When the piston moves up, the force on the governor speed setting lever is lowered and the governor speed setting is reduced.

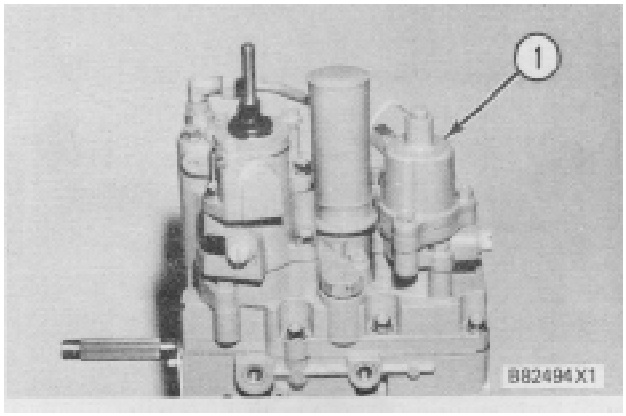
The speed setting piston moves up until the force of the feedback spring and the speed setting bellows moves the speed setting lever to close control oil to drain at the nozzle. At this time, the speed setting pilot valve plunger moves up to stop control oil movement above the speed setting piston. This results in the speed setting piston stopped in a new position that is proportional to the air pressure applied to the speed setting bellows.



PNEUMATIC SPEED SETTING CONTROL SCHEMATIC

1. Speed setting bellows. 2. Speed setting piston. 3. Orifice. 4. Spring seat. 5. Pilot valve loading spring. 6. Speed setting pilot valve plunger. 7. Base speed adjusting screw. 8. Upper speed setting bias spring. 9. Speed setting lever. 10. Lower speed setting bias spring. 11. Pivot. 12. Nozzle. 13. Feed-back spring.

AIR FUEL RATIO CONTROL



3161 GOVERNOR WITH AN AIR FUEL RATIO CONTROL
1. Air fuel ratio control.

The air fuel ratio control assembly (1) is installed on the right rear corner of the top cover. The control is factory calibrated and installed. This control is not for field installation.

The air fuel ratio control is similar to hydraulic air fuel ratio controls used on current Caterpillar engines. This control automatically controls the governor output shaft movement in the "fuel increase" direction, until air pressure in the engine inlet manifold is high enough to give complete fuel combustion.

The air fuel ratio control limits the fuel to the engine in proportion to the amount of turbocharger boost pressure (pressure above atmospheric) in the inlet manifold. The control is not activated during engine start up and is cocked (activated) by a combination of oil pressure and the initial surge of boost when the engine is first loaded.

Engine Start Up

As the engine is started and the speed or load is increased, air pressure from the inlet manifold increases and pushes up on the rolling diaphragm assembly to put the limiter spring under compression. As the rolling diaphragm assembly moves up, the fuel limiter plunger also moves up and closes off the port in the limiter piston. Now the supply oil can not drain through the limiter piston and the pressure of the oil starts to increase. When the oil pressure is high enough, the limiter piston is pushed down against the limiter servo spring force. The lower edge of the fuel limiter plunger opens the port in the limiter piston when the piston has moved down far enough. This lets supply oil go to drain. The air fuel ratio control is now activated and can operate as needed.

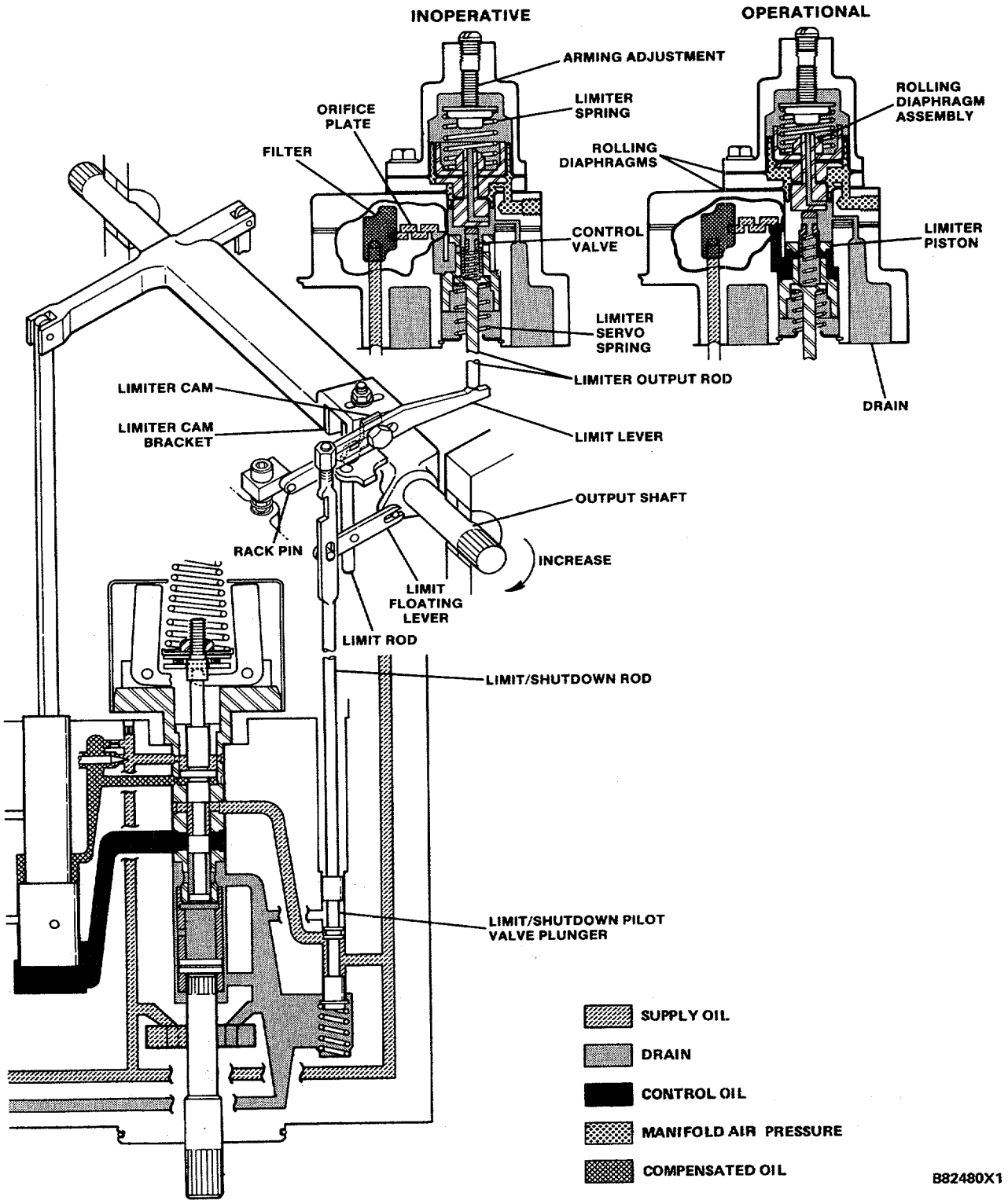
Engine Load Increases

As more load is put on the engine, the air pressure in the inlet manifold is increased. The increased air pressure pushes the rolling diaphragm assembly up and lifts the fuel limiter plunger more. Oil pressure on the limiter piston decreases as the limiter piston drain port is opened and the limiter piston moves up until the port is closed again. At this time the limiter piston is stopped in a new position that is proportional to the air pressure in the inlet manifold.

Now, with the engine in operation at a steady speed, load added decreases engine speed. The governor moves to increase fuel as the power piston moves up to turn the output shafts in the "increase" direction. As the output shafts turn, the right end of the limit floating lever is lifted. Because the limit floating lever is fastened to a pivot (pivot position is set by the air fuel ratio control), the left end of the lever pushes the limit/shutdown rod down. The limit/shutdown pilot valve plunger closes off governor control oil to the power piston and limits the power piston movement.

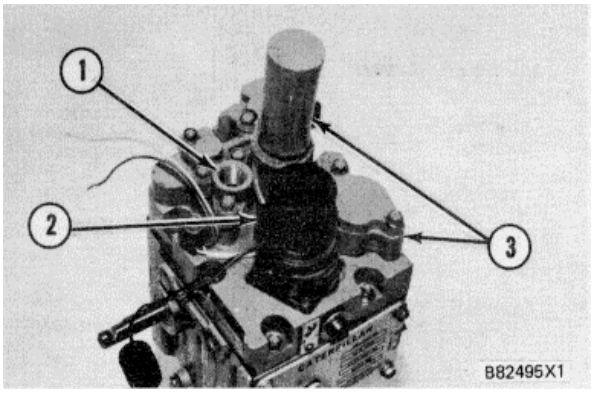
As the engine picks up load, air pressure to the air fuel ratio control increases. The rolling diaphragm assembly moves up and lifts the fuel limiter plunger which opens the port in the limiter piston. Oil pressure on the limiter piston is lowered, and lets the limit servo spring push the piston and output rod up. This lets the limit/shutdown pilot valve move up. Fuel limit level is then increased.

NOTE: The air fuel ratio control fuel limit range is set by the position of the limit cam on the limit lever. When the cam is moved away from the shutdown rod, the limit range is longer. When the cam is moved closer to the shutdown rod, the limit range is shorter.



SCHEMATIC OF AIR FUEL RATIO CONTROL ON THE 3161 GOVERNOR

SPEED ADJUSTING MOTOR GOVERNOR HEAD



3161 GENERATOR SET GOVERNOR
1. Conduit connection. 2. Speed adjusting meter.
3. Electric shutdown assembly.

The speed adjusting motor governor head includes a 24/32 Volt DC remote control speed adjusting motor (2) for changing engine speeds from remote locations. The speed adjusting motor is installed on the governor top cover and is connected to the governor speed setting mechanism through a friction clutch. The motor drives through the friction clutch and rotates the speed adjusting screw to position the governor's speed adjusting lever. The governor set speed may be increased or decreased at the rate of 13 rpm/ second. One revolution of the manual adjusting screw will increase engine speed 63 rpm (approximately).

To increase the speed setting, the motor shaft rotates clockwise. As the motor shaft rotates, it turns the speed adjusting screw to make contact with the speed adjusting lever and lowers it to increase the governor's speed setting. The motor shaft turns the speed adjusting screw until the speed adjusting lever contacts the high speed stop. If the motor continues to run, the clutch will slip to prevent damage to the motor.

NOTICE

The motor should not be left running with the clutch slipping, or clutch wear will occur. To decrease speed setting, the motor shaft turns counterclockwise and the speed adjusting screw backs out, allowing the speed adjusting lever to move to the "decrease speed" setting.

If the motor shaft is permitted to rotate counterclockwise after the speed adjusting lever has reached the low speed stop screw, the speed adjusting screw will turn out to the maximum position. The clutch will then slip until the motor is stopped.

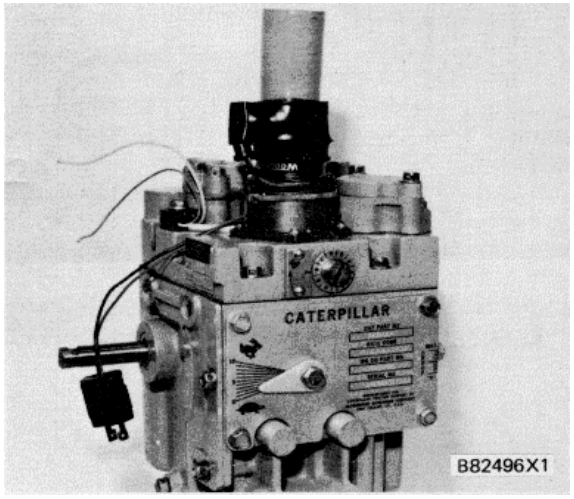
NOTE: If the speed adjusting motor has been allowed to run after the low speed setting has been reached, it may take a period of time for the speed adjusting screw to turn in and make contact with the speed adjusting lever (when an increase in speed setting is required).

All wiring and power to the remote speed setting motor on the governor must be low voltage DC. A converter drop box which will convert 115 or 230 volt AC (50 to 60 Hertz) to 24 volt DC is available (2W4523). This box should be remote mounted from the engine to isolate the engine wiring harness from high voltage AC currents.

An internal one-half inch thread conduit connection (1) is on top of the governor cover. It is used for installations which require conduit protection for the wiring.

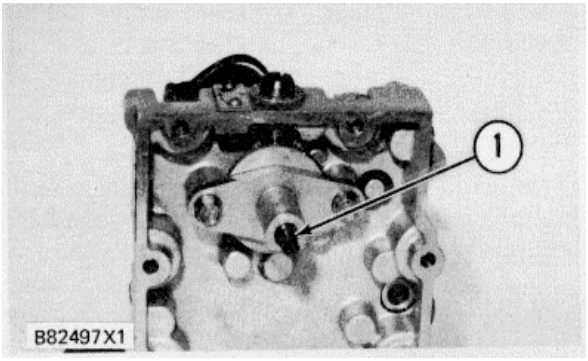
The top governor cover is made for installation of any of the three shutdown assemblies.

MANUAL SPEED SETTING CONTROL



3161 GENERATOR SET GOVERNOR

The manual speed setting control is located on the front of the speed adjusting motor governor head. Engine speed is set manually as the speed setting screw is turned. The high and low idle stops limit the speed range.



TOP COVER OF THE 3161 GENERATOR SET GOVERNOR
1. Speed adjusting screw.

An indicator lever is attached to the governor speed setting shaft with a bolt. The bolt can be loosened and the indicator lever can be set to the reference points on the identification and information plate to correspond with the number on the dial. The indicator lever will show the speed setting before the engine is started.

The manual speed setting control and the speed adjusting motor use a common speed adjusting screw which contacts the governor speed adjusting lever.

The speed adjusting motor clutch is above the gear and connects the motor to the speed adjusting screw. This clutch keeps force off of the speed adjusting motor as the speed setting is adjusted manually.

MANUAL MECHANICAL SPEED CONTROL

3161 GOVERNOR 1. Shaft. 2. Handle assembly. 3. Guide. 4. Hub. 5.

Quadrant. **6. Ratchet mounting plate.**

.70 **SYSTEMS OPERATION** The manual mechanical speed control with remote and positive lock is available for torque rise and non-torque rise equipped governors. The control is used for manually setting different ~,_ engine speeds, or it can be used as a remote speed control.

The shaft (1) goes through the handle assembly (2) and is threaded into the hub (4) on the spline of the speed setting shaft. The guide (3) rotates on the speed setting shaft and supports the handle assembly. The ratchet mounting plate (6) is bolted to the front of the governor and has notches to hold the handle for different engine speeds. The quadrant (5) can be engaged with the handle assembly and used as a mechanical linkage to the speed setting shaft.

A cable or rod can be connected to the quadrant and used for remote speed control.

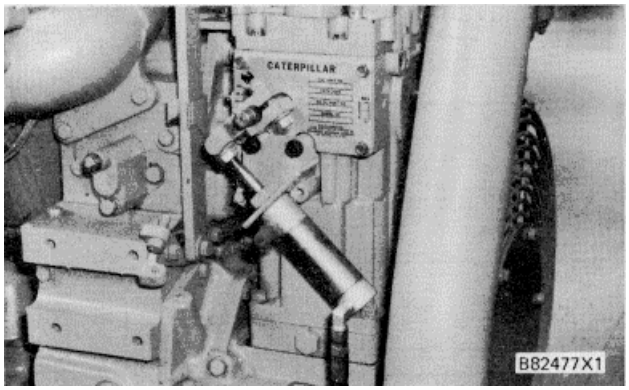
To increase or decrease engine speed, push on the shaft and lift on the handle assembly. This disengages the handle assembly from the ratchet mounting plate. The control can then move the speed setting shaft. Movement of the handle in the clockwise direction increases the engine speed.

To disengage the handle assembly from the ratchet and connect the quadrant, push on the shaft and lift on the handle assembly. With the handle assembly raised, turn it 180 degrees and connect it to the quadrant. The control can now be used for remote operation.

NOTE
: The manual mechanical speed control with remote and positive lock should not be used with a pneumatic speed control. Vibration can cause the manual mechanical speed control to engage and stop pneumatic speed control operation.

PNEUMATIC MID SPEED CONTROL A pneumatic speed control is normally used on 3161 Governors on vehicular engine arrangements to control the engine speed. A pneumatic mid speed control is also used to make the engine go from low idle to mid speed for dynamic braking with the direct current generator and drive motors.

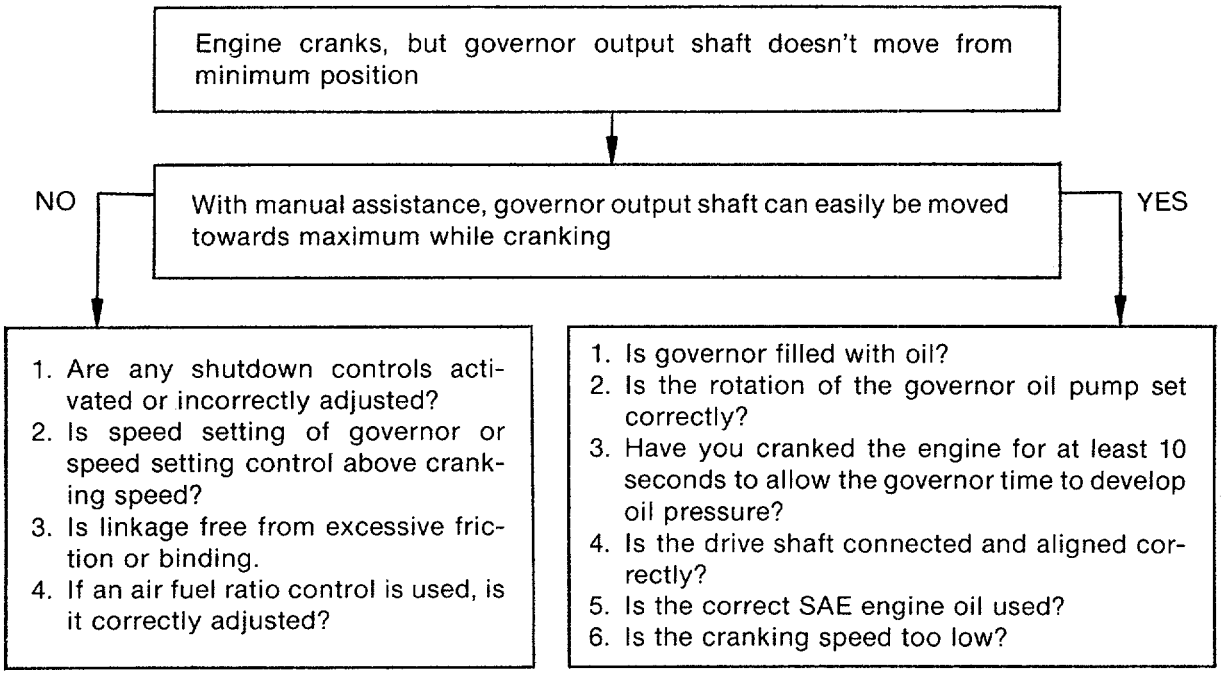
This control is installed on the front of the governor. With a lever fastened to the speed setting " control shaft, the control cylinder sets the engine speed from low idle to mid speed. The mid speed setting of the governor is set by the position the control lever is fastened to the speed setting control shaft.

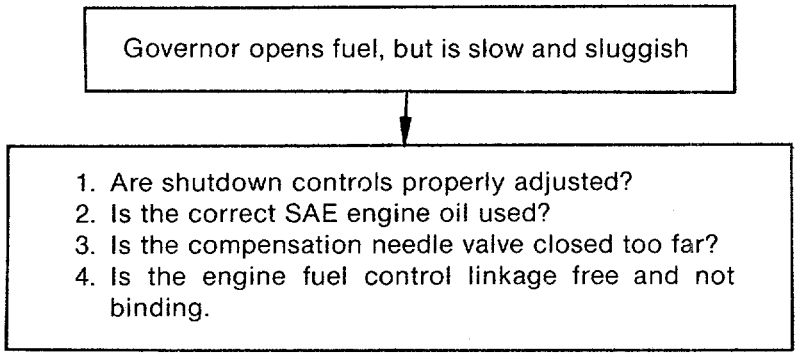


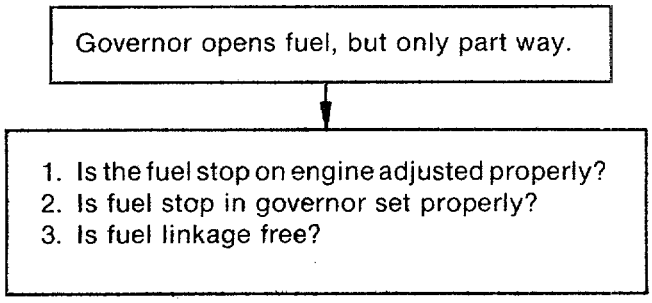
PNEUMATIC MID SPEED CONTROL

The control cylinder rod is spring activated (extended) and air retracted. When the cylinder rod is extended the lever moves the speed setting shaft in the "fuel increase" direction. As air pressure is supplied to the control cylinder, the cylinder rod moves away from the speed setting shaft lever. The governor turns the output shafts in the "fuel decrease" direction to lower the engine speed. When there is a loss or reduction of air pressure, the control moves the speed setting shaft and the engine runs at a speed set by the governor proportional to speed setting shaft position.

GOVERNOR TROUBLESHOOTING







Governor opens fuel and engine starts, but activates overspeed shutdown.

1. Is the overspeed protection group set properly?
2. Is the compensation needle valve closed too far?
3. Is the governor speed setting too high?

Engine will not accept full load.

Is the governor at full fuel?

NO

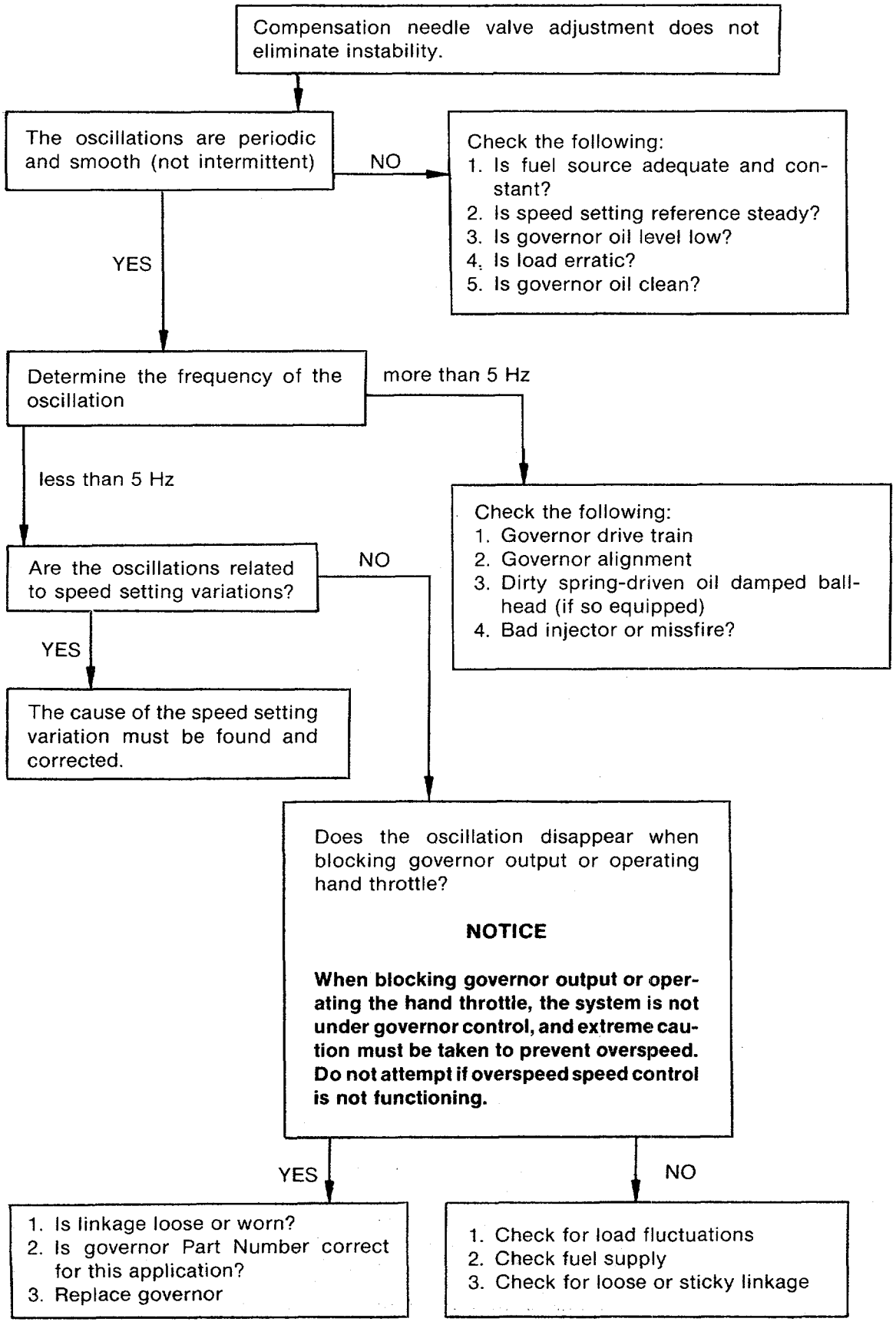
1. Is the air fuel ratio control (if so equipped) set too low?
2. Is there adequate air pressure for the air fuel ratio control?
3. Is the linkage sticky or improperly adjusted?

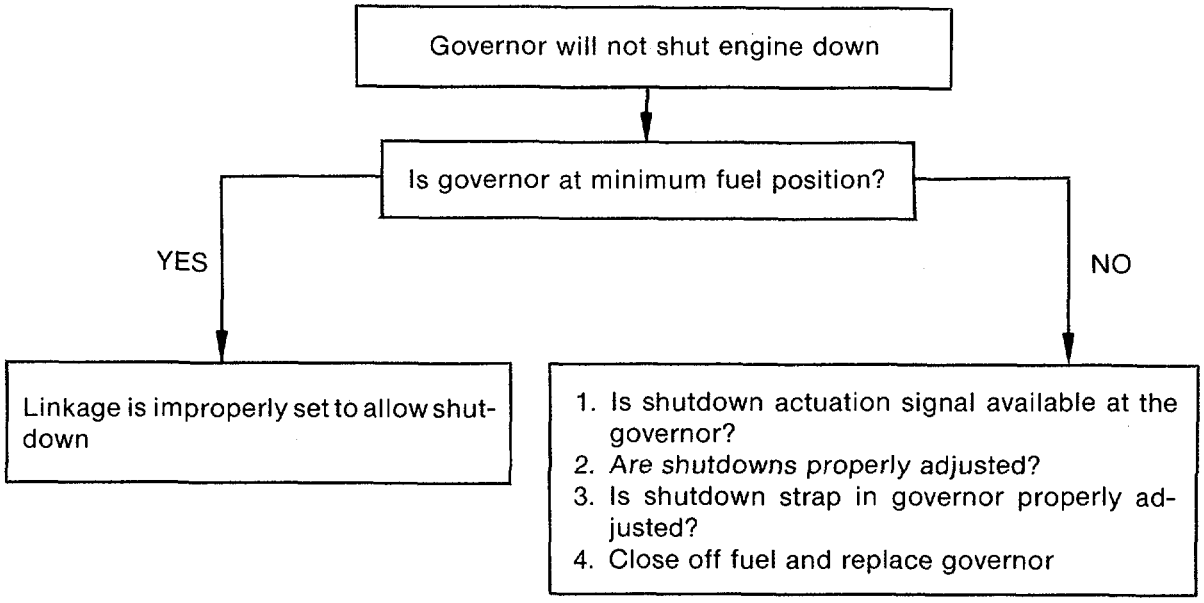
YES

1. Is the linkage adjusted properly?
2. Is load excessive?
3. Is voltage regulator for the electric speed control (if used) set properly?
4. Is the fuel stop on the engine set correctly?
5. Are the shutdown controls adjusted correctly?

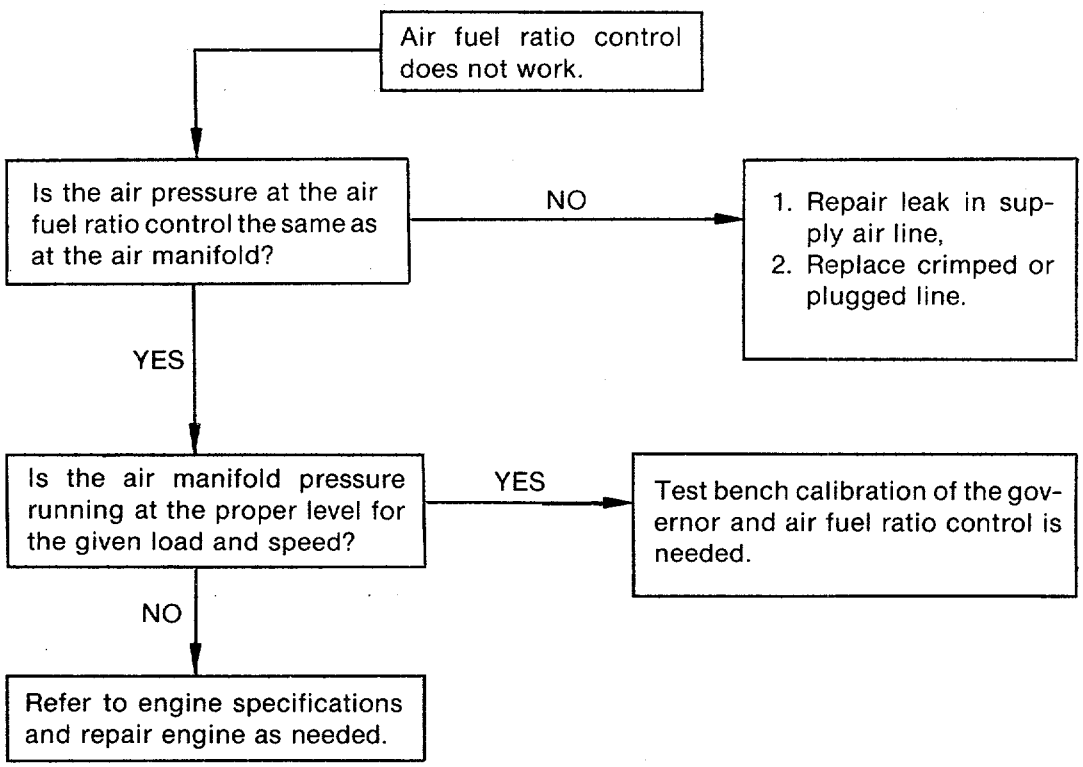
System oscillates and is unstable

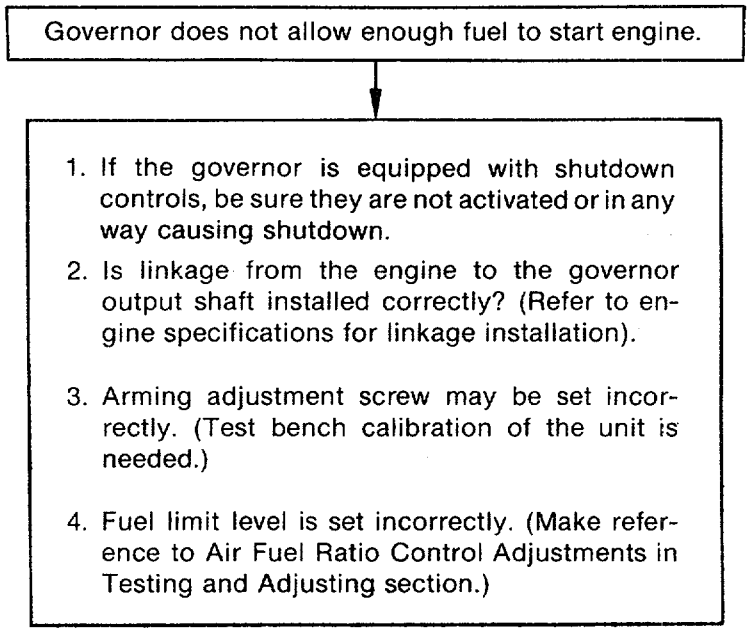
Check the following:
1. Is droop properly set?
2. Is compensation needle valve correctly adjusted?
3. Is fuel control linkage binding or worn?
4. Make sure all linkage or controls fastened to the governor speed control shaft are fastened tight to the control shaft.


Compensation needle valve adjustment does not eliminate instability.
The oscillations are periodic and smooth (not intermittent)
NO
Check the following:
1. Is fuel source adequate and constant?
2. Is speed setting reference steady?
3. Is governor oil level low?
4. Is load erratic?
5. Is governor oil clean?
YES
Determine the frequency of the oscillation
more than 5 Hz
less than 5 Hz
Check the following:
1. Governor drive train
2. Governor alignment
3. Dirty spring-driven oil damped ballhead (if so equipped)
4. Bad injector or missfire?
Are the oscillations related to speed setting variations?
NO
YES
The cause of the speed setting variation must be found and corrected.
Does the oscillation disappear when blocking governor output or operating hand throttle?
NOTICE
When blocking governor output or operating the hand throttle, the system is not under governor control, and extreme caution must be taken to prevent overspeed. Do not attempt if overspeed speed control is not functioning.
YES
NO
1. Is linkage loose or worn?
2. Is governor Part Number correct for this application?
3. Replace governor
1. Check for load fluctuations
2. Check fuel supply
3. Check for loose or sticky linkage


Governor will not shut engine down
Is governor at minimum fuel position?
YES
NO
Linkage is improperly set to allow shut-down
1. Is shutdown actuation signal available at the governor?
2. Are shutdowns properly adjusted?
3. Is shutdown strap in governor properly adjusted?
4. Close off fuel and replace governor

AIR FUEL RATIO CONTROL TROUBLESHOOTING





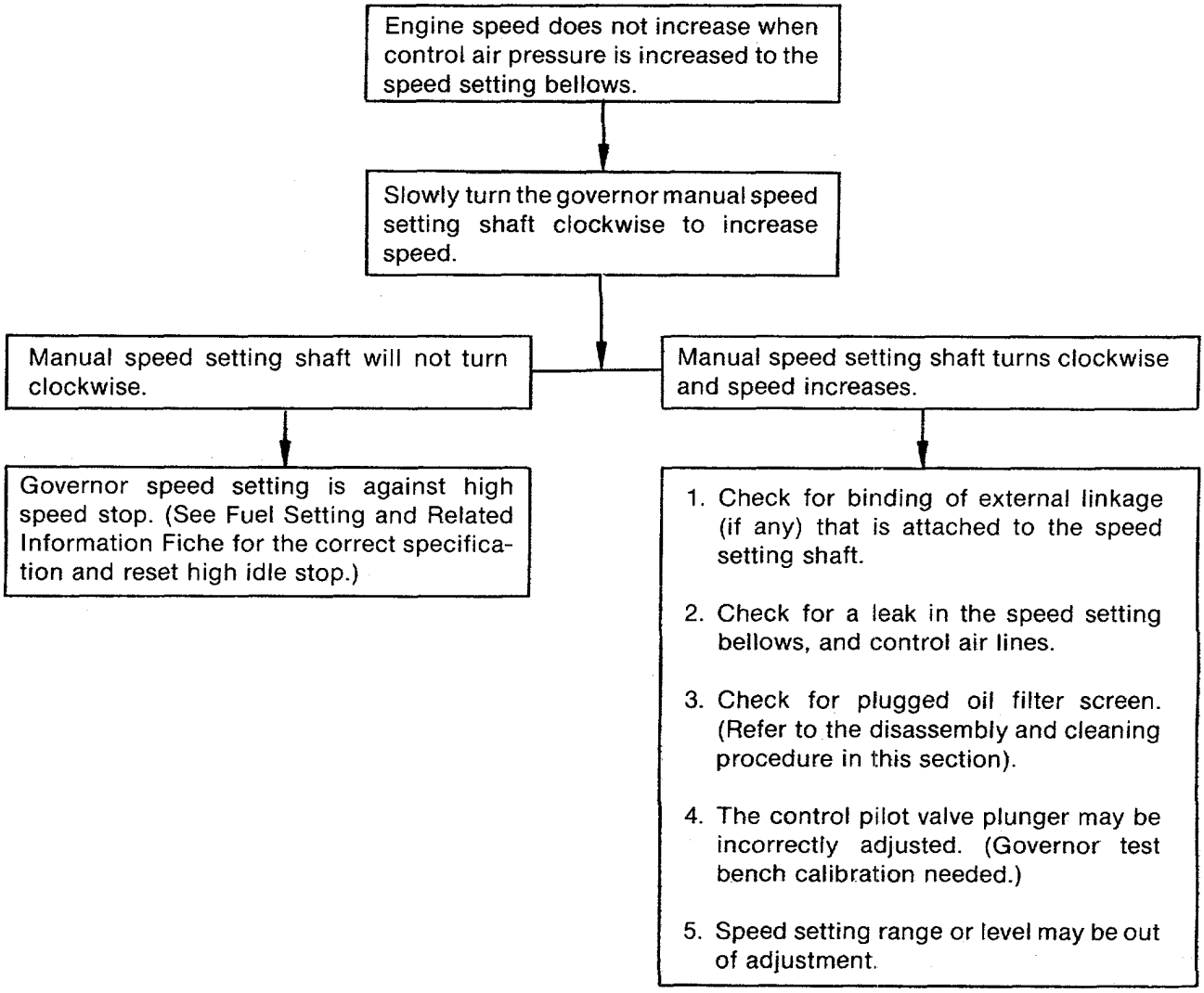
Engine is slow on acceleration.

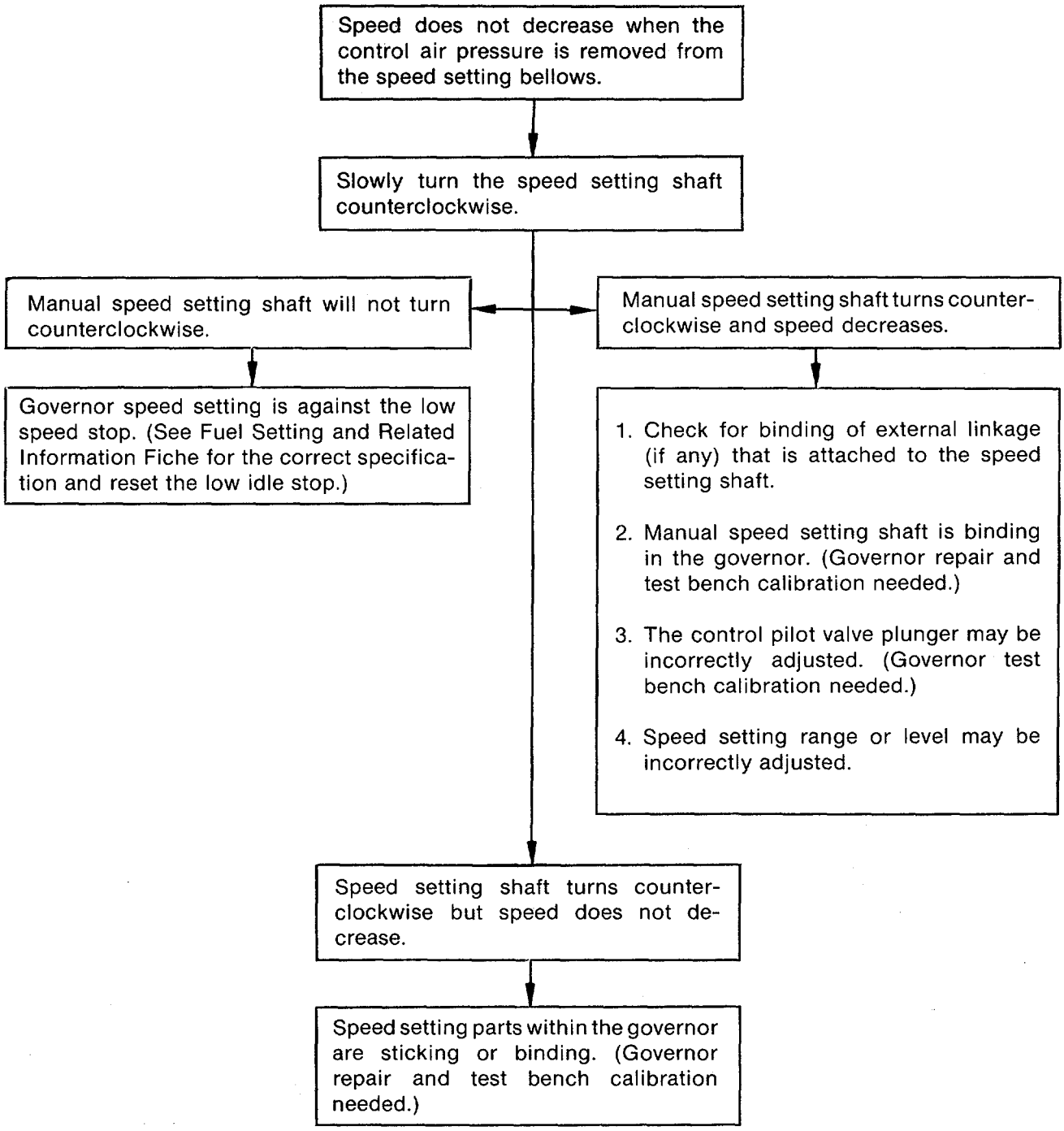
1. Inadequate manifold pressure.
2. Restricted air line or leaky air line connections.
3. Fuel limit level is set incorrectly. (Make reference to Air Fuel Ratio Control Adjustments in Testing and Adjusting section.)
4. Check to make sure the governor and engine fuel control linkage are installed and engaged correctly and there is no binding.

Excessive smoke during acceleration and when load is applied to the engine.

1. Fuel limit level is set too high. (Make reference to Air Fuel Ratio Control Adjustments in Testing and Adjusting section.)
2. Arming adjustment is set incorrectly. (Test bench calibration of the unit is needed.)

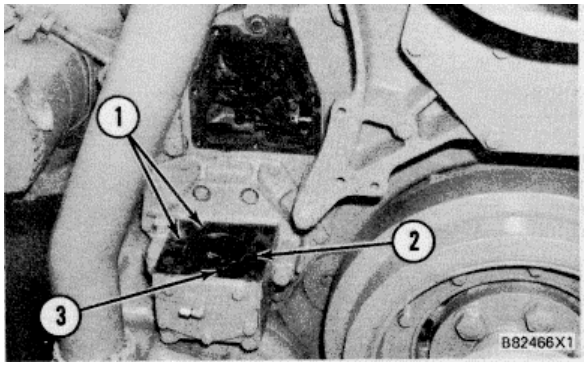
PNEUMATIC SPEED SETTING CONTROL
TROUBLESHOOTING




Speed does not decrease when the control air pressure is removed from the speed setting bellows.
Slowly turn the speed setting shaft counterclockwise.
Manual speed setting shaft will not turn counterclockwise.
Manual speed setting shaft turns counterclockwise and speed decreases.
Governor speed setting is against the low speed stop. (See Fuel Setting and Related Information Fiche for the correct specification and reset the low idle stop.)
1. Check for binding of external linkage (if any) that is attached to the speed setting shaft.
2. Manual speed setting shaft is binding in the governor. (Governor repair and test bench calibration needed.)
3. The control pilot valve plunger may be incorrectly adjusted. (Governor test bench calibration needed.)
4. Speed setting range or level may be incorrectly adjusted.
Speed setting shaft turns counterclockwise but speed does not decrease.
Speed setting parts within the governor are sticking or binding. (Governor repair and test bench calibration needed.)

GOVERNORS FOR 3500 SERIES ENGINES

GOVERNOR OIL PUMP

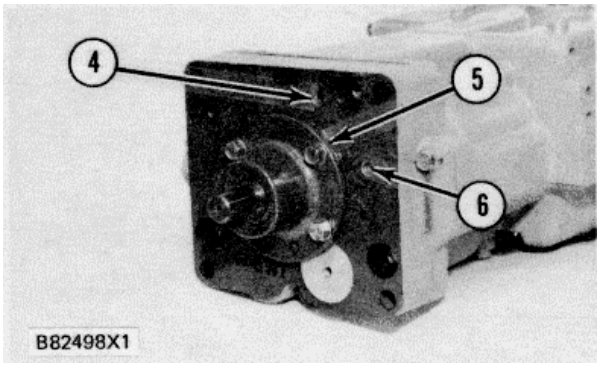


GOVERNOR OIL SUPPLY

1. Oil passages. 2. Passage for oil supply. 3. Passage for oil drain.

The governor drive adapter has four passages with seals. Passages (2 and 3) on the right side are used when the governor is installed -on the right side of the engine. Passage (2) is the oil supply to the governor. Passage (3) is the oil drain port for the governor.

Passages (I1) with the seals are used when the governor is installed on the left side of the engine.

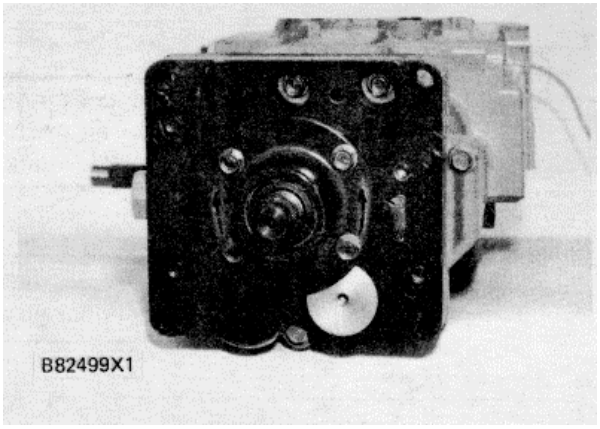


OIL PASSAGES IN GOVERNOR HOUSING

4. Passage (oil drain). 5. Groove in governor pump housing for O-ring seal. 6. Passage (oil supply).

Passage (4) is for oil drain and passage (6) is for -the -oil supply in the 316l Governors.

No gasket is used between the governor and the drive adapter housing. A seal in groove (5) on the outside of the oil pump housing seals between the governor and the large bore in the adapter housing. Replace the large seal and the four counterbore seals each time the governor is removed and installed.

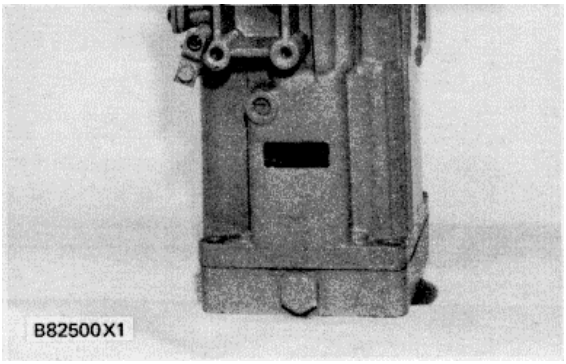


GOVERNOR OIL PUMP ROTATION

Check the direction of the oil pump rotation before the governor is installed on the engine.

Two arrows are cast into the oil pump housing. One arrow indicates counterclockwise, and the other clockwise. A reference ROTATION V is -cast in the bottom of the governor housing.

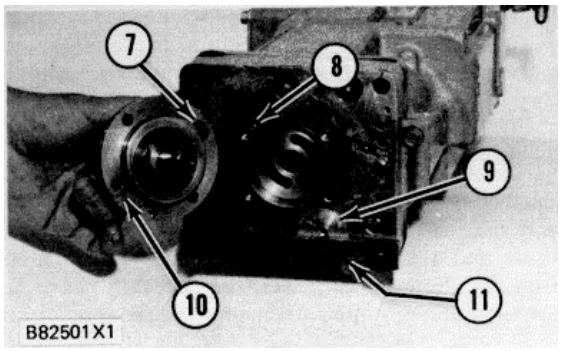
In the above illustration, the counterclockwise arrow is in alignment with the ROTATION V. This is the correct direction of rotation for the 3161 Governor when it is installed on the right hand side of standard rotation 3500 Series Engines.



PUMP ROTATION DECAL

A decal on the outside of the governor housing indicates the direction of governor rotation. This oil pump is set for counterclockwise direction as shown by the decal.

If the direction of rotation of the governor and oil pump is changed, a new decal must be installed with the decal arrow in the correct direction.



OIL PUMP INSTALLATION

7. Roll pin. 8. Reference hole for roll pin. 9. Plug. 10. Location hole for roll pin to change pump rotation. 11. Strap to hold plug in position when pump housing is removed.

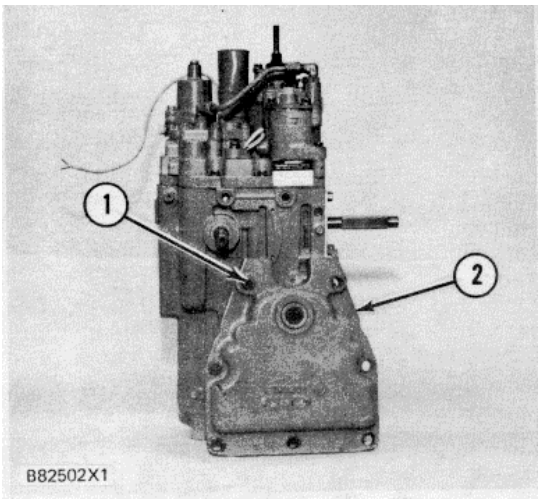
To change the direction of pump rotation do the following steps:

⚠ WARNING

The pump housing holds plug (9) in position. There is spring force on the plug. To prevent injury, mechanically hold plug (9) in the governor housing when the pump housing is removed.

1. Remove the four bolts that hold the pump in place.
2. Use two screwdrivers to lift the pump housing and O-ring seal from the governor.
3. Pull roll pin (7) from the pump housing flange and install it in location hole (10) in the opposite side of the flange.
4. Turn the pump housing and make an alignment of roll pin (7) and reference hole (8) in the governor base.
5. Put a new seal on the oil pump housing. Put clean engine oil on the seal and install the assembly part way into the bore in the base of the governor.
6. Make sure the external pump drive spline is in correct alignment with the internal coupling spline. If the splines are not in alignment, damage to the governor will be the result when the pump housing bolts are installed and tightened.
7. Use a soft faced hammer and hit the outer pump drive shaft so the pump snaps (moves suddenly) in place.
8. Install the four bolts and tighten them to a torque of 10 N-m (90 lb. in.).
9. Make sure the drive shaft turns freely after the bolts have been tightened.

GOVERNOR PREPARATION

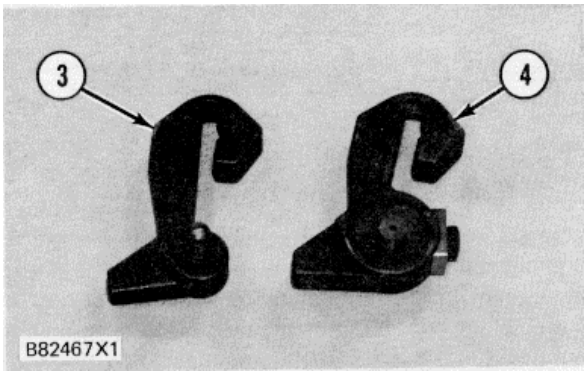


INSTALL COVER ON GOVERNOR

1. Location for bolt. 2. Cover.

Because of the close clearance between the fuel control linkage cover and governor, the upper left hand bolt must be installed at location (1) before cover (2) is put on the terminal shaft and the governor is bolted to the drive adapter housing. The other bolts can be put in place after the governor is in position on the engine.

Put clean engine oil on the lip of the seal and install cover over the governor terminal shaft.



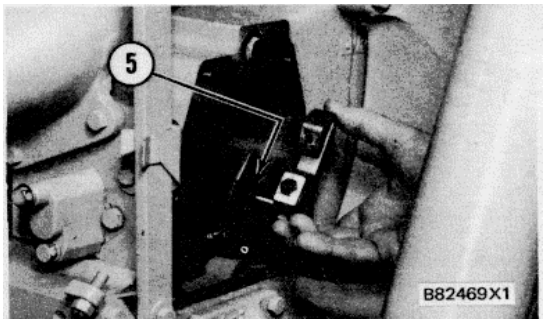
CONTROL LEVERS

3. Lever. 4. Lever.

There are two control levers for the 3161 Governor used on 3500 Series Engines. Lever (3) has a fixed pin and lever (4) has an adjustable pin. The fixed pin lever (3) is used on the 3161 Standard and Generator Set Governors.

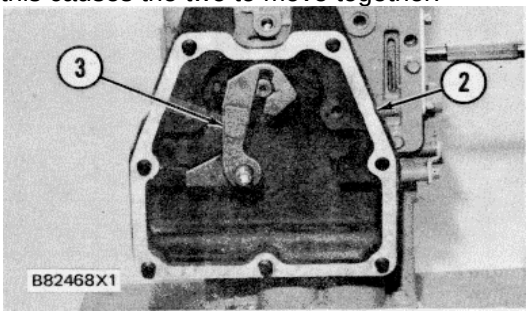
The adjustable pin lever (4) is used on 3161 Governors with torque rise. Lever (4) is used to synchronize governor torque rise set point (balance point) position to engine fuel setting position.

The adjustable pin lever (4) can be used on a right hand or left hand mounted governor. To convert the lever from right hand governor use to left hand governor use, remove the lock bolt and lock from the adjustable pin. Remove the adjustable pin from the lever, turn it around and install it into the lever the opposite way. Install the lock and bolt into the adjustable pin and tighten just enough to hold it in place. The lever can now be used on the other end of the terminal shaft for left hand mounted governors.



ALIGNMENT OF CONTROL LEVER
5. Notch in fuel control linkage stop lever.

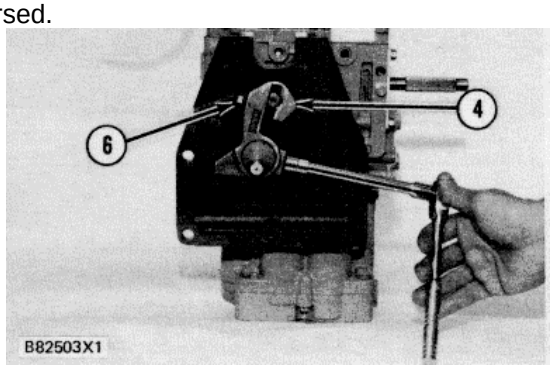
The lever and pin (fixed or adjustable) connect the governor terminal shaft to the fuel control linkage stop lever. The lever pin moves in notch (5) of the stop lever, this causes the two to move together.



INSTALL LEVER
2. Cover. 3. Lever.

The 3161 Standard and Generator Set Governors with fixed pin levers do not require any special adjustments or setting when installed on the engine.

After fuel control linkage cover (2) is in position, install lever (3) on the governor terminal shaft and tighten the bolt to a torque of 25 ± 7 N-m (18 ± 5 lb. ft.). Control levers will go on only the correct way because of the flat and groove of the terminal shaft and the lever pin. This control lever is for right-hand mounted governors. On control levers for left-hand mounted governors, the pin is reversed.



INSTALL LEVER
4. Lever. 6. Bolt.

For 3161 Governors with torque rise, the adjustable pin control lever is installed on the terminal_ shaft. Bolt (6) is then tightened to a torque of 25 ± 7 N°m (18 ± 5 lb. ft.).

Before the governor is installed on the engine, tighten the pin lock bolt enough to hold the pin in position when the governor is installed on an engine.

After the governor is installed on an engine, the adjustable pin is turned to synchronize the governor travel to the fuel control linkage. See Governor Installation for the correct adjustment and setting of these governors.

NOTICE

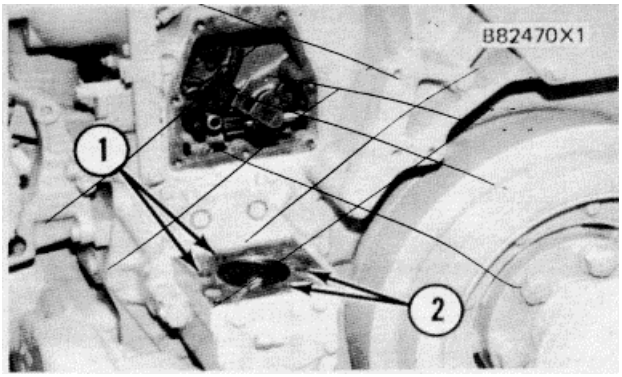
Before the governor is installed on an engine, make sure the pin of adjustable control lever (4) is at the bottom of the lever as shown. if the pin is not in this position, the control lever can bind or become disconnected from the engine fuel control linkage. Engine overspeed can be the result.

GOVERNOR INSTALLATION

NOTICE

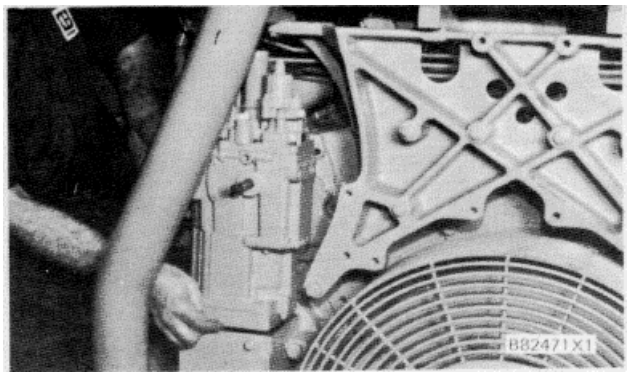
To prevent damage to the governor, do not drop the governor or set it on the drive shaft, terminal shaft or speed adjusting shaft.

3161 Standard and Generator Set Governors



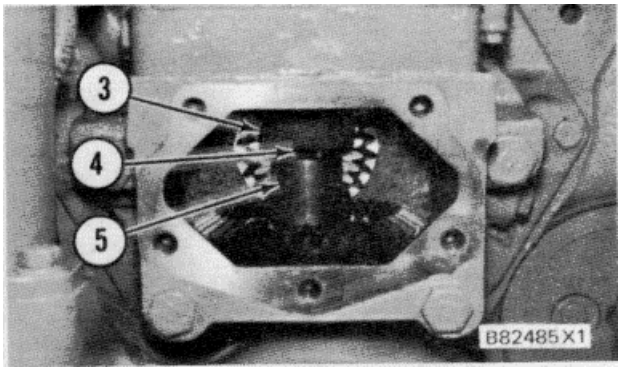
INSTALL SEALS
1. O-ring seals. 2. O-ring seals.

1. Make sure the four O-ring seals (1) and (2) are in position on the governor drive housing. Install the seal on the governor oil pump housing and put clean engine oil on all seals.



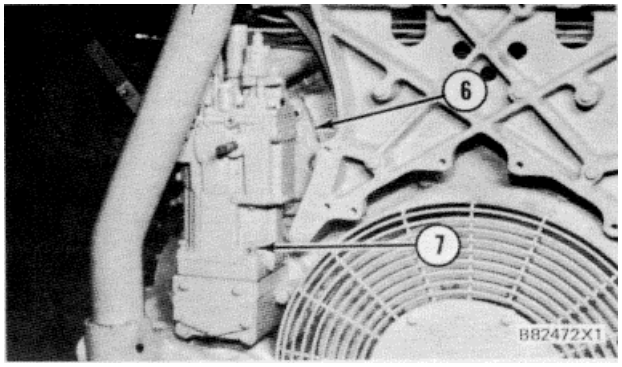
INSTALL GOVERNOR

2. Put the governor and cover gasket in position. Make sure the governor drive shaft and the spline drive are in correct alignment. Also, make sure the pin on the governor lever is engaged in the slot in the fuel control linkage stop lever.



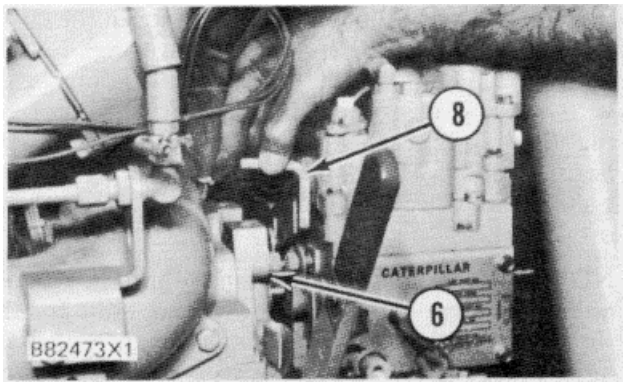
ALIGNMENT OF GOVERNOR AND DRIVE
(Cover removed for photo illustration only)

NOTE: Be sure there is no binding, side load on the drive shaft, or looseness in the drive coupling. The maximum runout of the governor drive shaft and coupling must be less than 0.15 mm (.006 in.). Parts that do not fit correctly or are not in alignment can cause early wear, shaft seizure, or governor drive shaft failure.



FASTEN GOVERNOR TO DRIVE HOUSING
6. Cover. 7. Bolts.

3. Move the governor to put cover (6) in correct alignment (square) with the front housing of the engine. With the governor in alignment, install and tighten bolts (7) to hold the governor to the drive housing.



INSTALL COVER AND BRACKET
6. Cover. 8. Bracket.

4. Put cover (6) against the front drive housing and make sure the gasket is in alignment. Install and tighten the bolts. Check the governor terminal shaft for free movement, see Step 6.

5. Install bracket (8) as follows:

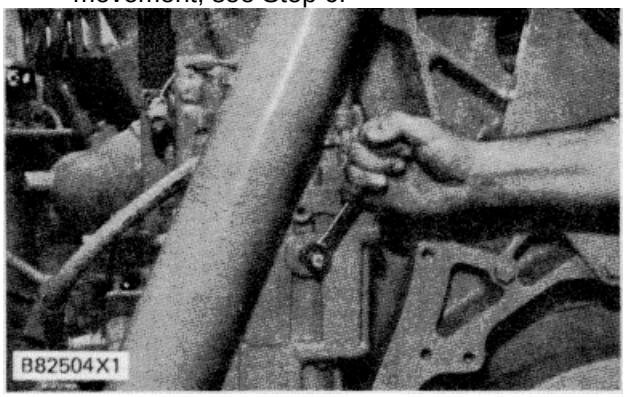
   a. Install two bolts in the side of the governor.

   b. Slide bracket (8) in place on the bolts. Tighten the bolts enough to hold bracket (8) in position. The bracket must be free enough to move.

   c. Install and tighten the two bolts that hold bracket (8) to the top of cover (6). This puts the bracket in correct alignment.

d. Tighten the two bolts that hold bracket (8) to the governor.

e. Check the governor terminal shaft for free movement, see Step 6.

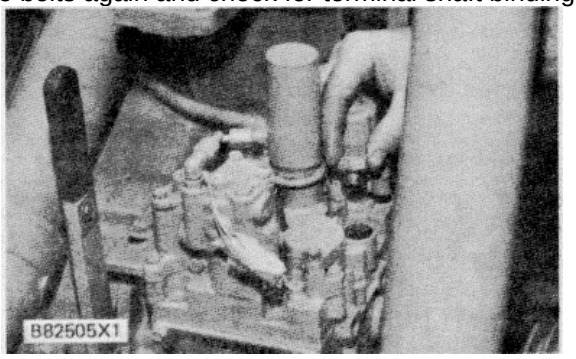


CHECK TERMINAL SHAFT MOVEMENT

6. Use a 7/16" wrench and move the governor terminal shaft several times in the 'FUEL ON" direction and release it. The terminal shaft must return completely to the "FUEL OFF" position each time. If the terminal shaft does not return, binding can be the result of parts not in correct alignment.

If the terminal shaft is binding, loosen the cover bolts, make an alignment of the cover again, then tighten the bolts again. Check for binding again with the above procedure. If this does not correct the binding, loosen the governor base to drive housing bolts. Move the governor and tighten the bolts again. Check for binding again with the above procedure.

NOTE: If the governor terminal shaft is binding after the above procedure, loosen the bolts for the fuel control linkage cover. Then loosen the bolts that hold the governor drive housing in position and move the housing to make an alignment of the cover bolt holes. Tighten all of the bolts again and check for terminal shaft binding.



CORRECT GOVERNOR OIL LEVEL

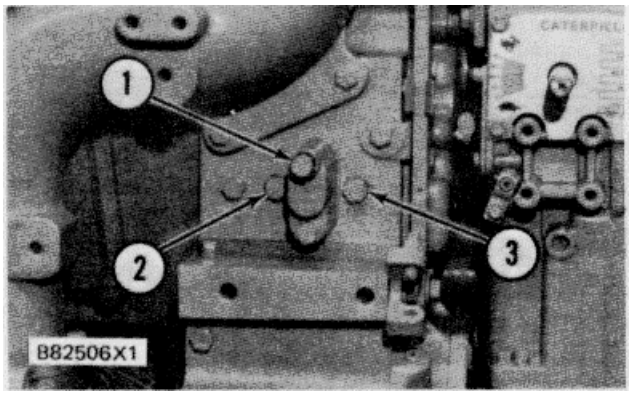
7. It is necessary to prime the governor. Remove the oil fill plug from the governor top cover. Add 1.8 liter (2 U.S. quarts) of clean engine oil to the governor before the first engine start up. Replace the plug in the top cover and tighten.

3161 Governor With Torque Rise

Tools Needed:

6V3139 Timing and Fuel Setting Tool Group.
5P4814 Collet.
6V3075 Dial Indicator (metric).
5P7263 Contact Point, 76.2 mm (3.00 in.) long.
FT1819g Governor Torque Arm Tool.

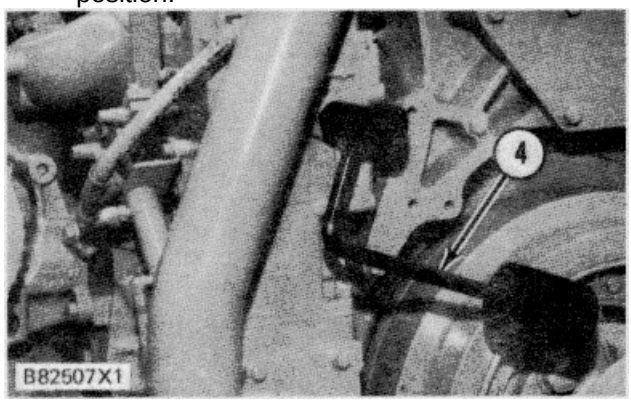
1. Put the governor in position on the engine as in Steps I through 3 for 3161 Standard and Generator Set Governors.



FUEL SETTING COVER
1. Synchronizing pin. 2. Plug. 3. Plug.

2. Remove plugs (2) and (3) from each side of the fuel setting cover.

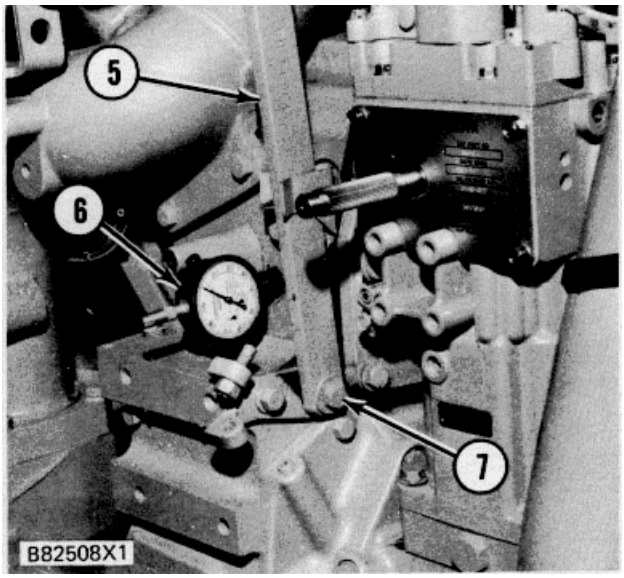
3. Remove synchronizing pin (1) from the fuel setting cover and remove the washer from it. Install synchronizing pin (I) in the threaded hole for plug (2). Tighten the synchronizing pin (1) in position.



MOVE FUEL CONTROL LINKAGE AGAINST SYNCHRONIZING PIN
4. FT1819 Governor Torque Arm Tool.

4. Use FT1819 Governor Torque Arm Tool (4) to move and hold the governor terminal shaft in the "FUEL ON" direction. This puts the fuel control linkage stop lever against the end of synchronizing pin (1). The FT1819 Governor Torque Arm Tool is to be attached only with the engine shut down.

NOTE: A torque wrench and a 7/16 in. crowfoot wrench can be used to move the terminal shaft in the "FUEL ON" direction. Hold the governor terminal shaft and fuel control linkage against the synchronizing pin with 10 N-m (90 lb. in.) force to give an accurate dial indicator setting.



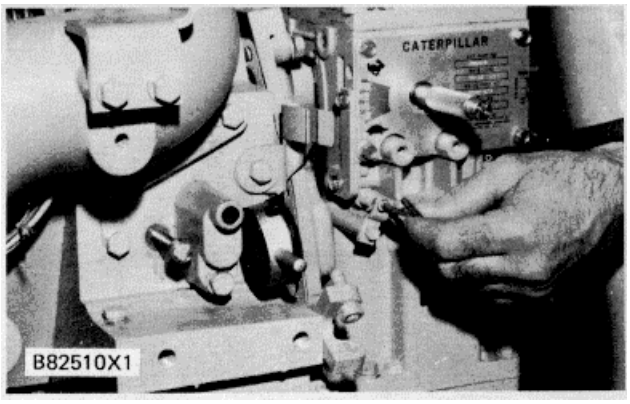
INSTALL DIAL INDICATOR

5. Manual fuel shutoff lever. 6. 6V3075 Dial Indicator with the 5P7263 Contact Point in the 5P4814 Collet. 7. Bolt.

5. Put 6V3075 Dial Indicator (6) with the 5P7263 Contact Point in the 5P4814 Collet. Install the dial indicator and collet in the threaded hole as shown. When the contact point seats against the fuel stop lever, slide the dial indicator in or out until the indicator reads zero. Now tighten the collet just enough to hold indicator at this position.

6. Remove tool (4) from the governor terminal shaft. Make sure the terminal shaft returns to the "FUEL OFF" position.
7. Remove bolt (7) and manual fuel shutoff lever (5).

8. Turn synchronizing pin (l) back out a minimum of 25 mm (I in.) or remove it completely.

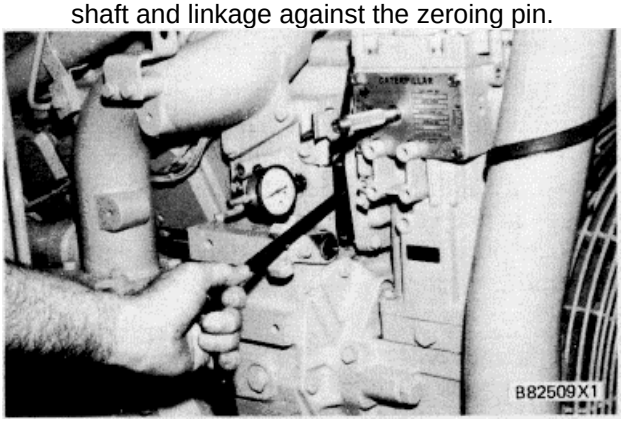


ENGAGE GOVERNOR ZEROING PIN

9. The zeroing pin is engaged to hold the governor at a fixed position for setting the adjustable pin lever to synchronize the governor travel with the engine fuel control linkage travel. This pin is to be engaged only with the engine shut down.

   Put a 5/32 inch hex wrench in the governor zeroing pin, push in and turn it counterclockwise until the roll pin locks squarely behind the bracket.

10. Install FT1819 Governor Torque Arm Tool (4) again to turn and hold the governor terminal shaft and linkage against the zeroing pin.



ADJ USTABLE PIN SETTING

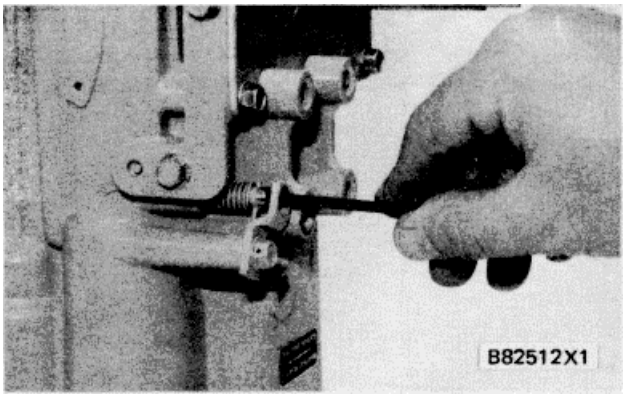
11. With a 1/2 in. by 3/8 in. drive socket on a 12 in. extension and ratchet put the socket and extension between the cover and housing. Put the socket on the bolt that holds the adjustable pin lock and loosen the bolt.

    NOTE: Later pins use a hex socket head bolt for use with 3/ 8in. drive sockets with a 12/4 in. hex bit.

    Move the ratchet and extension up or down until the dial indicator reads zero Put 0.13 mm while the terminal shaft is held in the "FUEL ON" direction against the governor zeroing pin.

Tighten the bolt on the lock to a torque of 25 ± 7 Nom (18 ± 5 lb. ft.).

Move tool (4) in the "FUEL OFF" position and release. The dial indicator must return to zero each time. If it does not, do the above procedure again.

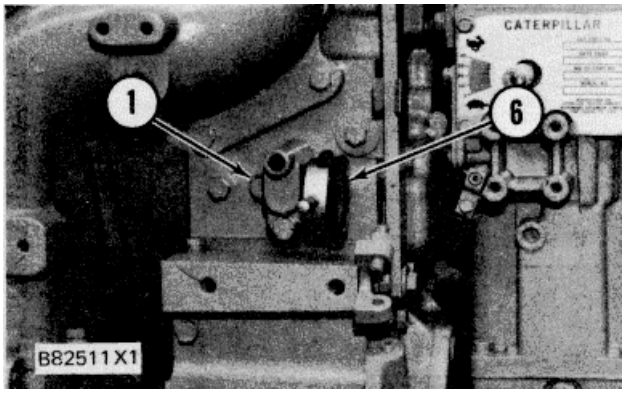


RELEASE GOVERNOR ZEROING PIN

12. Remove tool (4) from the governor terminal shaft.

13. Release the governor zeroing pin. Push on the hex wrench and turn it clockwise until the roll pin unlocks from the bracket. Release the hex wrench and the spring will return the pin to the disengaged position. Remove the hex wrench.

14. Turn synchronizing pin (1) in all of the way and tighten it (install the pin as in Step 4 if it was removed). Use tool (4) to hold the fuel control linkage against synchronizing pin 1) as in Step 5. Without change to the dial indicator position, make sure the reading is zero to indicate correct fuel control linkage setting.



REMOVE SYNCHRONIZING PIN AND DIAL INDICATOR

1. Synchronizing pin. 6. 6V3075 Dial Indicator.

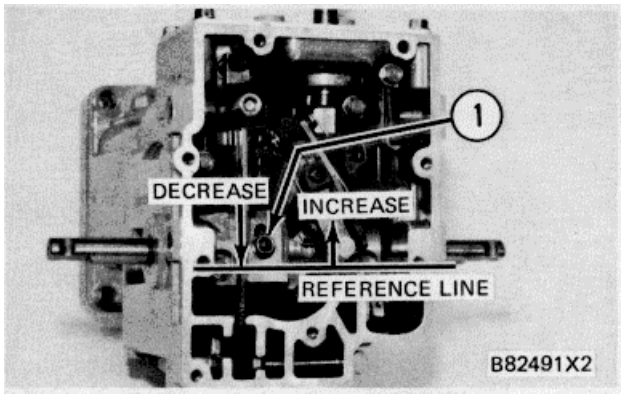
15. Remove 6V3075 Dial Indicator (6) and the collet. Remove synchronizing pin (3) and install it with the washer to hold the fuel setting cover in position.

16. Install the two plugs on each side of the fuel setting cover.

17. Follow Steps 4 through 7 for 3161 Standard and Generator Set Governors to install the cover, bracket and check for free movement of the fuel control linkage and governor.

GOVERNOR ADJUSTMENTS

DROOP SETTING - INTERNAL ADJUSTMENT



INTERNAL DROOP ADJUSTMENT
1. Locknut.

When the position of the droop pivot pin (internal or external) is changed on the terminal lever, the percent of governor droop changes.

To change the droop pivot pin setting on governors not equipped with an external adjustment lever, the governor top cover must be removed.

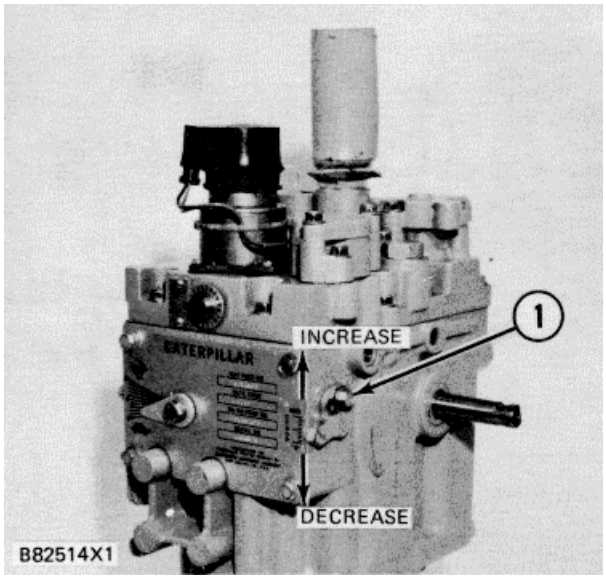
The droop pivot pin is fastened to the terminal lever with locknut (1). With the nut loosened, the pivot pin can be moved from minimum droop to maximum droop. It is shown here in the minimum droop position.

The terminal shafts are clamped in the ends of the terminal lever by two bolts. A line can be drawn through the center of the two bolt heads and used for reference in adjusting the droop pivot pin position.

When the pivot pin and nut is moved near the reference line as shown, the governor is set for minimum droop. As the pivot pin and nut are moved farther away from the reference line, the droop is increased. When the pivot pin and nut are moved to the farthest point away from the reference line the governor is set for maximum droop.

DROOP SETTING - EXTERNAL ADJUSTMENT

On the 3161 Generator Set Governor, the internal droop pivot pin locknut must be kept loose enough to be moved by the external droop adjustment lever. The external droop adjustment lever is held in place with a bolt which retains the droop setting.



EXTERNAL DROOP ADJUSTMENT
1. Bolt.

To change the droop setting, loosen the adjustment lever bolt (1) and move the lever down to decrease droop, and up to increase droop.

DROOP SETTING CHECK

After an adjustment has been made to the droop pivot pin (internal or external), the setting can be checked by alternately loading and checking the high idle speed.

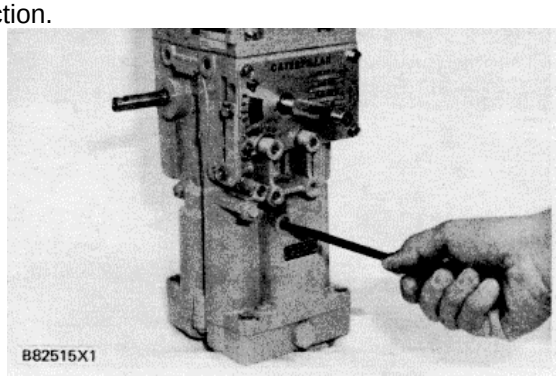
As this procedure is performed, the high idle screw will probably have to be adjusted. The full load speed of the engine will also adjust upward or downward.

As droop is decreased, full load speed is increased, high idle speed is decreased. The greater the percent droop, expect the full load speed to decrease, and the high idle speed to increase. Therefore high idle speed should be adjusted to set the full load speed at the correct rpm.

COMPENSATION NEEDLE VALVE ADJUSTMENT

After the engine has started and is under governor control, open the needle valve (turn it counterclockwise) until governor operation just becomes unstable (starts to hunt), then turn the needle valve in until engine speed has stability. Let the governor and engine get to operating temperature by operating a minimum of one-half hour. After the engine and governor are at the operating tempera-

ture, again check for stable operation. Adjust as necessary. DO NOT fully close the needle valve. This can cause excessive overshoot on startup, or load rejection.



NEEDLE VALVE ADJUSTMENT

With the engine at normal operating temperature and no load, operate the engine at low idle speed. Open the governor compensation needle valve and let the governor increase and decrease engine speed (hunt) for a minimum of 30 seconds to remove air from the system. If the governor does not hunt, rapidly move the speed control shaft to change governor stability.

After 30 seconds and the air is removed from the system, turn the needle valve in (clockwise) until the engine runs smoothly.

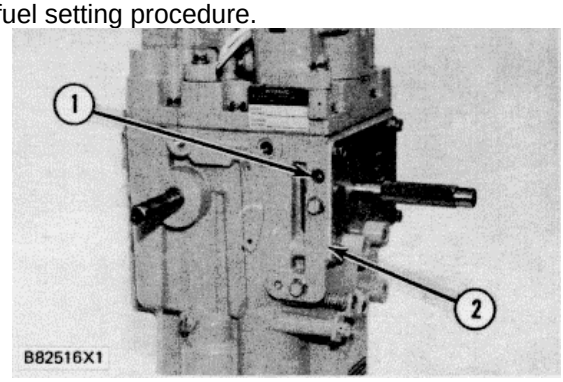
With the engine running at medium (mid) speed, load the engine (at least one-quarter load) to find the stability of the setting. Quickly remove the load. A slight overshoot of speed is ideal, as it reduces response time. The engine speed should return to smooth steady operation. If it does not have a slight overshoot and return to a smooth steady operation, adjust the needle valve and repeat the above procedure.

Governor terminal shaft "jiggle" or surge is an indication of:

1. Too little compensation (needle valve out too far);
2. Torsional vibration (pulsing);
3. Improperly aligned governor drive spline;
4. A binding or loose fuel control mechanism.

LOW AND HIGH IDLE ADJUSTMENTS

NOTE: Make sure the engine fuel setting is correct before low and high idle adjustments are made. See the engine TESTING AND ADJUSTING Service Manual for the fuel setting procedure.



LOW IDLE ADJUSTMENT
1. Low idle stop screw. 2. Plate.

Low and high idle speed stop screws are on the left side of the governor case, and are adjusted from the outside of the governor.

The low idle speed stop screw is not covered, and can be adjusted without breaking the wire seal (wire and seal not shown).

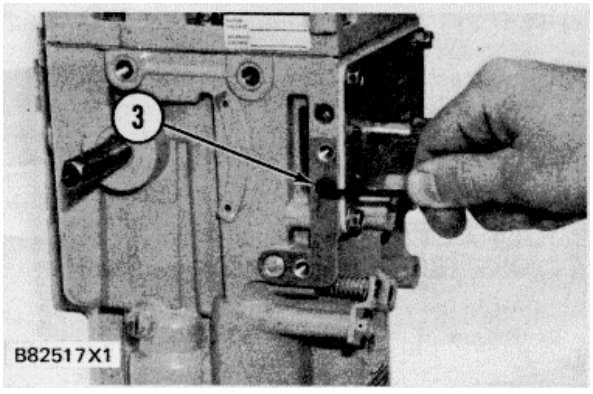
The high idle speed stop screw is covered by plate (2). The plate is held to the governor case with two wire lock bolts. Install a wire and seal on the high idle speed adjustment cover bolts to prevent tampering.

A 1/8 inch hex wrench is used for turning both low and high idle speed stop screws.

⚠ WARNING

The engine may overspeed due to improper reassembly or adjustment, which could result in personal injury, loss of life, and/or property damage.

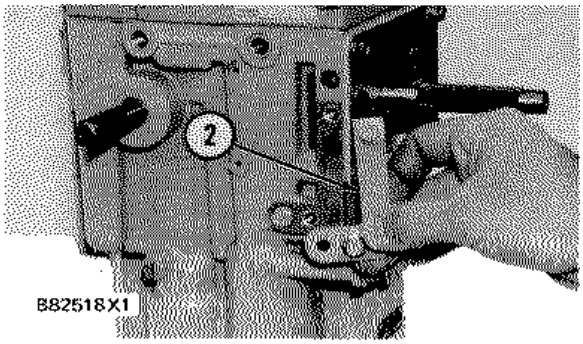
Be prepared to stop the engine by activating the emergency air shut off or closing the air inlets.



HIGH IDLE ADJUSTMENT
3. High idle stop screw.

To increase the engine low idle speed, turn screw (1) clockwise.

Turn high idle speed stop screw (3) clockwise to decrease high idle speed.



INSTALL COVER
2. Plate.

When the high and low idle speeds are adjusted to the specifications given in the Fuel Setting and Related Information Fiche, install the plate and the two bolts. Put a seal wire through the holes in the bolt heads and install the seal as required on other Caterpillar fuel systems.

TORQUE RISE SETTING (ON 3500 SERIES ENGINES)

Tools Needed:

6V3139 Timing and Fuel Setting Tool Group.
5P4814 Collet.
6V3075 Dial Indicator (two required).
5P7263 Contact Point, 76.2 mm (3.00 in.) long.
FT1819 Governor Torque Arm Tool.
9S228 Rack Position Tool Group.
9S225 Bracket Assembly.
3S3269 Contact Point, 25.4 mm (1.00 in.) long.

1. Look in the Fuel Setting and Related Information Fiche to find the correct engine fuel setting, torque rise and full load.

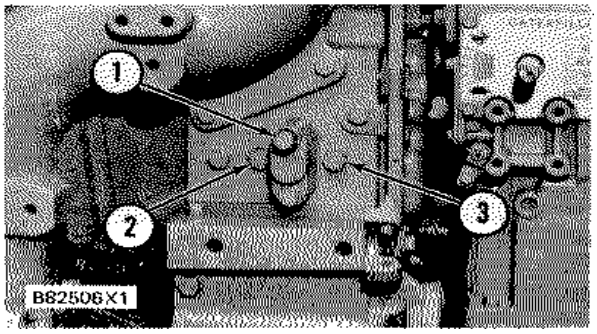
In the past only "static fuel setting" was listed in the Fuel Setting and Related Information Fiche for the 3500 Series Engines. This fuel setting was "maximum travel" and listed as "static fuel setting."

On 3500 Series Engines equipped with a 3161 Standard or Generator Set Governor, the fuel setting procedure has not changed. The fuel setting screw is used to set the "maximum travel" but the specification in the Fuel Setting and Related Information Fiche has changed and is shown as "full load."

On 3500 Series Engines equipped with 3161 Governors with torque rise there are two static fuel settings. One is torque rise, which is maximum travel, and is set with the fuel setting screw.

The second setting is full load, which is a "reference position" where the fuel control linkage is held while the torque rise cam is adjusted. This is a temporary setting set with the synchronizing pin. This setting is shown in the Fuel Setting and Related Information Fiche as "full load."

Torque rise fuel setting is greater than full load fuel setting, thus making the torque rise setting the "maximum travel" setting of the fuel control linkage.



INSTALL SYNCHRONIZING PIN

1. Synchronizing pin. 2. Plug. 3. Plug.

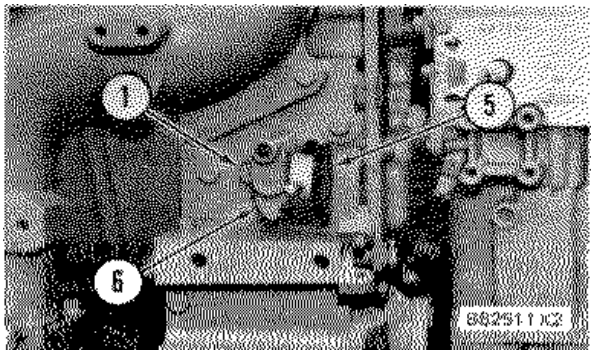
2. Remove plugs (2) and (3) from each side of the fuel setting cover.

3. Remove synchronizing pin (1) from the cover and remove the washer from it. Install synchronizing pin (1) in the threaded hole for plug (2) and tighten it.



MOVE FUEL CONTROL LINKAGE AGAINST THE SYNCHRONIZING PIN
4. FT1819 Governor Torque Arm Tool.

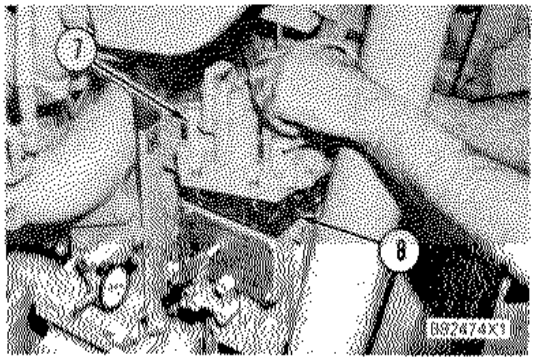
4. Use tool (4) to move and hold the fuel control linkage in the "FUEL ON" direction against the synchronizing pin.



INSTALL DIAL INDICATOR

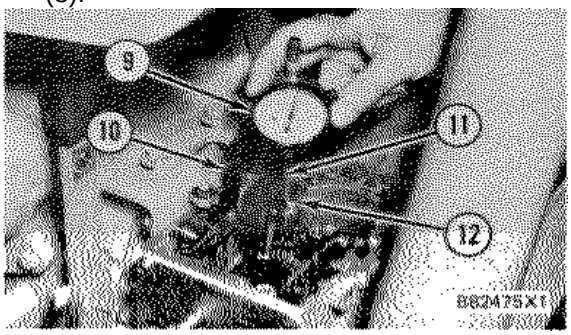
1. Synchronizing pin. 5. 6V3075 Dial Indicator. 6. Fuel setting cover.

5. Put dial indicator (5) with the 5P7263 Contact Point in the 5P4814 Collet. Install dial indicator (5) and the collet in the threaded hole for plug (3). When the contact point seats against the fuel stop lever, slide the dial indicator in or out until it reads zero. Now tighten the collet just enough to hold dial indicator (5) at this position.



REMOVE GOVERNOR TOP COVER
7. Cover. 8. Gasket.

6. Remove the bolts that hold cover (7) in position. Lift cover (7) off the governor and remove gasket (8).



INSTALL DIAL INDICATOR
9. 6V3075 Dial Indicator. 10. 9S228 Bracket Assembly. 11. 3S3269 Contact Point. 12. Bo8t.

7. Install dial indicator (9) on the top of the governor housing with bracket assembly (10) as follows:

Use a top cover bolt with three washers (as spacers under the bolt head) on it and put the bolt through the fixed diameter hole in the bracket. Fasten the bracket to the left side of the housing in the second threaded hole from the front. Put the dial indicator in the adjustable hole in the bracket assembly and position it so the indicator contact point (11) rests on the bolt head (12) of the torque control lever.

8. Check to make sure the cam follower is on the base circle of the governor torque rise cam. See Systems Operation section for a description of the base circle.

9. Move dial indicator (9) until it reads zero and fasten it in place.

10. Turn the synchronizing pin out of the engine front drive housing a minimum of half-way. As the synchronizing pin is backed out, dial indicator (5) will follow the fuel control linkage movement until the fuel control linkage stop lever contacts the fuel setting screw. Dial indicator (5) now shows the torque rise fuel setting. Make sure the torque rise fuel setting is correct. If not, an adjustment is necessary.

11. Look in the Fuel Setting and Related Information Fiche for the full load setting for the engine you are adjusting.

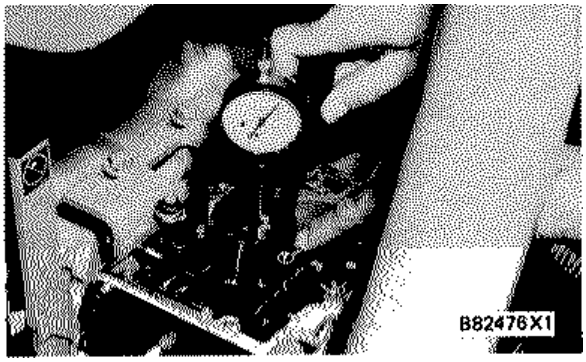
12. Turn the synchronizing pin in until dial indicator (5) reads the full load fuel setting. The full load setting is a reference position and is a temporary setting used to adjust the torque rise cam position.

The purpose of this procedure is to hold the fuel control linkage at the full load setting while the torque rise cam is adjusted.

13. Dial indicator (9) must read 1.00 + 0.05 mm, if it does not, an adjustment is needed. Loosen the bolt that holds the cam enough so the cam can be moved, but keep the bolt tight enough to provide a small drag on the cam.

14. Slide the cam to cause the torque control lever and dial indicator contact to lift 1.00 $\pm$ 0.05 mm.

15. Tighten the bolt while the cam is held in place. This adjustment of 1.00 $\pm$ 0.05 mm positions the torque control lever so the torque rise (additional fuel) begins to occur at the correct engine speed.



TORQUE RISE CAM ADJUSTMENT

16. Check the cam position by lifting and lowering governor torque arm tool (4) on the terminal shaft. The dial indicator (9) should return to the 1.00 ± 0.05 mm setting. If it does not, repeat the adjustment procedure and check again.

The following is an example of this torque rise cam setting. If the engine were running at a rated 1800 r/min with a load, the fuel control linkage would be at full load position and the torque rise cam follower would have lifted 1.00 mm. Torque rise would not have occurred, but would be at the starting point. Should more load be added, the engine speed would decrease. As the speed drops, the terminal shaft and torque rise cam will move and lift the torque rise pilot valve lever beyond the 1.00 + 0.05 mm set point. This will lift the pilot valve and provide additional fuel to the engine and give torque rise greater than the natural torque rise of the engine.

As more load is applied, engine speed will decrease. The fuel control linkage will continue to move in the "FUEL ON" direction, increasing the fuel rate until the fuel control linkage stop lever contacts the fuel setting screw. This is the torque rise fuel setting, and is maximum travel.

17. With the torque rise cam setting made, remove the dial indicator and bracket assembly and install the gasket and top cover on the governor.

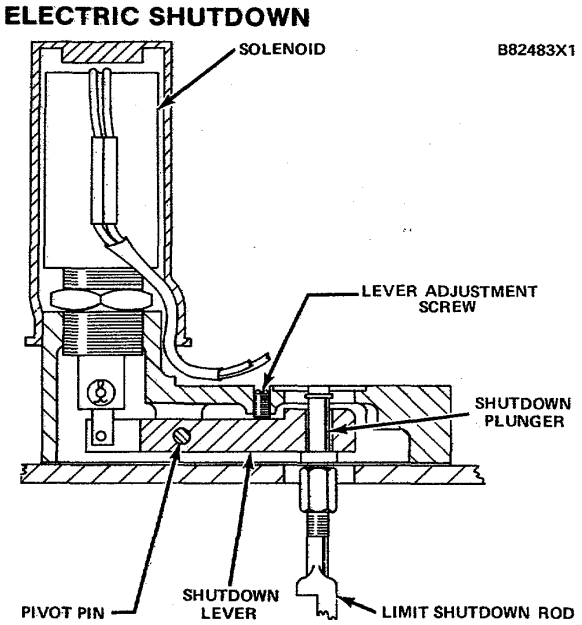
NOTE: Make sure the air fuel ratio control limit lever is engaged correctly in the notch of the governor housing before the top cover is installed.

18. Remove dial indicator (5) and the collet. Remove synchronizing pin (1) and install it with the washer to hold the fuel setting cover.

19. Install the two plugs on each side of the fuel setting cover.

AUXILIARY CONTROLS

ELECTRIC SHUTDOWN



The shutdown lever in the electric shutdown assembly is adjusted up or down to keep the shutdown/ limit rod in the correct position until the shutoff solenoid is activated.

1. Install the gasket and electric shutdown on top of the governor. Tighten the bolts to 10 Nom (90 lb. in.).

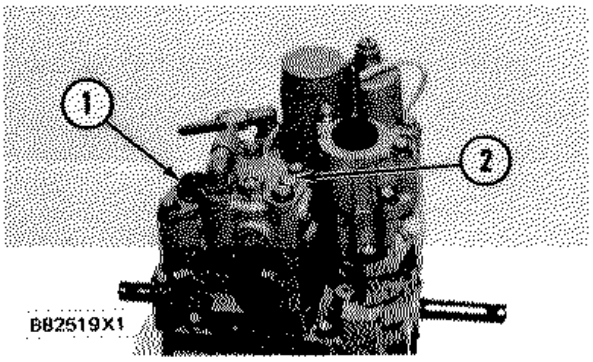
2. Remove the cover, manual shutdown or pressure shutdown, if so equipped, from the top of the electric shutdown assembly.

3. Turn the adjustment screw until the shutdown plunger is even with the top of the gasket for the cover or other shutdowns.

4. Install the cover, manual shutdown or pressure shutdown, if so equipped.

PNEUMATIC SPEED SETTING CONTROL ADJUSTMENTS

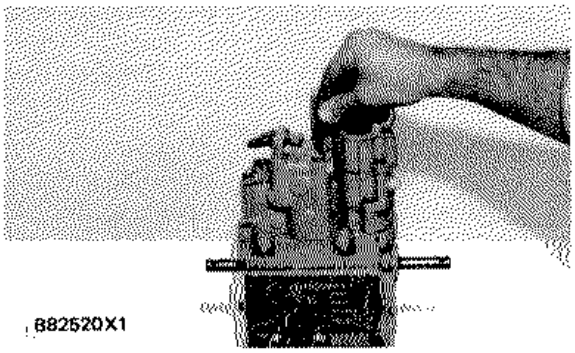
The pneumatic speed setting control has two adjustments. One is the speed range bellows adjustment made by turning the bellows (1) inside the bellows housing to increase or decrease the speed range.



PNEUMATIC SPEED SETTING CONTROL 1. Bellows. 2. Plug over low idle adjustment screw.

The other is the pneumatic speed level ratio (bias spring) adjustment, made by removing plug (2) and turning the adjustment screw with a 1/8 inch hex wrench.

Pneumatic Speed Level Ratio Adjustment



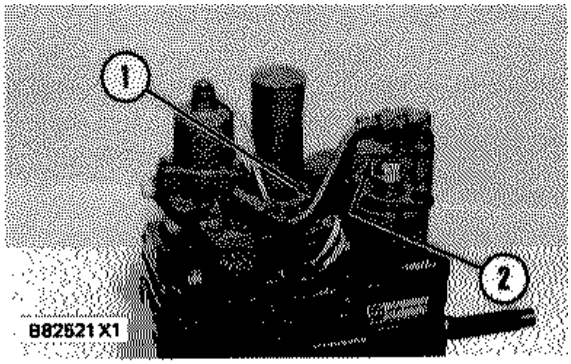
ADJUSTMENT OF LOW IDLE

When the speed level adjusting screw is turned the low speed setting of the pneumatic control is changed.

With the plug removed, put a 1/8 in. hex wrench in the hole until it engages with the adjustment screw. Turn the screw clockwise to decrease the low idle setting. Turn the screw counterclockwise to increase the low speed setting.

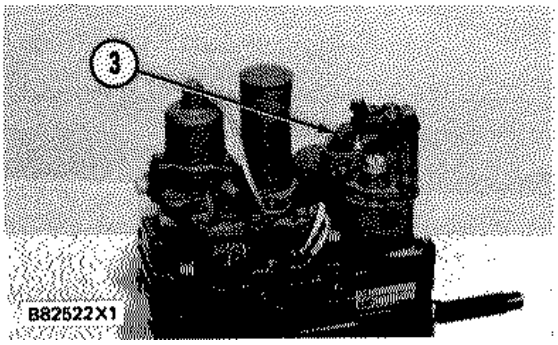
Feedback Spring

To use the pneumatic speed setting control with different air pressure ranges and engine speed settings the feedback spring must be changed.



REMOVE OIL LINE
1. Tube assembly. 2. Plate.

1. Remove tube assembly (I) and plate (2) from the governor.



REMOVE PLUG
3. Plug.

2. Install one of the bolts for plate (2) into plug (3) as shown and pull plug (3) out of its bore.

FEEDBACK SPRING AND SPEED SETTING PISTON POSITION
3. Plug. 4. Piston. 5. Spring.

3. With plug (3) out of the bore, speed setting piston (4) and feedback spring (5) can be lifted out of the bore with a magnet.

4. Find the correct feedback spring to use for the air pressure range and engine speed rating from the pneumatic speed control spring chart.

5. Install spring (5) in the bore over the speed setting rod.

6. Place piston (4) over spring (5) and push it down into the counterbore.

7. Install a new seal on plug (3), if the original seal is not in good condition.

8. Push plug (3) down in the bore and remove the bolt.

9. Put plate (2) in position, and install the three bolts and tighten them to 10 N-m (90 lb. in.).

10. Install tube assembly (1) on the governor.

NOTICE

Be careful not to get paint or other foreign material down in the bore, as this will affect the control operation.

3500 ENGINE PNEUMATIC SPEED CONTROL SPRING CHART

RATED SPEED RPM	LOW IDLE RPM *	HIGH IDLE RPM *	FEEDBACK SPRING PART NO.	SPRING IDENTIFICATIN **
900	450	897 to 1016	4W6628	79
1000		967 to 1165	4W6632	65
1100 1200 1300		1108 to 1397	4W6627	50 (std.)
1400 1500	600	1375 to 1670	4W6632	64
1600 1700 1800		1585 to 2018	4W6627	50 (std.)

*The speed settings shown are for the standard governor setting air pressure of:
Low Idle 35 kPa (5 psi) or 70 kPa (10 psi)
High Idle 380 kPa (55 psi) or 415 kPa (60 psi)
**The spring identification number is on the flat ground surface on one end of each spring.

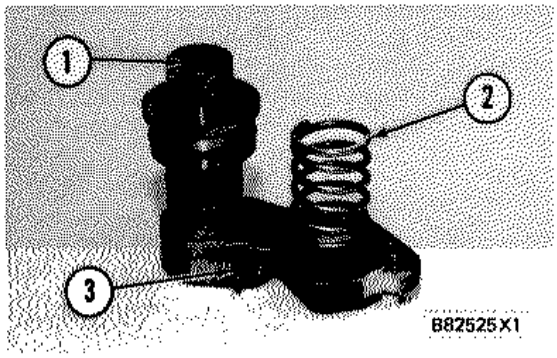
Speed Range Bellows Adjustment

The bellows is made off-center (eccentric) to the top flange area. The bottom of the bellows has a swivel pin that engages the hole in the end of the speed setting lever. The swivel pin is set off-center (eccentric) to the bottom of the bellows but is in line with the center of the air inlet port in the top of the flange.



SPEED SETTING BELLOWS AND LEVER

There is an index mark (notch) 0.76 mm (.030 in.) deep on the outer face of the bellows flange. The index mark is approximately mid range position when it is turned to the front of the governor (when facing the governor name plate).

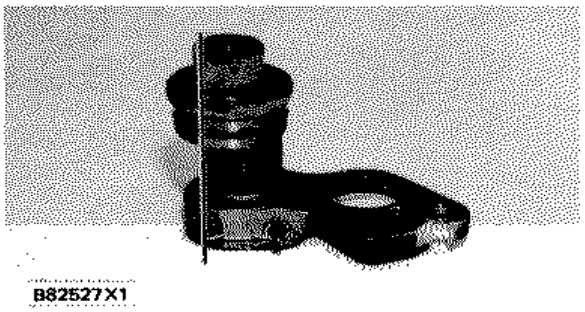


SPEED SETTING CONTROL
1. Air inlet port. 2. Feedback spring. 3. Pivot.

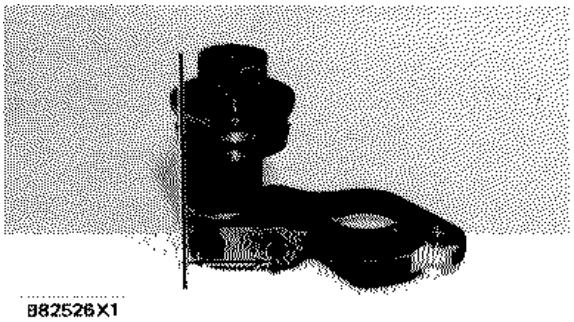
Control air pressure enters the bellows through air inlet port (1) at the top of the flange. Control air pressure expands the speed setting bellows, which pushes down on the lever at the left of pivot (3), raising the right end of the lever against feedback spring (2). The force of the feedback spring is marked on the end of the spring.

When the bellows is turned, the eccentric changes the position of the bellows on the speed setting lever. This changes the length of the lever arm. The lever arm is the distance from pivot (3) to the outer edge of the bellows.

When the bellows is turned with the index mark to the right side of the governor (counterclockwise as seen from governor nameplate), the bellows moves closer to the pivot pin. This makes the lever arm shorter and lowers engine speed for a given amount of air pressure.

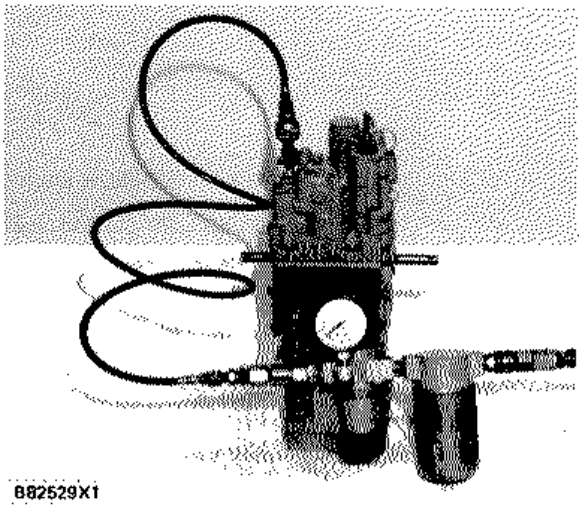


LOWER SPEED SETTING



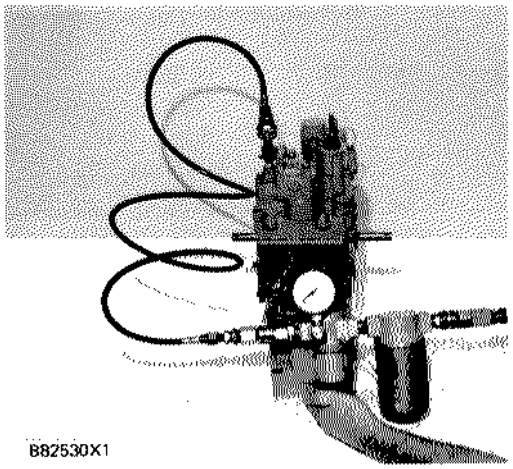
HIGHER SPEED SETTING

With the index mark to the left side of the governor (as seen from governor nameplate), the bellows is farther away from the pivot pin. The lever arm is now longer and engine speed is increased for a given amount of air pressure.



CONNECT PRESSURE REGULATOR AND GAUGE ASSEMBLY

Before the control adjustment can be made, install n pressure regulator and gauge assembly in the control air supply line. Also, connect a tachometer with good accuracy to the engine.



ADJUST AIR PRESSURE

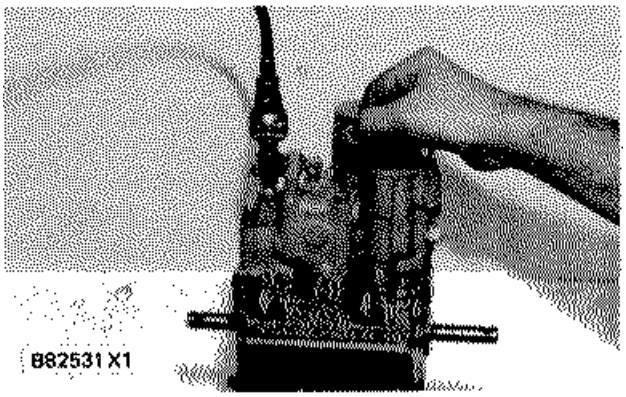
Start the engine and let it run at the low idle speed setting as given in the Fuel Setting and Related Information Fiche (for example, 600 rpm).

Turn the air pressure regulator and slowly increase and then decrease control air pressure. Engine speed must increase and decrease smoothly and return to the original speed setting (600 rpm).

Return the control air pressure with the regulator and gauge assembly to 0 kPa (O psi).

NOTE: The governor is shown off engine for photographic purposes. The pneumatic speed setting control adjustments must be made with the governor on the engine, and with the engine running.

Adjust the pressure regulator and apply the required low idle air pressure to the speed setting bellows [for example 76 kPa (11 psi)].

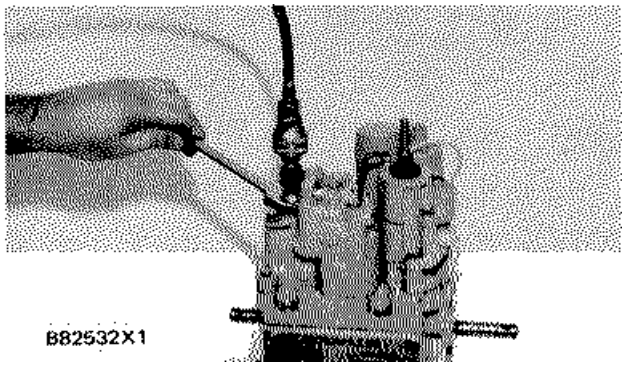


ADJUST LOW IDLE SPEED

Turn the speed level adjusting screw with a 1/8 inch hex wrench and bring the engine speed to the desired low idle speed setting (for example, 600 rpm).

Increase the control air to the high idle air pressure [for example 407 kPa (59 psi)] for the engine high idle speed setting (for example, 1980 rpm).

If the speed is too **high**, lower the air to the low idle air pressure setting [76 kPa (11 psi)].



ADJUST BELLOWS

Loosen the two bolts that hold the bellows clamp down. With a 3/4 inch wrench, rotate the bellows in a counterclockwise direction (as seen from governor nameplate). Again adjust the low idle speed setting back to 600 rpm at low air pressure [76 kPa (I psi)], turn the speed level adjusting screw clockwise.

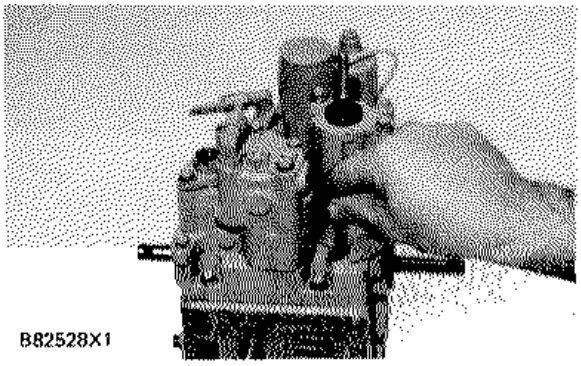
If the speed is too **low**, lower the air to the low idle air pressure [76 kPa (11 psi)].

Loosen the two bolts that hold the bellows clamp down. With the 3/4 inch wrench, turn the bellows in a clockwise direction (as seen from governor nameplate) and again adjust the low idle speed setting back to the 600 rpm at low air pressure [76 kPa (11 psi)].

Again, increase the control air to the pressure required for the high idle speed. If the speed range is still incorrect, repeat the above steps until the correct low idle speed and high idle speed setting is reached for each required air pressure. Make sure to tighten the bellows clamp bolts after the speed setting is correctly adjusted.

Check the pneumatic speed setting control for external leaks. Remove the air pressure regulator and pressure gauge assembly from the control air supply line.

AIR FUEL RATIO CONTROL ADJUSTMENTS (ON 3500 SERIES ENGINES)



ADJUSTMENT OF FUEL LIMIT LEVEL

There are three adjustments for the air fuel ratio control. One is the fuel limit level adjustment screw, the second is gain rate cam slide adjustment. The third is the cocking level setting. These last two are factory set and do not require adjustment. Any change to their settings will require the governor to be put on a test bench and correct settings made to test bench procedures.

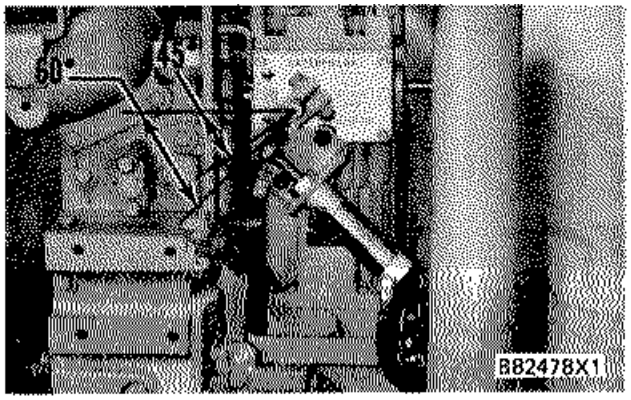
To adjust the fuel limit level, remove the plug from the right front corner of the top cover. Put a 3/16 inch hex wrench through the hole in the top cover until it engages the fuel limit level adjustment screw. Install and zero the dial indicator on the side of the engine front drive housing for checking fuel setting.

For an initial setting, turn the limit level screw in until it stops, then back it out 10 turns (about mid-travel). Start the engine and load it enough to generate boost of 10 inches of mercury to cock the control. Disconnect the air pressure line from the control to the manifold.

Rapidly move the speed control shaft in the speed increase direction. The dial indicator will go up to the fuel limit position, pause momentarily, then drop back. Do this several times and read the dial indicator during each pause. Or, load the engine until the dial indicator stops. Where the dial indicator pauses or stops, is the limit travel setting of the control. Turn the limit level screw until the dial indicator agrees with the specifications given in the Fuel Setting and Related Information Fiche.

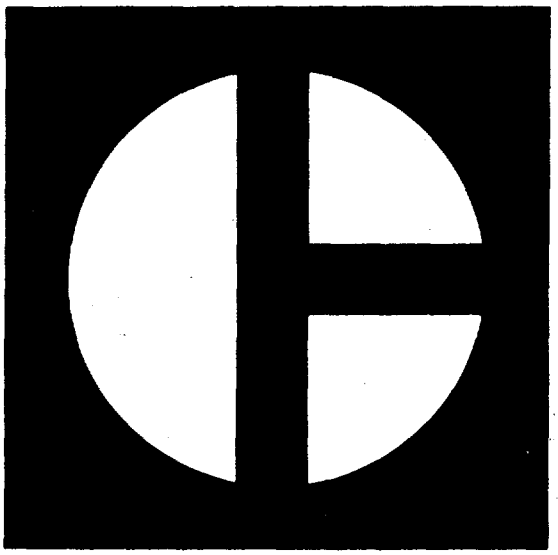
When the adjustment is correct, connect the air pressure line from the control to the manifold. Remove the hex wrench and install the plug in the top cover. Remove the dial indicator from the front drive housing.

PNEUMATIC MID-SPEED CONTROL (ON 3500 SERIES ENGINES)



PNEUMATIC MID-SPEED CONTROL ADJUSTMENT

The control cylinder mounts on the front of the governor. An adjustable lever is fastened on the speed setting control shaft. The cylinder rod is spring-actuated (extended) and air-retracted. With the cylinder retracted, and the speed setting shaft in the fuel shutoff position, set the lever at 60 degrees below the horizontal centerline. When the cylinder rod is extended the lever will move the speed setting shaft in the "FUEI ON" direction to 45 degrees below the horizontal centerline. If necessary, adjust the lever to achieve a 1400 rpm engine speed.



SPECIFICATIONS
SYSTEMS OPERATION
TESTING AND ADJUSTING

HYDRAMECHANICAL
PROTECTIVE SYSTEM

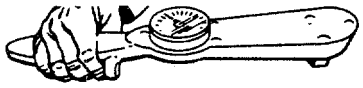
FOR

3500 SERIES ENGINES

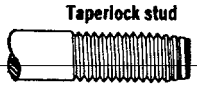
SHUTOFF CONTROL GROUP IDENTIFICATION					
Engine Model		**3508, 3512, 3516**			
Rated Engine RPM		**900-1100**	**1101-1300**	**1301-1650**	**1651-1800**
Shutoff Control Group	OS*	5N6050	5N6051	5N5338	5N5608
	LOP,* HWT, OS	5N5328	5N5329	5N5330	5N1960

*OS - Overspeed
LOP - Low Oil Pressure
HWT - High Water Temperature

GENERAL TIGHTENING TORQUE FOR BOLTS, NUTS AND TAPERLOCK STUDS



The following charts give the standard torque values for bolts, nuts and taperlock studs of SAE Grade 5 or better quality. Exceptions are given in other sections of the Service Manual where needed.

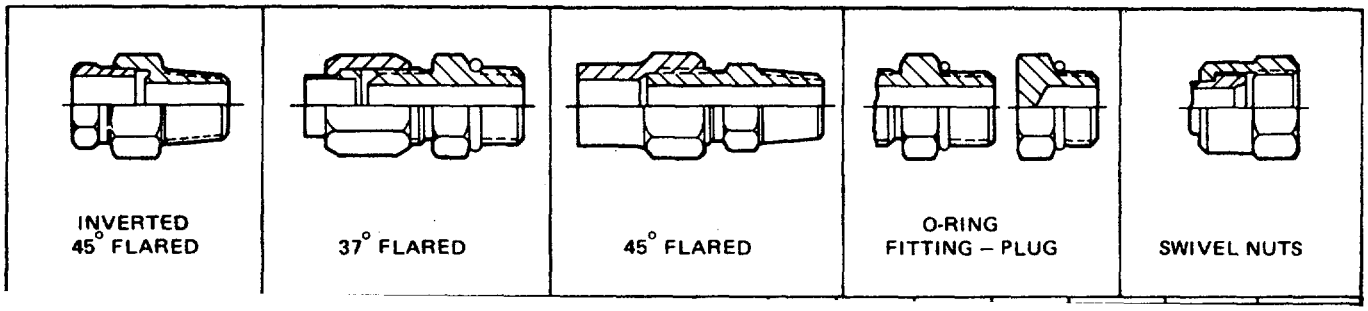
THREAD DIAMETER		STANDARD TORQUE	
inches	**millimeters**	**lb. ft.**	**N · m***
		Use these torques for bolts and nuts with standard threads (conversions are approximate).	
114	6.35	9 ± 3	12 ± 4
5/16	7.94	18 ± 5	25 ± 7
3/8	9.53	32 ± 5	45 ± 7
7/16	11.11	50 ± 10	70 ± 15
1/2	12.70	75 ± 10	100 ± 15
9/16	14.29	110 ± 15	150 ± 20
5/8	15.88	150 ± 20	200 ± 25
3/4	19.05	265 ± 35	360 ± 50
7/8	22.23	420 ± 60	570 ± 80
1	25.40	640 ± 80	875 ± 100
1 1/8	28.58	800 ± 100	1100 ± 150
1 1/4	31.75	1000 ± 120	1350 ± 175
1 3/8	34.93	1200 ± 150	1600 ± 200
1 1/2	38.10	1500 ± 200	2000 ± 275
		Use these torques for bolts and nuts on hydraulic valve bodies.	
5/16	7.94	13 ± 2	20 ± 3
3/8	9.53	24±2	35 3
7/16	11.11	39 ±2	50 ± 3
1/2	12.70	60 ±3	80 ± 4
5/8	15.88	118 ±4	160 ± 6
		Use these torques for studs with Taperlock threads.	
1/4	6.35	5 ± 2	7 ± 3
5/16	7.94	10 ± 3	15 ± 5
3/8	9.53	20 ± 3	30 ± 5
7/16	11.11	30 ± 5	40 ± 10
1/2	12.70	40 ± 5	55 ± 10
9/16	14.29	60 ± 10	80 ± 15
5/8	15.88	75 ± 10	100 ± 15
3/4	19.05	110 ± 15	150 ± 20
7/8	22.23	170 ± 20	230 ± 30
1	25.40	260 ± 30	350 ± 40
1 1/8	28.58	320 ± 30	400 ± 40
1 1/4	31.75	400 ± 40	550 ± 50
1 3/8	34.93	480 ± 40	650 ± 50
1 1/2	38.10	550 ± 50	750 ± 70

*1 newton meter (N · m) is approximately the same as 0.1 mkg.

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TORQUE FOR FLARED AND O-RING FITTINGS

The torques shown in the chart that follows are to be used on the part of 37° Flared, 45° Flared and Inverted Flared fittings (when used with steel tubing), O-ring plugs and O-ring fittings.



TUBE SIZE (O.D.)	mm	3.18	4.78	6.35	7.92	9.52	TUBE SIZE (O.D.)	mm	12.70	15.88	19.05	22.22	25.40	31.75	38.10	50.80
	in.	.125	.188	.250	.312	.375		in.	.500	.625	.750	.875	1.000	1.250	1.500	2.000
THREAD SIZE (in.)		5/16	3/8	7/16	1/2	9/16 5/8	THREAD SIZE (in.)		3/4	7/8	1 1/16	1 3/16 1 1/4	1 5/16	1 5/8	1 7/8	2 1/2
TORQUE N·m		5 ±1	11 ±1	16 ±2	20 ±2	25 ±3	TORQUE N·m		50 ±5	75 ±5	100 ±5	120 ±5	135 ±10	180 ±10	225 ±10	320 ±15
TORQUE lb.in.		45 ±10	100 ±10	145 ±20	175 ±20	225 ±25	TORQUE lb.ft.		35 ± 4	55 ± 4	75 ± 4	90 ± 4	100 ± 7	135 ± 7	165 ± 7	235 ± 10

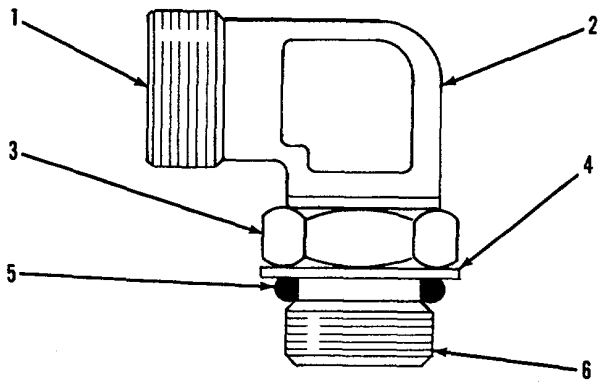
ASSEMBLY OF FITTINGS WITH STRAIGHT THREADS AND O-RING SEALS

1. Put locknut (3), backup washer (4) and O-ring seal (5) as far back on fitting body (2) as possible. Hold these components in this position. Turn the fitting into the part it is used on, until backup washer (4) just makes contact with the face of the part it is used on.

NOTE: If the fitting is a connector (straight fitting) or plug, the hex on the body takes the place of the locknut. To install this type fitting tighten the hex against the face of the part it goes into.

2. To put the fitting assembly in its correct position turn the fitting body (2) out (counterclockwise) a maximum of 359°. Tighten locknut (3) to the torque shown in the chart.

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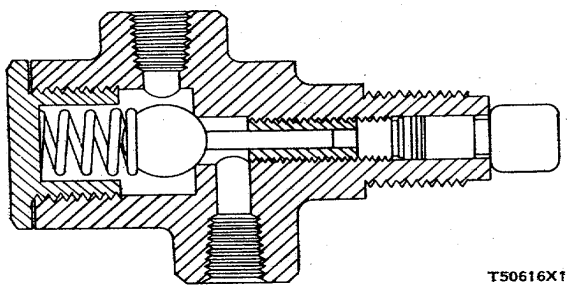


ELBOW BODY ASSEMBLY

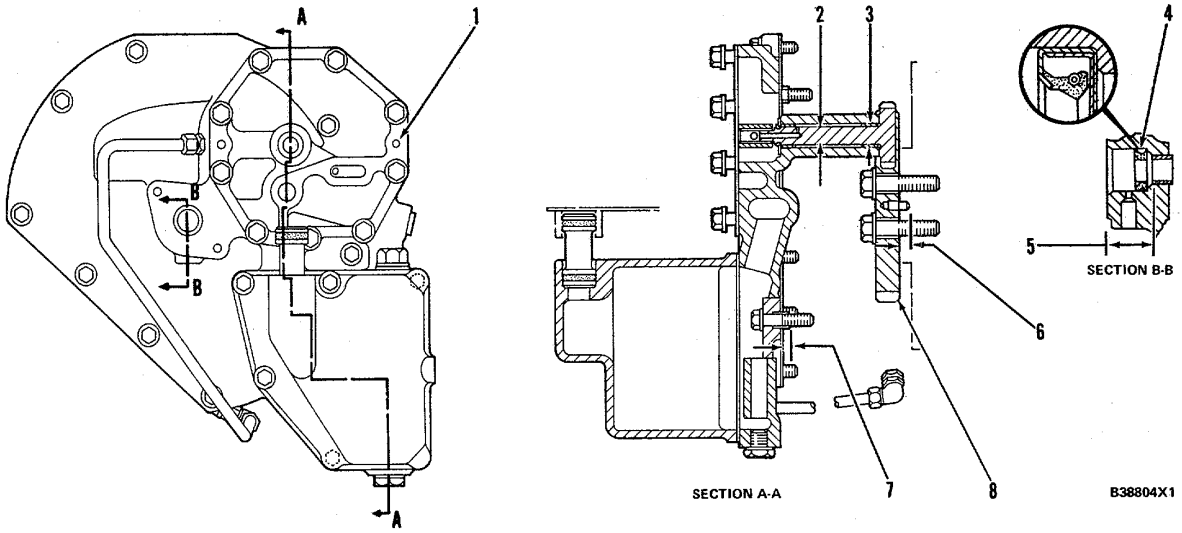
1. End of fitting body (connects to tube). 2. Fitting body. 3. Locknut. 4. Backup washer. 5. O-ring seal. 6. End of fitting that goes Into other part.

THERMOSTATIC PILOT VALVE (4L7108)

Temperature at which valve opens.....99 ± 2°C (210 ± 3°F)



ACCESSORY (SHUTOFF) DRIVE GROUP



(1) Distance dowels extend from housing..... 6.0 + 0.5 mm (.236 + .020 in.)

(2) Diameter of gear shaft - (new) .... 15.890 ± 0.013 mm (.6256 + .0005 in.)
Bore in bearings for gear shaft..... 16.027 + 0.013 mm (.6310 + .0005 in.)

(3) Diameter of bearings.... 20.70 + 0.013 mm (.8150 + .0005 in.)
Bore in housing for the bearings..... 20.66 + 0.03 mm (.813 + .001 in.)
Distance bearings are installed from ends of bore ..... 1.5 + 0.5 mm (.059 + .020 in.)

(4) Install the seal with the lip toward the engine as shown. Put clean engine oil on the lip of the seal.

(5) Distance bearing is installed ..... 26 + 1 mm (1.02 + .04 in.)

(6) Distance dowels extend from gear .....9.5 +- .0.5 mm (.374 + .020 in.)

(7) Distance two dowels extend from housing..... 6.0 + 0.5 mm (.236 + .020 in.)

(8) Drive gear. Tighten the bolts that hold drive gear (8) and the camshaft drive gear as follows:
   a. Use hand pressure to turn and hold camshaft drive gear in its of normal direction of rotation. This removes all gear clearance (backlash) between camshaft drive gear and the idler gear.
   b. Install drive gear (8) to hold camshaft drive gear to the camshaft.
   c. Tighten the bolts in steps to a torque of 100 ± 15 N ·m (75 ± 11 lb. ft.)
   d. Hit the face of drive gear (8) and tighten the bolts to a torque of 100 ± 15 N ·m (75 ± 11 lb. ft.).
   e. Again hit the face of drive gear (8) and again tighten the bolts to a torque of 100 4 15 N-m (75 + 11 lb. ft.).

NOTE: If necessary, repeat the steps above until the bolts hold torque (cannot be moved) to make sure the camshaft drive gear is in full contact with the taper of the camshaft.

NOTE: FOR TORQUE VALUES NOT GIVEN, SEE THE FIRST PAGE OF SPECIFICATIONS FOR GENERAL TIGHTENING TORQUES

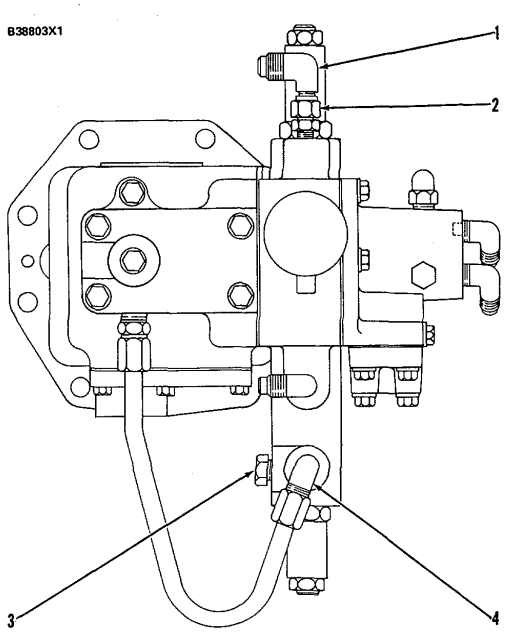
SHUTOFF CONTROL GROUP

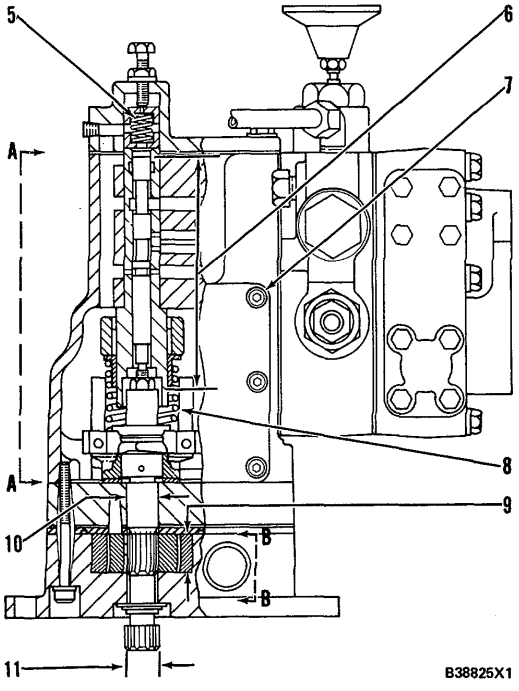
(1) Torque for 6K9194 Elbow...11 ± 3 N ·m (8 ± 2 lb. ft.)
(2) Torque for 321267 Connectors .....11 ± 3 N ·m (8 ± 2 lb. ft.)
(3) Torque for 5M6213 Plugs...11 ± 3 N ·m (8 ± 2 lb. ft.)
(4) Torque for 321268 Elbows ...11±3 N ·m (8 ± 2 lb. ft.)
(5) Spring for overspeed adjustment: See OVERSPEED SPRING CHART.

OVERSPEED SPRING CHART

Part No.	7B7714	2N7029	5N5297
Length under test force	18.3 mm (.72 in.)	31.0 mm (1.22 in.)	20.3 mm (.80 in.)
Test force	34.7 to 40.9 N (7.8 to 9.2 lb.)	18 N (4 lb.)	16 ± .05 N (3.6 ± .1 lb.)
Free length after test	33.7 mm (1.33 in.)	50.0 mm (1.97 in.)	37.3 mm (1.47 in.)
Outside diameter	11.94 mm (.470 in.)	9.53 mm (.375 in.)	9.22 mm (.363 in.)
Used with Shutoff Control Group	5N 1960 5N5608	5N5329 5N6051	5N5328 5N5330 5N5338 5N6050

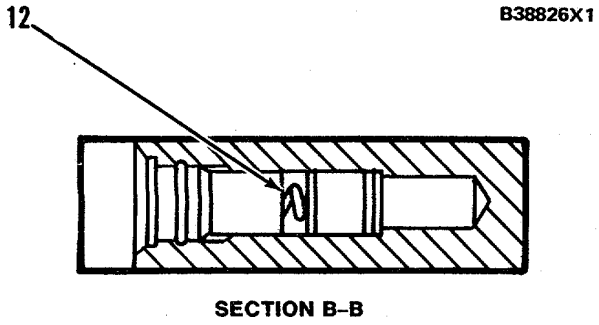
(6) Dimension from end of speed sensing valve to the seat..... 117.21 ± 0.25 mm (4.615 ± .010 in.)
(7) Torque for eight cover bolts.....3.4 ± 0.5 N-m (31 ± 4 lb. in.)
(8) Speeder Spring: See SPEEDER SPRING CHART.
(9) Thickness of geroter assembly.. 25.000 ± 0.006 mm (.9843 ± .0002 in.)
Depth of counterbore25.033 ± 0.006 mm (.9856 ± .0002 in.)
(10) Diameter of shaft ..... 14.750 ± 0.013 mm (.5807 ± .0005 in.)
Diameter of bore in cover..... 14.801 + 0.013 mm (.5827 ± .0005 in.)
(11) Diameter of shaft ..... 12.000 + 0.013 mm (.4724 ± .0005 in.)
Diameter of bore in housing.....12.051 4 0.013 (.4744 ± .0005 in.)





Shutoff Control Group (Cont.)

SPEEDER SPRING CHART					
Spring Part No.	8M 1682	3N5751	3N8403	5N5296	6N2129
Put a force on spring of	-	-	-	-	8.9 N (2.00 lb.)
Then add more force to make spring shorter by	-	-	-	-	17.8 mm (.70 in.)
Total test force	-	-	-	-	36.92 ± 0.89 N (8.307 ± .200 lb.)
Length under test force	15.8 mm (.62 in.)	38.2 mm (1.50 in.)	38.2 mm (1.50 in.)	38.2 mm (1.50 in.)	
Test force	44.5 ± 3.6 N (10 ± .8 lb.)	14.2 N (3.2 lb.)	6.23 N (1.4 lb.)	8.01 N (1.8 lb.)	
Free length after test	41.2 mm (1.62 in.)	45.0 mm (1.77 in.)	41.2 mm 1.62 in.)	45.72 mm (1.80 in.)	44.2 ± 0.5 mm (1.74 ± .02 in.)
Outside diameter	35.33 mm (1.391 in.)	35.00 mm (1.378 in.)	35.00 mm (1.378 in.)	34.60 mm (1.362 in.)	37.84 mm (1.490 in.)
Used with Shutoff Control Group	5N6051	5N1960 5N5608	5N5330 5N5338	5N5328 5N5060	5N5329

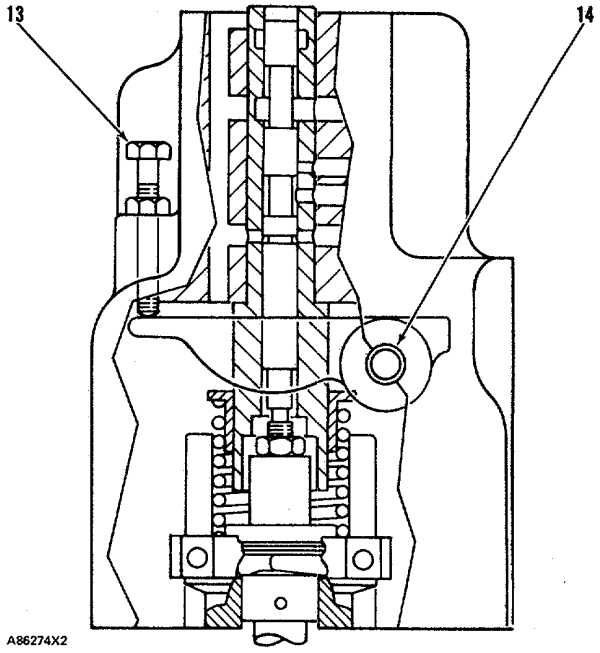


SECTION B–B

(12) 5N6449 Spring for oil pump relief valve:
Length under test force ..... 41.25 mm (1.624 in.)
Test force ..... 226.9,N (51 lb.)
Free length after test ..... 53.37 mm (2.101 in.)
Outside diameter ..... 10.59 mm (.417 in.)

(13) Speeder spring adjustment bolt used with two step oil pressure protection function.

(14) Install shaft so end is even with side of housing within..... 0.25 mm (± .010 in.)



VIEW A–A

NOTE: FOR TORQUE VALUES NOT GIVEN, SEE THE FIRST PAGE OF SPECIFICATIONS FOR GENERAL TIGHTENING TORQUES

Shutoff Control Group (Cont.)

(15) 3N5757 Spring for selector valve:
Length under test force .....25.50 mm (1.004 in.)
Test force ..... 9.8 N (2.20 lb.)
Free length after test .....37.69 mm (1.484 in.)
Outside diameter .....8.81 mm (.347 in.)

(16) 3N5738 Spring for low range oil pressure valve:
Length under test force .....30.17 mm (1.188 in.)
Test force ..... 39.1 N (8.79 lb.)
Free length after test .....66.62 mm (2.623 in.)
Outside diameter .....12.62 mm (.497 in.)

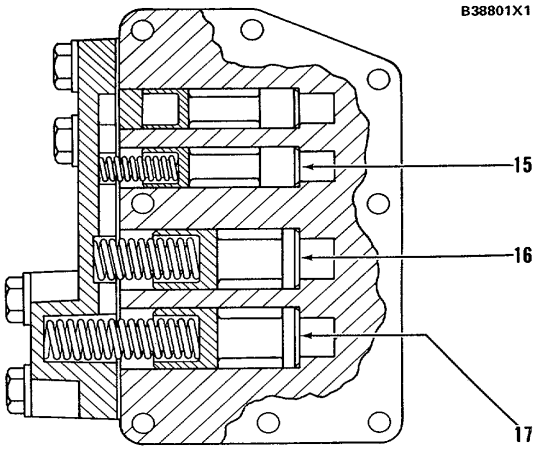
(17) 3N5739 Spring for high range oil pressure valve:
Length under test force .....44.45 mm (1.750 in.)
Test force ..... 68.9 N (15.5 lb.)
Free length after test .....111.56 mm (4.392 in.)
Outside diameter .....11.99 mm (.472 in.)

(18) 5N5755 Fuel (Rack) Shutoff Circuit Sequence Valve:
Tighten valve to a torque of 58±4 N ·m (43±3 lb. ft.)
Set valve to bypass at.....806 ± 28 kPa (117 - 4 psi) at7.57 liter/min (2 U.S. gpm)

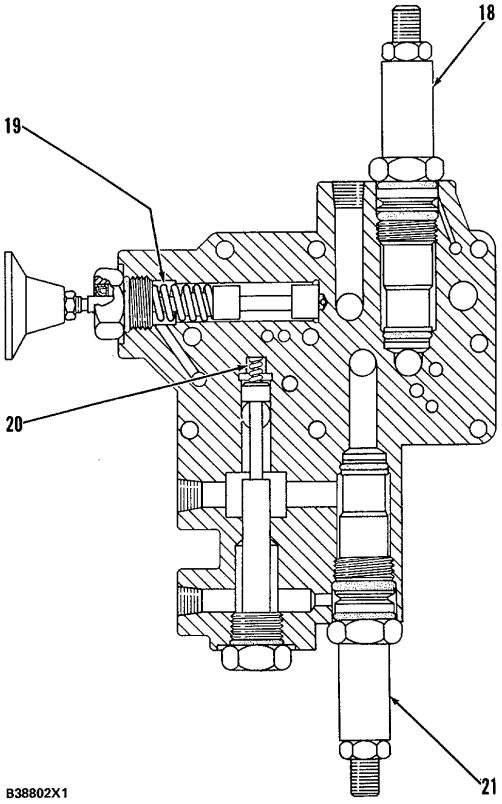
(19) 5N6096 Spring for manual shutoff valve:
Length under test force.....25.50 mm (1.004 in.)
Test force..... 19.6 N (4.4 lb.)
Free length after test .....48.77 mm (1.920 in.)
Outside diameter .....13.82 mm (.544 in.)

(20) 8H8731 Spring for pilot valve:
Length under test force.....17.86 mm (.703 in.)
Test force..... 4.3 N (.95 lb.)
Free length after test .....22.23 mm (.875 in.)
Outside diameter .....5.94 mm (.234 in.)

(21) 5N4749 Air Inlet Shutoff Circuit Sequence Valve:
Tighten valve to a torque of 58 ± 4 N ·m (43 ± 3 lb. ft.)
Set valve to bypass at....103 + 14 kPa (15 + 2 psi)

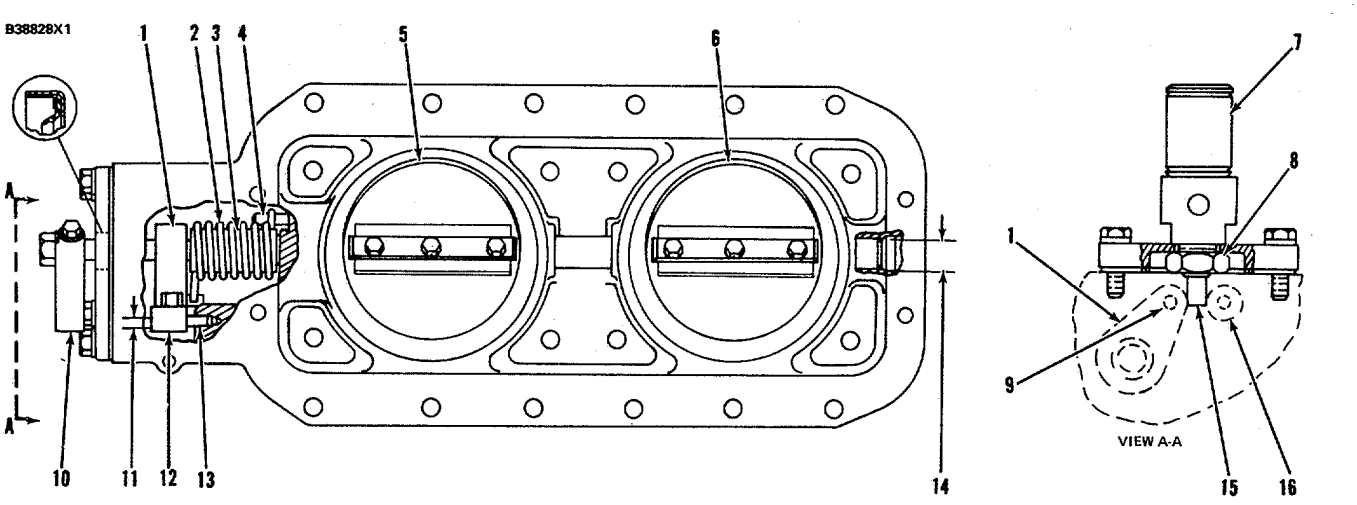


ACTUATOR VALVE



PRESSURE CONTROL VALVE

AIR INTAKE SHUTOFF
(5N9060)



(1) Install shaft assembly in housing as follows:
   a. Install spacer (3) and spring (2) on shaft assembly (1).
   b. Install the assembly in the housing. Turn spring (2) until it engages correctly with pin (4).
   c. Install handle (10) on the shaft assembly (1). Turn shaft assembly (1) upward and install pin (13) so handle (10) can rest on pin (13).
   d. With the shaft assembly and handle (10) in contact with pin (13), install plate assemblies (5) and (6) on the shaft assembly.
   e. Remove pin (13) to release the handle and let plate assemblies (5) and (6) move to the "shutoff" position. A 0.08 mm (.003 in.) feeler gauge should not pass between each plate assembly and the housing.
   f. Remove handle (10) and install spacer assembly (12), pin (13), the gasket, cover assembly and handle(10).

(2) Spring.

(3) Spacer for spring (2):
   Bore in spacer for shaft..... 20.80±0.25 mm (.819±.010 in.)
   Diameter of shaft.. 18.94 4±0.02 mm (.746±.001 in.)

(4) Pin.

(5) Plate assembly.

(6) Plate assembly.

(7) Hydraulic cylinder must be installed before the air shutoff can be installed on the engine. Put the air shutoff group in the "open" position and install the gasket, flange and cylinder with cylinder shaft (15) between the spacer assembly in the shaft lever and spacer assembly (16). The bolts that hold the unit to the aftercooler housing can now be installed.

(8) Torque for nut that holds cylinder to flange ..... 45±7 N·m (33±5 lb. ft.)

(9) Diameter of pin .....6.299 + 0.008 mm (.2480±.0003 in.)
   Bore in spacer bushing for pin (after assembly).....6.314±0.011 mm (.2486±.0004 in.)
   Bore in spacer for bushing.....7.938±0.013 mm (.3125±.0005 in.)

(10) Handle.

(11) Diameter of pin (13).....6.299±0.008 mm (.2480±.0003 in.)
   Bore in housing for pin .....6.408±0.051 mm (.2523±.0020 in.)
   Bore in spacer bushing for pin (after assembly).....6.314±0.011 mm (.2486±.0004 in.)
   Bore in spacer for bushing.....7.938±0.013 mm (.3125±.0005 in.)

(12) Spacer.

(13) Pin.

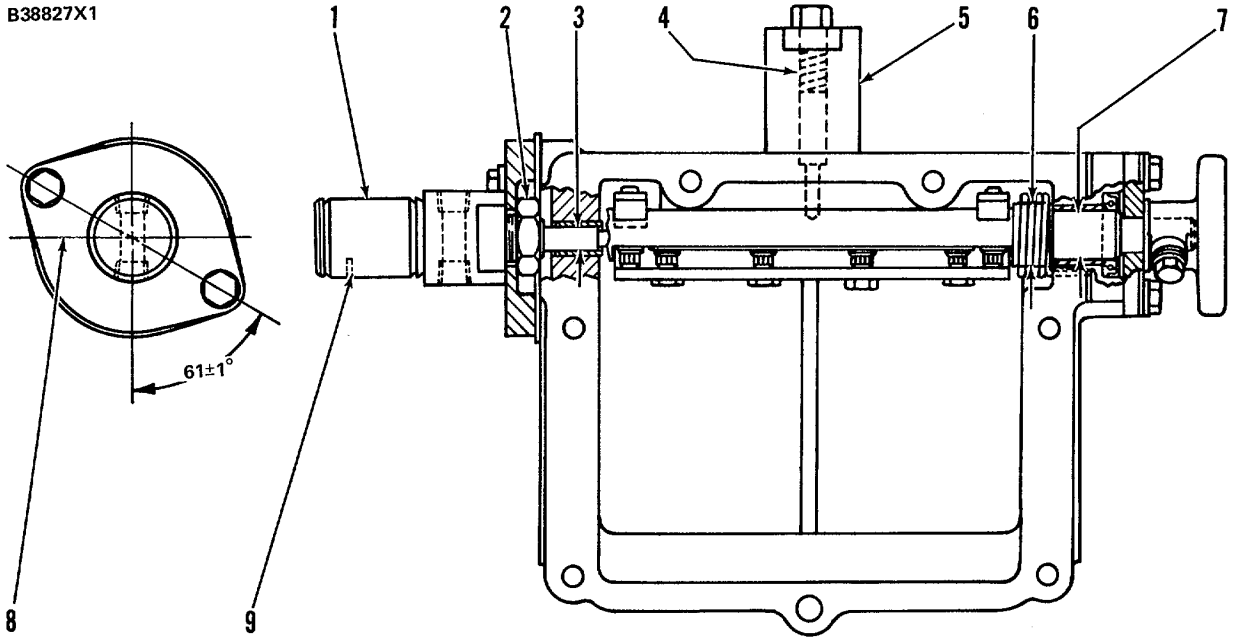
(14) Diameter of shaft.18.94±0.02 mm (.746±.001 in.)
   Inside diameter of bushings for shaft .....19.050±0.044 mm (.7500±.0017 in.)

(15) Hydraulic cylinder shaft

(16) Spacer assembly.

NOTE: FOR TORQUE VALUES NOT GIVEN, SEE THE FIRST PAGE OF SPECIFICATIONS FOR GENERAL TIGHTENING TORQUES

AIR INTAKE SHUTOFF
(2W7163)



(1) Hydraulic shutoff cylinder. Make an alignment of cylinder port and vent hole (9) in a vertical downward position at assembly.

(2) Torque for nut that holds cylinder (1) to the flange.....45±7 N ·m (33±5 lb. ft.)

(3) Diameter of cylinder rod .....7.920±0.013 (.3118±.0005 in.)
Bore in bushing after assembly ..... 7.996±0.044 mm (.3148±.0017 in.)
Bore in housing for bushing..... 9.525±0.013 mm (.3750±.0005 in.)
Install bushing with split along centerline (8) toward front or rear.

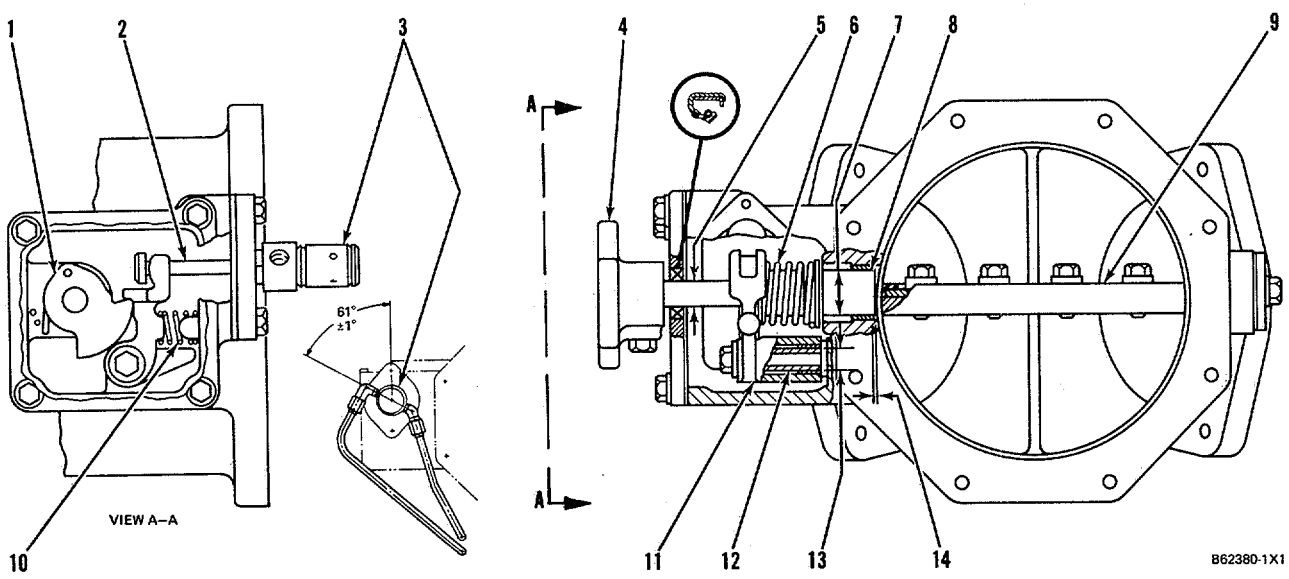
(4) 2V244 Spring for shutoff actuator pin:
Length under test force ..... 29.2 mm (1.15 in.)
Test force .....8.9±0.7 N (2.00±.16 lb.)
Free length after test.....54.6 mm (2.15 in.)
Outside diameter.....9.04 mm (.356 in.)

(5) Torque for carrier (put 2P2506 Thread Lubricant on the threads).....70±10 N ·m (50±7 lb. ft.)

(6) Bore in spring bushing.....19.30±0.25 mm (.760±.010 in.)
Diameter of shaft .....18.97±0.02 mm (.747±.001 in.)

(7) Diameter of shaft .....18.97±0.02 mm (.747±.001 in.)
Bore in two shaft bushings (after assembly)....19.050±0.044 mm (.7500±.0017 in.)
Bore in housing for bushings.....22.205±0.013 mm (.8742±.0005 in.)

AIR INTAKE SHUTOFF
(2W5216)



(1) Latch.
(2) Shutoff cylinder rod.
(3) Install shutoff cylinder as follows:
  a. Assemble shutoff cylinder on the flange at the angle shown.
  b. Tighten the nut that holds the shutoff cylinder to the flange to a torque of .....45±7 N ·m (33±5 lb. ft.)
  c. Install the flange on the air shutoff housing. Make sure cylinder rod (2) is engaged in the notch of lever (11).

NOTE: The cylinder vent hole, between the ports, must be in the downward position.

(4) Knob.
(5) Diameter of shaft assembly at seal..... 15.88±0.05 mm (.625±.002 in.)
(6) Air shutoff spring.
(7) Diameter of shaft assembly ..... 24.88±0.02 mm (.980±.001 in.)
Bore in bushings for shaft assembly (after assembly) . 25.017±0.040 mm (1.0035±.0016 in.)
Bores in housing for bearings ....27.997±0.010 mm (1.1230±.0004 in.)
(8) Shaft assembly.
(9) Plate assembly.

NOTE: With plate assembly (9) in the closed (shutoff) position, a 0.8 mm (.03 in.) feeler gauge must not pass between the plate assembly and the housing bore at any position.

(10) Lever return spring.
(11) Lever.
(12) Sleeve.
(13) Diameter of sleeve.....14.945±0.009 mm (.5995±.0004 in.)
Bore in bushing (after assembly)....15.024±0.034 mm (.6026±.0014 in.)
Bore in lever for bushing.....17.009±0.009 mm (.6823±.0004 in.)

NOTE: Install both bushings to a dimension of 0.8 + 0.3 mm (.03 + .01 in.) below the surface of lever ends.

(14) Dimension to install end of two bushings from machined housing bore .....0.35±0.15 mm (.014±.006 in.)

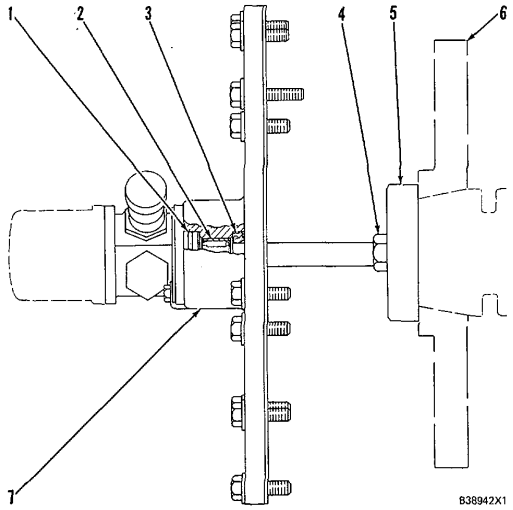
NOTE: FOR TORQUE VALUES NOT GIVEN, SEE THE FIRST PAGE OF SPECIFICATIONS FOR GENERAL TIGHTENING TORQUES

TACHOMETER AND SERVICE METER DRIVE

(1) Put clean engine oil or glycerin on the O-ring seal at assembly.
(2) Bearing.
(3) Install seal in cover (7) with the lip of the seal toward bearing (2). Put clean engine oil on the lip of the seal after it is installed.
(4) Bolts. Tighten the bolts as follows:
   a. Use hand pressure to turn and hold camshaft drive gear (6) in its normal direction of rotation. This removes all gear clearance (backlash) between camshaft drive gear (6) and the idler gear.
   b. Install tachometer drive adapter (5) to hold the camshaft drive gear to the camshaft.
   c. Tighten the bolts in steps to a torque of 100±15 N ·m (75 = 11 lb. ft.)
   d. Hit the face of tachometer drive adapter (5) and tighten bolts to a torque of 100±15 N ·m (75±11 lb. ft.).
   e. Again hit the face of tachometer drive adapter (5) and again tighten the bolts to a torque of 100 + 15 N ·m (75 + 11 lb. ft.).

NOTE: If necessary, repeat steps above until the bolts hold torque (cannot be moved) to make sure the camshaft drive gear is in full contact with the taper on the camshaft.

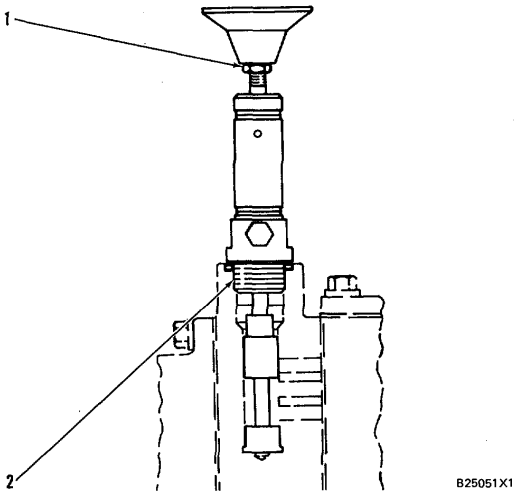
(5) Tachometer drive adapter.
(6) Camshaft drive gear.
(7) Cover.



REMOTE SHUTOFF VALVE GROUP

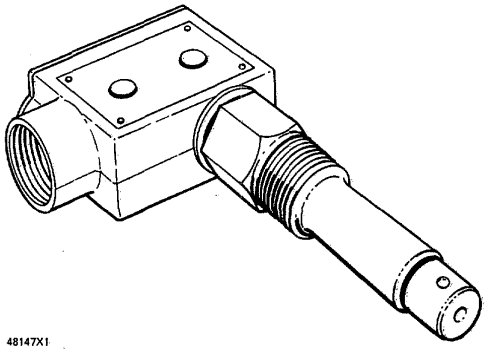
(1) Locknut.
(2) Cylinder threads.

Clean threads of cylinder and locknut (1) thoroughly. Put 9S3265
Retaining Compound on threads of cylinder and locknut at
assembly.

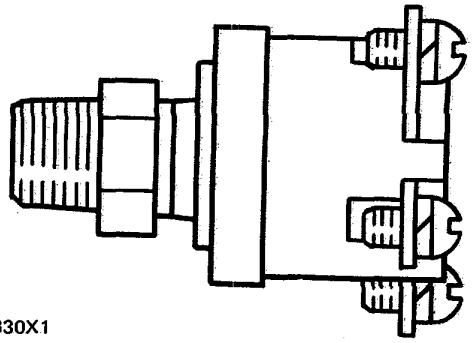


ELECTRICAL SWITCHES

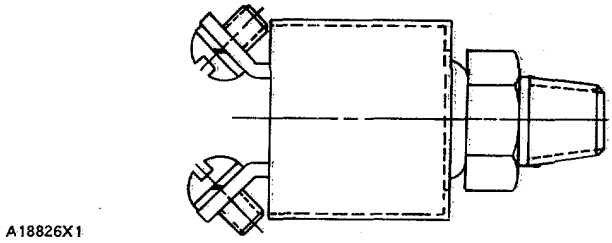
5N8597 Contactor (Coolant)
Switch operates when temperature increases
to.....98.3±0.6°C (208±1°F)



7N5946 Pressure Switch
Circuit 1: normally closed
Circuit 2: normally open
With an increase in pressure, circuit 1 opens and
circuit 2 closes at .....145 kPa (21 psi) max.
With a decrease in pressure, circuit 2 opens and
circuit 1 closes at ..... 75±20 kPa (11±3 psi)



9D7032 Pressure Switch,
With an increase In pressure; switch closes
at ..... 517±35 kPa (75±5 psi)
With a decrease in pressure, switch opens
at..... 415±35 kPa (60 4±5 psi)



NOTE: FOR TORQUE VALUES NOT GIVEN, SEE THE FIRST PAGE OF SPECIFICATIONS FOR GENERAL TIGHTENING TORQUES

HYDRAMECHANICAL PROTECTIVE SYSTEM

The hydramechanical protective system is designed as a self contained system separate from the engine governor. This system is used to activate an alarm or shutdown an engine for low oil-pressure, high coolant temperature or engine overspeed conditions.

OVERSPEED

In general, an overspeed condition is the result of a fuel system that fails to operate correctly. This in turn allows the combustion system to get more fuel than the engine load needs. The excess fuel can accelerate the engine to a point that engine failure can be the result.

The rate of engine acceleration is controlled by several factors. Friction horsepower, attached inertial loads and operating loads make up the main affects on acceleration. In most all cases, the protective system must have a response time of less than one second. Response time is the time interval between the overspeed and the actuation of the protective system. The protective system must provide this response under different conditions such as engine start up at extreme ambient temperatures and under full load operation.

For an overspeed condition the fuel control linkage is moved to the "SHUTOFF" position and the engine combustion air supply is stopped.

LOW ENGINE OIL PRESSURE

As engine speed increases, the required oil pressure for main bearing protection increases. The engine oil pump is a positive displacement type pump, therefore, engine oil pressure varies in direct proportion to speed until the pump goes on controlled bypass.

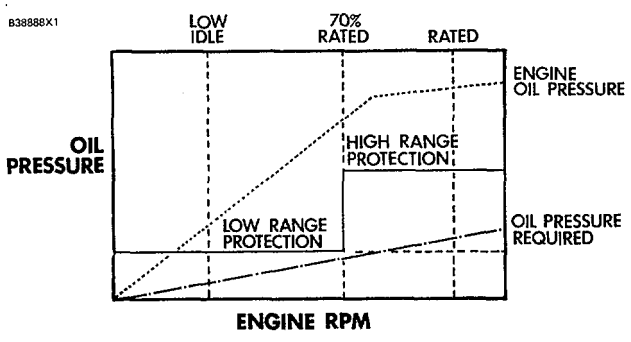


FIGURE 1. TWO-STEP OIL PRESSURE PROTECTION

From Figure 1, it can be seen that if only the low range oil pressure protection level was used for the full speed range, the engine could operate at rated speed with oil pressure below the required level. Also, if only the high range oil pressure protection level was used for the full speed range, the system would shutdown the engine at low idle, since the engine oil pump develops lower pressure at that speed. Therefore, the protective system must operate between the required oil pressure curve and the engine oil pressure curve. This is done with a step action of pressure versus speed.

The hydramechanical protective system operates within the two ranges of engine oil pressure. As engine speed increases, the minimum oil pressure needed at the main bearings also increases. At low engine speed, an alarm or fuel shutoff actuator will activate when oil pressure is reduced to within 140 $\pm$ 35 kPa (20 $\pm$ 5 psi). At high engine speeds, an alarm or fuel shutoff actuator will activate when oil pressure is reduced to within 205 $\pm$ 35 kPa (30 $\pm$ 5 psi).

For a low oil pressure condition, the protective system activates an alarm or moves the fuel control linkage, through the governor, to the "SHUTOFF" position. The combustion air supply is not shutoff for this condition.

HIGH COOLANT TEMPERATURE

If the coolant temperature of an engine goes above a set limit, the protective system activates an alarm or moves the fuel control linkage to the "SHUTOFF" position to shutdown the engine. The combustion air supply is not stopped under this condition.

SYSTEM COMPONENTS

The system consists of an emergency manual shut- off, a shutoff control group, a diverter valve, a thermostatic pilot valve, an air inlet shutoff and a fuel shutoff actuator for the governor.

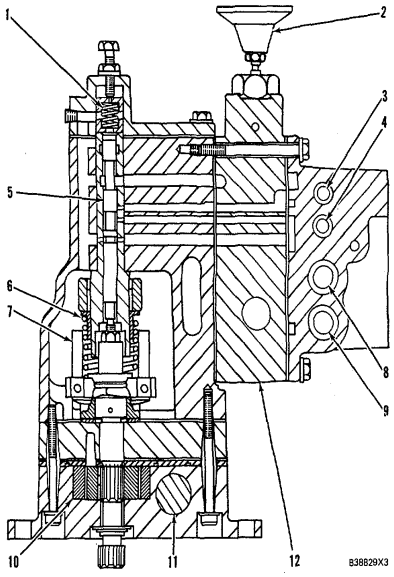
The air and fuel shutoff systems are separate from each other to give complete engine shutdown for an overspeed condition. If the engine fuel is held in the "ON" position, the air inlet shutoff must work to shutdown the engine.

Emergency Manual Shutoff

This shutoff is used under emergency conditions to shutdown the engine manually. When operated, this shutoff simulates an engine overspeed condition in the protective system. Thus, the air and fuel to the combustion chambers is stopped. The shutoff is also used to check the protective system for correct operation at regular engine maintenance periods.

The emergency manual shutoff can be operated at the engine or from a remote location. For remote operation, either air or electric power can be used.

Shutoff Control Group



SHUTOFF CONTROL GROUP

1. Spring for overspeed adjustment. 2. Emergency manual shutoff valve. 3. Valve spool (not used). 4. Selector valve. 5. Speed sensing valve spool. 6. Speeder spring. 7. Flyweights. 8. Low speed oil protection valve. 9. High speed oil protection valve. 10. Oil pump. 11. Oil pressure relief valve. 12. Pressure control valve group which consists of: the fuel and air inlet sequence valves, the two-way pilot operated valve and emergency manual shutoff valve (2).

A flyweight controlled, speed sensing valve spool is used to feel engine speed. The speed sensing valve spool is moved by flyweights which are turned by a drive shaft. The drive shaft is driven by the engine camshaft through an accessory drive group that has an oil reservoir for the shutoff system. When engine speed increases, the flyweights move out and push the speed sensing valve spool out to open and close passages to put oil pressure into the correct system circuits. This gives correct protective system operation under the two engine oil pressure ranges.

Diverter Valve

If there is a low oil pressure, high coolant temperature or engine overspeed condition, the diverter valve moves to put system oil pressure in the fuel shutoff circuit. This moves the governor and fuel control linkage to the "SHUTOFF" position to shutdown the engine.

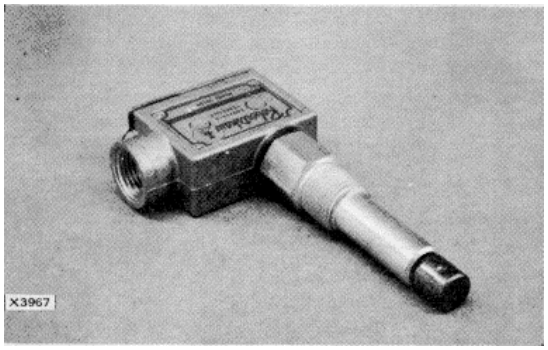
Thermostatic Pilot Valve

This valve is used to feel engine coolant temperature. If the coolant temperature goes above the limit of the thermostatic pilot valve, the valve opens and causes engine shutdown through the fuel shutoff circuit of the protective system.

Water Temperature Contactor

The contactor switch for water temperature is installed in the water manifold housing (below the regulator housing). This is normally where the thermostatic pilot valve is installed. No adjustment to the temperature range of the contactor can be made. The element feels the temperature of the coolant and then operates a micro switch (in the contactor) when the coolant temperature is too high. The element must be in contact with the coolant to operate correctly. If the cause for the engine being too hot is because of low coolant level or no coolant, the contactor switch will not operate.

The switch is connected to an alarm system and activates an alarm under high coolant temperature conditions. When the temperature of the coolant lowers to the operating range, the contactor switch opens automatically.



WATER TEMPERATURE CONTACTOR SWITCH

Air Inlet Shutoff

The air inlet shutoff consists of a shutoff valve in the engine air inlet housing and a hydraulic actuator that holds the shutoff valve in the "OPEN" position.

If an engine is operated in a combustible atmosphere, such as an oil or gas blow out on an oil rig, the air supply must be stopped to give a positive method of engine shutdown. If only the fuel control linkage was moved to the "SHUTOFF" position, the engine may continue to run on the air-oil-gas mixture pulled into the engine air intake.

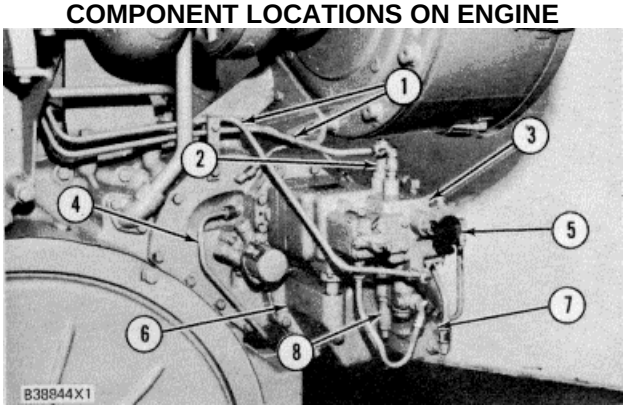
The hydramechanical protective system closes the air inlet shutoff valve to stop combustion air supply to the engine in an overspeed condition, to give a more positive shutdown. The air inlet shutoff valve is also closed when the emergency manual shutoff is operated.

Since overspeed is a serious occurrence, the air inlet shutoff must be manually reset. This action requires a person t6 physically go to the engine and see if any damage has occurred.

Fuel Shutoff Actuator

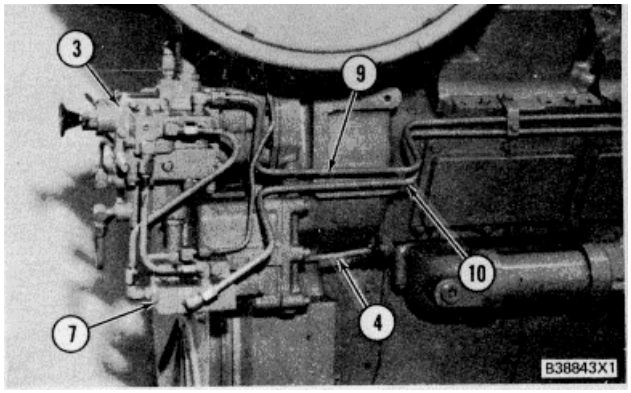
This actuator is located on top of the Woodward UG-8 or the Caterpillar 3161 Governor. The actuator can be either an electric or hydraulic actuator that is operated any time the hydramechanical protective system causes engine shutdown. When operated by the diverter valve, the actuator moves the governor shutoff strap which causes the governor to move the engine fuel control linkage to the "SHUTOFF" position.

COMPONENT LOCATIONS ON ENGINE



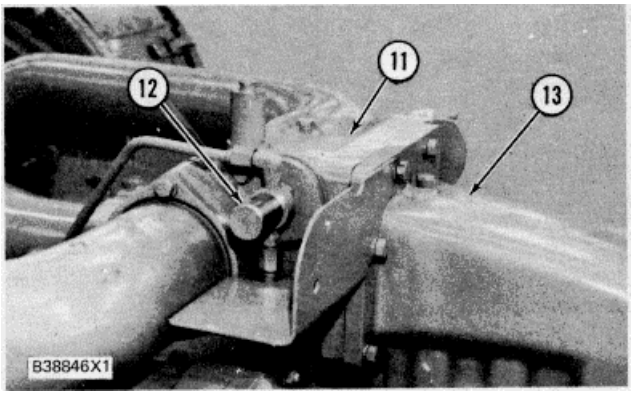
SHUTOFF CONTROL GROUP

1. Oil lines to air inlet shutoff actuator. 2. Rack sequence valve. 3. Shutoff control group. 4. Engine oil pressure line. 5. Emergency manual shutoff valve. 6. Cover (oil reservoir). 7. Diverter valve. 8. Air inlet sequence valve.



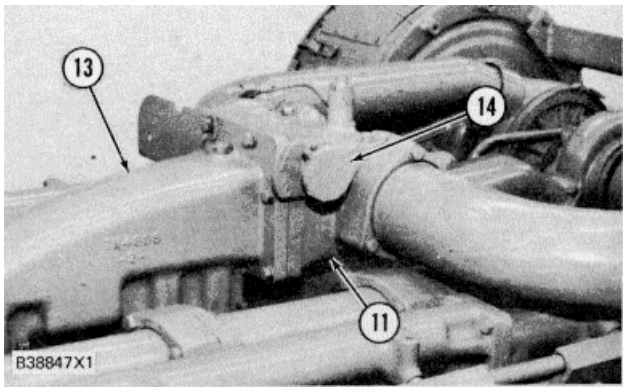
SHUTOFF CONTROL GROUP

3. Shutoff control group. 4. Engine oil pressure line. 7. Diverter valve. 9. Oil line to thermostatic pilot valve. 10. Oil line to fuel shutoff actuator.



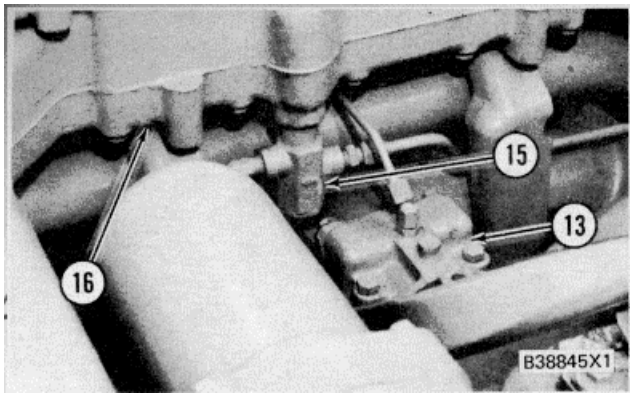
AIR INLET SHUTOFF

11. Air inlet shutoff housing. 12. Air inlet shutoff actuator. 13. Aftercooler housing.



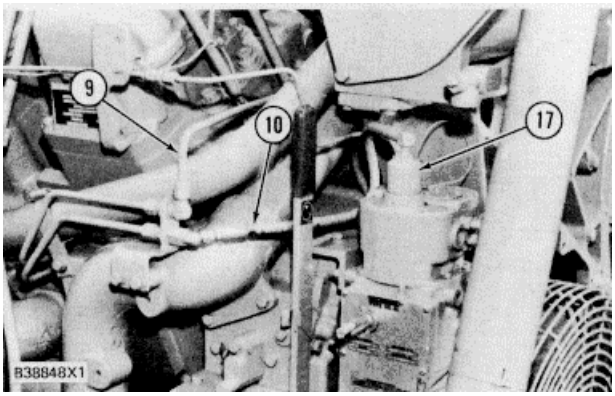
AIR INLET SHUTOFF

11. Air inlet shutoff housing. 13. Aftercooler housing. 14. Reset knob.



COOLANT TEMPERATURE PROTECTION

13. Aftercooler housing (coolant inlet). 15. Thermostatic pilot valve. 16. Housing (below regulator housing).



GOVERNOR SHUTOFF ACTUATOR
(Woodward UG-8 Governor Shown)

9. Oil line to thermostatic pilot valve. 10. Oil line to fuel shutoff actuator. 17. Fuel shutoff actuator.

SYSTEM HYDRAULICS

Engine lubrication oil (under pressure) is sent to the oil reservoir for the shutoff control. The reservoir keeps the correct level of oil for the system and drains the excess oil back into the engine. This gives a constant oil supply to the system.

An oil pump and pressure relief valve (located in the shutoff control group) supplies oil flow and pressure for the protective system hydraulic circuits.

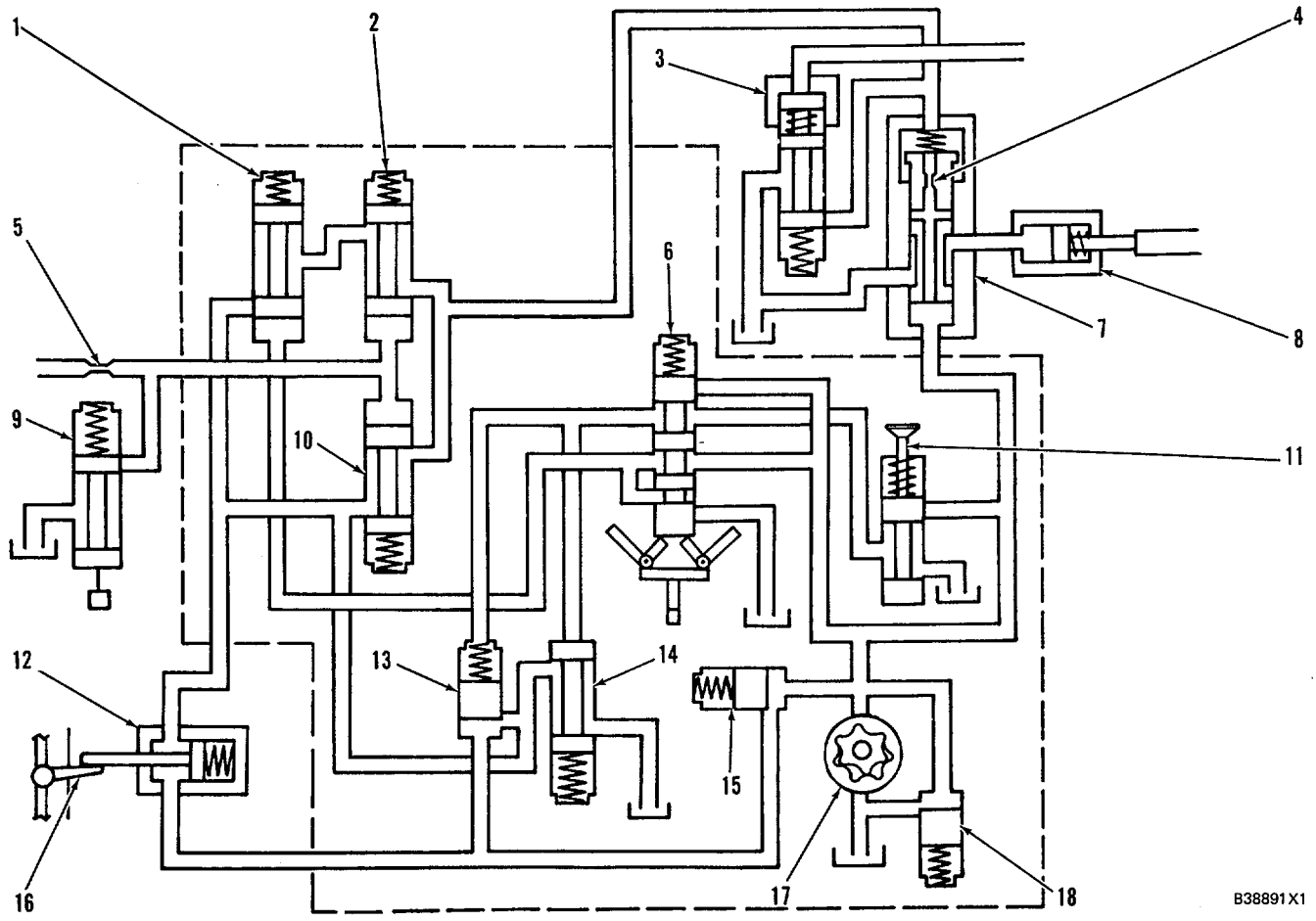
There are two main hydraulic circuits in the protective system. One circuit is for the fuel shutoff and the other is for air inlet shutoff. A constant flow of oil through the air inlet shutoff circuit removes (bleeds) air and keeps the lines full of oil to give a minimum time for system response. If a fault condition occurs, the oil pressure in one or both hydraulic circuits is increased to operate an actuator to shutdown an engine or activate an alarm.

HYDRAULIC CIRCUITS (EARLIER)

(Without Check Valves In Diverter Valve)

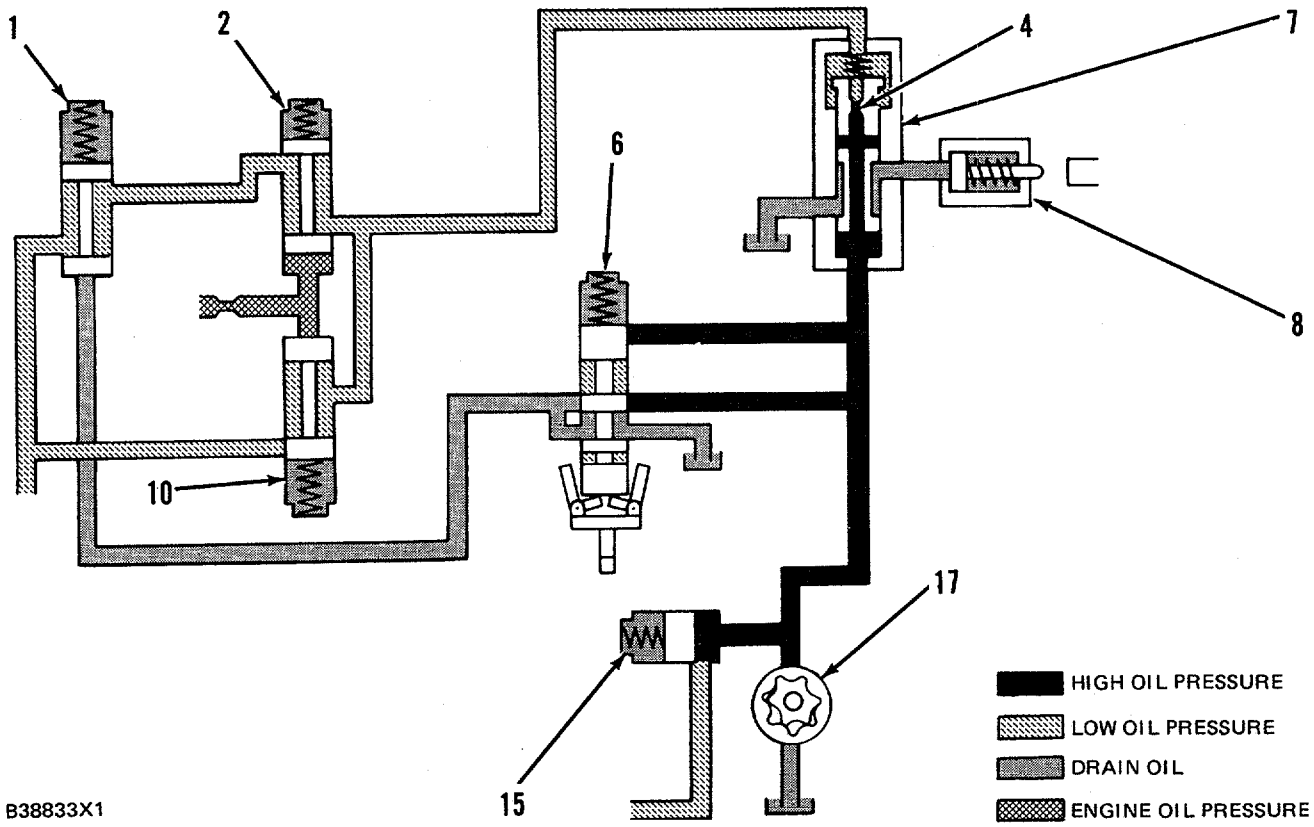
The schematics that follow, show only hydraulic actuators that are filled to cause engine shutdown. The fuel shutoff actuator can be replaced with an electric solenoid that is operated by the system hydraulics with the use of a pressure switch.

NOTE: Some of the schematics show only the components needed for explanation and do not show the complete hydramechanical protective system circuits.



SCHEMATIC NO. 1 (COMPLETE HYDRAMECHANICAL PROTECTIVE SYSTEM)

1. Selector valve. 2. Low speed oil protection valve. 3. Start-up override valve. 4. Diverter valve orifice. 5. Engine oil pressure orifice. 6. Speed sensing valve spool. 7. Diverter valve. 8. Fuel shutoff actuator. 9. Thermostatic pilot valve. 10. High speed oil protection valve. 11. Emergency manual shutoff valve. 12. Air inlet shutoff actuator. 13. Air inlet sequence valve. 14. Pilot operated two-way valve. 15. Fuel shutoff sequence valve. 16. Air inlet shutoff valve. 17. Oil pump. 18. Oil pressure relief valve.



SCHEMATIC NO. 2 (LOW ENGINE OIL PRESSURE CIRCUIT)
(Low Speed Range)

1. Selector valve. 2. Low speed oil protection valve. 4. Diverter valve orifice. 6. Speed sensing valve spool. 7. Diverter valve. 8. Fuel shutoff actuator. 10. High speed oil protection valve. 15. Fuel shutoff sequence valve. 17. Oil pump.

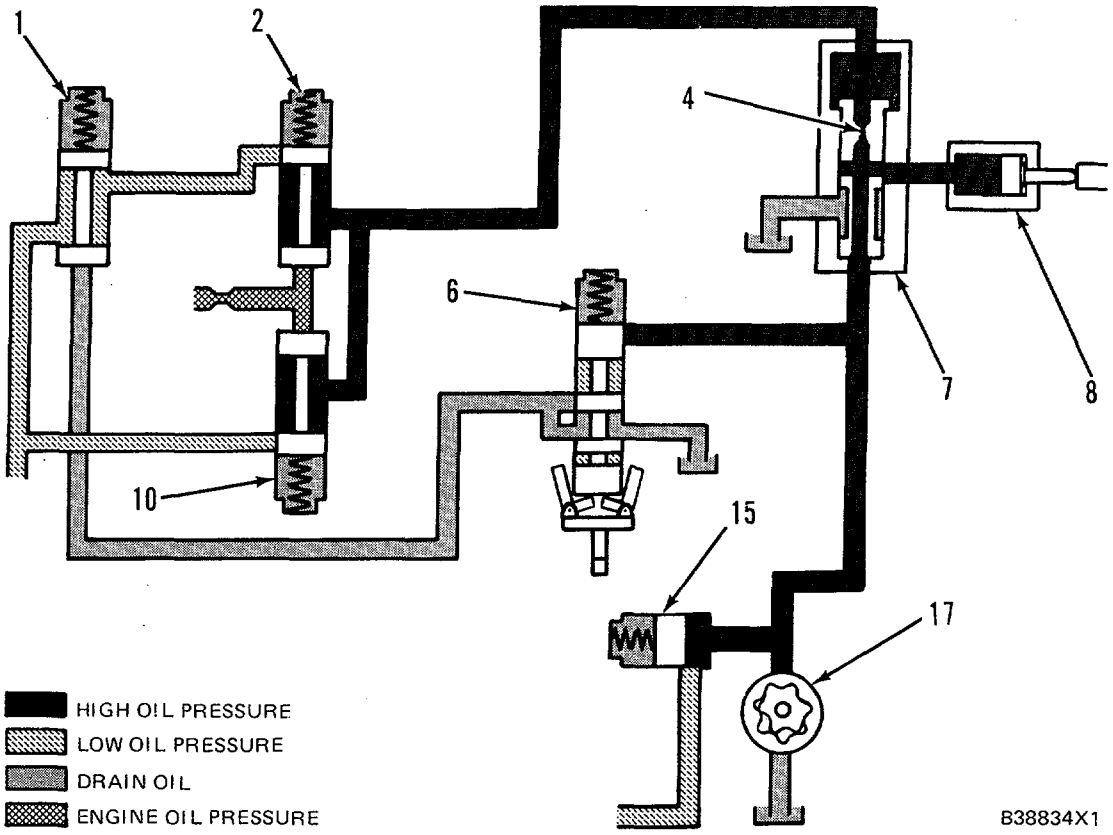
LOW SPEED RANGE (NORMAL ENGINE OIL PRESSURE)

Make Reference to Schematic No. 2

When an engine is started and speed increases, engine oil pressure moves low speed oil protection valve (2) open. At the same time, oil in the protective system flows from oil pump (17) to fuel shutoff sequence valve (15) and diverter valve (7). Fuel shut- off sequence valve (15) keeps the inlet pressure to diverter valve (7) at 760 kPa (110 psi) and then directs the remainder of oil flow through the air inlet shutoff circuit. Most of the air inlet shutoff circuit has been left out since it is not directly in use at this point.

At diverter valve (7), the oil flows through orifice (4) which causes a pressure difference across both ends of the valve spool. The valve spool is then moved by system oil pressure, against a spring force, to keep the fuel shutoff actuator from being operated. The oil then flows from diverter valve (7) to drain through low speed oil protection valve (2) and selector valve (I).

NOTE: Engine oil pressure is not high enough at this point to move valve (10) against the force of the spring.



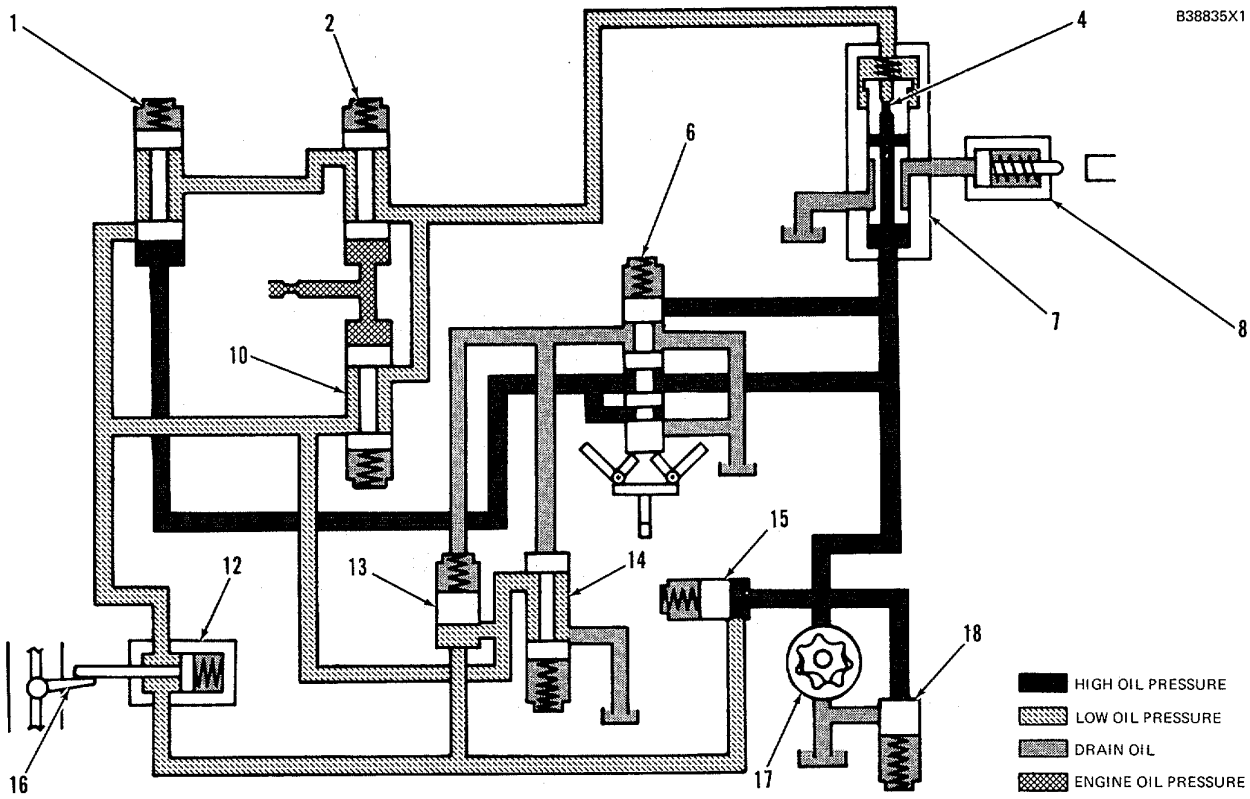
SCHEMATIC NO. 3 (LOW ENGINE OIL PRESSURE FAULT)
(Low Speed Range)

1. Selector valve. 2. Low speed oil protection valve. 4. Diverter valve orifice. 6. Speed sensing valve spool. 7. Diverter valve. 8. Fuel shutoff actuator. 10. High speed oil protection valve. 15. Fuel shutoff sequence valve. 17. Oil pump.

LOW SPEED RANGE (LOW ENGINE OIL PRESSURE FAULT)

Make Reference to Schematic No. 3

If the engine oil pressure goes below 140 kPa (20 psi), the spring force on low speed oil protection valve (2) will close the valve. The oil flow in the circuit is then stopped and can not flow to drain. The pressure of the oil will become equal to both sides of diverter valve orifice (4). Spring force will move the valve spool of diverter valve (7) down so that there is alignment with the passage that leads to fuel shutoff actuator (8). Oil pressure will now activate the fuel shutoff actuator, which will cause the governor to move the fuel control linkage to the "SHUTOFF" position and shutdown the engine.



SCHEMATIC NO. 4 (LOW ENGINE OIL PRESSURE CIRCUIT)
(High Speed Range)

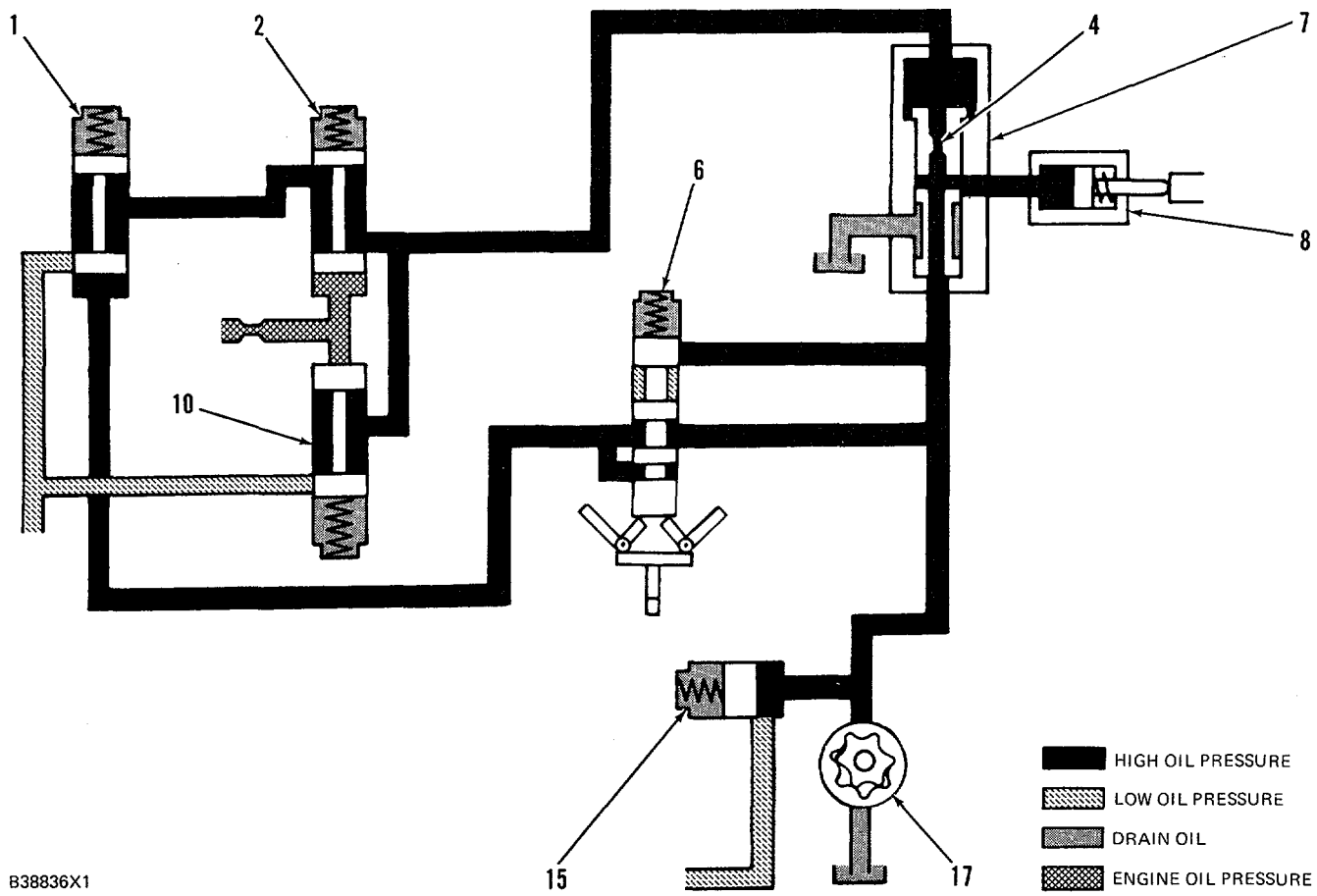
1. Selector valve. 2. Low speed oil protection valve. 4. Diverter valve orifice. 6. Speed sensing valve spool. 7. Diverter valve. 8. Fuel shutoff actuator. 10. High speed oil protection valve. 12. Air inlet shutoff actuator. 13. Air inlet sequence valve. 14. Pilot operated two-way valve. 15. Fuel shutoff sequence valve. 16. Air inlet shutoff valve. 17. Oil pump. 18. Oil pressure relief valve.

HIGH SPEED RANGE (NORMAL ENGINE OIL PRESSURE)

Make Reference to Schematic No. 4

At approximately 70% of engine full load speed, the oil pressure protection changes from the low speed range to the high speed range. At this point engine oil pressure is high enough to open high speed oil protection valve (10).

System oil flow to diverter valve (7) is the same as it is for the low speed range except speed sensing valve spool (6) has been shifted. When the engine speed increases to the high speed range, speed sens- ing valve spool (6) will be moved up by the fly- weights. This directs system oil pressure at 760 kPa (110 psi) to selector valve (1). The valve closes toL/ remove low range oil pressure protection valve (2) from the circuit. The oil now flows from diverter valve (7) to drain through high speed oil protection valve (10) and pilot operated two-way valve (14).



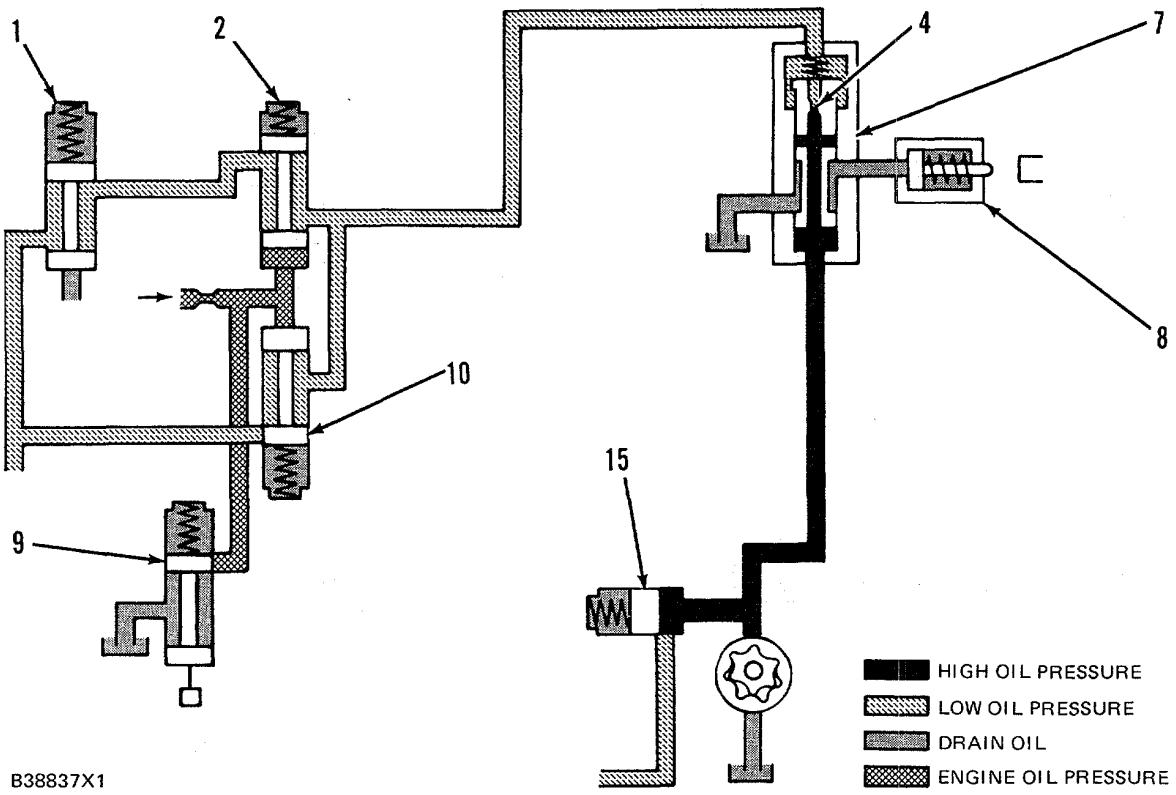
SCHEMATIC NO. 5 (LOW ENGINE OIL PRESSURE FAULT)
(High Speed Range)

1. Selector valve. 2. Low speed oil protection valve. 4. Diverter valve orifice. 6. Speed sensing valve spool. 7. Diverter valve. 8. Fuel shutoff actuator. 10. High speed oil protection valve. 15. Fuel shutoff sequence valve. 17. Oil pump.

HIGH SPEED RANGE (LOW ENGINE OIL PRESSURE FAULT)

Make Reference to Schematic No. 5

When engine oil pressure decreases to 205 kPa (30 psi), the spring force on high speed oil protection valve (10) will move the valve to stop oil flow to the drain. The difference in oil pressure across diverter valve orifice (4) will now go to zero. The valve spool of diverter valve (7) will move down by spring force, which will cause alignment of the ports to fuel shut-off actuator (8). The actuator now causes the governor to move the fuel control linkage to the "SHUT- OFF" position and shutdown the engine.



SCHEMATIC NO. 6 (ENGINE COOLANT TEMPERATURE CIRCUIT)
(Low Speed Range Shown)

1. Selector valve. 2. Low speed oil protection valve. 4. Diverter valve orifice. 7. Diverter valve. 8. Fuel shutoff actuator. 9. Thermostatic pilot valve. 10. High speed oil protection valve. 15. Fuel shutoff sequence valve.

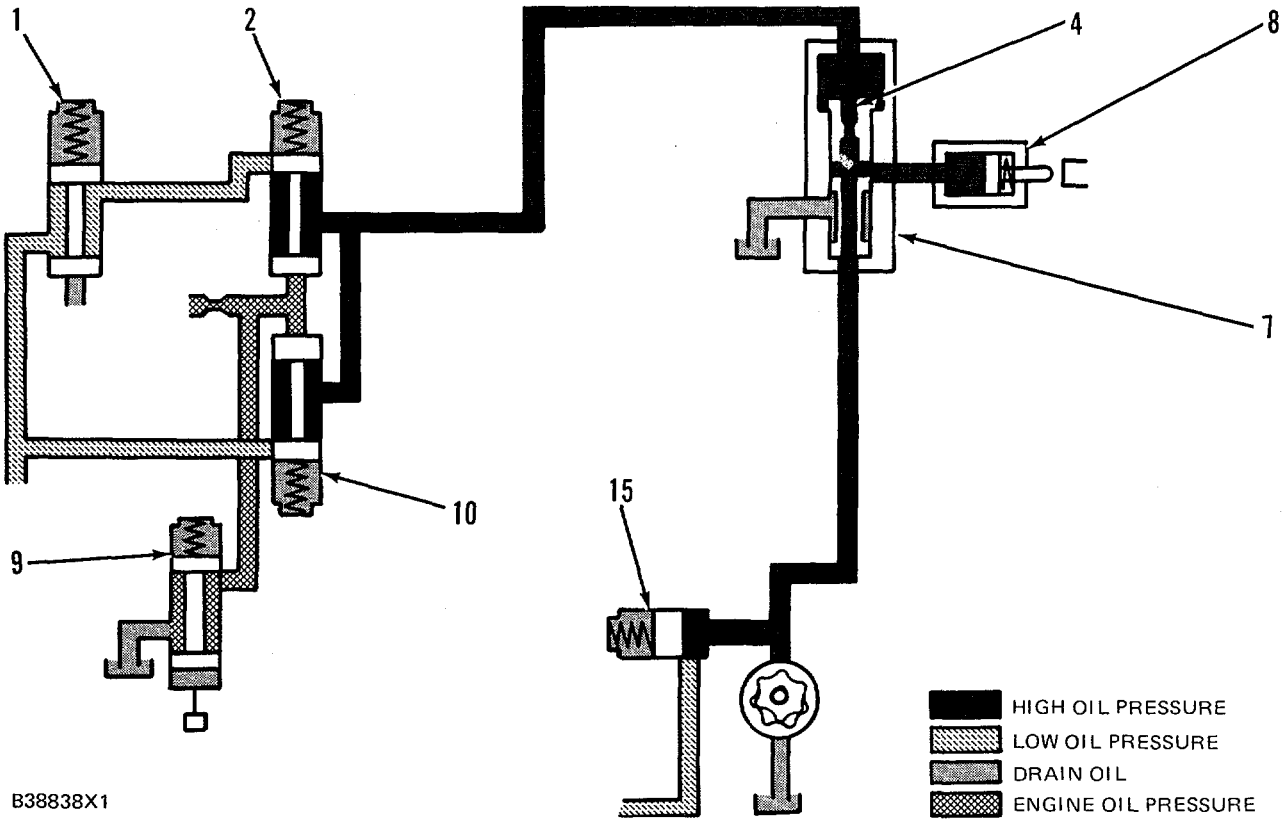
HIGH, ENGINE COOLANT TEMPERATURE CIRCUIT (NORMAL CONDITIONS)

Make Reference to Schematic No. 6

Under high coolant temperature conditions, the low engine oil pressure circuits are used to shutdown an engine. The schematic shows the low speed range engine oil pressure circuit in use and the coolant temperature circuit added to the engine oil pressure line. Engine temperature is normal and thermostatic pilot valve (9) is closed.

Oil flow through the system is the same as in the low and high speed range of the LOW ENGINE OIL PRESSURE CIRCUIT.

NOTE: The sensor of the thermostatic pilot valve (9) must be below the water level in the coolant manifold to operate.



SCHEMATIC NO. 7 (HIGH ENGINE COOLANT TEMPERATURE FAULT)

1. Selector valve. 2. Low speed oil protection valve. 4. Diverter valve orifice. 7. Diverter valve. 8. Fuel shutoff actuator. 9. Thermostatic pilot valve. 10. High speed oil protection valve. 15. Fuel shutoff sequence valve.

HIGH ENGINE COOLANT TEMPERATURE CIRCUIT (FAULT CONDITION)

Make Reference to Schematic No. 7

When engine coolant temperature increases to 99°C (2100F), thermostatic pilot valve (9) will open. This will let engine oil in the circuit drain and cause a decrease in oil pressure on low speed oil protection valve (2) and high speed oil protection valve (10). Valves (2) and (10) will close and stop oil flow from diverter valve (7). The difference in oil pressure across diverter valve orifice (4) will now go to zero. The valve spool of diverter valve (7) will move down by spring force, which will cause alignment of the ports to fuel shutoff actuator (8). The actuator now causes the governor to move the fuel control linkage to the "SHUTOFF" position and shutdown the engine.

OVERSPEED CIRCUIT (NORMAL CONDITIONS)

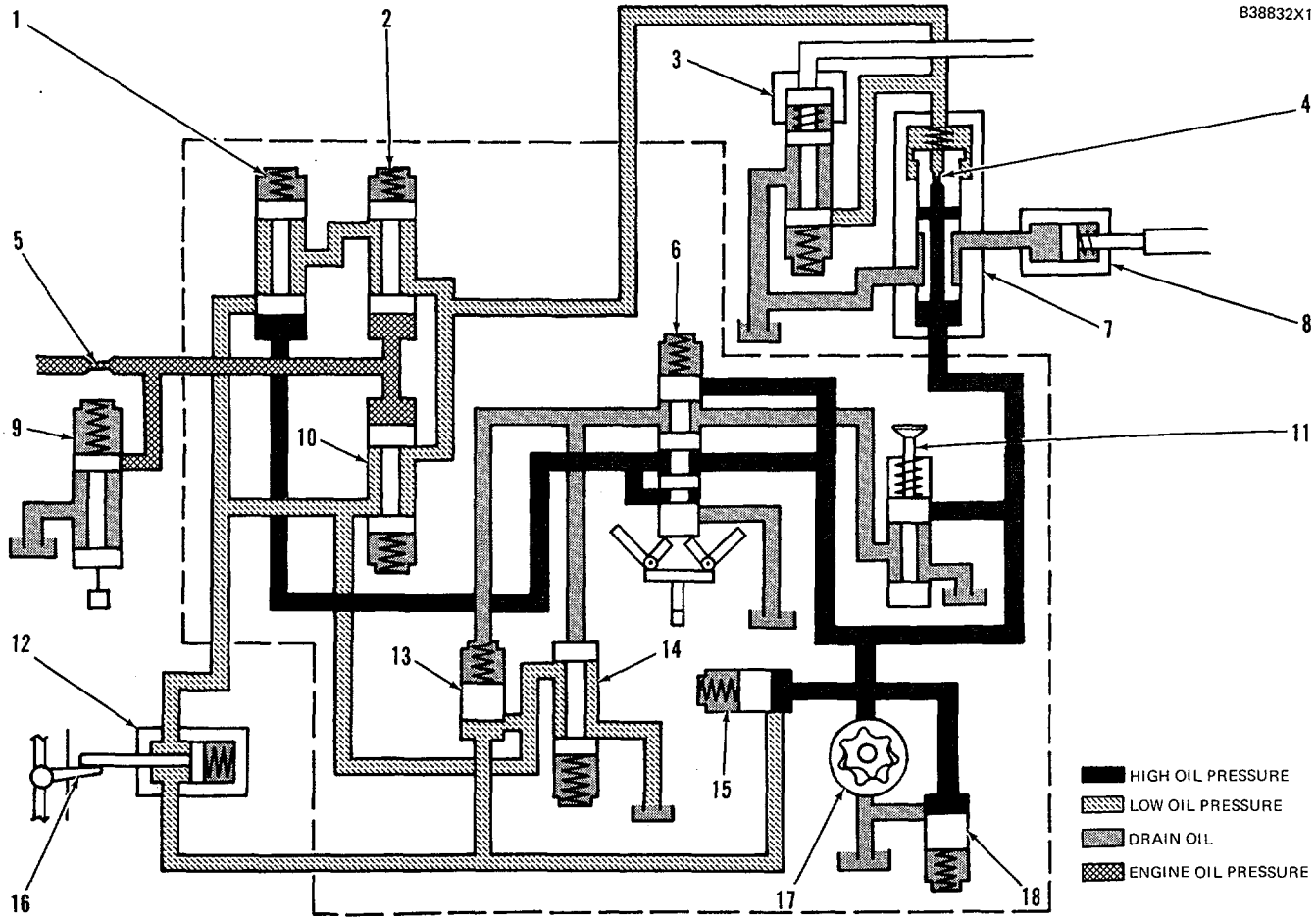
Make Reference to Schematic No. 8

When an engine is started and speed increases, engine oil pressure opens low speed oil protection valve (2) and high speed oil protection valve (10). At the same time, oil in the protective system flows from oil pump (17) to fuel shutoff sequence valve (15), speed sensing valve spool (6) and diverter valve (7). Fuel shutoff sequence valve (15) keeps the oil pressure to diverter valve (7) and speed sensing valve spool (6) at 760 kPa (110 psi) and then directs the remainder of oil flow through the air inlet shutoff circuit. At higher engine speeds, speed sensing valve spool (6) directs oil pressure to close selector valve (1).

Oil in the air inlet shutoff circuit is directed to air inlet sequence valve (13) and air inlet shutoff actuator (12). Air inlet sequence valve (13) keeps the oil pressure in air inlet shutoff actuator (12) at 105 kPa (15 psi) and then directs the remainder of oil flow to drain through pilot operated two-way valve (14), which is normally open. Pilot operated two-way valve (14) is held open by spring force and the pilot oil pressure is connected to the drain through speed sensing valve spool (6).

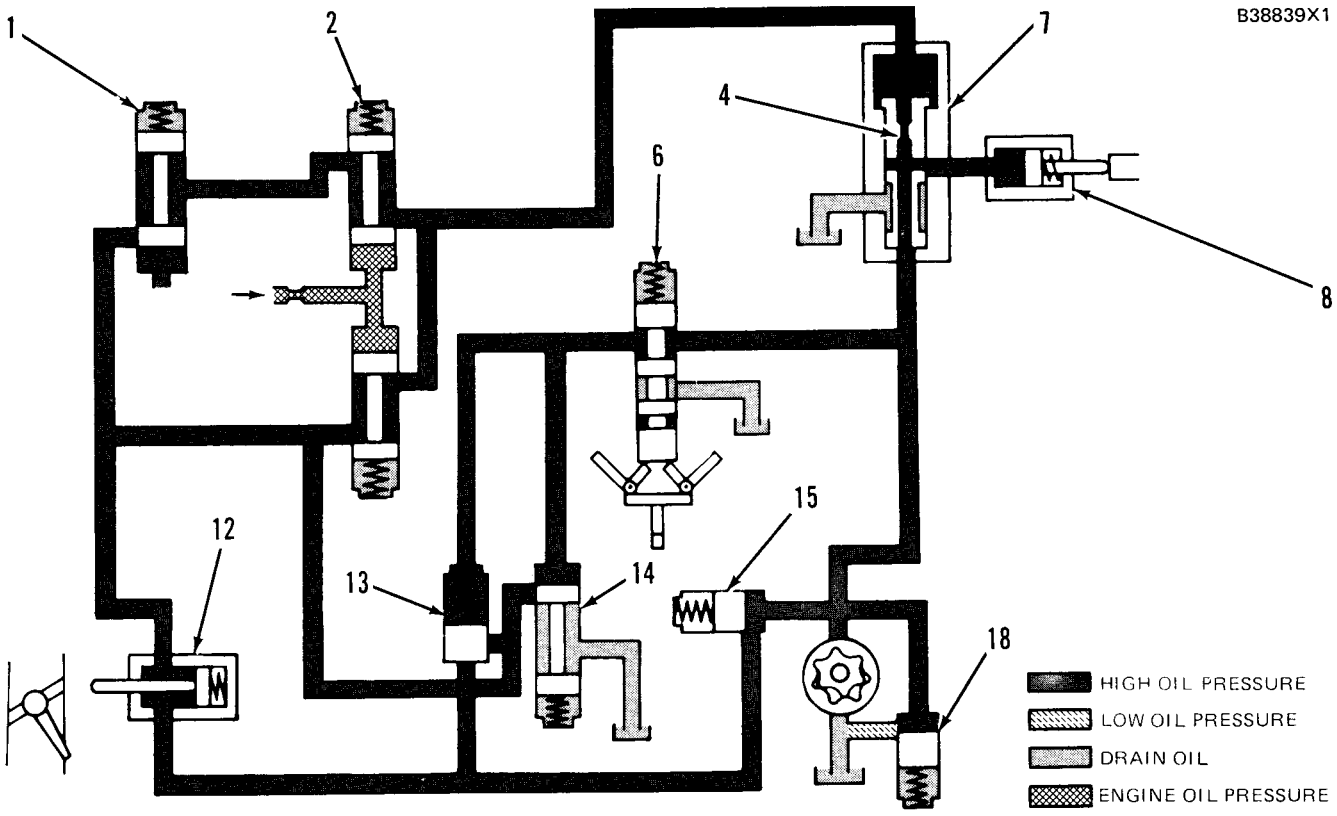
At diverter valve (7), the oil flows through orifice (4) which causes a pressure difference across both ends of the valve spool. The valve spool is then moved by system oil pressure, against a spring force, to keep the fuel shutoff actuator from being operated. The oil then flows from diverter valve (7) to drain through high speed oil protection valve (10) and pilot operated two-way valve (14).

NOTE: Low engine oil pressure or high coolant temperature conditions do not change the oil flow in the air inlet shutoff circuit.



SCHEMATIC NO.8 (OVERSPEED CIRCUIT)

1. Selector valve. 2. Low speed oil protection valve. 3. Start-up override valve. 4. Diverter valve orifice. 5. Engine oil pressure orifice. 6. Speed sensing valve spool. 7. Diverter valve. 8. Fuel shutoff actuator. 9. Thermostatic pilot valve. 10. High speed oil protection valve. 11. Emergency manual shutoff valve. 12. Air inlet shutoff actuator. 13. Air inlet sequence valve. 14. Pilot operated two-way valve. 15. Fuel shutoff sequence valve. 16. Air inlet shutoff valve. 17. Oil pump. 18. Oil pressure relief valve.



SCHEMATIC NO. 9 (OVERSPEED FAULT)

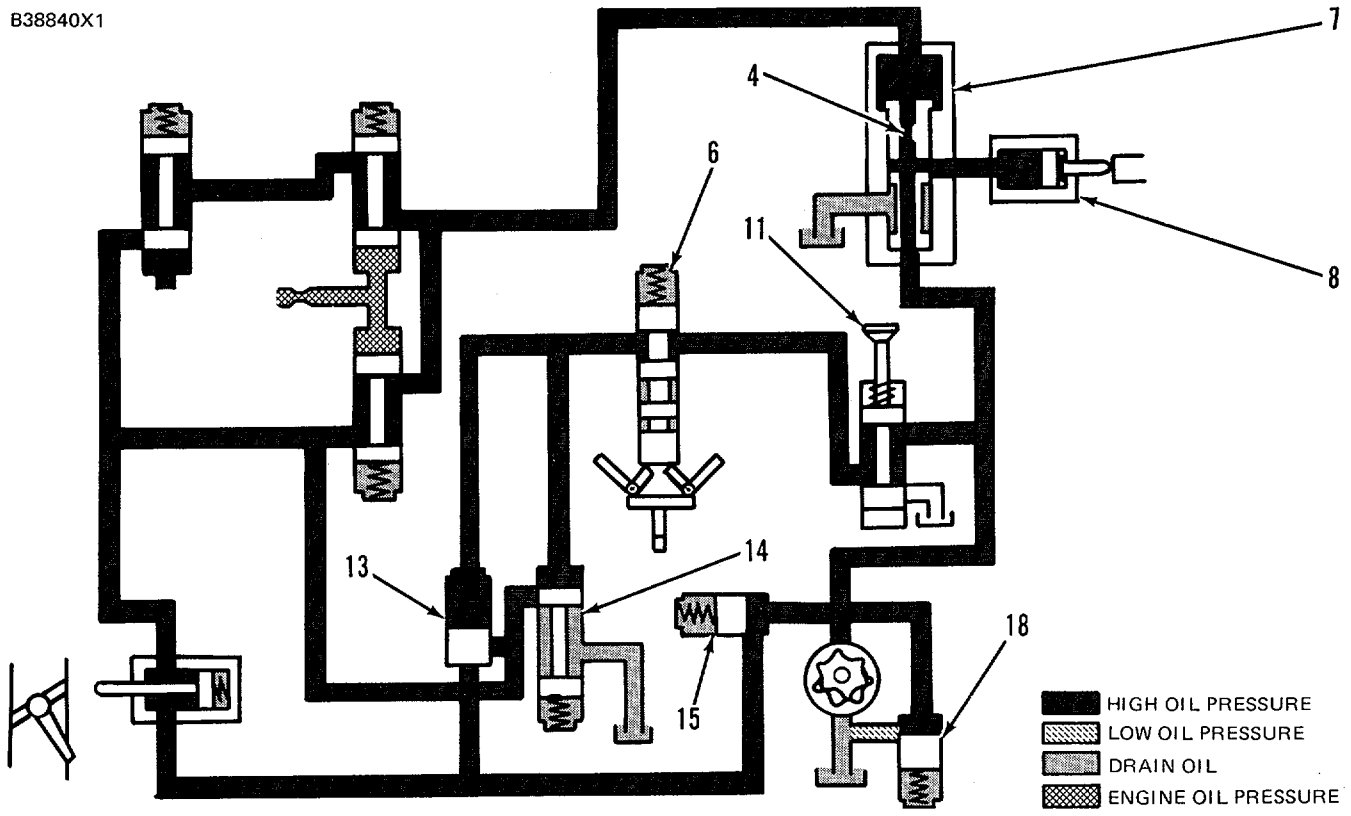
1. Selector valve. 2. Low speed oil protection valve. 4. Diverter valve orifice. 6. Speed sensing valve spool. 7. Diverter valve. 8. Fuel shutoff actuator 12. Air inlet shutoff actuator 13. Air inlet sequence valve. 14. Pilot operated two-way valve. 15. Fuel shutoff sequence valve. 18. Oil pressure relief valve.

OVERSPEED CIRCUIT (OVERSPEED FAULT)

Make Reference to Schematic No. 9.

When the engine speed is 18% above full load speed, speed sensing valve spool (6) will be moved up by the flyweights. This will send oil to pilot operated two-way valve (14) and to the spring side of air inlet sequence valve (13). The oil pressure will close both valves and oil in the air inlet shutoff system can not go to drain. The oil pressure in the system will i crease until oil pressure relief valve (18) opens at 1720kPa (250psi). The increase pressure will move air inlet shutoff actuator (12), which will release the air inlet shutoff valve. This stops the combustion air supply to the engine. Fuel shutoff circuit oil also can not go to drain. The difference in oil pressure across diverter valve orifice (4) will now go to zero. The valve spool of diverter valve (7) will move down by spring force, which will cause alignment of the ports to fuel shutoff actuator (8). Now, oil pressure in the fuel shutoff circuit will activate fuel shutoff actuator (8), which will cause the governor to move the fuel control linkage to the "SHUTOFF" position.

NOTE: Because the air inlet shutoff is the most positive way to shutdown an engine, air inlet shutoff actuator (12) is activated by the protective system before fuel shutoff actuator (8) is activated.



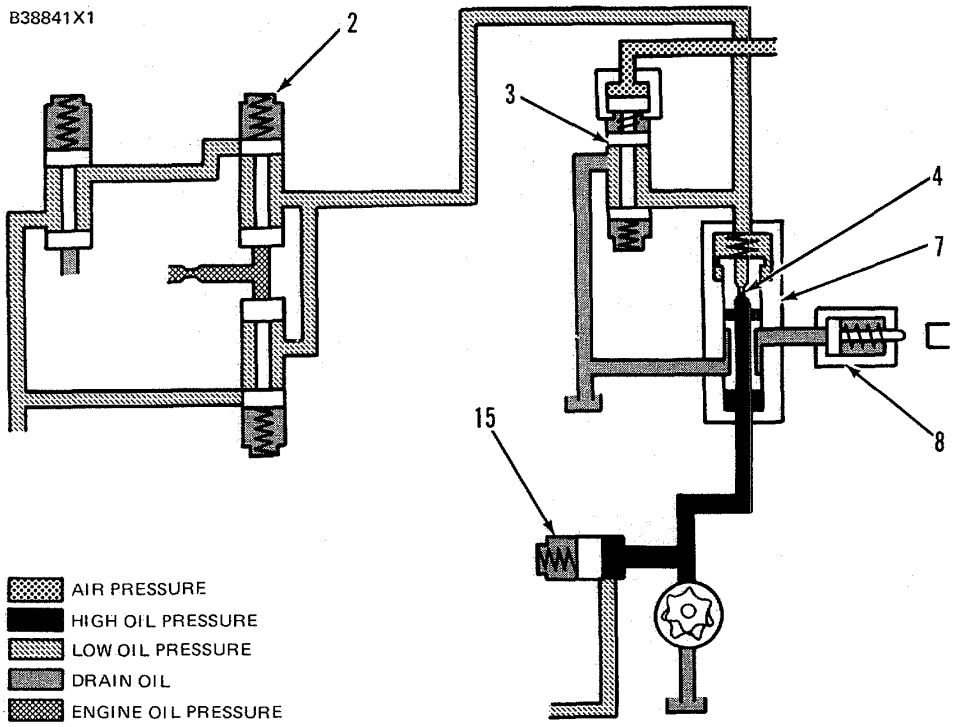
SCHEMATIC NO. 10 (EMERGENCY MANUAL SHUTOFF)

4. Diverter valve orifice. 6. Speed sensing valve spool. 7. Diverter valve. 8. Fuel shutoff actuator. 11. Emergency manual shutoff valve. 13. Air inlet sequence valve. 14. Pilot operated two-way valve. 15. Fuel shutoff sequence valve. 18. Oil pressure relief valve.

EMERGENCY MANUAL SHUTOFF

Make Reference to Schematic No. 10

When the knob on emergency manual shutoff (11) is pulled, system oil flow is directed to pilot operated two-way valve (14) to close the valve. This stops oil flow to drain in both the fuel and air inlet shutoff circuits. The protective system then, shuts down the engine in the same sequence as for an overspeed fault condition. The combustion air supply is stopped and the fuel control linkage is moved to the "SHUT- OFF" position to shutdown the engine.



SCHEMATIC NO. 11 (START-UP OVERRIDE)

2. Low speed oil protection valve. 3. Start-up override valve. 4. Diverter valve orifice. 7. Diverter valve. 8. Fuel shutoff actuator. 15. Fuel shutoff sequence valve.

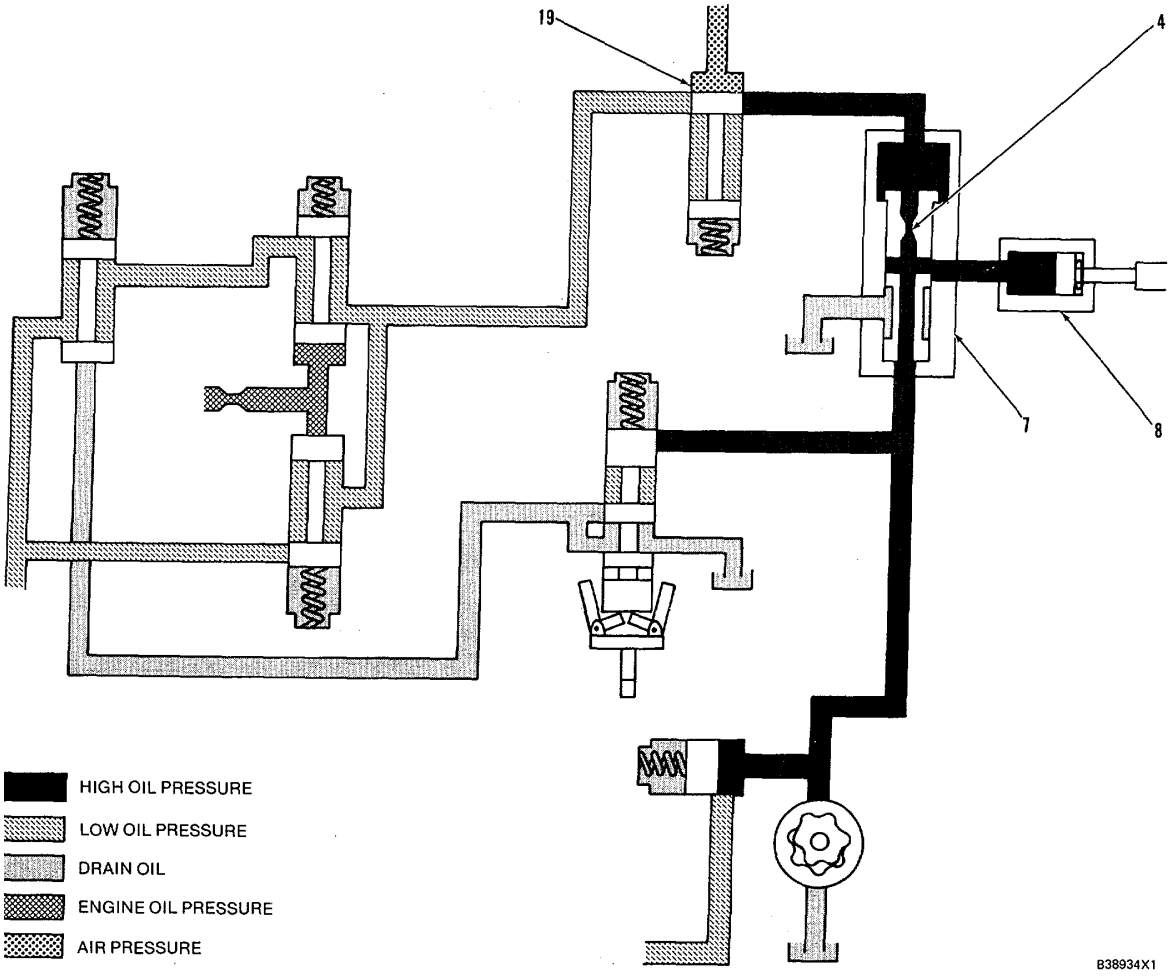
START-UP OVERRIDE OF LOW ENGINE OIL PRESSURE

Make Reference to Schematic No. 11

On a hot restart, after severe operating conditions, the engine oil pressure can increase slowly. If the rate of pressure increase is too slow, the protective system activates fuel shutoff actuator (8) to move the fuel control linkage to the "SHUTOFF" position be- cause of a low engine oil pressure fault condition. Therefore, an override of the engine oil pressure circuit is needed in the protective system.

An electric solenoid or air operated start-up over- ride valve (3) is installed in the diverter valve return line. The valve is normally closed. When start-up override valve (3) is operated, the outlet of the diverter valve is connected to drain. This maintains a pressure drop across diverter valve orifice (4) and does not let the diverter valve shift to the shutdown position.

When start-up override valve (3) is not in use, the engine oil circuit is put back into normal operation as in Schematics No. 2 and No. 4.



SCHEMATIC NO. 12 (REMOTE NORMAL SHUTOFF)

4. Diverter valve orifice. 7. Diverter valve. 8. Fuel shutoff actuator. 19. Remote normal shutoff valve.

REMOTE NORMAL SHUTOFF

Make Reference to Schematic No. 12.

The remote normal shutoff is an option that can be used with the hydramechanical protective system. An air or electric operated remote normal shutoff valve (19) is installed in the diverter valve return line. When remote normal shutoff valve (19) is operated, the outlet of the diverter valve is stopped. The oil pressure becomes equal on both sides of diverter valve orifice (4). Spring force will move the valve spool of diverter valve (7) to make an alignment of the oil passage with the oil line to fuel shutoff actuator (8). Oil pressure can now activate fuel shutoff actuator (8) which causes the governor to move the fuel control linkage to the "SHUTOFF" position and shutdown the engine.227

HYDRAULIC CIRCUITS (LATER)

(With Check Valves in Diverter Valve)

Later hydramechanical protective systems have hydraulic circuits that use check valves to hold hydraulic pressure on (lock) the fuel shutoff actuator in the "SHUTOFF" position, after the engine has been shutdown. In this system, the start-up override valve must be operated to release the hydraulic pressure from the fuel shutoff actuator before the engine can be started. Also, make sure the air inlet shutoff is in the open position before the engine is started.

The operation of these hydraulic circuits is - the same as that of the earlier hydraulic circuits except for the check valves in the diverter valve for the fuel shutoff circuit.

START-UP OVERRIDE

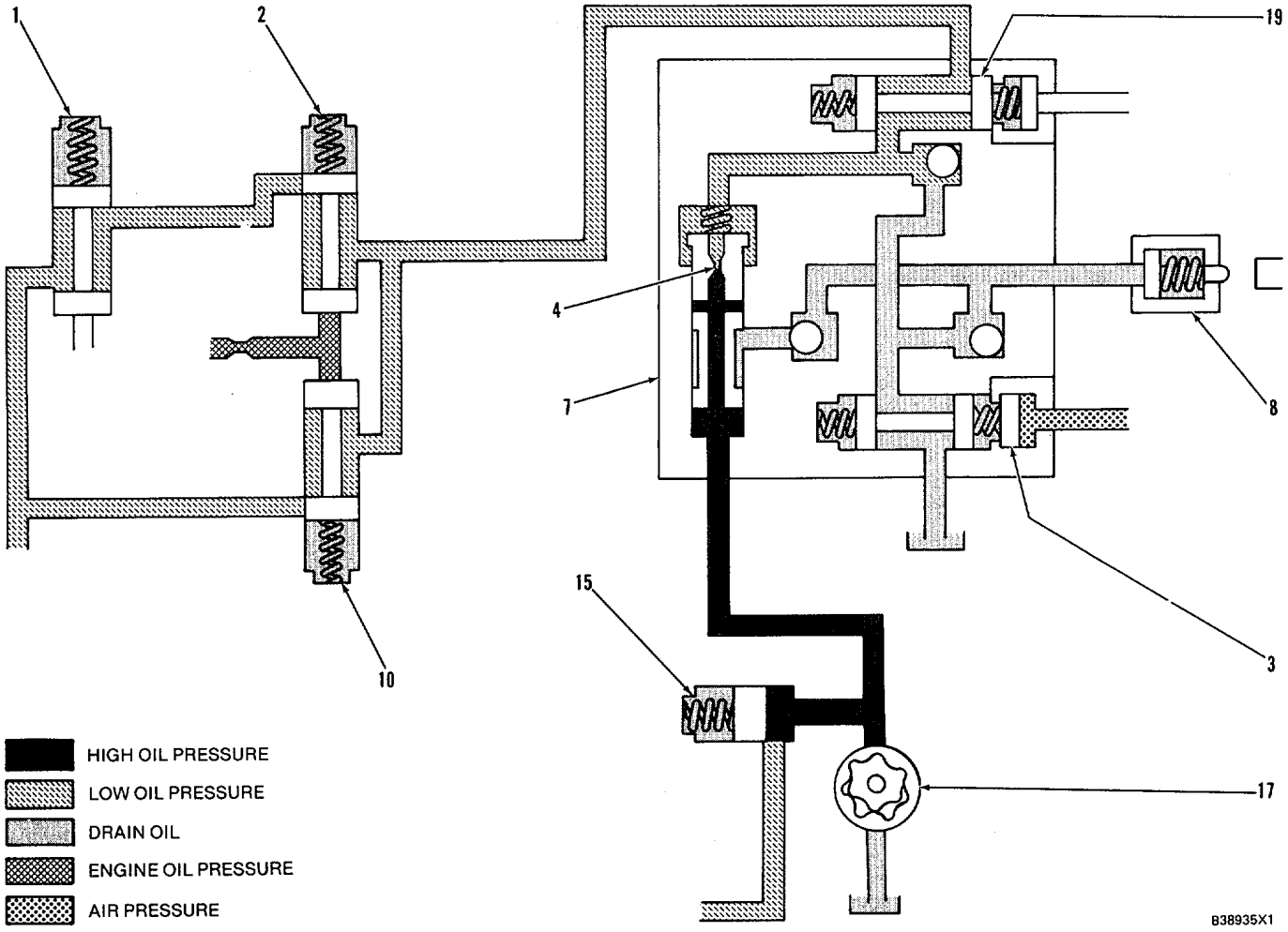
Make Reference to Schematic No. 13

When operated, the start-up override valve connects the fuel shutoff actuator circuit to drain. This removes any hydraulic pressure on the actuator so the governor can move the fuel control linkage and the engine can be started.

Also, on hot restart, after severe operating conditions, the engine oil pressure can increase slowly. If the rate of pressure increase is too slow, the protective system activates actuator (8) to move the fuel control linkage to the "SHUTOFF" position be- cause of a low engine oil pressure fault. Therefore, an override of the low engine oil pressure circuit is needed in the protective system.

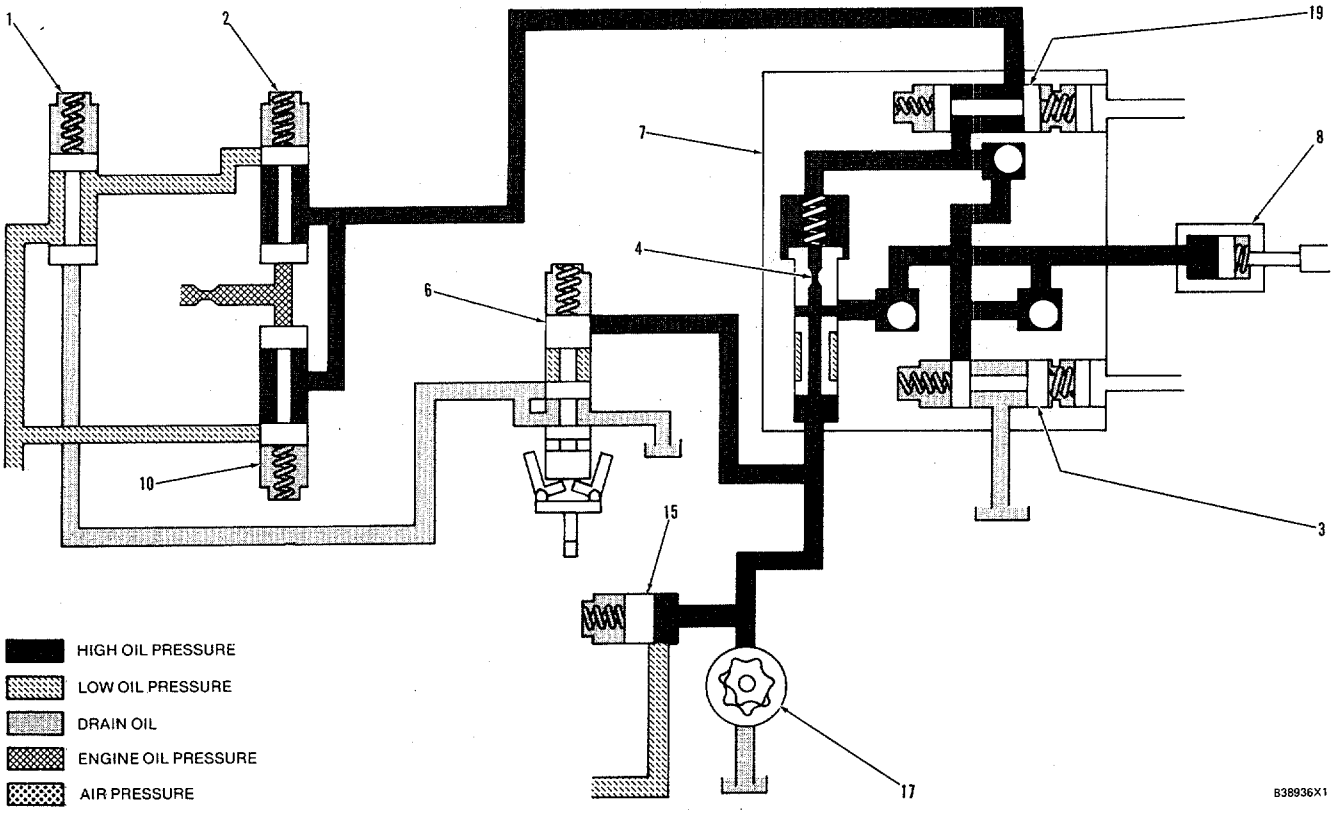
An electric solenoid or air operated start-up over- ride valve (3) is installed in the diverter valve return line. The valve is normally closed. When start-up override valve (3) is operated, the outlet of the di- verter valve is connected to drain. This maintains a pressure drop across orifice (4) and does not let the diverter valve shift to the shutdown position. The fuel shutoff actuator line is also connected to drain to make sure fuel shutoff actuator (8) does not hold the governor shutoff strap in the off position.

When start-up override valve (3) is not in use, the engine oil circuit is put back into normal operation as in Schematics No. 2 and No. 4.



SCHEMATIC NO. 13 (START-UP OVERRIDE)

1. Selector valve. 2. Low speed oil protection valve. 3. Start-up override valve. 4. Diverter valve orifice. 7. Diverter valve. 8. Fuel shutoff actuator. 10. High speed oil protection valve. 15. Fuel shutoff sequence valve. 17. Oil pump. 19. Remote normal shutoff valve.



SCHEMATIC NO. 14 (LOW ENGINE OIL PRESSURE FAULT)'

(Low Speed Range)

1. Selector valve. 2. Low speed oil protection valve. 3. Start-up override valve. 4. Diverter valve orifice. 6. Speed sensing valve spool. 7. Diverter valve. 8. Fuel shutoff actuator. 10. High speed oil protection valve. 15. Fuel shutoff sequence valve. 17. Oil pump. 19. Remote normal shutoff valve.

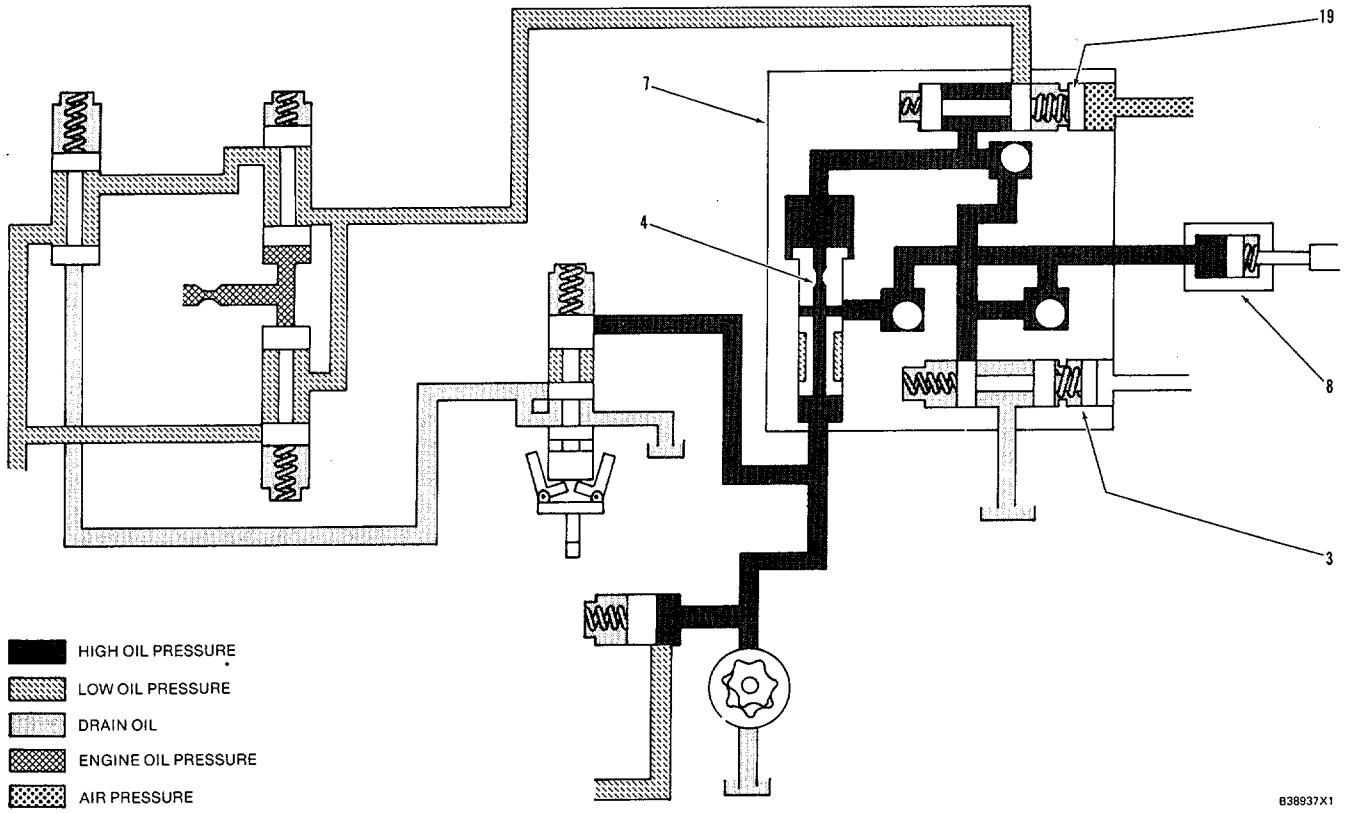
LOW SPEED RANGE (LOW ENGINE OIL PRESSURE FAULT)

Make Reference to Schematic No. 14

If the engine oil pressure goes below 140 kPa (20 psi), the spring force on low speed oil protection valve (2) will close the valve. The oil flow in the circuit is then stopped and can not flow to drain. The pressure of the oil will become equal on both sides of diverter valve orifice (4). Spring force will move the valve spool of diverter valve (7) down so that there is alignment with the passage that leads to fuel shutoff actuator (8). Oil pressure will now move the fuel shutoff actuator which will cause the governor to move the fuel control linkage to the "SHUTOFF" position and shutdown the engine.

As the crankshaft rpm becomes slower, the governor feels the speed reduction and moves the terminal shaft and linkage in the fuel "ON" direction, against fuel shutoff actuator (8). This moves the protective system oil back toward the system oil pump. The check valves in diverter valve (7) move to stop this oil flow and keep the engine from surging.

NOTE: The start-up override valve (3) must be operated to release the fuel shutoff actuator hydraulic pressure before the engine can be started.



SCHEMATIC NO. 15 (REMOTE NORMAL SHUTOFF)

3. Start-up override. 4. Diverter valve orifice. 7. Diverter valve. 8. Fuel shutoff actuator. 19. Remote normal shutoff valve.

REMOTE NORMAL SHUTOFF

Make Reference to Schematic No. 15

The remote normal shutoff is an option that can be used with the hydramecahnical protective system. An air or electric operated remote normal shutoff valve (19) is installed in the diverter valve return line. When remote normal shutoff valve (19) is operated, the outlet of the diverter valve is stopped. The oil pressure becomes equal on both sides of diverter valve orifice (4). Spring force will move the valve spool of diverter valve (7) to make an alignment of the oil passage with the oil line to fuel shutoff actuator (8). Oil pressure can now activate the fuel shutoff actuator, which causes the governor to move the fuel control linkage to the "SHUTOFF" position and shutdown the engine.

As the crankshaft rpm becomes slower, the governor feels the speed reduction and moves the terminal shaft and linkage in the fuel "ON" direction, against fuel shutoff actuator (8). This moves the protective system oil back toward the system oil pump. The check valves in diverter valve (7) move to stop this oil flow and keep the engine from surging.

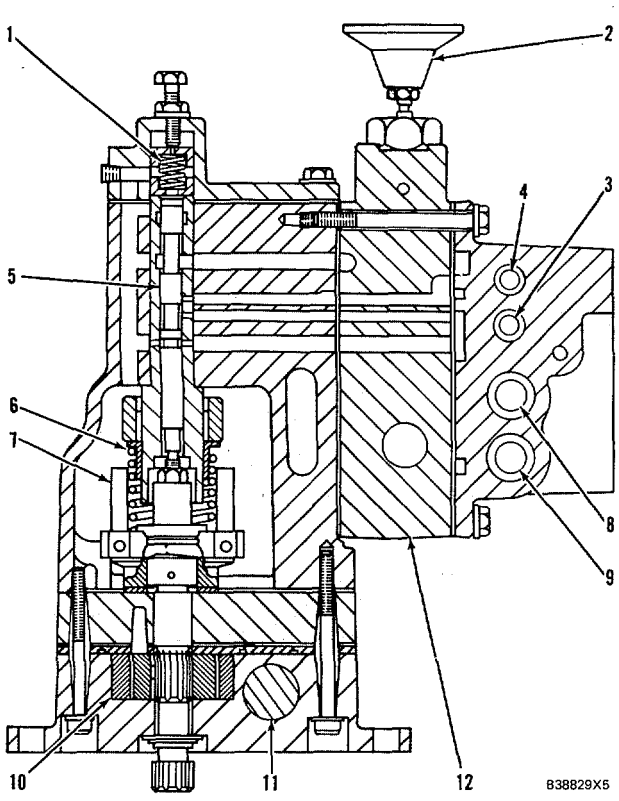
NOTE: The start-up override valve (3) must be operated to release the fuel shutoff actuator hydraulic pressure before the engine can be started.

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LATER HYDRAULIC CIRCUITS WITH AN ALARM SYSTEM

This hydramechanical protective system is designed to give automatic engine shutdown from an overspeed condition only. An alarm is activated for low engine oil pressure and high coolant temperature conditions.

The main difference between this system and systems shown in the EARLIER and LATER HYDRAULIC CIRCUITS, is that the fuel shutoff circuit oil return from the diverter valve is connected with the air inlet shutoff circuit return, and not to the normal fuel shutoff return port on the shutoff control group. A normally open pressure switch (13) is in- stalled in the shutoff control group at the location the diverter valve oil return line is normally connected. Also, there is an orifice plug [orifice (14)] installed in the shutoff control group. The orifice plug is located in the valve body that holds valves (4), (8) and (9). In the hydraulic circuit, this orifice is between the oil pressure supply and the low and high oil pressure protection valves (8) and (9).



SHUTOFF CONTROL GROUP

1. Spring for overspeed adjustment. 2. Emergency manual shutoff valve. 3. Selector valve. 4. Valve spool (not used). 5. Speed sensing valve spool. 6. Speeder spring. 7. Flyweights. 8. Low speed oil protection valve. 9. High speed oil protection valve. 10. Oil pump. 11. Oil pressure relief valve. 12. Pressure control valve group which consists of: the fuel and air inlet sequence valves, the two-way pilot operated valve and emergency manual shutoff valve (2).

OVERSPEED CIRCUIT (NORMAL CONDITIONS)

Make Reference to Schematic No. 16

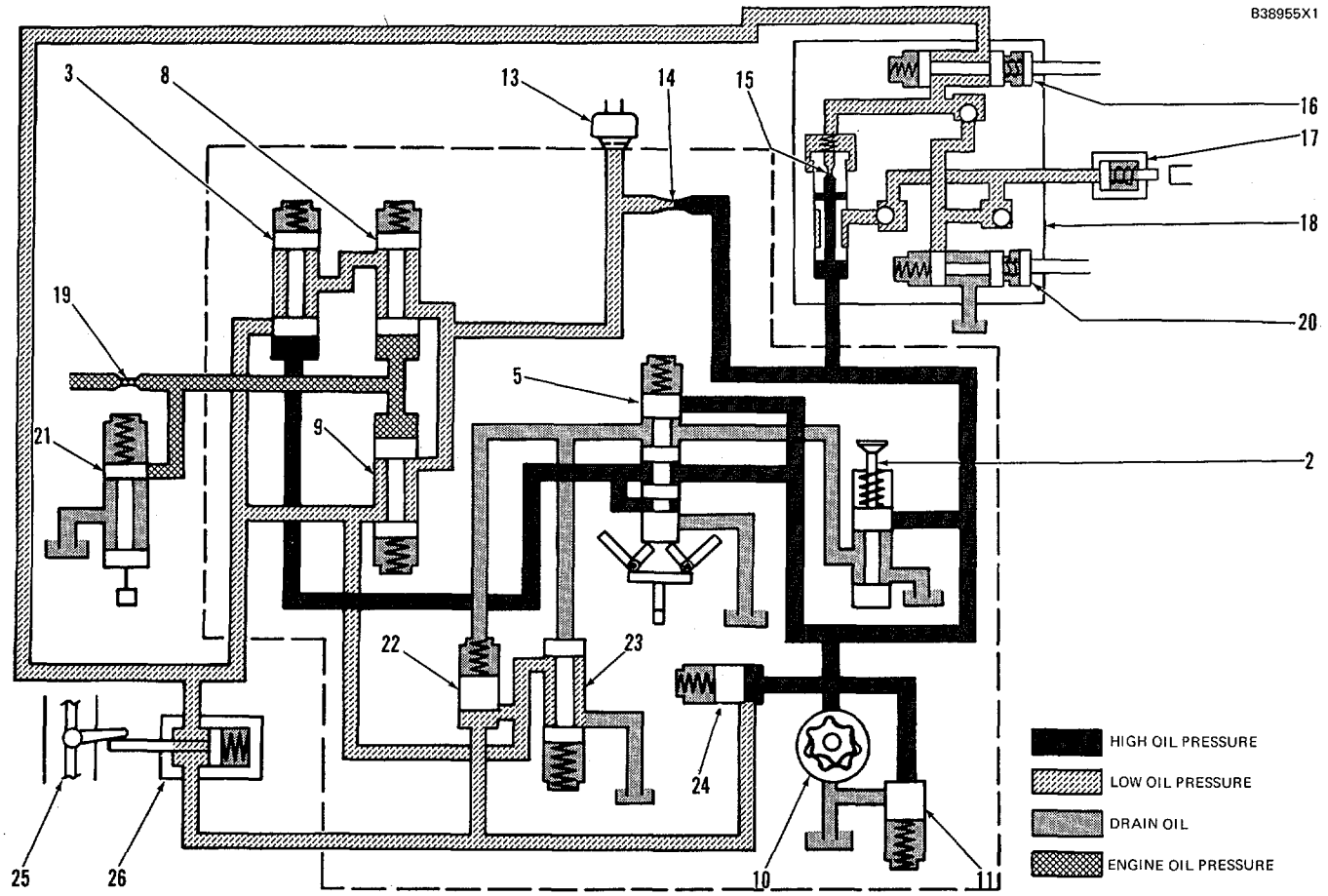
When an engine is started and speed increases, engine oil pressure opens low speed oil protection valve (8) and high speed oil pressure protection valve (9). At the same time, oil in the protective system flows from oil pump (10) to fuel shutoff sequence valve (24) and is divided between the fuel shutoff and air inlet shutoff circuits. Fuel shutoff sequence valve (24) keeps the oil pressure at the start of the fuel shutoff circuit at 760 kPa (110 psi).

Oil in the air inlet shutoff circuit is directed to air inlet sequence valve (22) and air inlet shutoff actuator (26). Air inlet sequence valve (22) keeps the oil pressure in air inlet shutoff actuator (26) at 105 kPa (15 psi) and then directs the remainder of oil flow to drain through pilot operated two-way valve (23) which is normally open. Pilot operated two-way valve (23) is held open by spring force and the pilot oil pressure is connected to drain through speed sensing valve spool (5).

Oil flow in the fuel shutoff circuit is divided into different directions as follows:

1. Oil from fuel shutoff sequence valve (24) goes to speed sensing valve spool (5) and is stopped at low engine speeds. When engine speed is high enough, speed sensing valve spool (5) moves to direct the oil pressure and close selector valve (3). This changes the oil flow in the alarm circuit from the low speed range to the high speed range and connects system oil pressure to drain through high speed oil protection valve (9) and pilot operated two-way valve (23).

2. Oil flow from fuel shutoff sequence valve (24) goes through orifice (14), low speed oil protection valve (8) or high speed oil protection valve (9) and to drain through pilot operated two-way valve (23). This circuit has an oil pressure switch (13), that is normally open. Switch (13) is connected to the alarm circuit oil pressure after orifice (14) and senses the lower system oil pressure. The switch activates an alarm, without engine shutdown, if there is a low engine oil pressure or high coolant temperature condition. (Make reference to Schematic No. 18).



SCHEMATIC NO. 16 (OVERSPEED CIRCUIT)

2. Emergency manual shutoff valve. 3. Selector valve. 5. Speed sensing valve spool. 8. Low speed oil protection valve. 9. High speed oil protection valve. 10. Oil pump. 11. Oil pressure relief valve. 13. Oil pressure switch. 14. Orifice. 15. Diverter valve orifice. 16. Remote normal shutoff valve. 17. Fuel shutoff actuator. 18. Diverter valve. 19. Engine oil pressure orifice. 20. Start-up override valve. 21. Thermostatic pilot valve. 22. Air inlet sequence valve. 23. Pilot operated two-way valve. 24. Fuel shutoff sequence valve. 25. Air inlet shutoff. 26. Air inlet shutoff actuator.

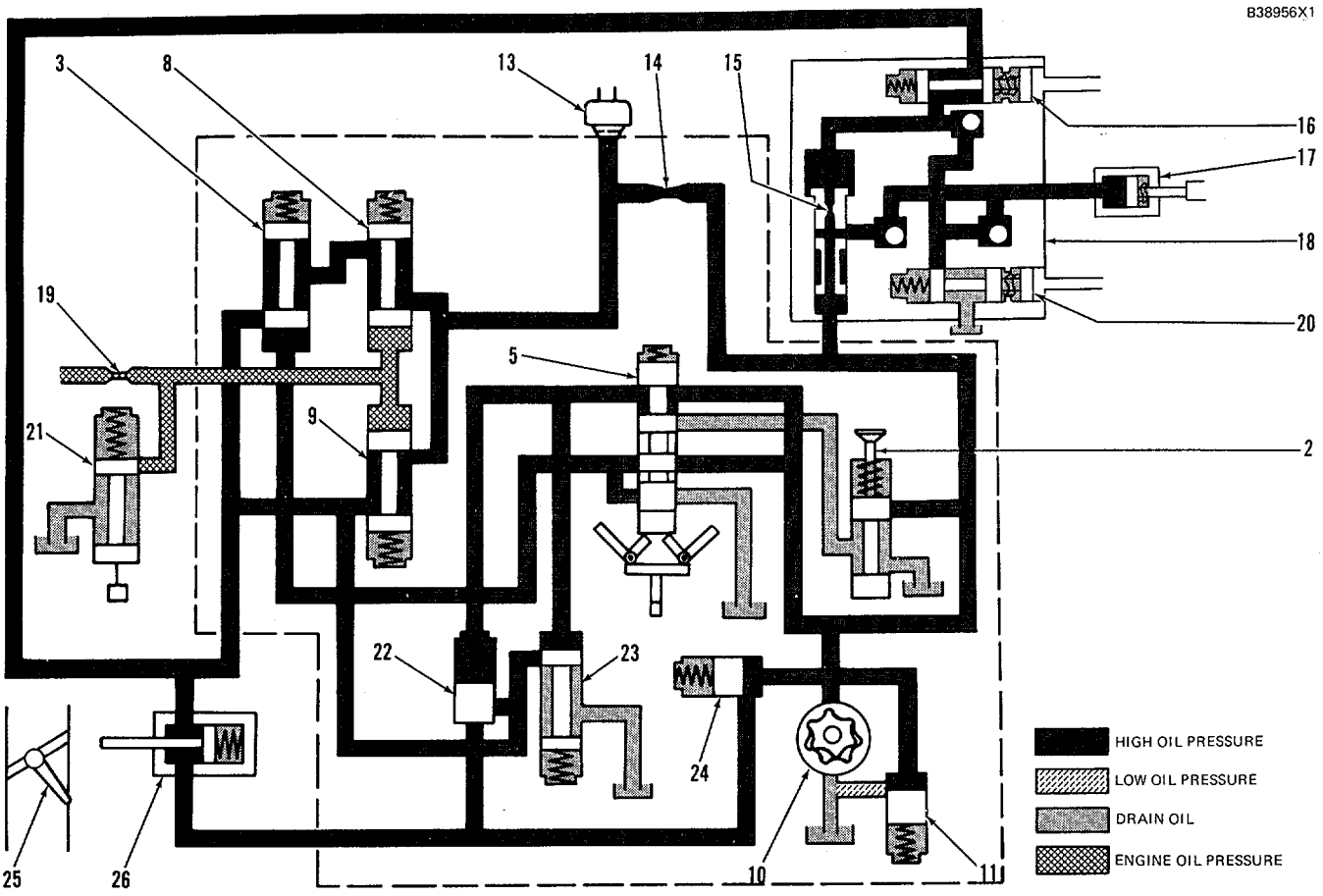
3. Oil from fuel shutoff sequence valve (24) goes to the inlet of diverter valve (18) then to orifice (15) in the valve spool. The oil goes through orifice (15) and goes to the system drain through two-way pilot operated valve (23). The pressure of the oil is lowered after the oil goes through orifice (15), this causes the oil pressure to move the diverter valve spool against a spring force and connect the fuel shutoff actuator oil circuit to the system drain. Thus, the actuator will not shutdown the engine. Engines with electric shut-off solenoids on the governors have a pressure switch installed in the diverter valve outlet for the shutoff actuator. The pressure switch will not shutdown the engine until system oil pressure is directed to it.

OVERSPEED CIRCUIT (OVERSPEED FAULT)

Make Reference to Schematic No. 17

When the engine speed is 18% above full load speed, speed sensing valve spool (5) will be moved up by the flyweights. This will send oil to pilot operated two-way valve (23) and to the spring side of air inlet sequence valve (22). The oil pressure will close both valves and oil in the air inlet shutoff system can not go to drain. The oil pressure in the system will in- crease until oil pressure relief valve (11) opens at 1720 kPa (250 psi). The increased pressure will move air inlet shutoff actuator (26), which will release air inlet shutoff valve (25). This stops the combustion air supply to the engine. Fuel shutoff circuit oil also can not go to drain. The difference in oil pressure across orifices (14) and (15) will now go to zero. The valve spool of diverter valve (18) will move down by spring force, which will cause alignment of the ports to the fuel shutoff actuator (17). The blocked oil pressure in the fuel shutoff circuit will activate fuel shutoff actuator (17), which will cause the governor to move the fuel control linkage to the "SHUTOFF" position. Also, oil pressure switch (13) will be closed by the higher pressure oil and will activate an alarm.

When the emergency manual shutoff knob is pulled, system oil flow is directed to pilot operated two-way valve (23) and the spring side of air inlet sequence valve (22). Valve (23) stops oil flow to drain in both the fuel and air inlet shutoff circuits. The protective system then, shuts down the engine in the same sequence as for an overspeed fault condition. The combustion air supply is stopped and the fuel control linkage is moved to the "SHUTOFF" position to shutdown the engine.



SCHEMATIC NO. 17 (OVERSPEED FAULT)

2. Emergency manual shutoff valve. 3. Selector valve. 5. Speed sensing valve spool. 8. Low speed oil protection valve. 9. High speed oil protection valve. 10. Oil pump. 11. Oil pressure relief valve. 13. Oil pressure switch. 14. Orifice. 15. Diverter valve orifice. 16. Remote normal shutoff valve. 17. Fuel shutoff actuator. 18. Diverter valve. 19. Engine oil pressure orifice. 20. Start-up override valve. 21. Thermostatic pilot valve. 22. Air inlet sequence valve. 23. Pilot operated two-way valve. 24. Fuel shutoff sequence valve. 25. Air inlet shutoff. 26. Air inlet shutoff actuator.

LOW OIL PRESSURE OR HIGH COOLANT TEMPERATURE FAULT

Make Reference to Schematic No. 18

Under normal operation at low engine speeds, the engine oil pressure must be 140 kPa (20 psi) to move low speed oil protection valve (8). The fuel shutoff circuit oil can then flow from pump (10) at 760 kPa (110 psi) through orifice (14), oil pressure switch (1 3), low speed oil protection valve (8), selector valve (3) and pilot operated two-way valve (23) to drain.

If the engine oil pressure goes below 140 kPa (20 psi), the spring force on low speed oil protection valve (8) will close the valve. The oil flow in the circuit is then stopped and can not flow to drain. The pressure of the oil will become equal on both sides of orifice (14) and oil pressure switch (13) senses 760 kPa (I 10 psi). The normally open switch closes and activates an alarm.

At approximately 70% of engine full load speed, the oil pressure protection changes from the low speed range to the high speed range.

When the engine speed increases to the high speed range, speed sensing valve spool (5) will be moved up by the flyweights. This will send pilot oil to selector valve (3). This will close selector valve (3) and re- move low speed oil protection valve (8) from the circuit. The oil must now flow to drain through high speed oil protection valve (9) and pilot operated two- way valve (23).

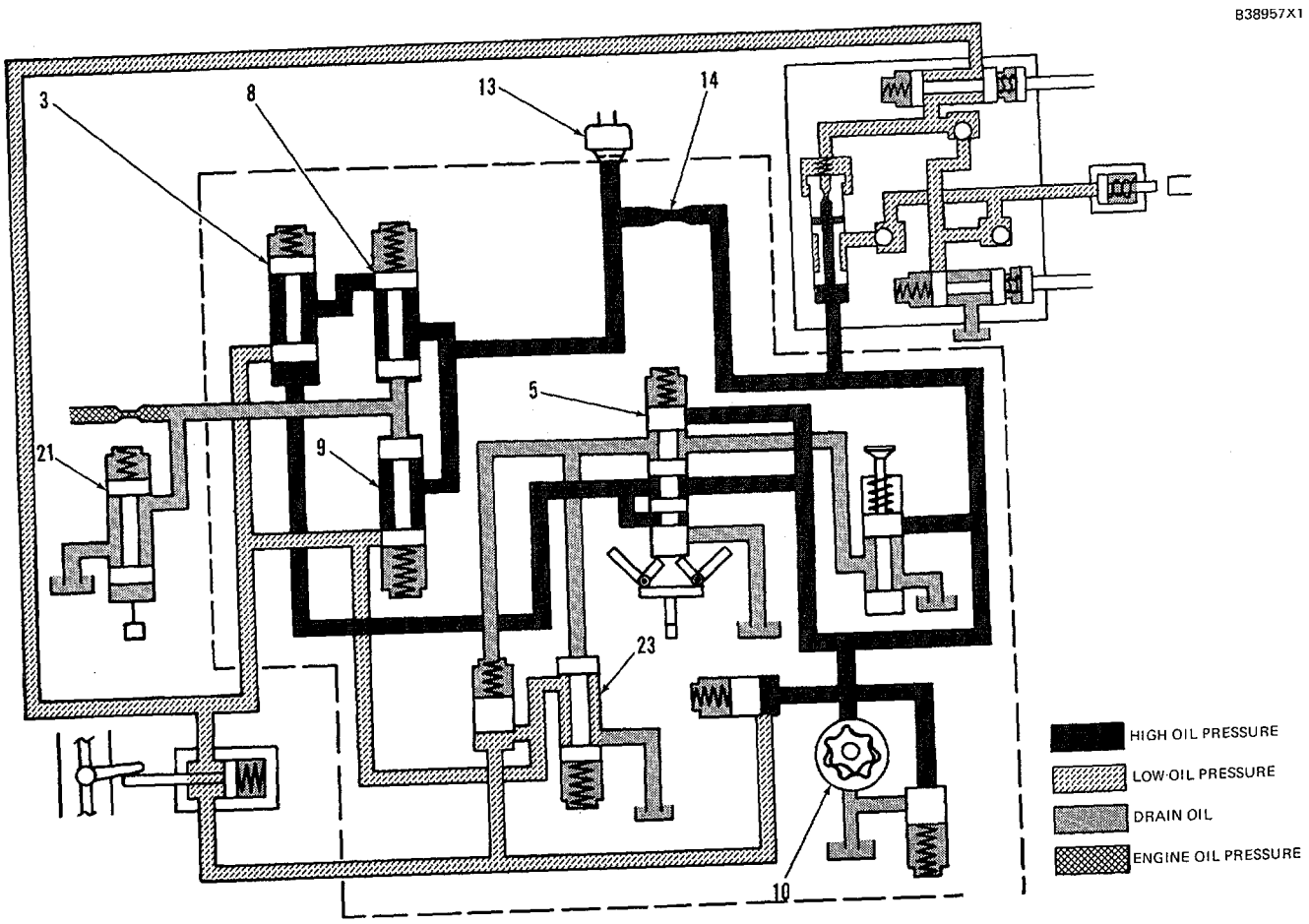
If the engine oil pressure decreases to 205 kPa (30 psi), the spring force on high speed oil protection valve (9) will move the valve and stop the oil flow to drain. The pressure of the oil will become equal onj both sides of orifice (14) and oil pressure switch (13) senses 760 kPa (110 psi). The normally open switch closes and activates an alarm.

For the engine coolant temperature circuit, a ther- mostatic pilot valve (21) is connected to the engine oil pressure supply. Thermostatic pilot control valve (21) is normally closed.

NOTE: The sensor of thermostatic pilot valve (21) must be below the water level in the coolant manifold to operate correctly.

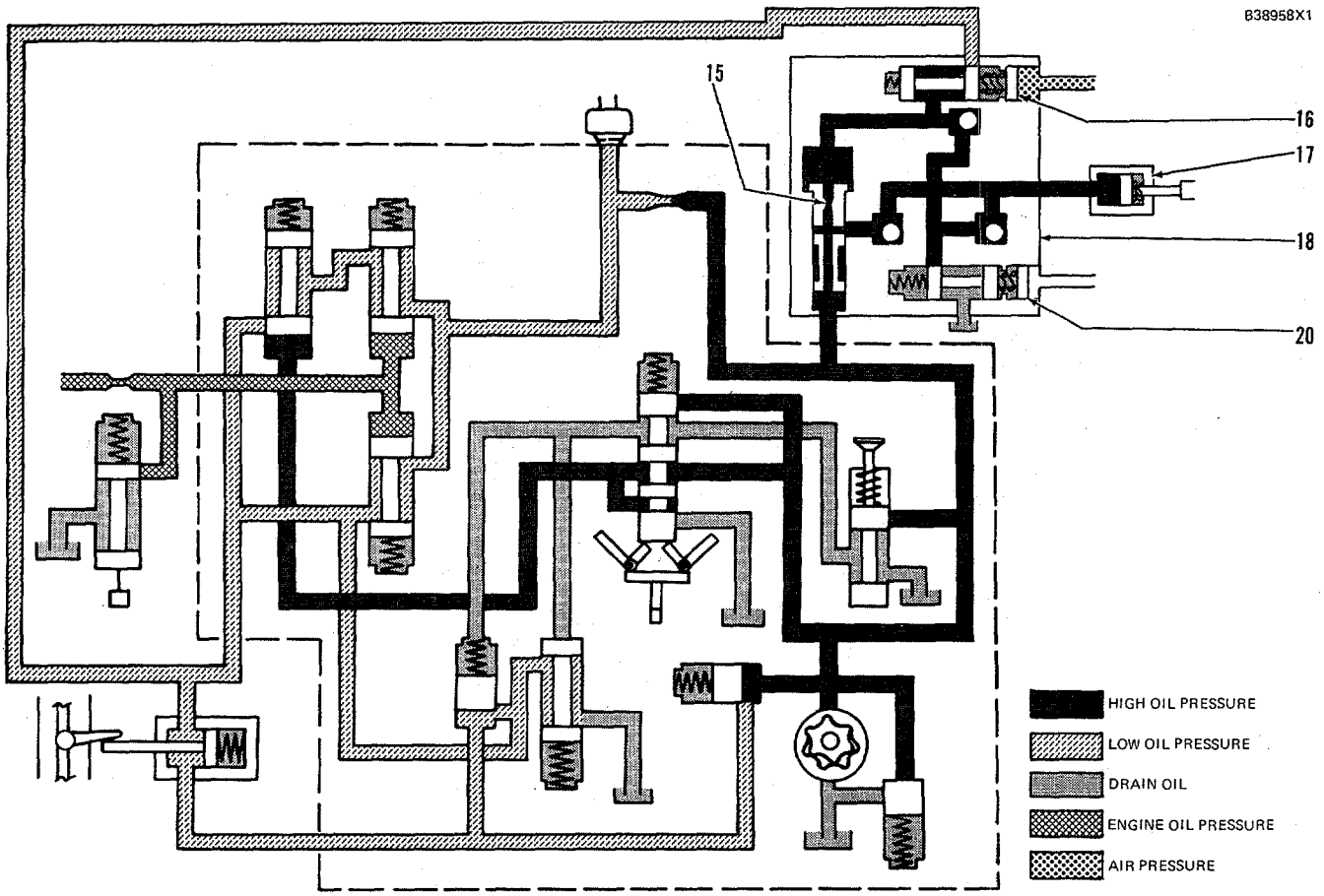
When coolant temperature increases to 99°C (210°F), thermostatic pilot valve (21) will open. This will let oil in the circuit go to drain and cause a decrease in engine oil pressure at low speed oil protection valve (8) and high speed oil protection valve (9). The valves close and stop oil flow through orifice (14). The pressure of the oil will become equal on both sides of orifice (14) and oil pressure switch (13) senses 760 kPa (I10 psi). The normally open switch closes and activates an alarm.

NOTE: When the engine is started, the low oil pressure - high coolant temperature alarm will be activated for a short time until the engine has enough oil pressure to open low speed oil protection valve (8) or' high speed oil protection valve (9).



SCHEMATIC NO. 18 (LOW OIL PRESSURE OR HIGH COOLANT TEMPERAFAULT)
(High Speed Range)

3. Selector valve. 5. Speed sensing valve spool. 8. Low speed oil protection valve. 9. High speed oil protection valve. 10. Oil pump. 13. Oil pressure switch. 14. Orifice. 21. Thermostatic pilot valve. 23. Pilot operated two-way valve.



SCHEMATIC NO. 19 (REMOTE NORMAL SHUTOFF)

15. Diverter valve orifice. 16. Remote normal shutoff valve. 17. Fuel shutoff actuator. 18. Diverter valve. 20. Start-up override valve.

REMOTE NORMAL SHUTOFF

Make Reference to Schematic No. 19

The remote normal shutoff is an option that can be used with the hydramechanical protective system. An air or electric operated remote normal shutoff valve (16) is installed in the diverter valve return line. When remote normal shutoff valve (16) is operated, the outlet of the diverter valve is stopped. The oil pressure becomes equal on both sides of diverter valve orifice (15). Spring force will move the valve spool of diverter valve (18) to make an alignment of the oil passage with the oil line to fuel shutoff actuator (17). Oil pressure can now activate fuel shutoff actuator (17), which causes the governor to move the fuel control linkage to the "SHUTOFF" position and shutdown the engine.

TROUBLESHOOTING

Troubleshooting can be difficult. On the following pages there is a list of possible problems. To make a repair to a problem, make reference to the cause and correction.

This list of problems, causes, and corrections, will only give an indication of where a possible problem can be, and what repairs are needed. Normally, more or other repair work is needed beyond the recommendations in the list.

Remember that a problem is not normally caused only by one part, but by the relation of one part with other parts. This list can not give all possible problems and corrections. The serviceman must find the problem and its source, then make the necessary repairs.

TROUBLESHOOTING INDEX

Item **Problem**

1. Engine Will Not Start.
2. Engine Will Start, But Shuts Down When Oil Pressure Override is Released.
3. Engine Will Only Run Below 70% of Rated Speed.
4. Air Inlet Shutoff Activates on Load Rejection.
5. Air Inlet Does Not Close.
6. Engine Will Not Restart After Operation of Emergency Manual Shutoff.
7. Engine Will Not Shutdown When Checking Low Engine Oil Pressure Protection Circuit.
8. Shutoff Control Unit Does Not Operate.

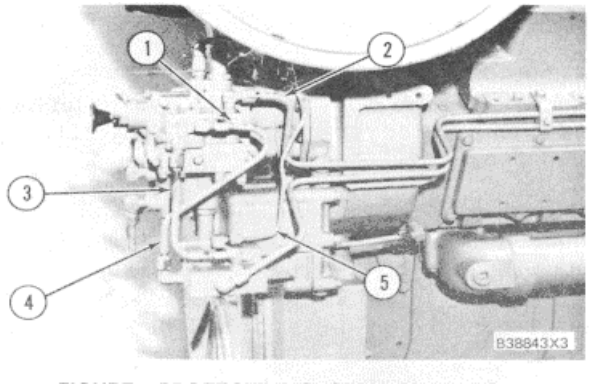


FIGURE 1.PROTECTIVE SYSTEM OIL LINES

1. Plug. 2. Oil line to thermostatic pilot valve. 3. Oil return line from diverter valve. 4. Oil supply line to diverter valve. 5. Oil drain line from diverter valve.

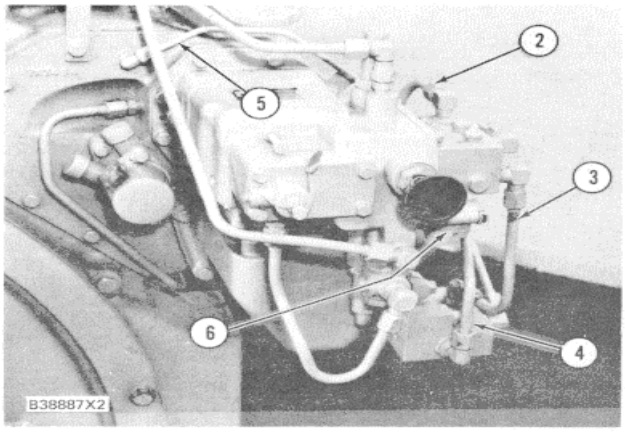


FIGURE 2. PROTECTIVE SYSTEM OIL LINES

2. Oil line to thermostatic pilot valve. 3. Oil return line from diverter valve. 4. Oil supply line to diverter valve. 5. Oil drain line from diverter valve. 6. Cover on actuator valve body.

1. ENGINE WILL NOT START

Cause	Correction
Engine Start-Up Override Not By-Passing Oil Pressure By Shut- off Control Group To Drain	Disconnect drain line (5), See Figure 1. Operate the override (push button switch for electric, push button valve for air) and crank the engine. Oil should flow from drain line. If not, inspect the solenoid or air operated two-way valve and the push button switch or push button air valve and lines.
Fuel Shutoff Actuator Stuck In The Shutoff Position	Make sure that the start-up override system is operating correctly. Operate the start-up override and crank the engine. Check the governor linkage and fuel control linkage to see if they are in the run position. If not, check the shutoff actuator for binding.

2. ENGINE WILL START, BUT SHUTS DOWN WHEN START-UP OVERRIDE IS RELEASED

Cause	Correction
Engine Oil Pressure Is Too Low	Install a pressure gauge in oil line (2) or in port (I) behind oil supply line (4), see Figure 1. Operate the start-up override and start the engine. Engine oil pressure must be 175 kPa (25 psi) minimum at low idle and 240 kPa (35 psi) minimum at rated speed.
Engine Oil Pressure Sensing Orifice Plugged	Remove the control group from the engine to disassemble and clean orifice if necessary.
The Oil Return Line Between Diverter Valve And Shutoff Control Group Is Plugged	Disconnect oil return line (3) at the shutoff control group, see Figure 1. Crank the engine without using the start-up override valve. Oil should flow out of the oil return line. Check the oil line for damage and clean or replace as needed.
Remote Normal Shutoff Still Activated	Disconnect oil return line (3) at the shutoff control group, see Figure 1. Crank the engine without using the start-up override valve. Oil should flow out of the oil return line. If there is no oil flow and the line is not plugged or damaged, check the remote normal shutoff system. Make a repair or replacement of worn or damaged parts and clean the valve if necessary.
Engine Oil Pressure Is Drained Through Thermostatic Pilot Valve	Check drain side of valve. Replace valve, if flow is present at cranking and engine coolant temperature is normal.
Engine Oil Pressure Sensing Portion Of The Control Group Has Malfunctioned	Remove cover (6), see Figure 2. Inspect the valve spools in the actuator valve body to make sure valves are not stuck. Replace cover (6) after inspection. Check the engine oil pressure. Install a pressure gauge in oil line (2) or in port (1) behind oil supply line (4), see Figure 1. Operate start-up override and start the engine. If the engine oil pressure is equal to or greater than 175 kPa (25 psi) at low idle and 240 kPa (35 psi) at rated speed, replace-the oil pressure sensing group (part of the shutoff control group). actuator valve body to make sure valves are not stuck. Replace cover (6) after inspection.

3. ENGINE WILL ONLY RUN BELOW 70% OF RATED SPEED

Cause	Correction
Engine Oil Pressure Is Not High Enough In The High Speed Range	Check engine oil pressure in oil line (2), see Figure 1. A minimum of 240 kPa (35 psi) is required in high speed range. Clean the engine oil pressure line to the shutoff control group, if needed. Also, engine repair may be needed.

4. AIR INLET SHUTOFF ACTIVATES ON LOAD REJECTION

Cause	Correction
Governor Overshoot Lets Engine Speed Exceed Overspeed Setting	Correct governor overshoot. If this can not be done, increase over- speed setting to a maximum of 25% of rated speed.

5. AIR INLET DOES NOT CLOSE

Cause	Correction
Tube Fittings At Hydraulic Actuator Are Installed Too Far. The End Of The Fitting Is Binding The Cylinder Rod	Turn fittings out until cylinder rod is free to move.
Air Inlet Valve Shaft Sticking Or Binding	Check for corrosion on shaft bearing surfaces or improper alignment.

6. ENGINE WILL NOT RESTART AFTER OPERATION OF EMERGENCY MANUAL SHUTOFF

Cause	Correction
The 5N5880 Remote Emergency Manual Shutoff Did Not Fully Return To The Run Position When Switch Or Valve Was Released	Check for binding of 5N5878 valve in the valve bore.
Fuel Shutoff Actuator Stuck In The Shutoff Position	Remove the actuator. Check surface finish of bore and polish, if necessary. Put a small amount of clean oil in the bore and on the seal. Move the rod and piston in the actuator cylinder to check for free movement. Replace actuator, if necessary.
Air Inlet Valve Shaft Sticking Or Binding	Check for corrosion on shaft bearing surfaces or improper alignment.

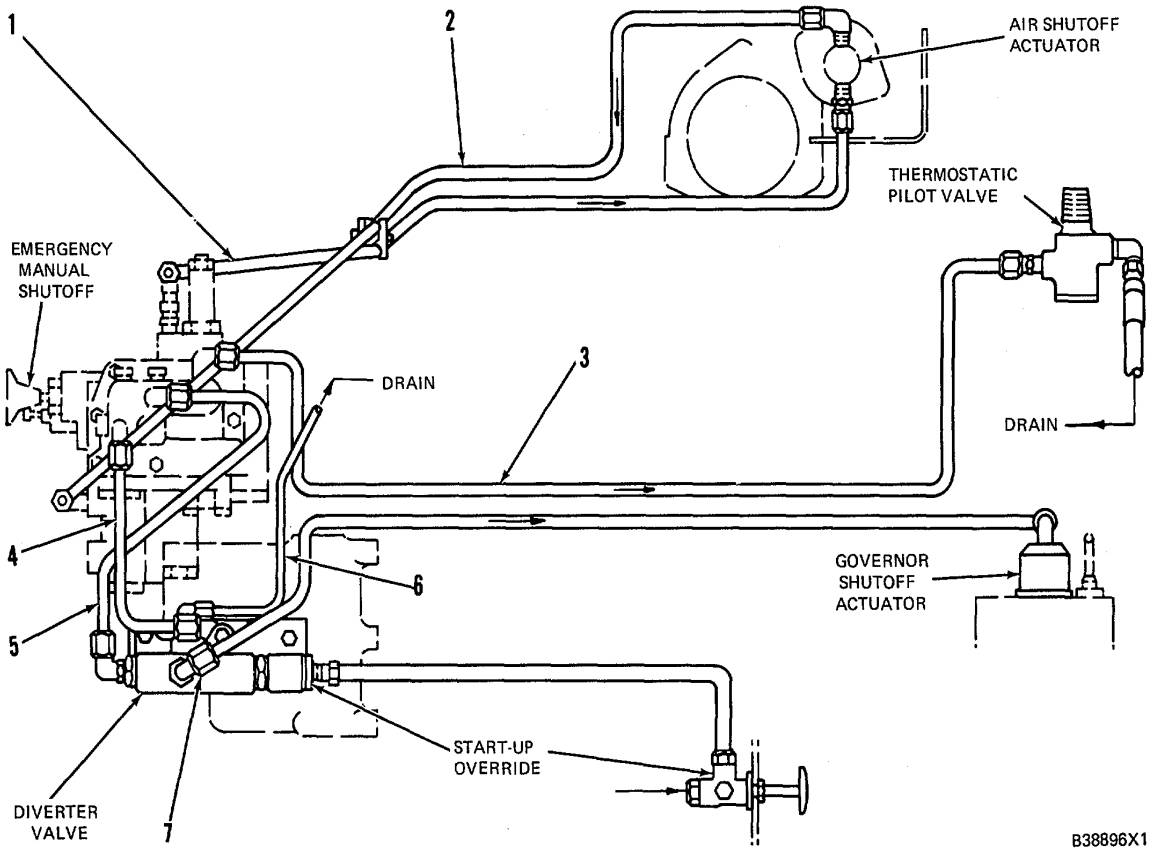
7. ENGINE WILL NOT SHUTDOWN WHEN CHECKING LOW ENGINE OIL PRESSURE PROTECTION CIRCUIT

Cause	Correction
Fuel Shutoff Actuator Stuck In The Run Position Remove	Remove the actuator. Check surface finish of bore and polish, if necessary. Put a small amount of clean oil in the bore and on the seal. Move the rod and piston in the actuator cylinder to check for free movement. Replace actuator, if necessary.
Orifice Plugged In Diverter Valve	Disconnect oil return line (3) at the diverter valve. Crank the engine without using the start-up over-ride valve. Oil should flow from the diverter valve outlet port.
Orifice Not Installed In Control Group	Remove control group from engine and disassemble. Install or replace orifice if needed.
Oil Flow To Drain Is Not Enough To Create A Fault Condition	Install a manual operated ball or gate valve in the engine oil pressure sensing line. Slowly close the valve to add more restriction to flow. If engine shutdown does not occur, the shutoff control group needs repair.

8. SHUTOFF CONTROL UNIT DOES NOT OPERATE

Cause	Correction
Drive Coupling Failure	Start the engine and run supply line at low idle. Loosen the nut that holds oil supply line (4) at the shutoff control group, see Figure 1. Oil under pressure present should be present. If not, remove shutoff control group and inspect the drive coupling. Make a replacement of parts as needed. A pressure gauge installed in oil supply line (4) [see Figure 1] can also be used to make this check. A minimum pressure of 590 kPa (85 psi) at high idle should be the reading.
Not enough System Oil Pressure	Make sure there is oil in the reservoir for the system. Low oil pressure can be caused by a faulty oil pump relief valve (18) or fuel shutoff sequence valve (15), see Schematic No. I in the System Operation section for part locations. Make a replacement or repair as needed.

HYDRAMECHANICAL PROTECTIVE SYSTEM



PROTECTIVE SYSTEM WITH ENGINE SHUTDOWN FOR ALL FUNCTIONS (LOP, HWT, OS)

1. Oil line to air inlet shutoff actuator. 2. Return line from air inlet shutoff actuator. 3. Oil line to thermostatic pilot valve. 4. Return line from diverter valve. 5. Oil line to diverter valve. 6. From two-way valve at the diverter valve to drain. 7. From diverter valve to governor (fuel) shutoff actuator.

Many engines run thousands of hours in continuous-duty applications without any operation of the protective system shutoff actuators, valves and alarms (if so equipped).

Every 500 Service Meter Units, the emergency manual shutoff should be operated. This will check the protective system for correct operation.

NOTICE

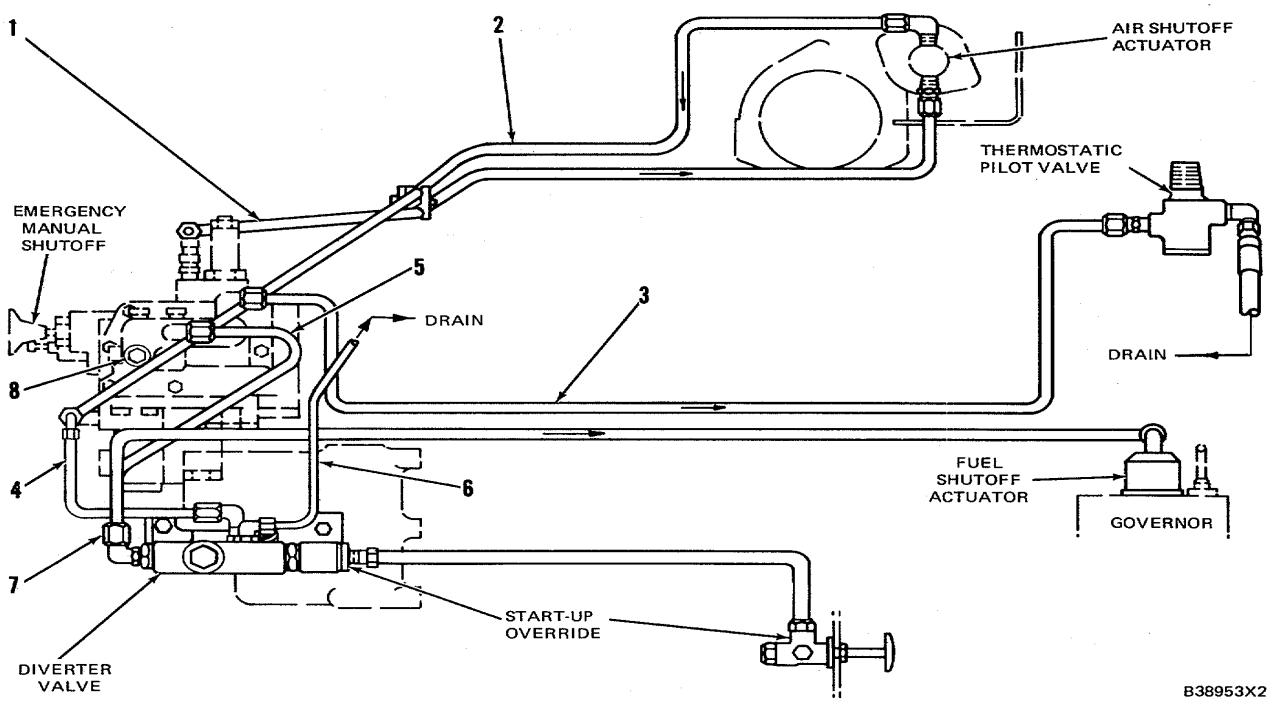
After the emergency manual shutoff has been operated, the air inlet shutoff valve must be opened. Also, the start-up override must be operated to release hydraulic pressure from the fuel shutoff actuator before the engine can be started again.

If no engine shutdown occurs, further inspection of the system is needed. The drive coupling and the two-way, 5N641 1 Valve (palm valve) can be tested while the engine is operating under full load. However, tests of the air inlet shutoff and the (fuel) shutoff are done with the engine at low idle. Use the following procedures to check the system more completely.

DRIVE COUPLING CHECK

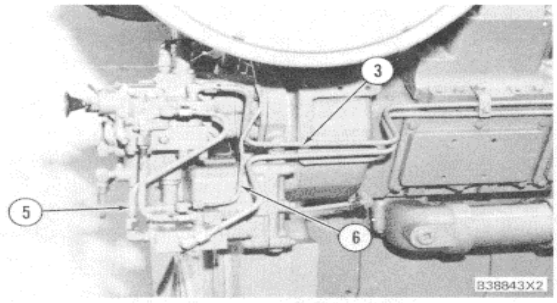
Put a rag around the fitting to prevent oil spray on oil supply line (5) at the diverter valve.

Operate the engine at low idle and loosen the nut on the fitting at the diverter valve one-half to three-quarters of a turn. Shake the line to break the paint. If any oil comes out under pressure, the shutoff is being driven through the coupling. Tighten the nut.



PROTECTIVE SYSTEM WITH ENGINE SHUTDOWN FOR OVERSPEED ONLY, ALARMS FOR OTHER FUNCTIONS (LOP, HWT)

1. Oil line to air inlet shutoff actuator. 2. Return line from air inlet shutoff actuator. 3. Oil line to thermostatic pilot valve. 4. Return line from diverter valve. 5. Oil line to diverter valve. 6. From two-way valve at the diverter valve to drain. 7. From diverter valve to governor (fuel) shutoff actuator. 8. Oil pressure switch for alarms.



PROTECTIVE SYSTEM OIL LINES

3. Oil line to thermostatic pilot valve. 5. Oil line to diverter valve. 6. From two-way valve (at the diverter valve) to drain.

START-UP OVERRIDE VALVE CHECK

On an engine with an air start system, start and operate the engine at low idle. Loosen the drain line from the two-way (palm) valve. There should be no oil present. If there is any oil flow, the valve has failed and replacement is necessary.

AIR INLET SHUTOFF CHECK

Operate the engine at low idle and pull the red, emergency knob. The air inlet shutoff valve must close and stop the engine. Low oil pressure and high coolant temperature alarms should also be activated, if so equipped.

The fuel shutoff actuator must also move the governor and fuel control linkage to the "SHUTOFF" position.

NOTICE

After this test has been performed, the air inlet shutoff valve must be opened. Also, the startup override valve must be operated to release hydraulic pressure from the governor shutoff actuator before the engine can be started again.

FUEL SHUTOFF TEST

Hold open the air inlet shutoff valve with a length of wire. (If another person is present, the valve can be held open by hand.) Pull the red, emergency. knob. Since the air inlet shutoff valve has been held open, the fuel shutoff actuator should stop the engine. The low oil pressure, high coolant temperature alarms should also be activated, if so equipped.

NOTICE

Before starting the engine, make sure the air inlet shutoff is reset so the protective system can operate, if needed, and to prevent damage to the engine at start up.

LOW OIL PRESSURE TEST

Disconnect the oil supply line that is installed between the thermostatic pilot valve and the shutoff control group, at the control group. Attach a 3N4847 Hose Assembly to the control. Use a 7D5363 Connector to adapt a 3R3837 Shutoff Valve to the end of the hose.

NOTE: If the engine is not equipped with a thermostatic pilot valve, remove the plug from where line (4) would connect to the shutoff control group.

Close the valve and start the engine and operate it at low idle. The engine will run normally.

Place the end of the hose in a bucket or other container and open the valve to drain approximately one-half liter (one U.S. pint) of oil to lower the oil pressure.

This will actuate the low oil pressure protection circuit and cause engine shutdown through the fuel shutoff actuator or activate the low oil pressure, high coolant temperature alarms, if so equipped. The air inlet shutoff should not be activated by this test.

NOTE: The fuel shutoff actuator will not be activated in a protective system that gives overspeed protection only, when a low oil pressure fault is simulated.

If the fuel shutoff actuator is not activated by this test, check the actuator, oil lines or electrical connections, and the shutoff control group for defects.

If the alarms fail to activate, make sure the pressure switch on the control valve group, the wiring and alarms work correctly to locate and repair parts as needed.

Remove the hose assembly, connector and shutoff valve from the engine. Connect the oil supply to the thermostatic pilot valve.

All of the above tests are performed at low idle. Successful shutdowns and alarms at low idle indicate correct operation. Therefore, it is not necessary to perform the tests at high idle.

SHUTOFF SPEED SETTING ADJUSTMENT

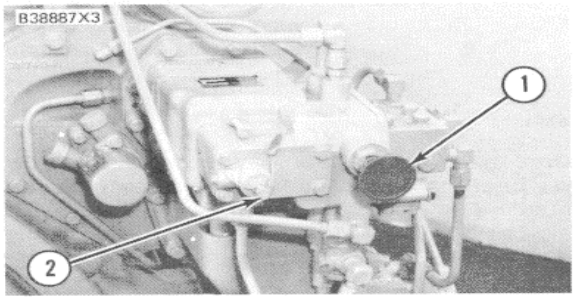
NOTE: When major disassembly or adjustment of the shutoff control group is needed, see CATERPILLAR FUEL INJECTION TEST BENCH BOOK, FORM NO. SEHS7466 for the complete specifications and test bench procedures to use.

NOTICE

A mechanic with training in governor adjustments is the ONLY one that should perform the following procedure. Severe engine damage could occur if this procedure is not followed. Also, check the capabilities of driven equipment to make sure damage will not occur if run at overspeed.

1. Check and make sure the engine fuel settings are correct. See FUEL SETTING CHECK in the Engine TESTING AND ADJUSTING section of this Service Manual.

2. Start the engine and operate it at low idle.



SHUTOFF CONTROL GROUP

1. Emergency manual shutoff. 2. Overspeed setting adjustment bolt.

3. Before any adjustment to the shutoff control overspeed setting is made, check for correct operation of the hydramechanical protective

system. Pull emergency manual shutoff knob (I). Successful shutdown of intake air and fuel indicate correct operation.

NOTICE

After the emergency manual shutoff has been operated, the air inlet shutoff valve must be opened. Also, the start-up override must be operated to release hydraulic pressure from the fuel shutoff actuator before the engine can be started again.

4. Remove seal and wire from the bolts and remove the cover from over the high idle adjustment screw on the Caterpillar 3161 Governor, or the seal wire from high idle screw lock nut on Woodward UG-8L Governor.

5. Connect a tachometer of known accuracy to the engine.

NOTE: Some types of engine driven equipment, such as generators, pumps or compressors, can be damaged if operated at 18% above full load speed. If so, the driven equipment must be disconnected from the engine during this test. If this cannot be done, adjustment of the shutoff control group can be made on the CATERPILLAR FUEL INJECTION TEST BENCH. See Form No. SEHS7466 for the complete test bench procedures.

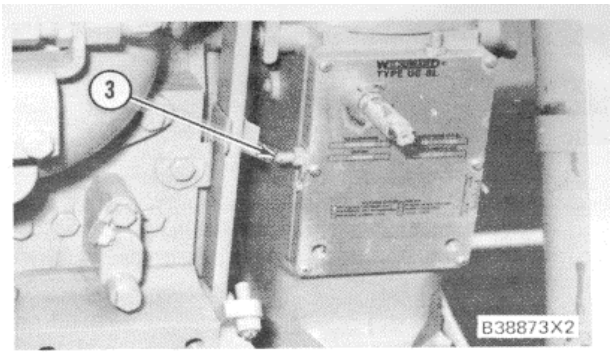
6. Start the engine again and operate it at high idle with no load.

7. Turn the governor high idle adjustment screw slowly to increase engine rpm. The air inlet shutoff must close and the fuel must be shut off through the governor and fuel control linkage at 18% + 25 rpm above full load rpm. For example, this is 2124 + 25 rpm for an engine rated at 1800 rpm.

NOTICE

After the hydramechanical protective system has been activated, the air inlet shutoff valve must be opened. Also, the start-up override must be operated to release hydraulic pressure from the fuel shutoff actuator before the engine can be started again.

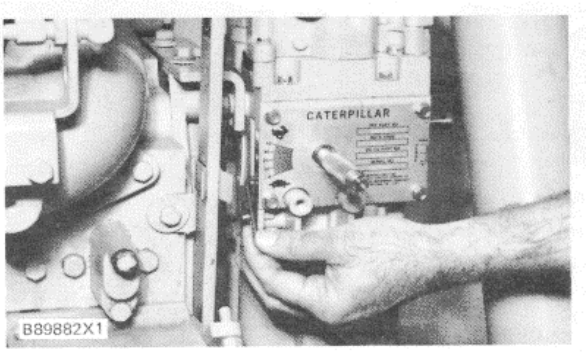
8. If engine shutdown does not occur at 18% + 25 rpm above full load rpm, slowly increase engine rpm 50 rpm more. For example, this is 2174 rpm for an engine rated at 1800 rpm. If engine shutdown still does not occur, decrease the engine rpm and remove the seal and lockwire and turn overspeed adjusting bolt (2) one turn counter



UG-8L GOVERNOR

3. High idle adjustment screw.

clockwise. Again, slowly increase the engine rpm to check for engine shutdown at 18% ± 25 rpm above full load rpm.



ADJUSTMENT OF HIGH IDLE ON 3161 GOVERNOR

NOTE: If engine shutdown occurs before 18% ± 25 rpm of full load rpm, turn overspeed adjusting bolt (2) clockwise to increase the shutoff control group overspeed setting.

9. Repeat the above procedure until engine shutdown occurs at the correct rpm.

10. Adjust engine high idle to the specifications shown on the Engine Information Plate which is attached to one of the right side camshaft inspection covers. If the Engine Information Plate is missing, see the FUEL SETTING AND RELATED INFORMATION FICHE for the correct specifications to use.

11. Install the seals and lockwires for the shutoff control group and the governor high idle adjustment screw.

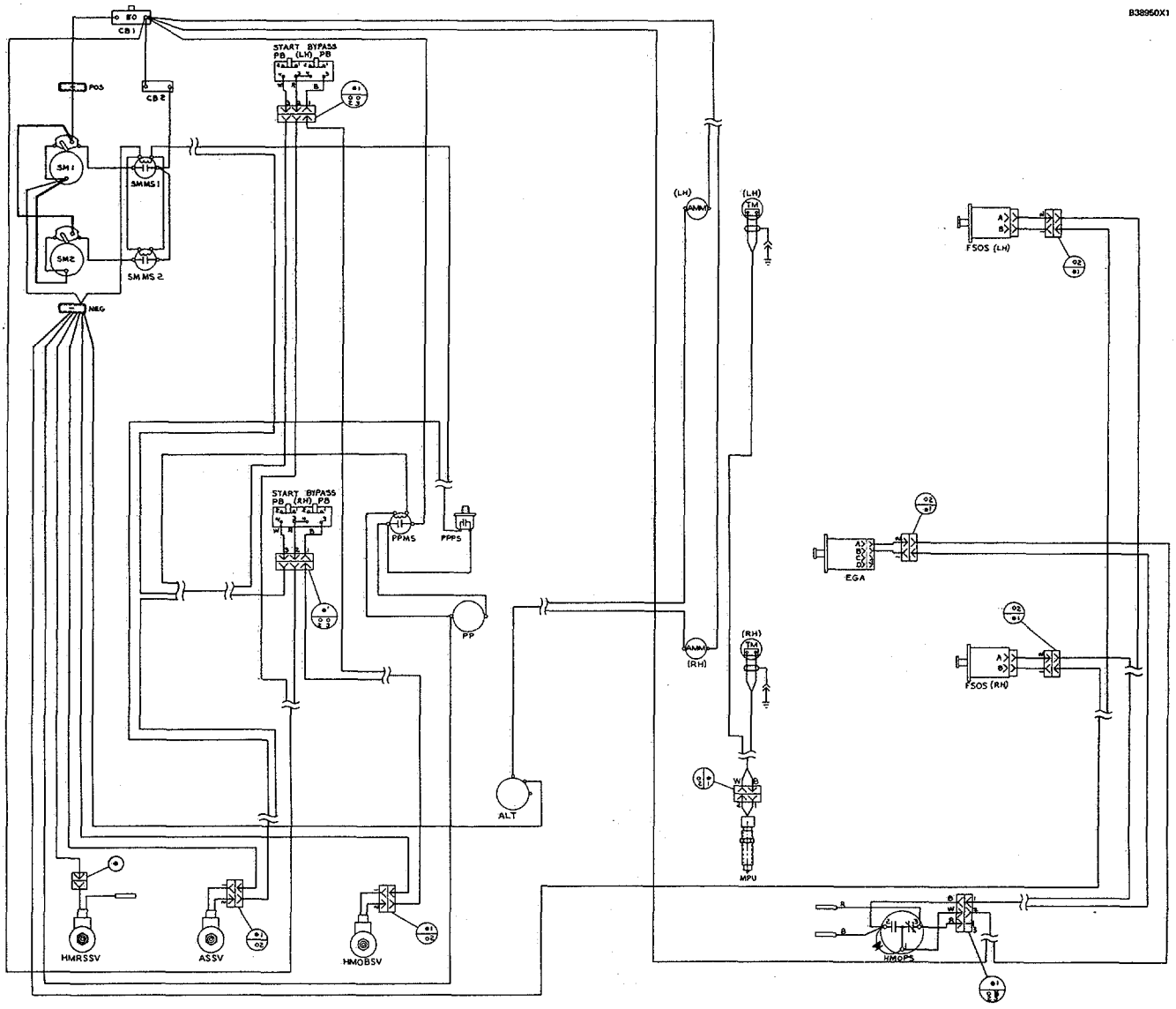
HYDRAMECHANICAL PROTECTIVE SYSTEM
WIRING DIAGRAMS

COMPONENT ABBREVIATIONS

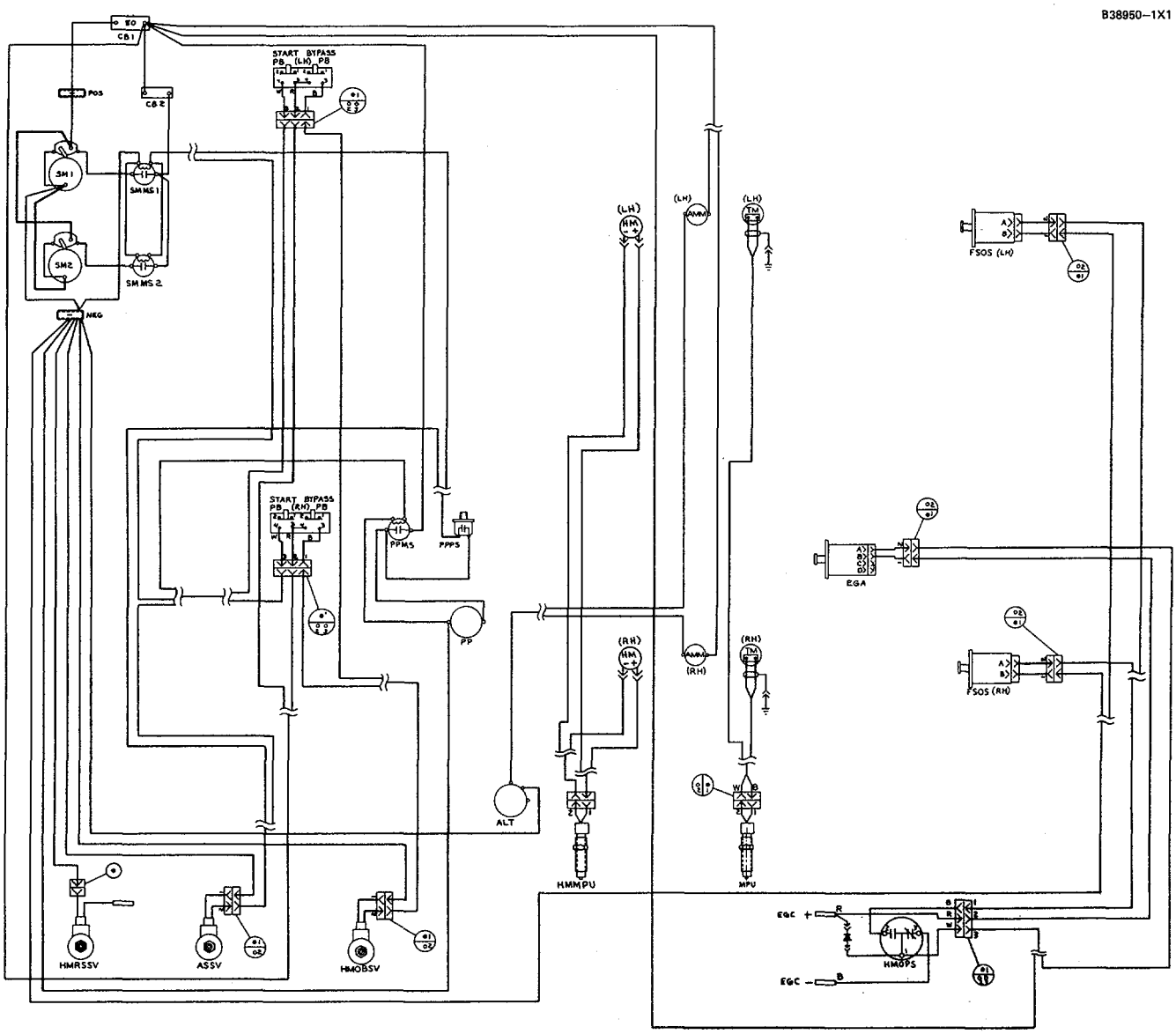
ALT	ALTERNATOR
AMM	AMMETER
ASOS	AIR SHUTOFF SOLENOID
ASSV	AIR START SOLENOID VALVE
B-	BATTERY NEGATIVE
B+	BATTERY POSITIVE
BATT	BATTERY
CB	CIRCUIT BREAKER
EGA	ELECTRIC GOVERNOR ACTUATOR
EGC	ELECTRIC GOVERNOR CONTROL
ENCL	ENCLOSER
FSOS	FUEL SHUTOFF SOLENOID
HM	HOUR METER
HMMPU	HOUR METER MAGNETIC PICK-UP
HMOBSV	HYDRAMECHANICAL OIL BYPASS SOLENOID VALVE
HMOPS	HYDRAMECHANICAL OIL PRESSURE SWITCH
HMRSSV	HYDRAMECHANICAL REMOTE SHUTOFF WTS SOLENOID VALVE
HWTAS	HIGH WATER TEMPERATURE ALARM SWITCH
LOPAS	LOW OIL PRESSURE ALARM SWITCH
LWTAS	LOW WATER TEMPERATURE ALARM SWITCH
MGOPG	MARINE GEAR OIL PRESSURE GAGE
MGOPSU	MARINE GEAR OIL PRESSURE SENDING UNIT
MGOTAS	MARINE GEAR OIL TEMPERATURE ALARM SWITCH
MPU	MAGNETIC PICK-UP
OPG	OIL PRESSURE GAGE
OPS	OIL PRESSURE SWITCH
OPSU	OIL PRESSURE SENDING UNIT
PB	PUSH BUTTON
PP	PRELUBE PUMP
PPMS	PRELUBE PUMP MAGNETIC SWITCH
PPPS	PRELUBE PUMP PRESSURE SWITCH
RNS	REMOTE NORMAL SHUTOFF SWITCH
SM	STARTER MOTOR
SMMS	STARTER MOTOR MAGNETIC SWITCH
TM	TACHOMETER
TMMPU	TACHOMETER MAGNETIC PICK-UP
TS	TERMINAL STRIP
WTG	WATER TEMPERATURE GAGE
WTSU	WATER TEMPERATURE SWITCH WATER TEMPERATURE SENDING UNIT

WIRE COLOR CODE ABBREVIATIONS

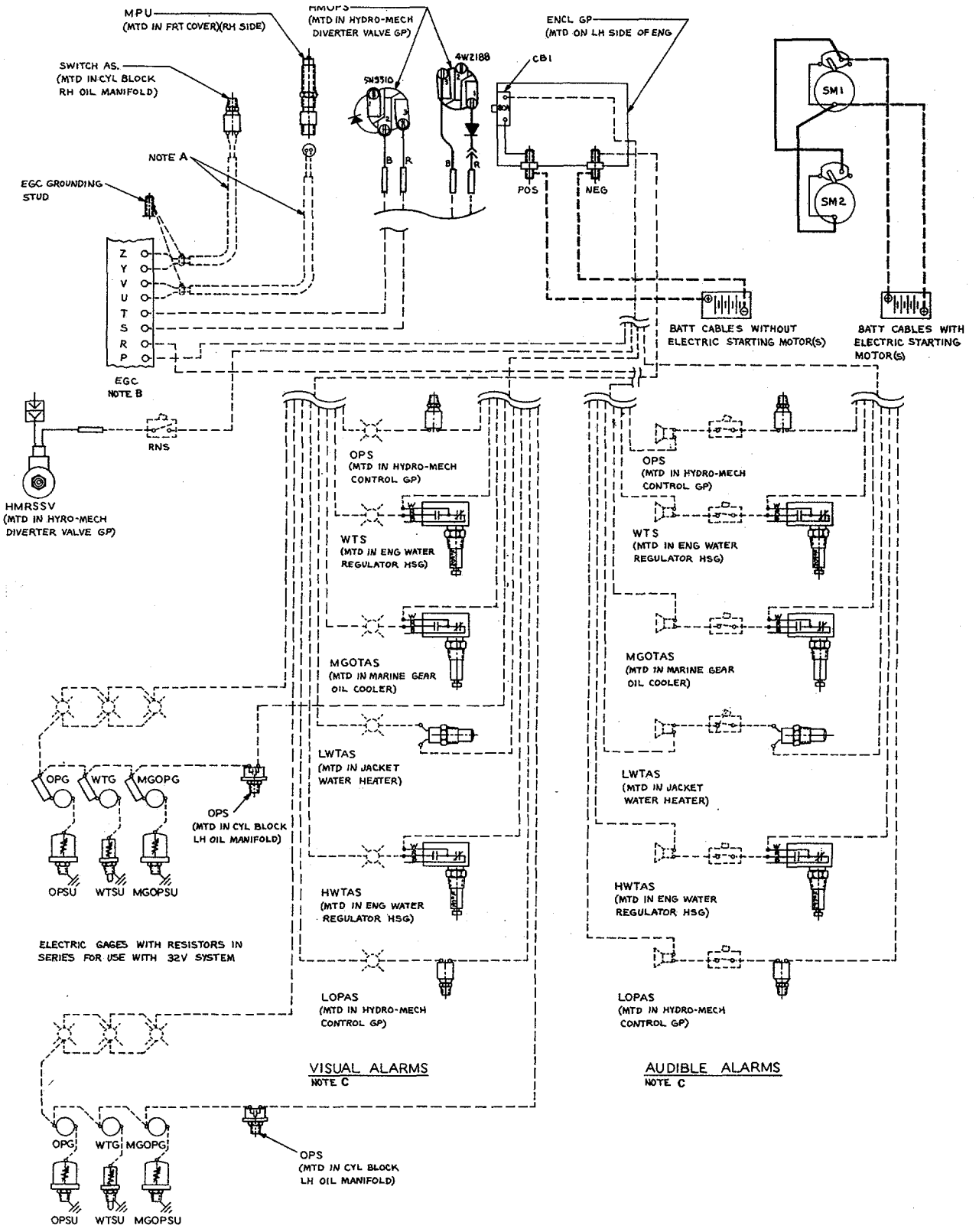
B	BLACK
BR	BROWN
B/W	BLACK WITH WHITE STRIPE
CU	COPPER (BARE WIRE)
DK BL	DARK BLUE
DK GR	DARK GREEN
GR	GREEN
LT BL	LIGHT BLUE
O	ORANGE
O/B	ORANGE WITH BLACK STRIPE
P/B	PINK WITH BLACK STRIPE
PUIW	PURPLE WITH WHITE STRIPE
R	RED
W	WHITE
W/O	WHITE WITH ORANGE STRIPE
W/R	WHITE WITH RED STRIPE
Y	YELLOW
Y/BR	YELLOW WITH BROWN STRIPE



3500 ENGINE WIRING DIAGRAM (REF. 5N8944)
(Earlier Systems With 5N9310 Pressure Switch Assembly)



3500 ENGINE WIRING DIAGRAM (REF. 5N8944)
(Later Systems With 4W2188 Pressure Switch Assembly)



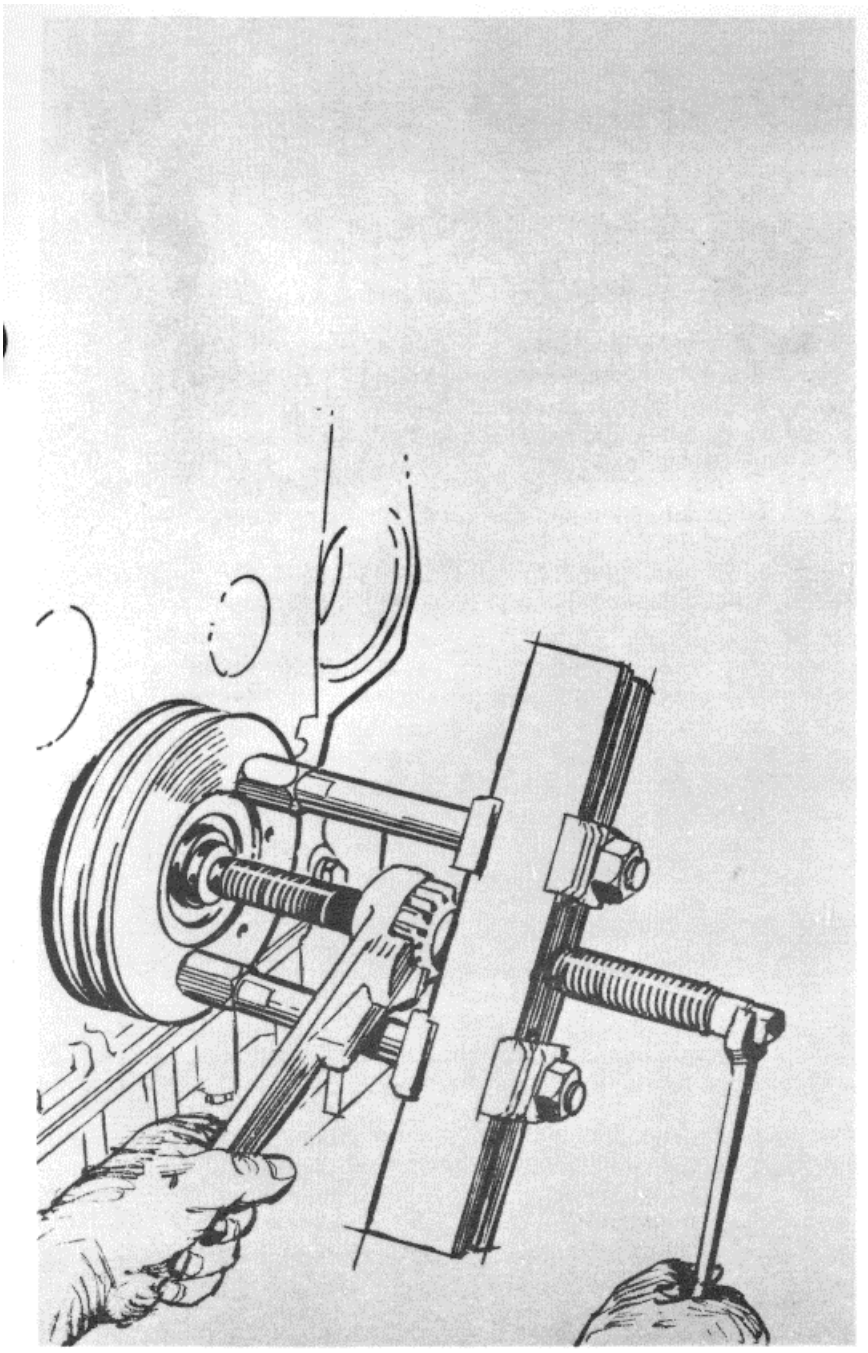
SEE NOTES ON PAGE THAT FOLLOWS

NOTE A: Magnetic pick-up and oil pressure switch to be wired to electric governor control (Woodward 2301) with a two conducter shielded cable (Belden Corp. type 8780 or equivalent). Shields are to be grounded at electric governor control grounding stud. Each shield should not have more than one ground connection.

NOTE B: Woodward 2301 Electric Governor Control terminal identification chart:

SYMBOL	FUNCTION	STAND-BY TS NO.
P	Batt +	2
R	Batt-	1
S	EGA +	6
T	EGA -	5
U	Mag Pick-up	7
V	Mag Pick-up	8
Y	Oil Pressure Speed Limiter	9
Z	Oil Pressure Speed Limiter	10

NOTE C: Caterpillar alarm and prealarm contacts are rated for a maximum of 3 amps inductive at the charging system voltage.

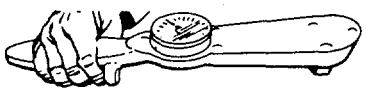


DISASSEMBLY AND ASSEMBLY

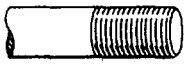
3500 INDUSTRIAL ENGINES

SERIAL NUMBERS:
68Z1-UP, 65Z1-UP

GENERAL TIGHTENING TORQUE FOR BOLTS AND NUTS



The following charts give the standard torque values for bolts, nuts and taperlock studs of SAE Grade 5 or better quality. Exceptions are given in other sections of the Service Manual where needed.

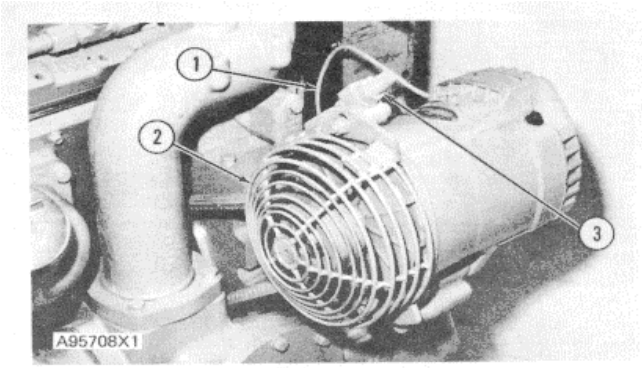
THREAD DIAMETER		STANDARD TORQUE	
inches	**millimeters**	**lb. ft.**	**N·m**
Standard thread 		**Use these torques for bolts and nuts with standard threads.**	
1/4	6.35	9 ± 3	12 ± 4
5/16	7.94	18 ± 5	24 ± 7
3/8	9.53	32 ± 5	43 ± 7
7/16	11.11	50 ± 10	68 ± 14
1/2	12.70	75 ± 10	100 ± 14
9/16	14.29	110 ± 15	150 ± 20
5/8	15.88	150 ± 20	205 ± 27
3/4	19.05	265 ± 35	360 ± 47
7/8	22.23	420 ± 60	570 ± 80
1	25.40	640 ± 80	870 ± 110
1-1/8	28.58	800 ± 100	1085 ± 135
1-1/4	31.75	1000 ± 120	1355 ± 165
1-3/8	34.93	1200 ± 150	1625 ± 205
1-1/2	38.10	1500 ± 200	2035 ± 270
		Use these torques for bolts and nuts on hydraulic valve bodies with standard threads.	
5/16	7.94	13 ± 2	18 ± 3
3/8	9.53	24 ± 2	33 ± 3
7/16	11.11	39 ± 2	53 ± 3
1/2	12.70	60 ± 3	80 ± 4
5/8	15.88	118 ± 4	160 ± 5
Taperlock stud 		**Use these torques for studs with Taperlock threads.**	
1/4	6.35	5 ± 2	7 ± 3
5/16	7.94	10 ± 3	14 ± 4
3/8	9.53	20 ± 3	27 ± 4
7/16	11.11	30 ± 5	40 ± 7
1/2	12.70	40 ± 5	55 ± 7
9/16	14.29	60 ± 10	80 ± 14
5/8	15.88	75 ± 10	100 ± 14
3/4	19.05	110 ± 15	150 ± 20
7/8	22.23	170 ± 20	230 ± 27
1	25.40	260 ± 30	355 ± 40
1-1/8	28.58	320 ± 30	435 ± 40
1-1/4	31.75	400 ± 40	540 ± 55
1-3/8	34.93	480 ± 40	650 ± 55
1-1/2	38.10	550 ± 50	745 ± 68

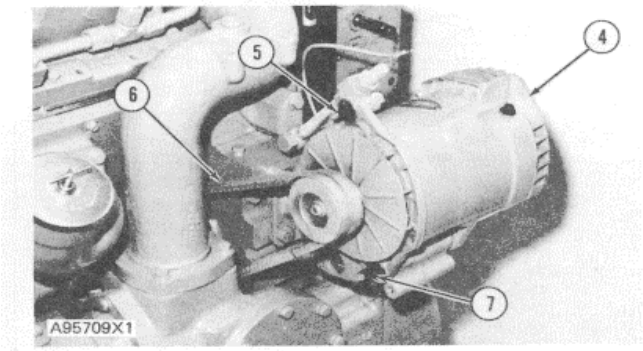
T95416-8

ALTERNATOR (AN ATTACHMENT)

REMOVE ALTERNATOR **1405-11**

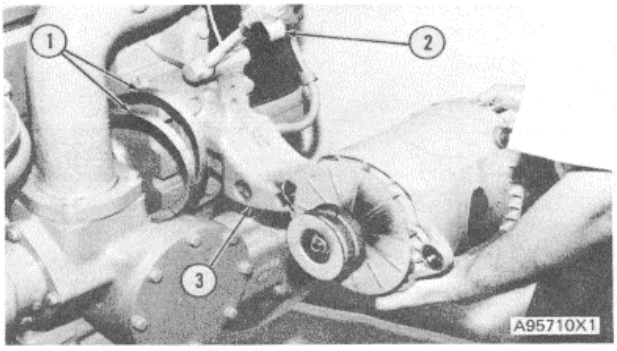
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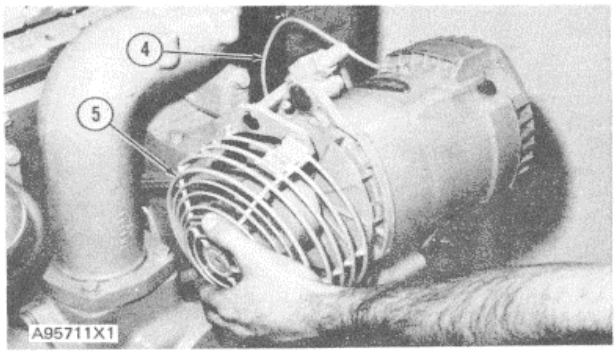




INSTALL ALTERNATOR **1405-12**

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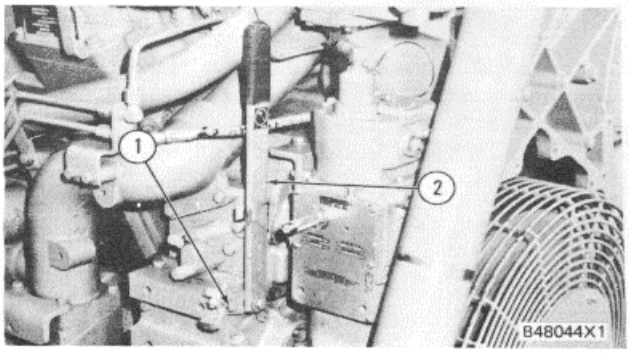


MANUAL SHUTOFF

REMOVE MANUAL SHUTOFF 7418-11

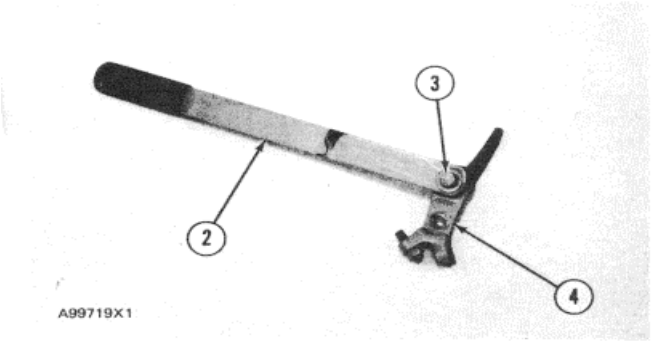
	Tools Needed	A
1P1856	Pliers	1

1. Remove bolt (1) and the washer. Pull lever (2), the adapter and lever from the front drive housing. There is an O-ring seal that holds the adapter in the front drive housing.



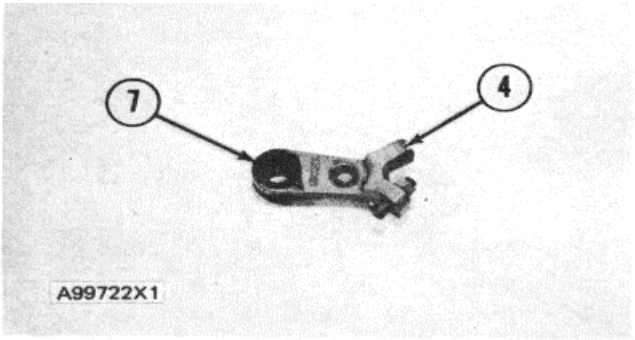
2. Remove bolt (3) and the washer to remove lever (2) from adapter (4).

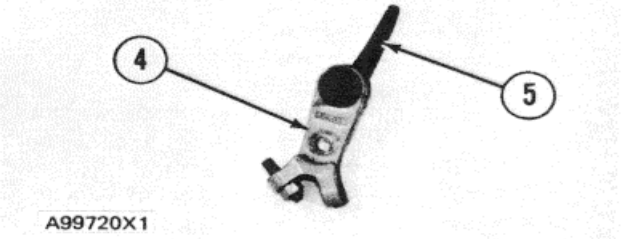
3. Use tool (A) and remove the ring that holds lever (5) in adapter (4). Remove lever (5) from adapter (4).

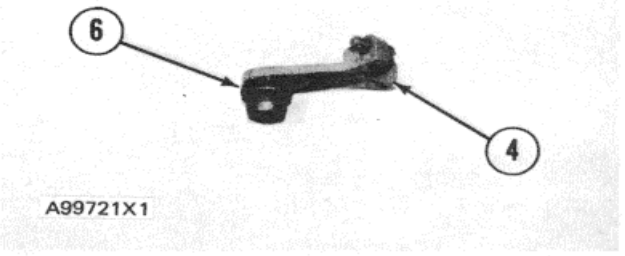


4. Remove 0-ring seal (6) from adapter (4).

5. Remove seal (7) from adapter (4).





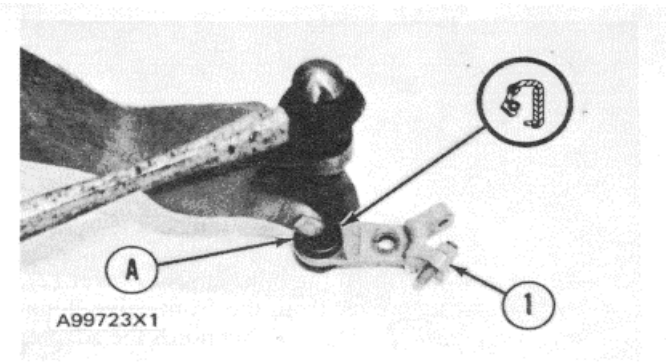


MANUAL SHUTOFF

INSTALL MANUAL SHUTOFF 7418-12

	Tools Needed	A	B
1P510	Driver Group	1	
1P1856	Pliers		1

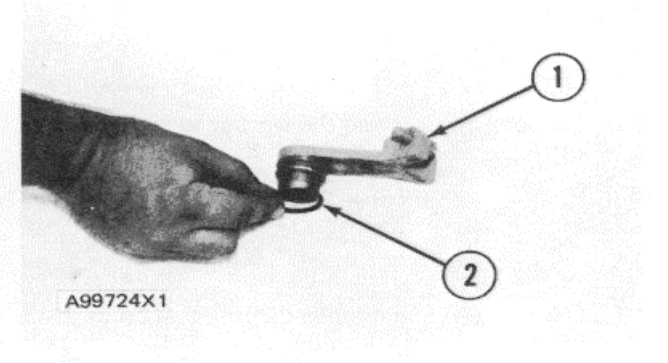
1. Use tool group (A) and install the seal in adapter (1) with the lip of the seal toward the inside as shown. Put clean engine oil on the lip of the seal.



2. Install O-ring seal (2) on adapter (1) and put clean engine oil on it.

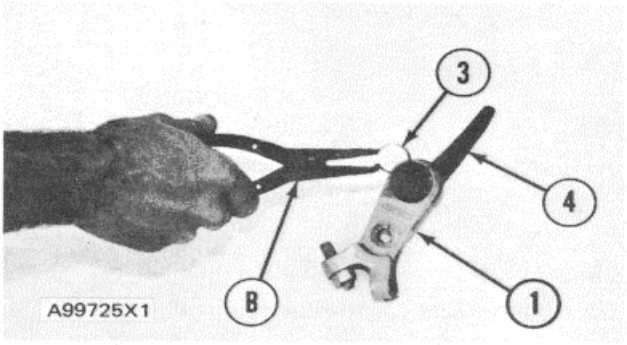
3. Put lever (4) in adapter (1) and use tool (B) to install ring (3) to hold the unit together.

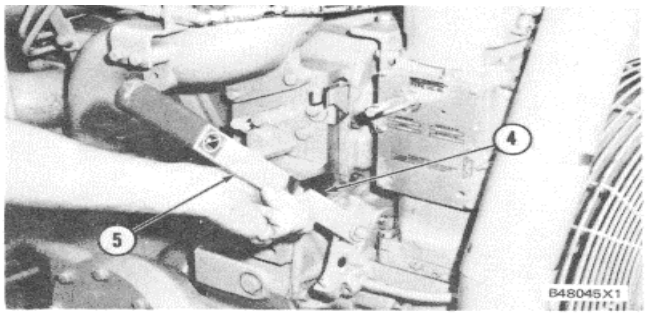
4 Put lever (5) in position and install the washer and bolt to hold it to lever (4).

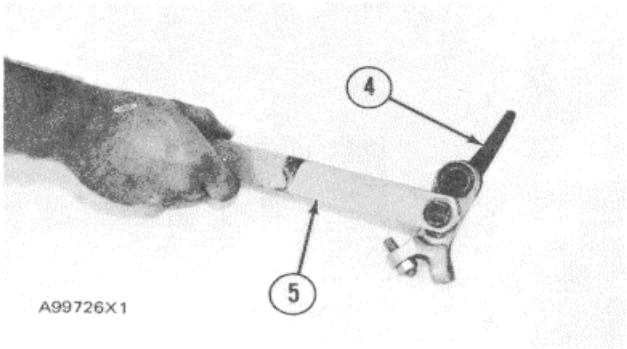


5. Install the levers and adapter in the front drive housing. Make sure lever (4) is under and in contact with the governor stop lever. Install the bolt and washer to hold the unit in position.

6. To make an adjustment of the shutoff levers, loosen the locknut and screw on the adapter. Pull lever (5) until the governor linkage makes contact with its stop and hold lever (5) in this position. Turn the adjustment screw until it makes contact with lever (5) and then turn it one more complete turn. Tighten the locknut.



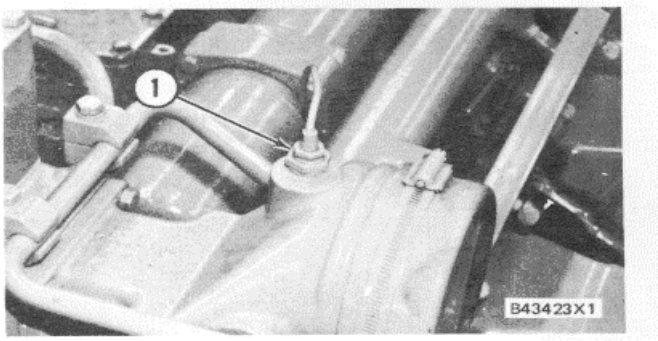




GAUGE PANEL

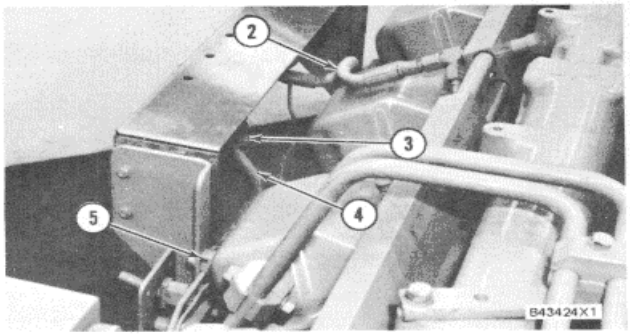
REMOVE GAUGE PANEL 7450-11

1. Remove water jacket temperature sending unit (1) from the regulator housing adapter.



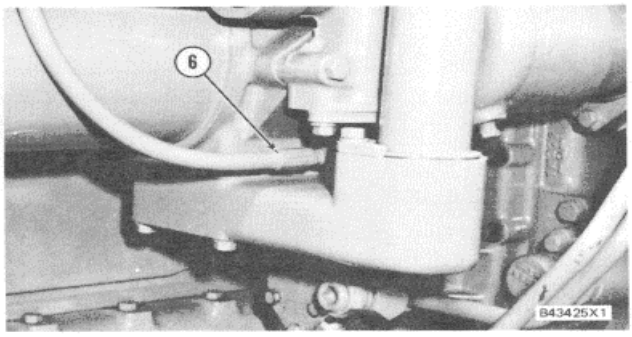
2. Disconnect hoses (2) and (4) from the engine and disconnect hose (3) from the gauge panel. Remove clamp (5) from the gauge panel bracket.

3. Disconnect hose (6) from the oil cooler.

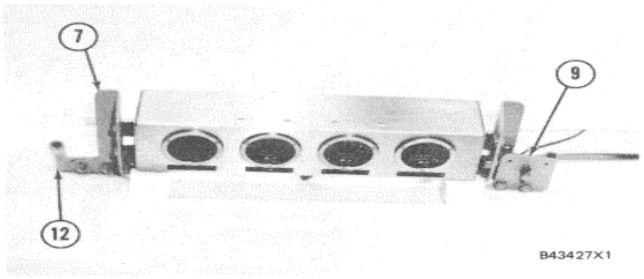


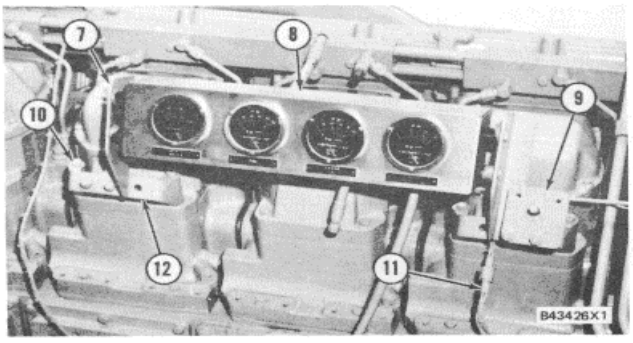
4. Disconnect wiring harness (11) from engine shutdown switch (9).

5. Remove four bolts (10) from supports (12) and remove gauge panel (8), brackets (7), supports (12) and switch (9) as a unit from the engine.



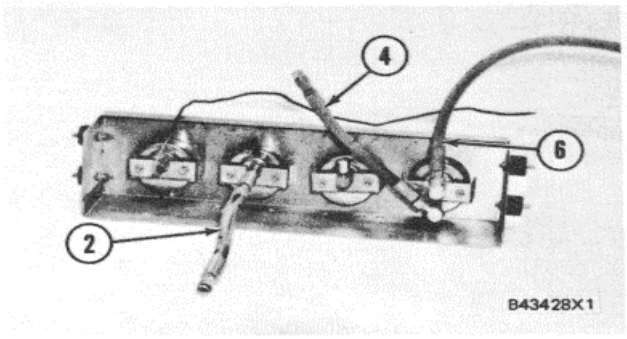
6. Remove the nuts and remove brackets (7), supports (12) and shutdown switch (9) from the gauge panel.



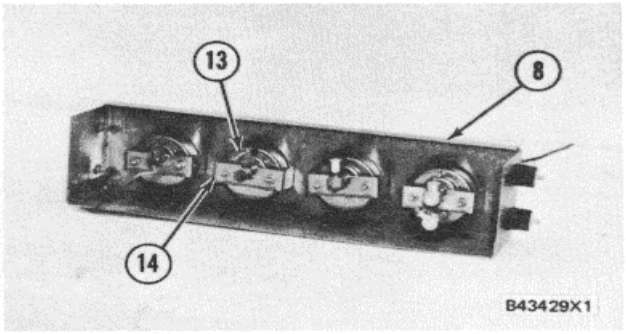


GAUGE PANEL

7. Put identification marks on hoses (2), (4) and (6) for correct installation, and remove the hoses from the gauges.

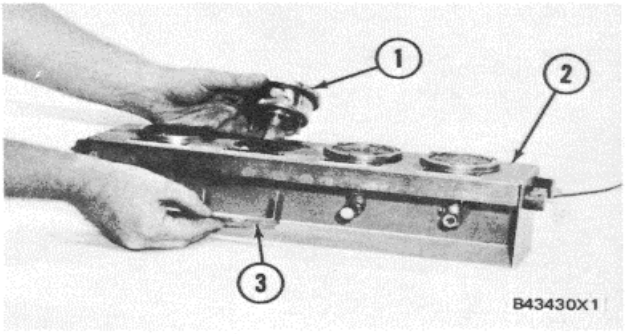


8. Remove the nuts and brackets (14) to remove the four gauges (13) from the front of panel (8).

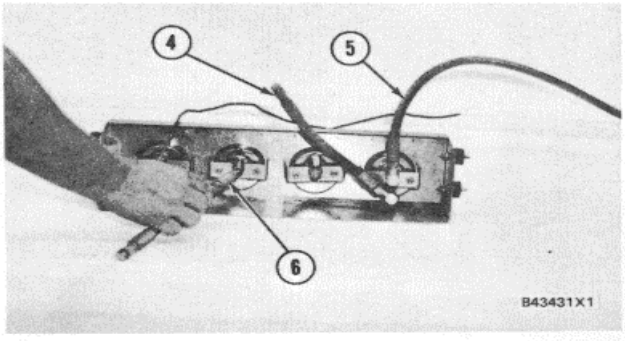


INSTALL GAUGE PANEL 7450-12

1. Put the four gauges (1) in position in panel (2) and install brackets (3) and the nuts to hold the gauges in position.

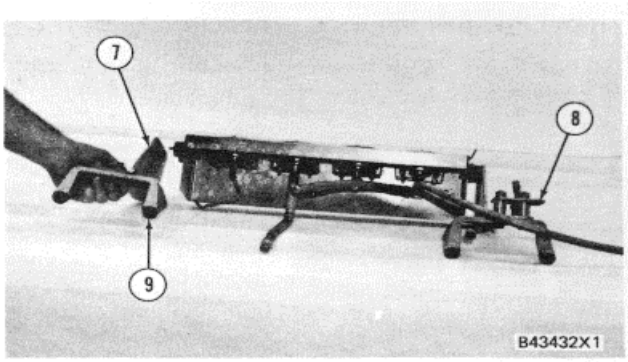


2 Install hoses (4), (5) and (6) on the gauges.

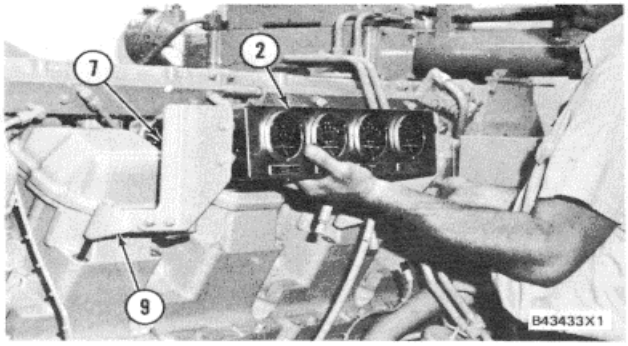


GAUGE PANEL

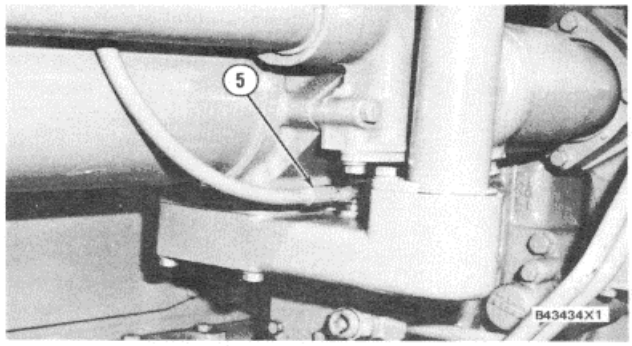
3. Put brackets (7), supports (9) and engine shutdown switch (8) in position on the gauge panel and install the nuts to hold these in position.



4. Put gauge panel (2), brackets (7), supports (9) and the shutdown switch as a unit in position on the engine. Install the bolts to hold the unit in position.



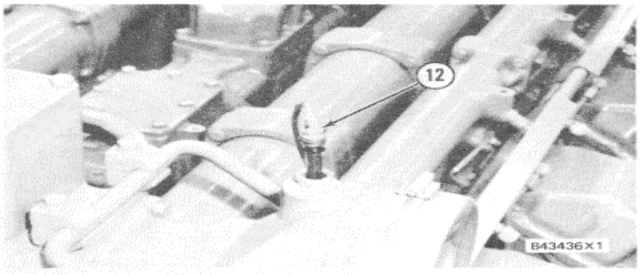
5. Connect hose (5) to the oil cooler.

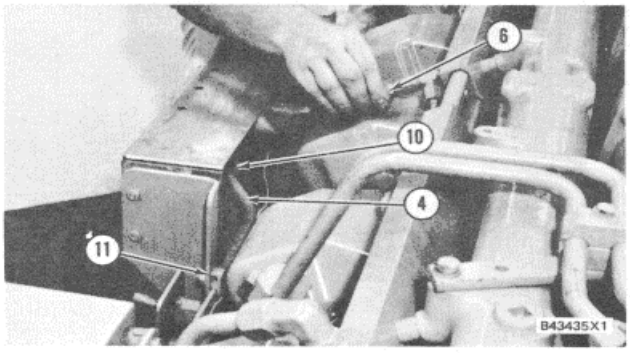


6. Install clamp (I 1) on the gauge panel bracket. Connect hose (10) to the gauge panel and connect hoses (4) and (6) to the engine.

NOTE: Make sure the capillary tube from sending unit (12) does not make direct contact with the engine.

7. Install water jacket temperature sending unit (12) in the regulator housing adapter.

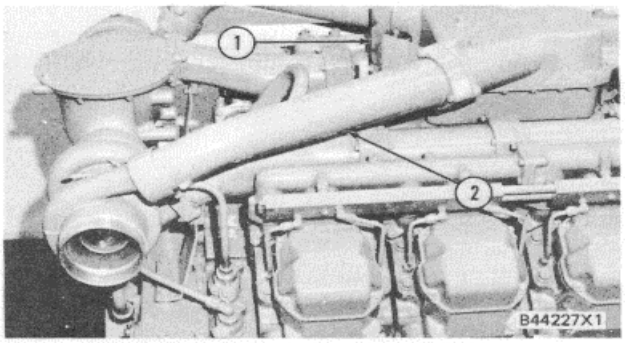




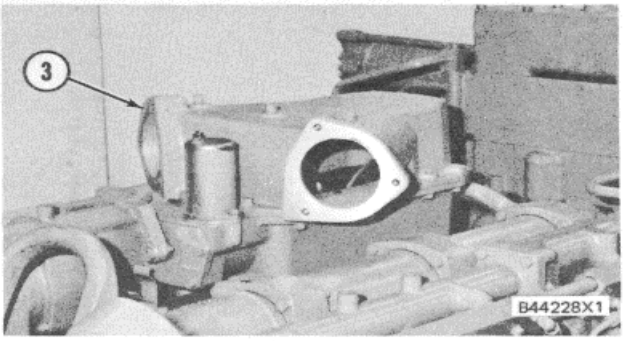
AIR INTAKE SHUTOFF (3508)

REMOVE AIR INTAKE SHUTOFF 1078-11

1. Disconnect the harness assembly to the shutoff solenoid.

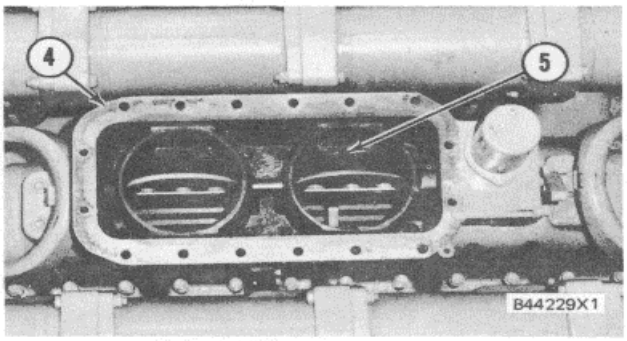


2. Remove the bolts to remove shield ( ) and pipes (2) from the engine.



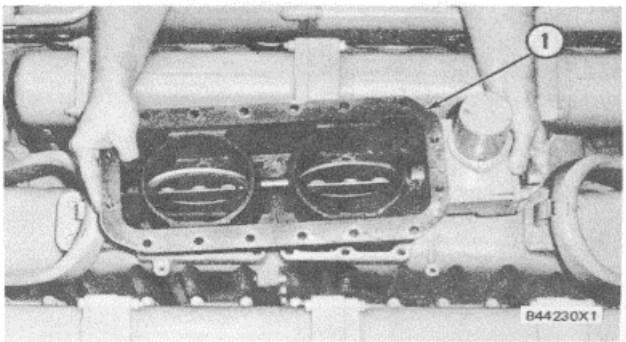
3. Remove the bolts and remove air intake cover (3) from the air shutoff group.

4. Remove bolts (5) and remove air shutoff group (4) from the aftercooler housings.



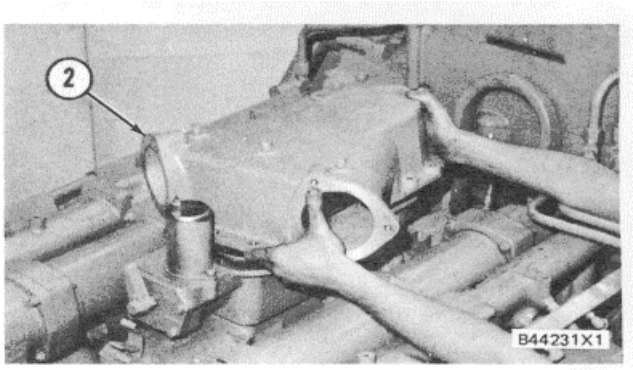
INSTALL AIR INTAKE SHUTOFF 1078-12

1. Put the gaskets and air shutoff group (1) in position on the aftercooler housings. Install the bolts to hold the group in position.

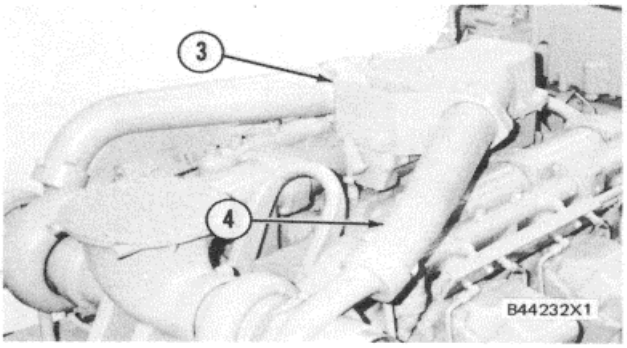


AIR INTAKE SHUTOFF (3508)

2. Put the gasket and air intake cover (2) in position on the air shutoff group. Install the bolts to hold cover (2) in position.

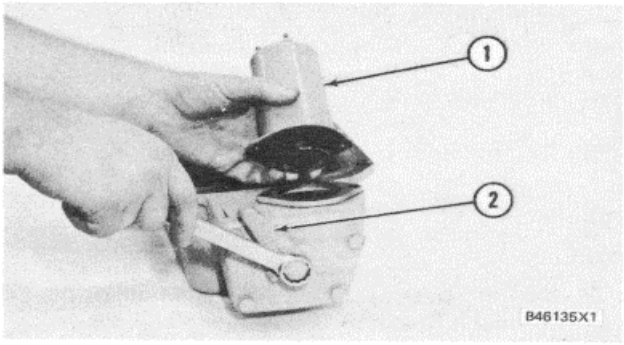


3. Put clean engine oil on the O-ring seals on pipes (4). Put pipes (4) and shield (3) in position on the engine and install the bolts to hold these in position.



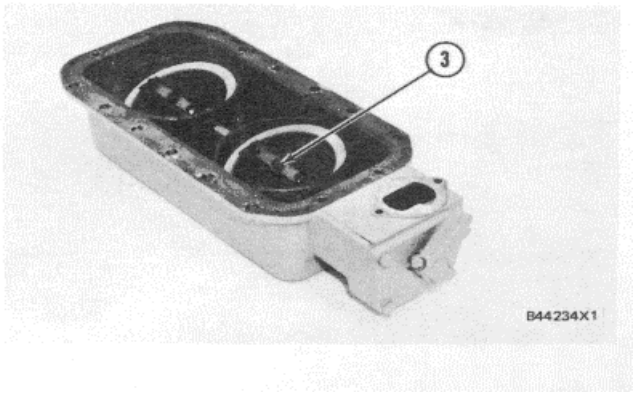
DISASSEMBLE AIR INTAKE SHUTOFF 1078-15

start by:
a) remove air intake shutoff



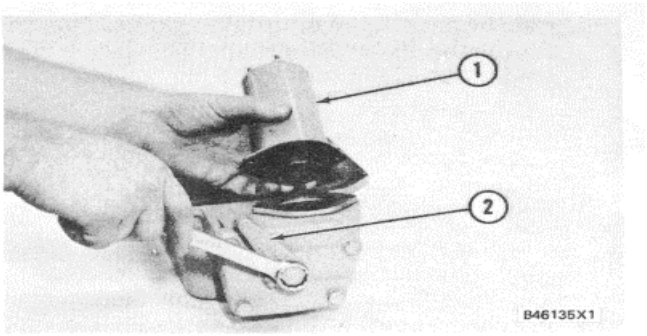
1. Remove the bolts from solenoid (1). Hold handle (2) in the position as shown by hand or with a wrench and remove solenoid (1) from the air shutoff group. Slowly release handle (2) to the shutoff position.

2. Bend the locks away from bolts (3) and loosen all of bolts (3) that hold the plate assemblies to the shaft assembly.



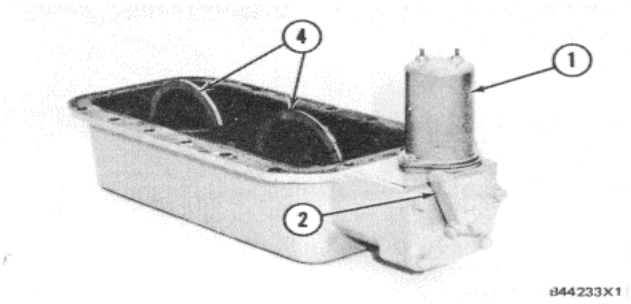
AIR INTAKE SHUTOFF (3508)

3. Move handle (2) back to the position as shown by hand or with a wrench and put solenoid (1) in position in the shutoff housing assembly. Install the bolts and release the handle.



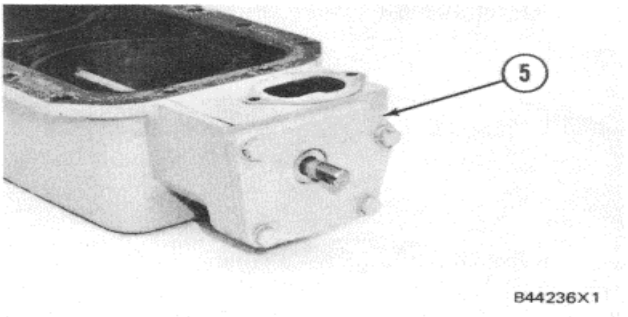
4. Remove the bolts, the locks, the plates and bushings from plate assemblies (4). Remove plate assemblies (4) from the shaft assembly.

5. Do Step I again to remove solenoid (1).



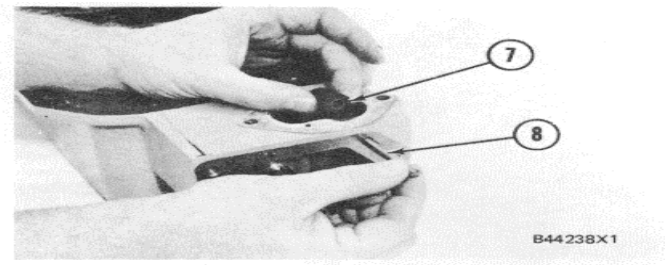
6. Remove the bolt and remove handle (2) from the shaft assembly.

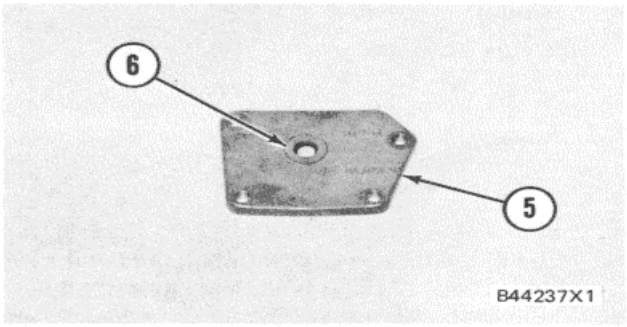
7. Remove the bolts and remove cover assembly (5) from the housing assembly.



8. Remove seal (6) from cover assembly (5).

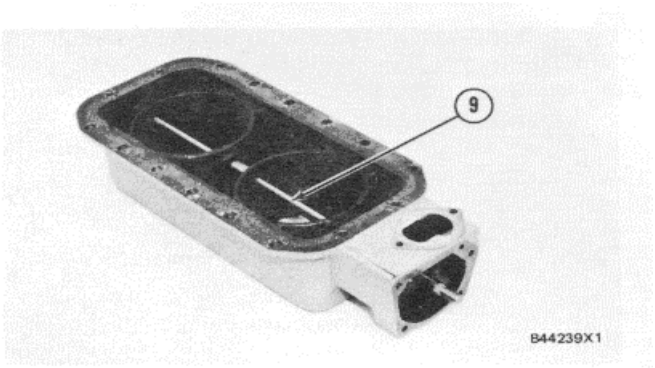
9. Remove pin (8) to remove spacer assembly (7) from the housing assembly.



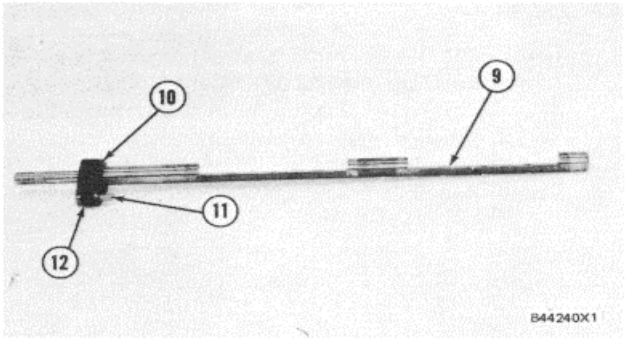


AIR INTAKE SHUTOFF (3508)

10. Remove shaft assembly (9), the spacer and spring from the housing assembly. Remove the spring and spacer from the shaft assembly.



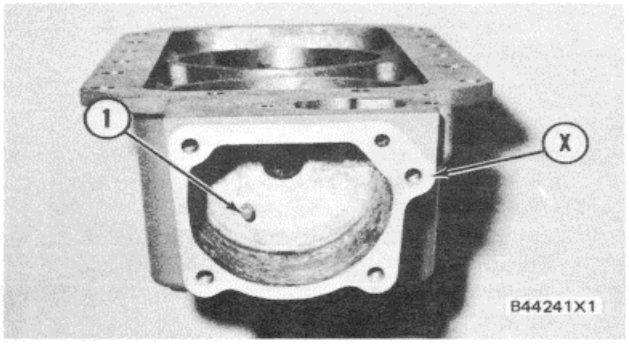
11. If necessary, remove the dowel and remove lever (10), spacer assembly (12) and pin (11) as a unit from shaft assembly (9). Remove pin (11) from lever (10) to remove spacer assembly (12) from lever (10) if necessary.



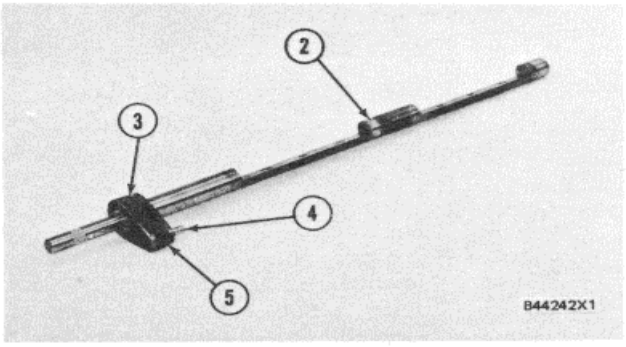
ASSEMBLE AIR INTAKE SHUTOFF 1078-16

	Tools Needed	A
1P510	Driver Group	1

1. If necessary, make a replacement of dowel (1) and make sure the end of the dowel as shown is 83.0 ± 0.5 mm (3.268 ± .020 in.) below surface (X).

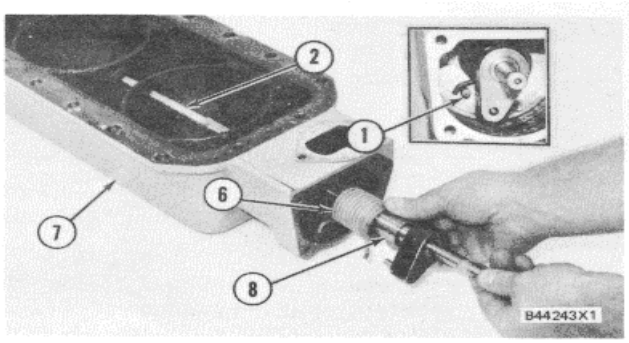


2. If shaft assembly (2) was disassembled, put spacer assembly (5) in position on lever (3) and use a press to install pin (4) until it is even (flush) with the surface of lever (3) as shown. Put lever (3), spacer assembly (5) and pin (4) as a unit in position on shaft assembly (2). Install the dowel to hold the unit on shaft assembly (2) and put marks (stake) the end of the dowel.

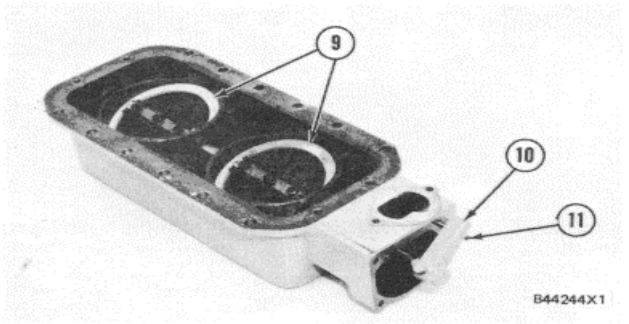


AIR INTAKE SHUTOFF (3508)

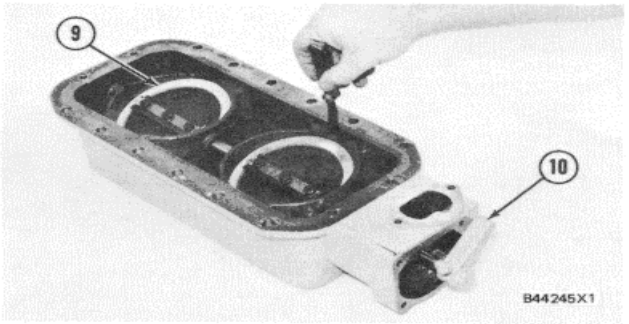
3. Install spacer (8) and spring (6) on shaft assembly (2). Install shaft assembly (2) in housing assembly (7). Make sure spring (6) is correctly engaged with dowel (I) as shown.



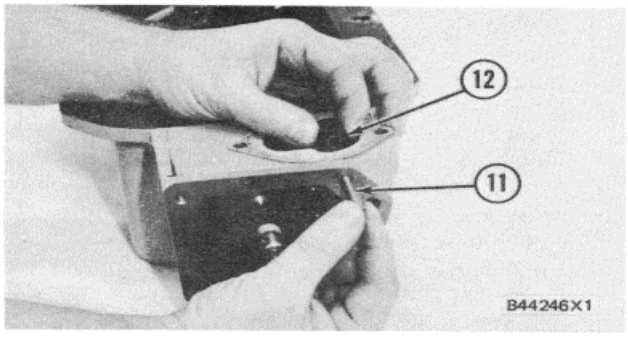
4. Install handle (10) on the shaft assembly. Turn handle (10) up (upward) and install pin (11) so handle (10) can be put in contact with pin (1). With handle (10) in contact with pin (11), install plate assemblies (9) on the shaft assembly.



5. Release handle (10) from the pin and remove the pin so plate assemblies (9) can move to the "SHUTOFF" position. A 0.076 mm (.003 in.) feeler gauge must not pass between plate assemblies (9) and the housing assembly as shown. Remove handle (10) from the shaft assembly.

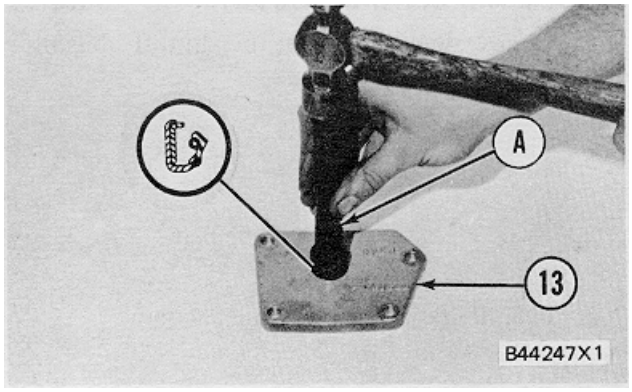


6. Put spacer assembly (12) in position and install pin (11) in the housing assembly through the spacer assembly.

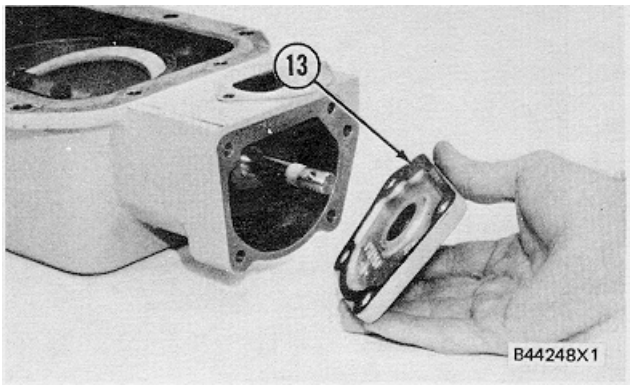


AIR INTAKE SHUTOFF (3508)

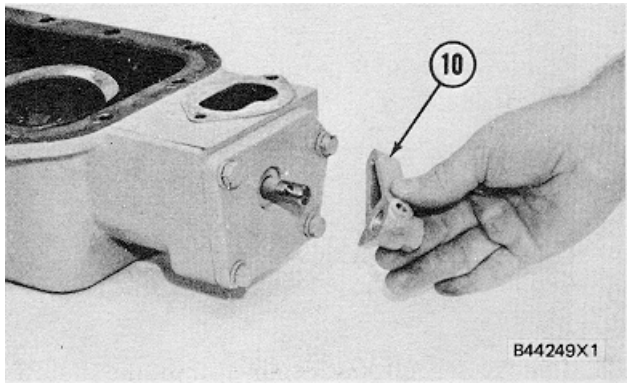
7. Use tool group (A) to install the seal until it is even (flush) with the inside surface of cover assembly (13). Make sure the lip of the seal is toward the outside surface of the cover as shown.



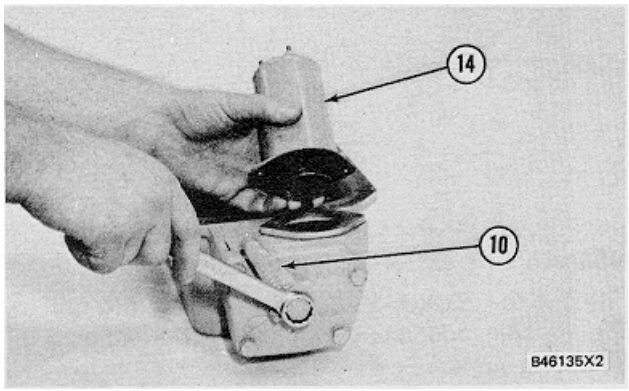
8. Install cover assembly (13) on the housing assembly and the bolts to hold it.



9. Install handle (10) on the shaft assembly and the bolts to hold it.



NOTE: To make the installation of the bolts in the air shutoff group easier, the electric solenoid must be installed before the air shutoff group is installed on the engine.



10. Turn handle (10) to the open position as shown and put the gasket and solenoid (14) in position on the housing assembly. Release the handle and install the bolts to hold the solenoid in position.

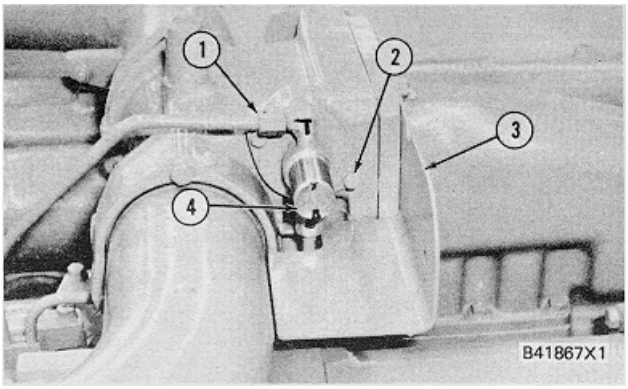
end by:

a) install air intake shutoff

AIR INTAKE SHUTOFF (3512)

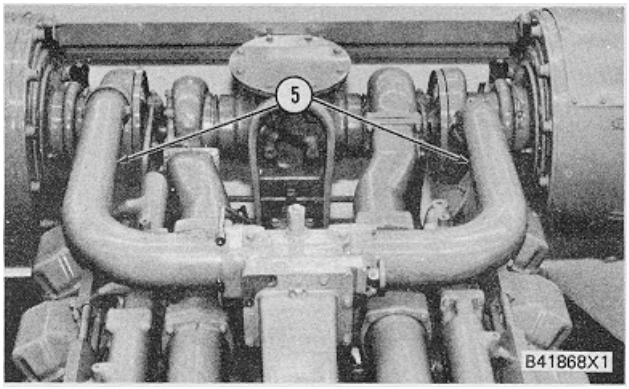
REMOVE AIR INTAKE SHUTOFF 1078-11

1. Remove shield (3) from the shutoff housing.

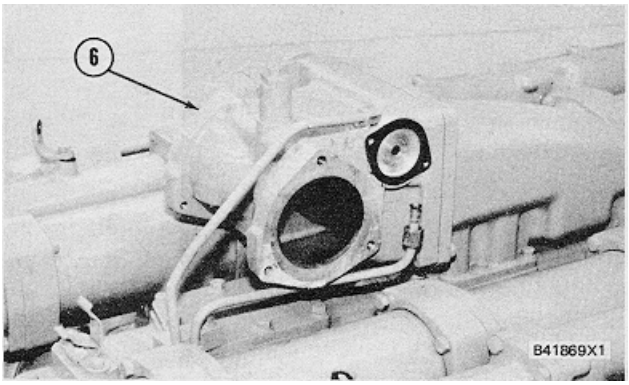


2. Turn off the air supply to the engine.

3. Disconnect tube assemblies (1) and remove bolts (2). Remove air shutoff cylinder (4) and the flange from the shutoff housing.



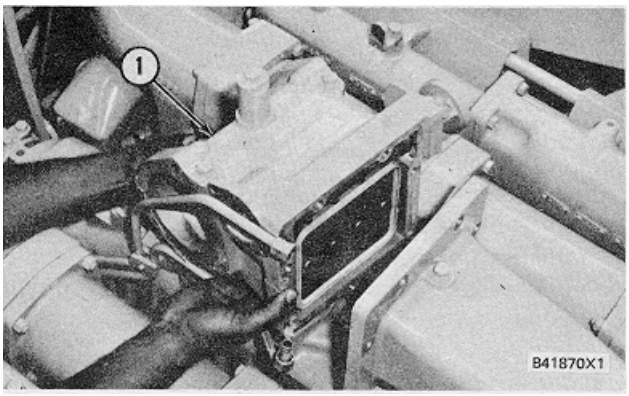
4. Remove pipes (5) from the turbochargers and shutoff housing.



5. Remove the bolts and remove air intake shutoff (6) from the engine.

INSTALL AIR INTAKE SHUTOFF 1078-1

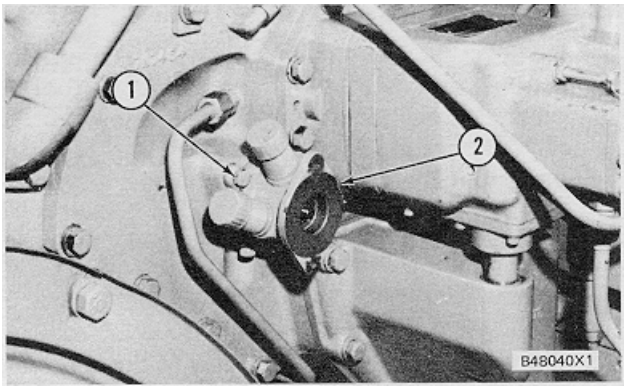
1. Put the gasket and air intake shutoff (I) in position and install the bolts that hold it in position.



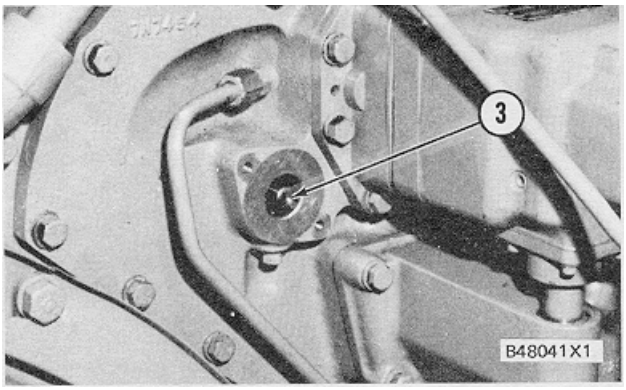
TACHOMETER DRIVE

REMOVE TACHOMETER DRIVE 7487-11

start by:
a) remove service meter

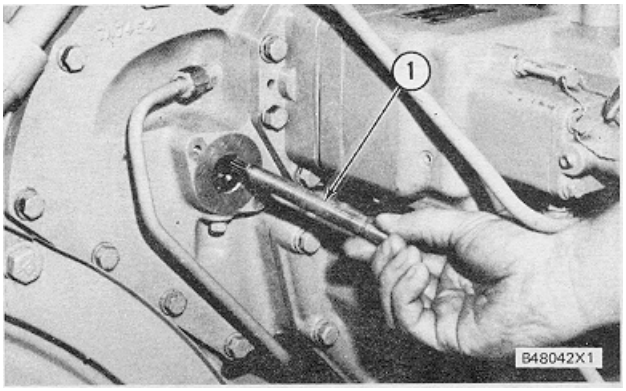


1. Disconnect the harness assemblies from the adapter assembly.



2. Remove bolts (1) and the clamps to remove adapter assembly (2) from the shutoff drive housing assembly.

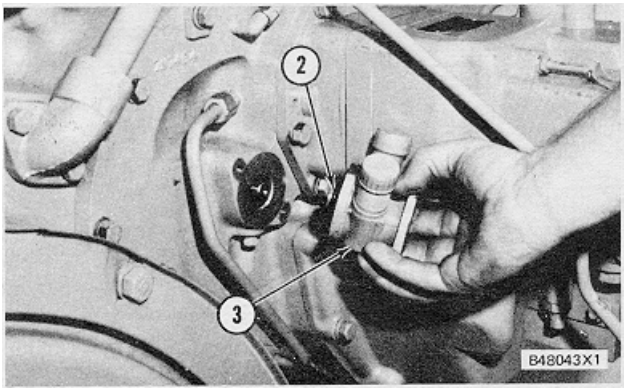
3. Remove shaft (3) from the gear assembly on the end of the camshaft and the shutoff drive housing assembly.



INSTALL TACHOMETER DRIVE 7487-12

1. Install shaft (1) through the shutoff drive housing assembly and into the gear assembly on the end of the camshaft.

2. Put clean engine oil on O-ring seal (2) and install adapter assembly (3) in the shutoff drive assembly. Make sure the shaft of the adapter assembly engages in the groove (slot) on the end of shaft (1). Install the bolts and the clamps to hold the adapter assembly.

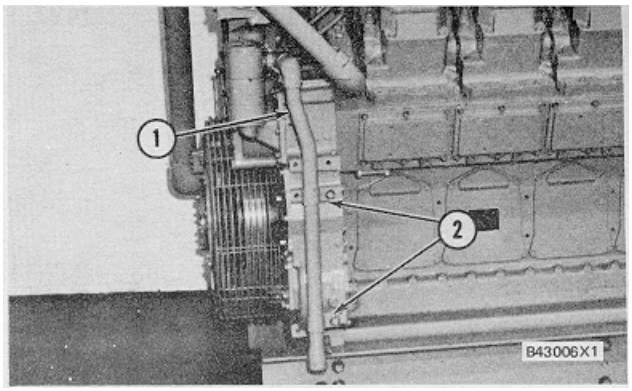


3. Connect the harness assemblies to the adapter assembly.
end by:
a) install service meter

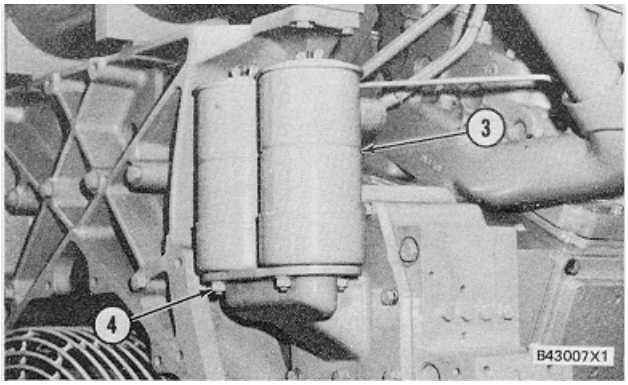
CRANKCASE BREATHER

REMOVE CRANKCASE BREATHER 1317-11

1. Remove the bolts from clips (2). Loosen the clamps that hold the hose assembly to the crankcase breather assemblies. Remove fumes disposal group (1) and the hose assembly as a unit from the breather assemblies.

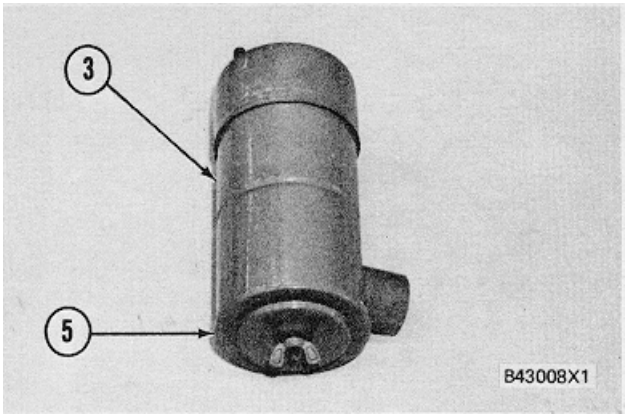


2. Remove four nuts (4) and remove breather assemblies (3) from the elbow.



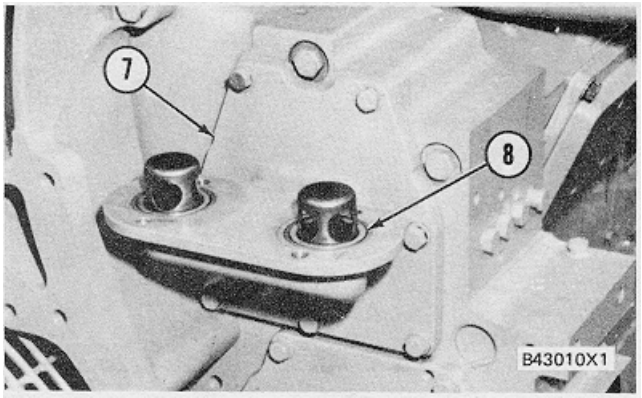
3. Remove cover assembly (5) from each breather assembly (3).

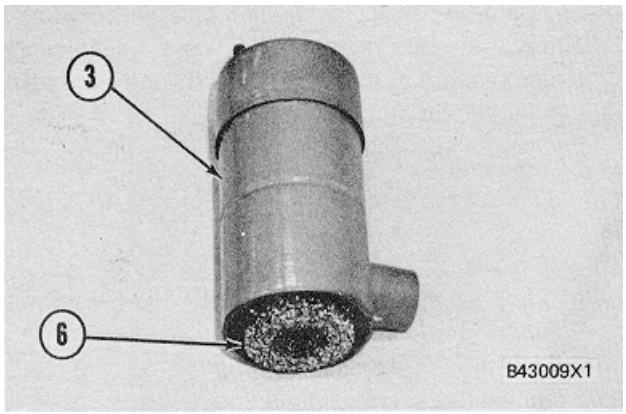
4. Remove filter element (6) from each breather assembly (3).



5. Remove O-ring seals (8) from elbow (7).

6. Remove elbow (7) and the gasket from the front drive housing.

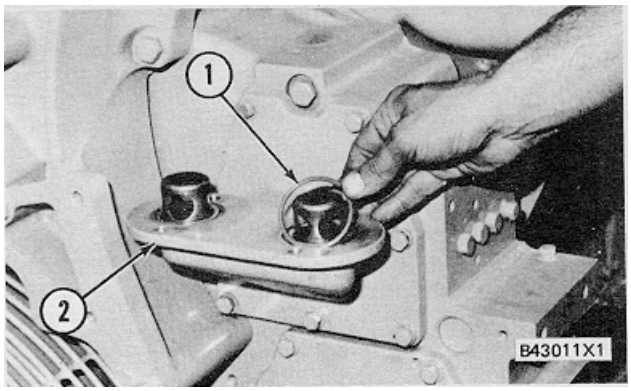




CRANKCASE BREATHER

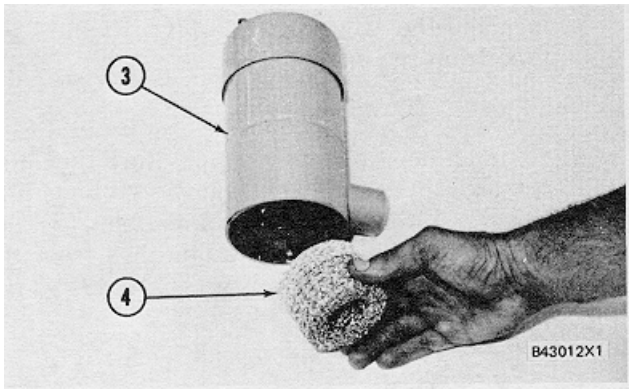
INSTALL CRANKCASE BREATHER 1317-12

1. Install the gasket and elbow (2) on the front drive housing.



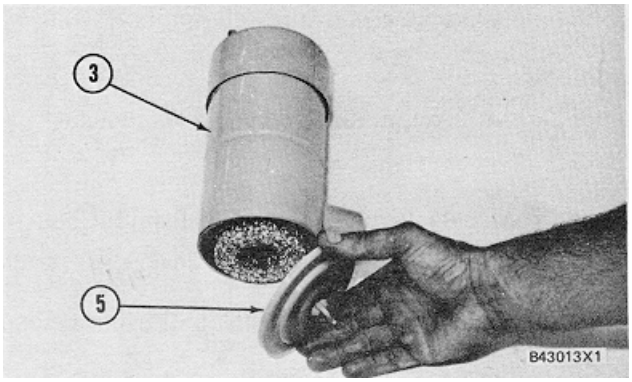
2. Install O-ring seals (1) on the elbow and put clean oil on the seals.

3. Install element (4) in each breather assembly (3).

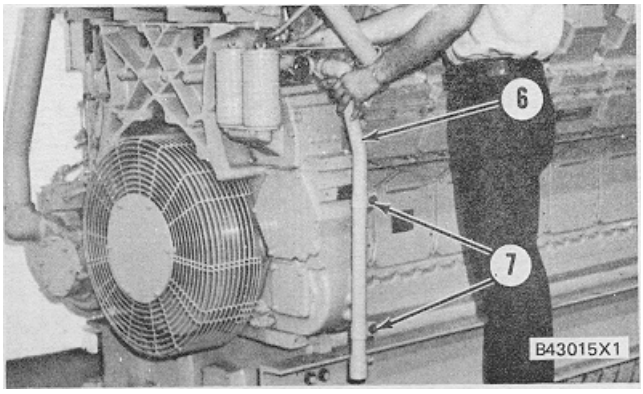


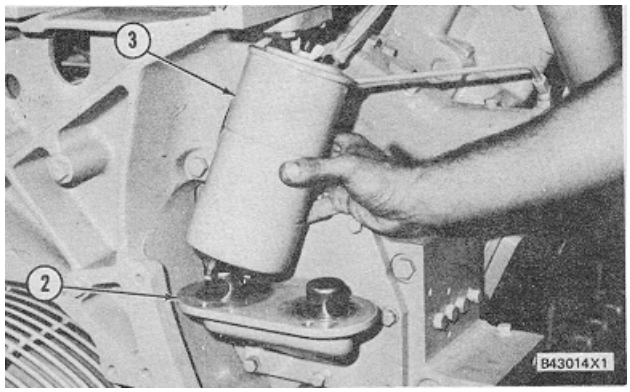
4. Install cover assembly (5) on each breather assembly (3).

5. Put breather assemblies (3) in position on elbow (2) and install the four nuts to hold the breathers in position.



6. Put fumes disposal group (6) and the hose assembly in position on the breather assemblies. Tighten the clamps for the hose assembly and install the bolts to hold clips (7) to the front drive housing.



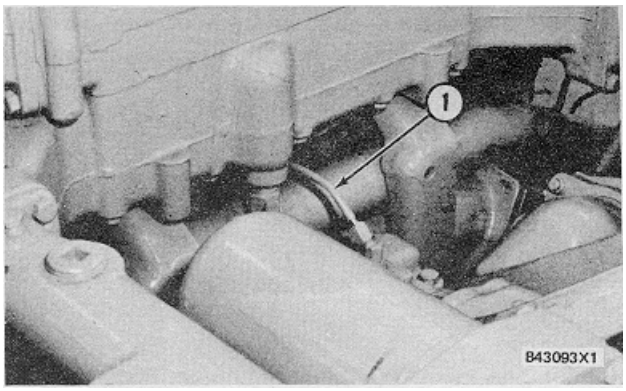


WATER TEMPERATURE REGULATORS

REMOVE WATER TEMPERATURE REGULATORS 1355-11

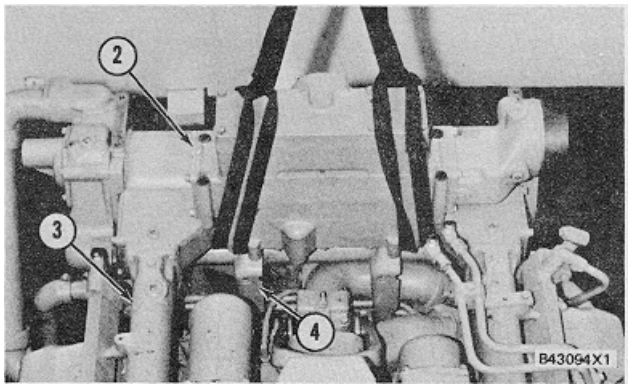
start by:
a) remove fuel filter housing

1. Remove the clamps to remove the fuel lines from the water temperature regulator housings and remove the plate on top of the oil filter housing.



2. Disconnect tube (I) from the regulator housings and the aftercooler adapter. Remove the tube from the engine.

3. Fasten a hoist to water temperature regulator housings (2) as shown. Remove the bolts that hold housings (2) to water manifolds (3) and brackets (4). Remove the housings from the engine. The weight of housings (2) is 49 kg (108 lb.).

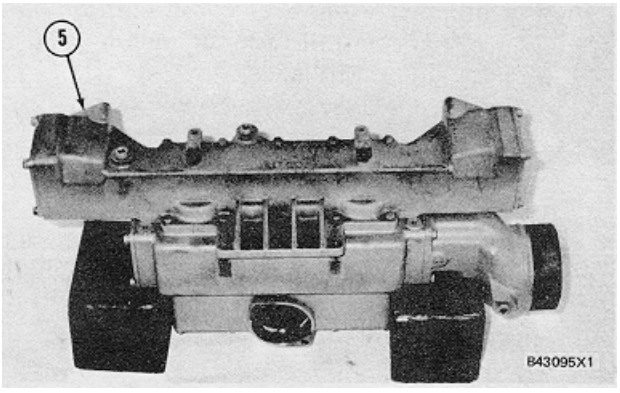


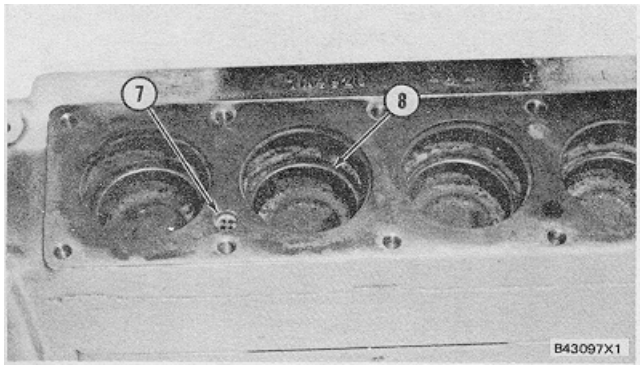
4. Remove the bolts and remove housing (5) from the water temperature regulators.

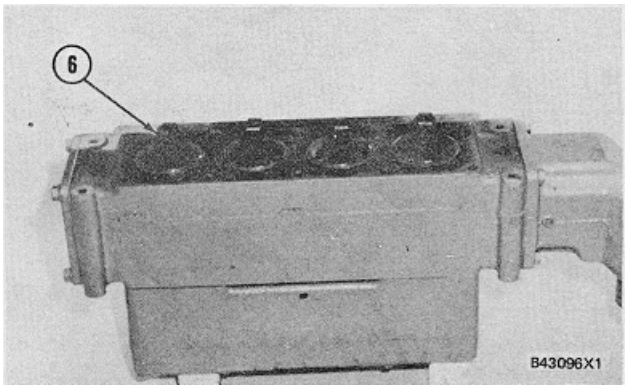
5. Remove regulators (6) from the housing.

6. If necessary, remove seals (8) from the housing.

7. Remove ferrule (7) and the ball from the housing necessary.







WATER TEMPERATURE REGULATORS

INSTALL WATER TEMPERATURE REGULATORS 1355-12

	Tools Needed	A
1P510	Driver Group	1

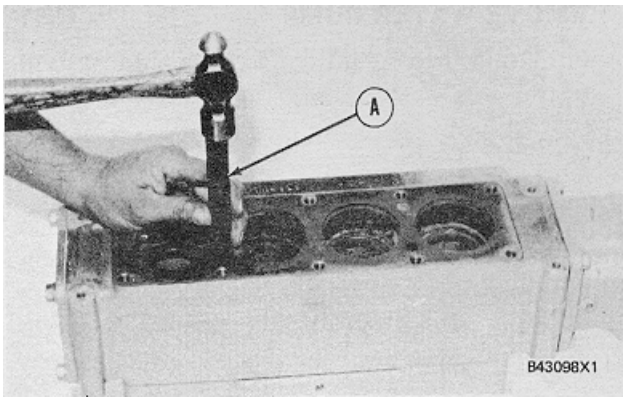
1. If the ball and ferrule were removed, install the ball and use tooling (A) to install the ferrule until it makes contact with the bottom of the bore. Make sure the open end of the ferrule is toward the outside of the housing.'

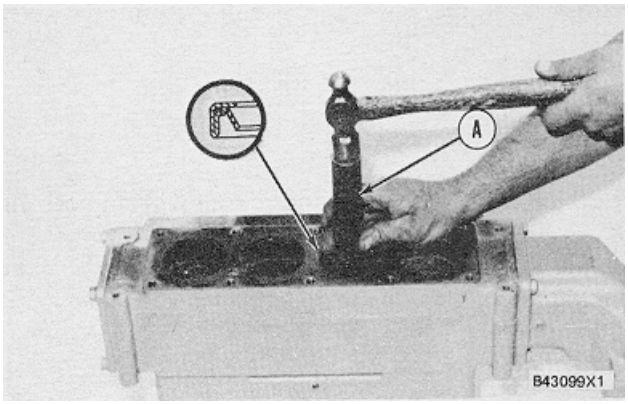
2. If the seals were removed, use tooling (A) to install the seals in the housing. Make sure the lip of the seal is toward the inside of the housing as shown.

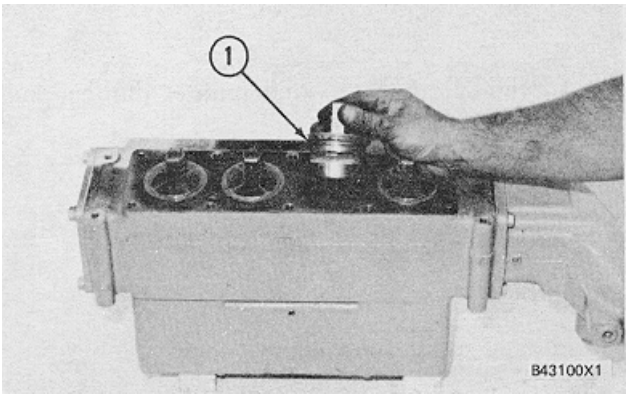
NOTICE

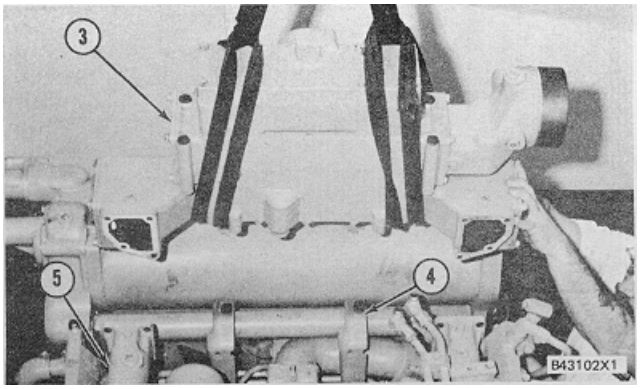
If the water temperature regulators are installed wrong, it will cause the engine to overheat.

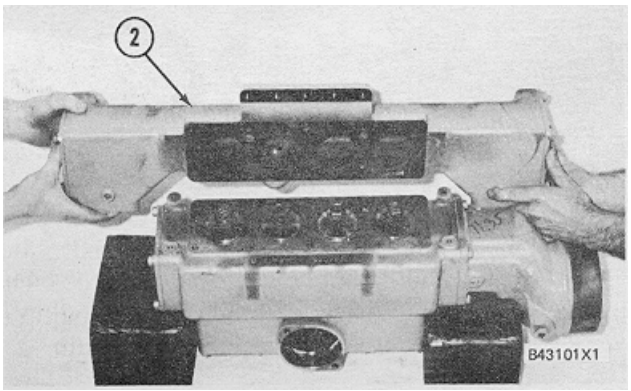
3. Install water temperature regulators (1) in the, housing with the spring up as shown.
4. Put housing (2) and the gasket in position on the regulators. Install the bolts to hold the housing in position.
5. Fasten a hoist to water temperature regulator housings (3) and put the housings and gaskets in position on the engine. Install the bolts to hold the housings to water manifolds (5) and brackets (4).
6. Install the tube between the aftercooler adapter and the regulator housings.
7. Put the plate on top of the oil lifter housing and install the bolts. Install the fuel lines and the clamps on the water temperature regulator housings.
   end by:
   a) install fuel filter housing







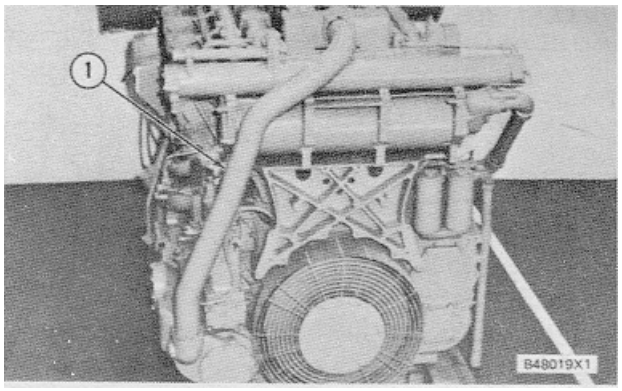




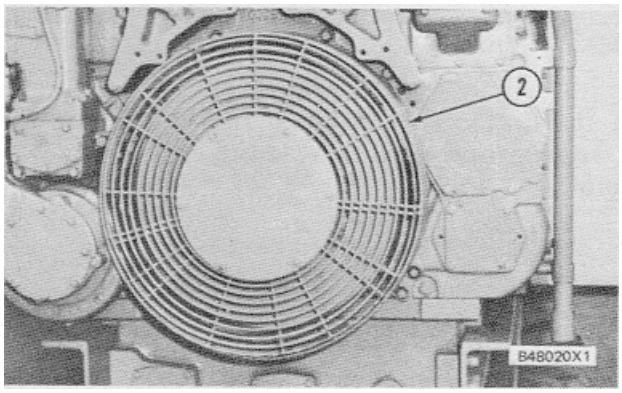
WATER PUMP

REMOVE WATER PUMP 1361-11

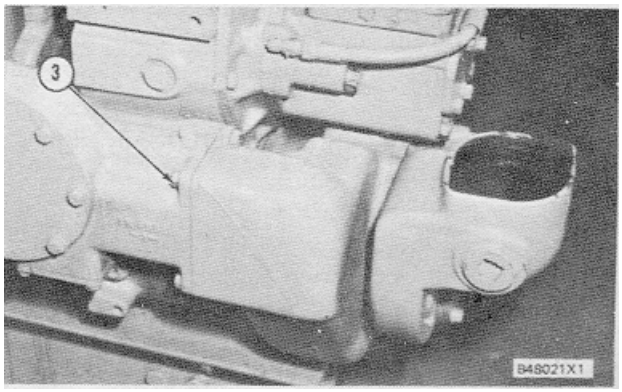
1. Drain the coolant from the cooling system.



2. Disconnect the water supply line from the water pump inlet.

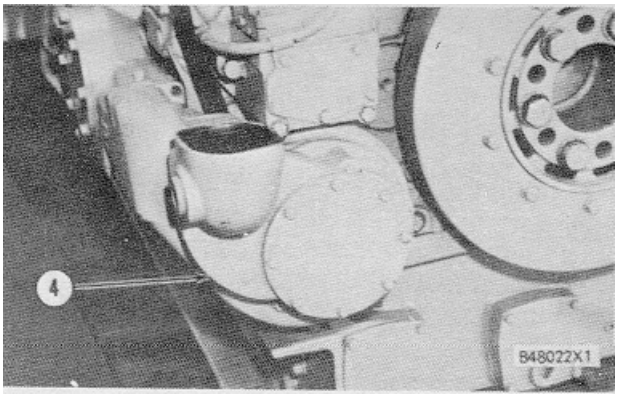


3. Remove the bolts and retainers from both ends, of tube (1) and remove tube (1) from the engine.



4. Remove the bolts and remove damper guard (2) from the engine.

5. Remove bolts (3) that hold the pump to the water line adapter.

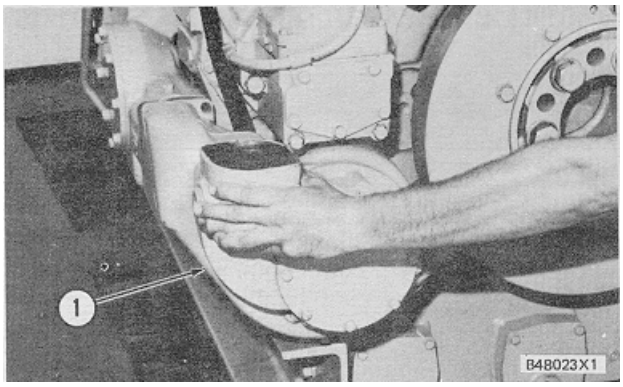


6. Fasten a hoist to water pump (4) and remove the four bolts that hold the pump to the oil and water pump drive adapter. Remove pump (4) from the engine. The weight of the pump is 39 kg (85 lb.).

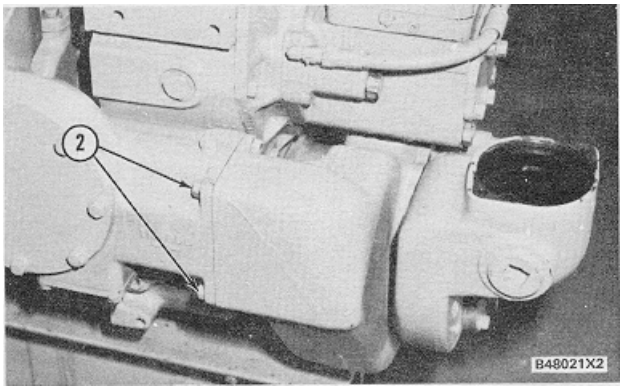
WATER PUMP

INSTALL WATER PUMP 1361-12

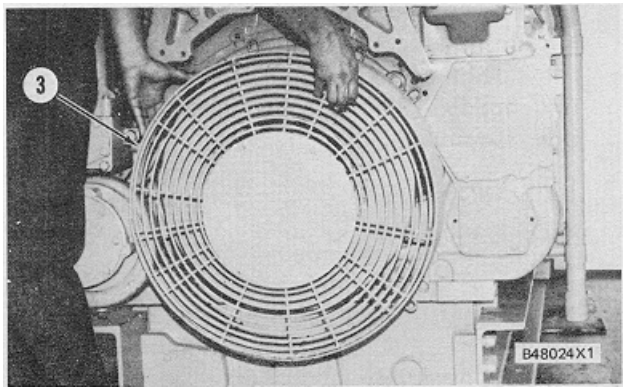
1. Make sure the gasket for the water line adapter and the O-ring seal on the pump are in position. Put clean engine oil on the O-ring seal. Fasten a hoist to water pump (1) and put water pump (1) in position on the engine. Make sure the splines on the pump shaft are correctly engaged and install the bolts to hold the pump to the oil and water pump drive adapter.



2. Install bolts (2) to hold the pump to the water line adapter.

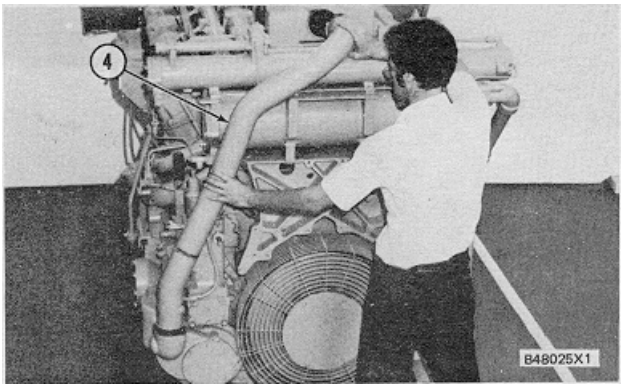


3. Install damper guard (3) on the engine.



4. Make sure the O-ring seals on both ends of tube (4) are in position and put clean engine oil on the seals. Put tube (4) in position and install retainers and bolts to hold the tube in position.

5. Connect the water supply line to the water pump inlet.



6. Fill the cooling system with coolant to the correct level.

WATER PUMP

DISASSEMBLE WATER PUMP 1361-15

	Tools Needed	A
5F7465	Puller Assembly	1
4B3903	Bolt (5/16"-18 NC x 4 in. long)	2
4B5270	Washer (5/16")	2
4B5271	Washer (3/8")	2
4B5273	Washer (1/2")	2
1P458	Drive Plate	1

start by:
a) remove water pump

1. Remove elbow (1) from housing assembly (2). Remove the 0-ring seal from elbow (1).

2. Remove O-ring seal (5) from the back of housing assembly (2).

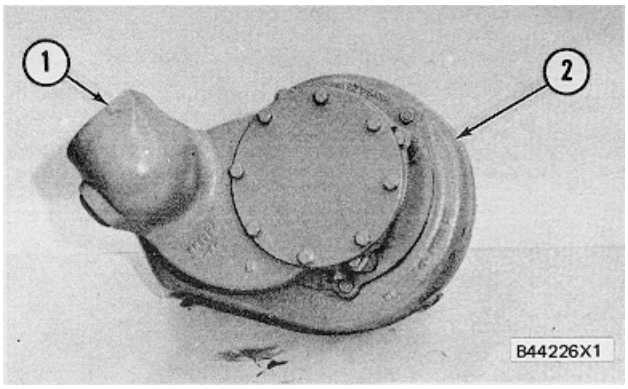
3. Remove washer (4) that holds shaft assembly (3) in housing assembly (2).

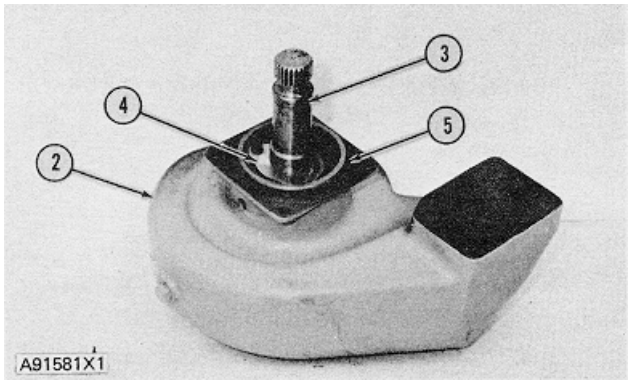
4. Remove cover (6) from housing assembly (2). Remove the O-ring seal from cover (6).

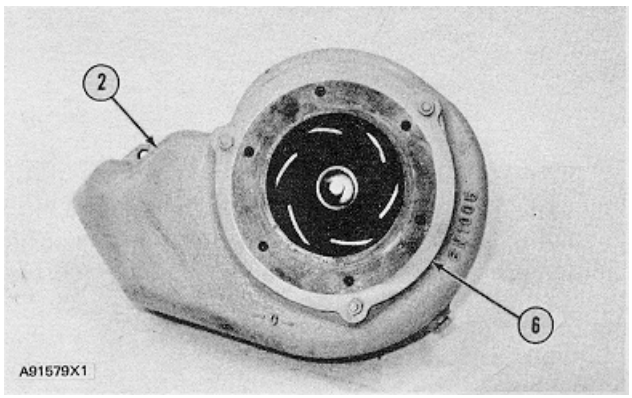
5. Loosen bolt (8) and the washer that hold impeller (7) to the pump shaft. Use tooling (A) to loosen impeller (7) from the end of the pump shaft. Remove tooling (A), bolt (8), the washer and impeller (7) from the pump shaft and housing assembly (2).

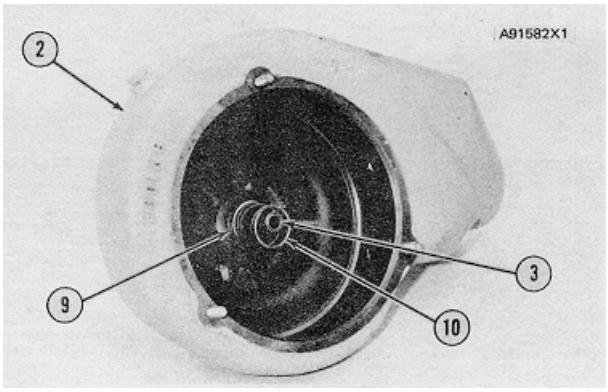
6. Remove spring (10) from seal assembly (9) and shaft assembly (3).

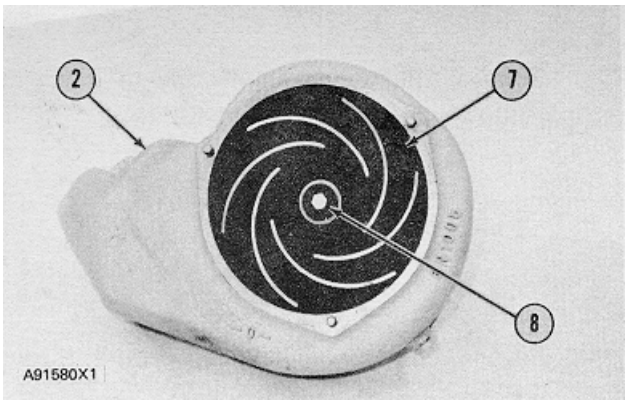
7. Use a soft faced hammer and push shaft assembly (3) out of seal assembly (9) and housing assembly (2). Remove seal assembly (9) from housing assembly (2).







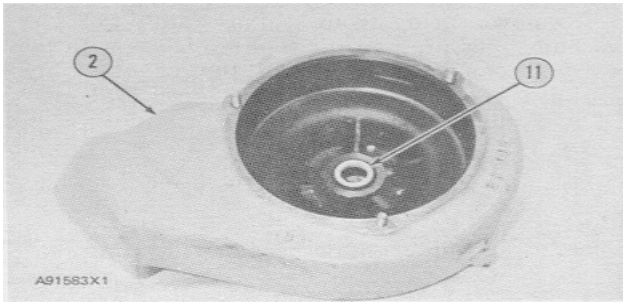




WATER PUMP

8. Remove ceramic seal (11) from the rubber ring. Remove the rubber ring from housing assembly (2).

9. Remove seal (12) from the back of housing assembly (2).



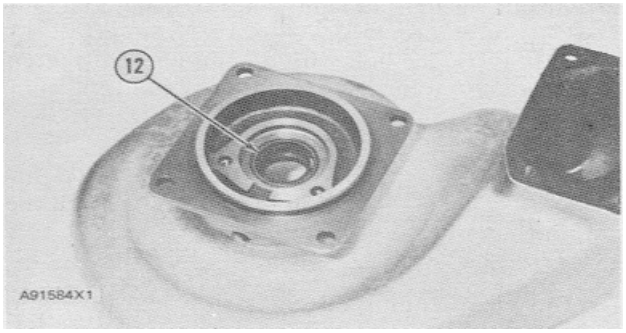
ASSEMBLE WATER PUMP 1361-16

Tools Needed	A
1P510 Driver Group	1

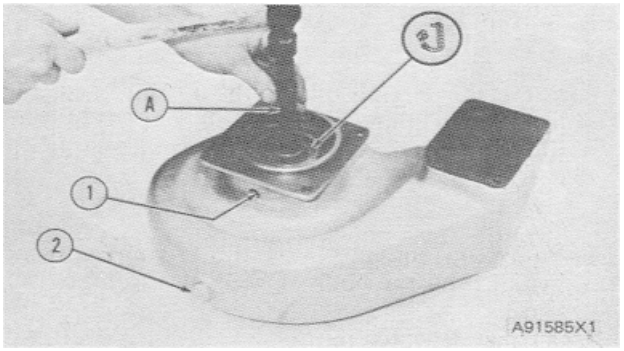
1. If necessary, make a replacement of the two filters in the pump housing at location (1).

2. If necessary, make a replacement of plug (2) and the seal.

3. Use tool group (A) to install the seal in the housing assembly. Make sure the lip of the seal is toward the outside as shown. Put clean engine oil on the lip of the seal.



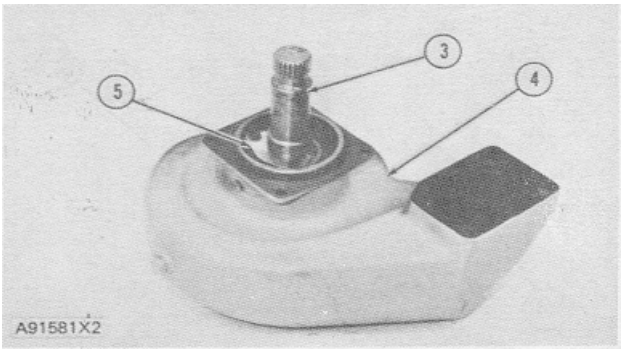
4. Install shaft assembly (3) in housing assembly (4). Install washer (5) and the bolts to hold shaft assembly (3) in position.

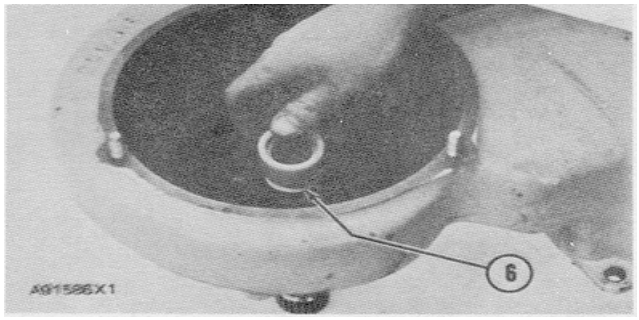


NOTICE

Clean water only is permitted for use as a lubricant for assembly. Do not damage or put hands on the wear surface of the carbon ring or the ceramic ring. Install the ceramic ring with the smoothest face of the ring toward the carbon seal assembly.

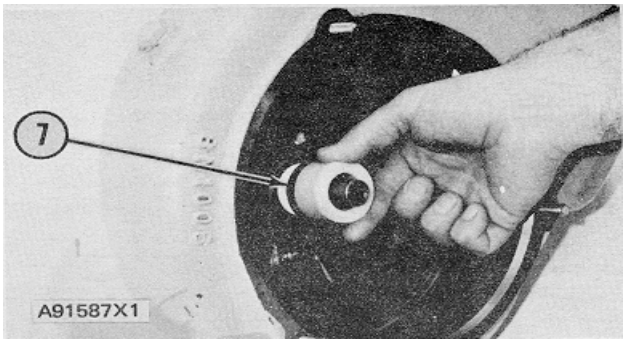
5. Put ceramic seal (6) in position in the rubber ring. Use hand pressure and the tool (which is with the replacement seal) to install the ceramic seal.





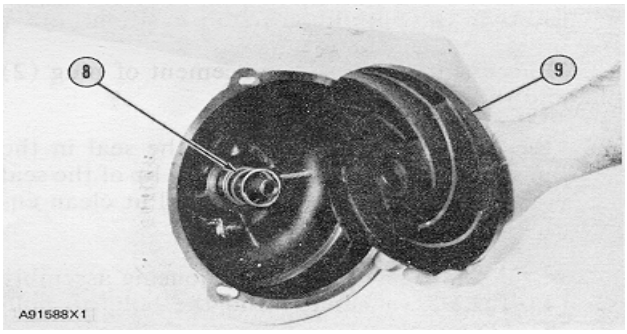
WATER PUMP

6. Remove spring from seal assembly (7). Use hand pressure and the tool (which is with the replacement seal) to install the seal assembly. Push seal assembly on shaft until seal faces make light contact.



7. Install spring (8) on the carbon seal assembly.

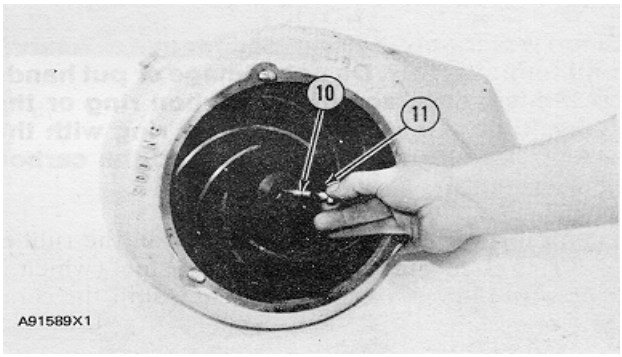
8. Put impeller (9) in position on the pump shaft as shown.



9. Install washer (11) and bolt (10). Tighten bolt (10) to a torque of 90 ± 15 N•m (66 ± 11 lb.ft.). Hit the bolt with a hammer and tighten it again to a torque of 90 ± 15 N.m (66 ± 11 lb.ft.).

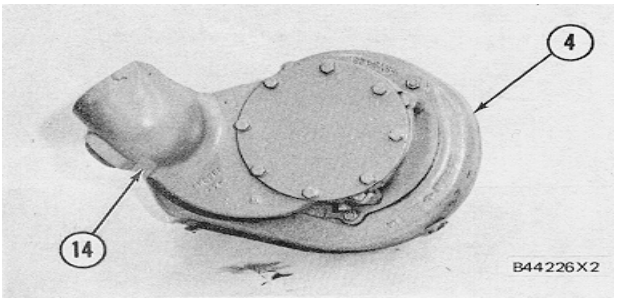
NOTE: Make sure the studs for cover (12) are tightened to a torque of 27 ± 4 N.m (20 ± 3 lb.ft. in the pump housing.

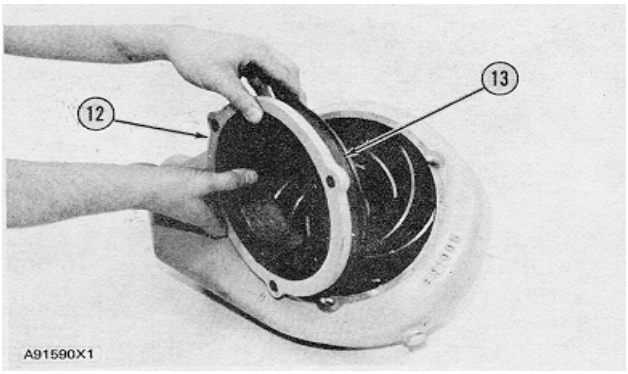
10. Put clean engine oil on O-ring seal (13) and install it on cover (12). Put cover (12) in position and install the nuts to hold it to the pump housing.



11. Put clean engine oil on the O-ring seal and install it in elbow (14). Put elbow (14) in position on housing assembly (4) and install the bolts to hold the unit together.

12. Put clean engine oil on the O-ring seal and install it on the back of housing assembly (4).
end by:
a) install water pump

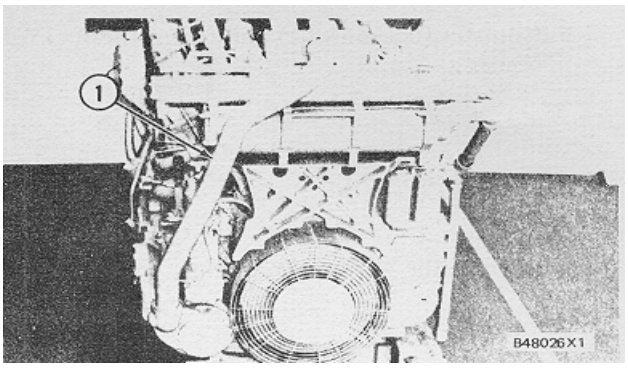




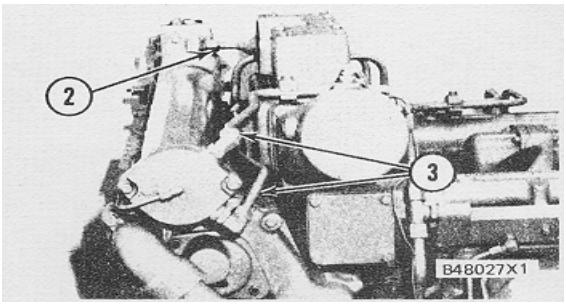
FUEL FILTER HOUSING

REMOVE FUEL FILTER HOUSING 1262-11

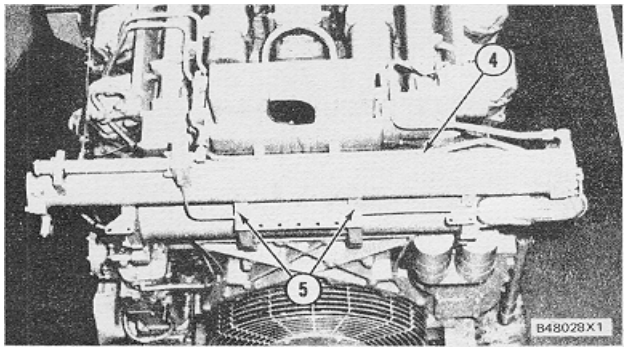
1. Close the fuel supply to the engine.



2. Drain the coolant from the cooling system.



3. Remove tube (1) from the engine.

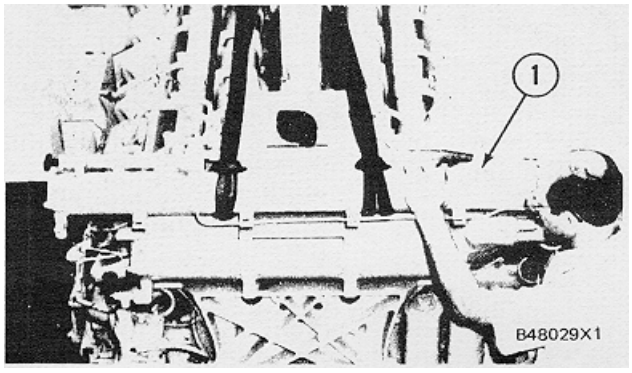


4. Disconnect fuel lines (2) and (3) from the fuel filter housing.

5. Remove eight bolts (5) and fasten a hoist or use two men to remove fuel filter housing (4) from the engine. The weight of the housing is 25 kg (55 lb.).

INSTALL FUEL FILTER HOUSING 1262-12

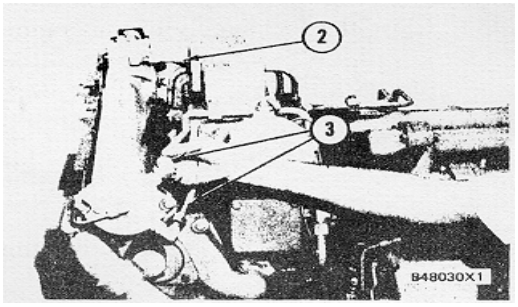
1. Fasten a hoist to fuel filter housing (1) and put it in position on the oil filter housing. Install the bolts to hold housing (1) in position.



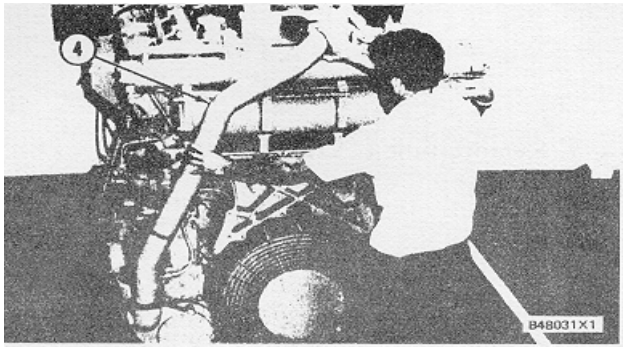
7

FUEL FILTER HOUSING

2. Connect fuel lines (2) and (3) to the fuel filter housing.



3. Install tube (4) on the engine.



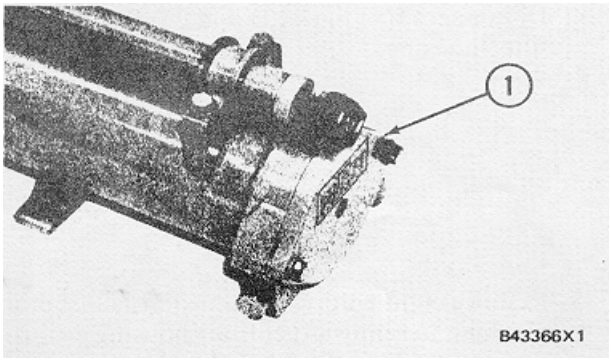
4. Fill the cooling system to the correct level.

5. Open the fuel supply to the engine.

DISASSEMBLE FUEL FILTER HOUSING 1262-15

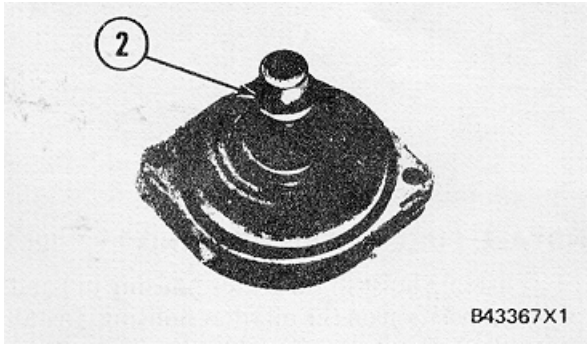
	Tools Needed	A
1P1855	Pliers	1

start by:
a) remove fuel filter housing



B43366X1

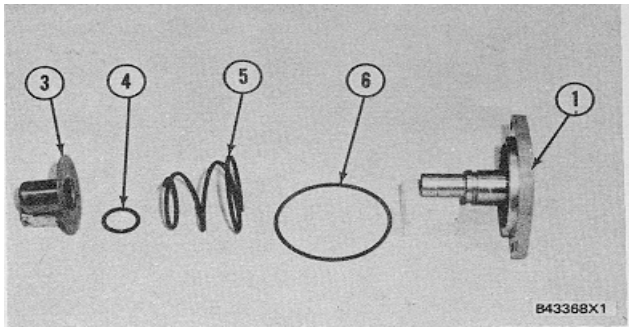
1. Remove cover (I) from the end of the filter housing.



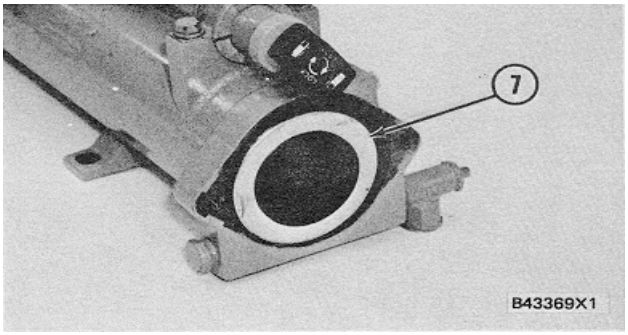
2. Use tool (A) to remove ring (2) from the cover.

FUEL FILTER HOUSING

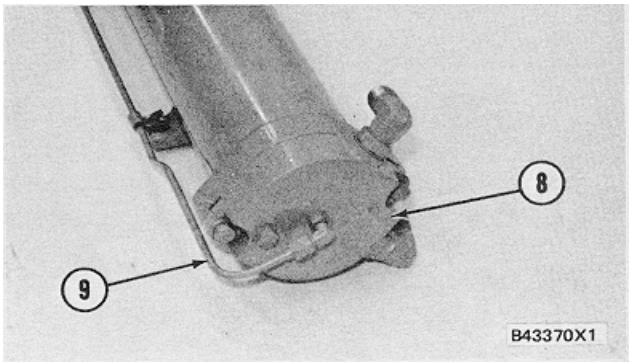
3. Remove retainer (3), O-ring seal (4), spring (5) and O-ring seal (6) from cover (1).



4. Remove the five filter elements (7) from the filter housing.



5. Disconnect fuel line (9) from cover (8). Remove cover (8) from the filter housing and remove the O-ring seal from the cover.

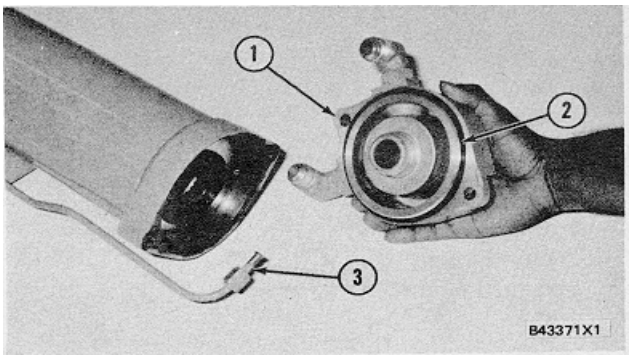


ASSEMBLE FUEL FILTER HOUSING 1262-16

Tools Needed	A
1P1855 Pliers	1

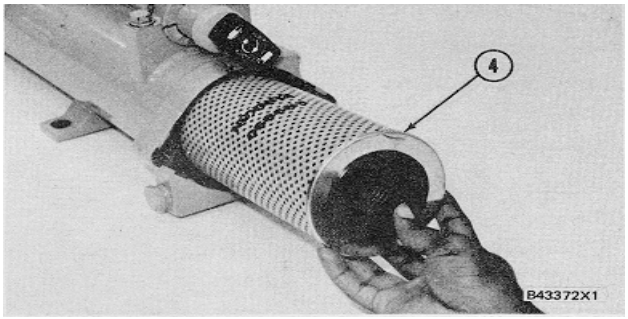
1. Install O-ring seal (2) on cover (1) and put clean engine oil on the seal.

2. Install cover (1) on the end of the filter housing. Connect fuel line (3) to the cover.

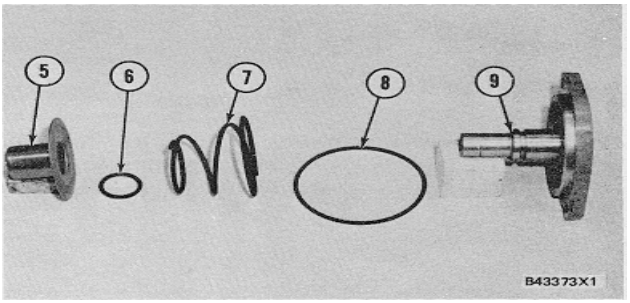


FUEL FILTER HOUSING

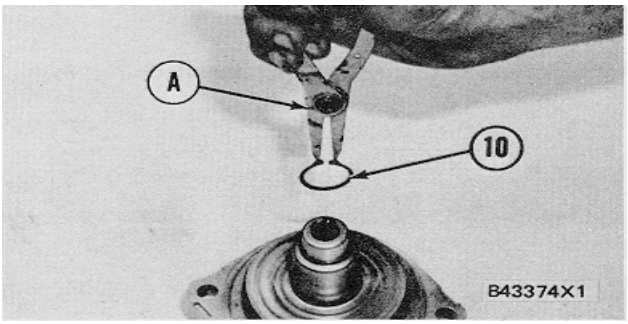
3. Install the five filter elements (4) in the filter housing.



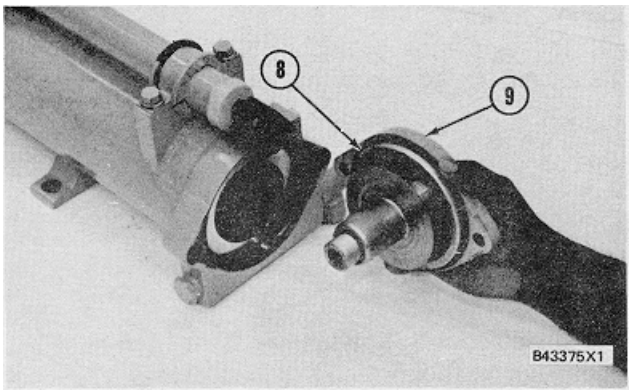
4. Put O-ring seal (6), spring (7) and retainer (5) in position on cover (9).



5. Use tool (A) to install ring (10) on the cover.



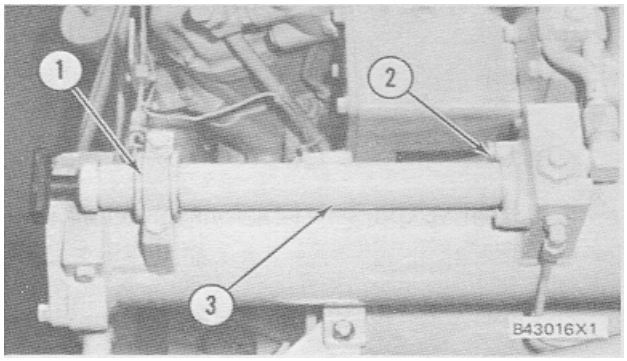
6. Install O-ring seal (8) on cover (9) and put clean engine oil on it. Install cover (9) on the end of the filter housing.
end by:
a) install fuel filter housing



FUEL PRIMING PUMP, FUEL TRANSFER PUMP

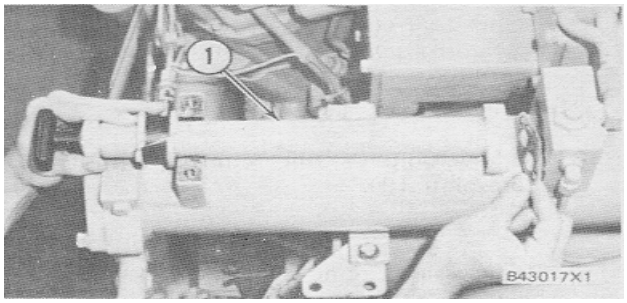
REMOVE FUEL PRIMING PUMP 1258-11

1. Close the fuel supply line to the engine.
2. Remove the bolts and clamp (1) from the pump.
3. Remove bolts (2) and remove fuel priming pump (3) and the gasket from the fuel filter housing.



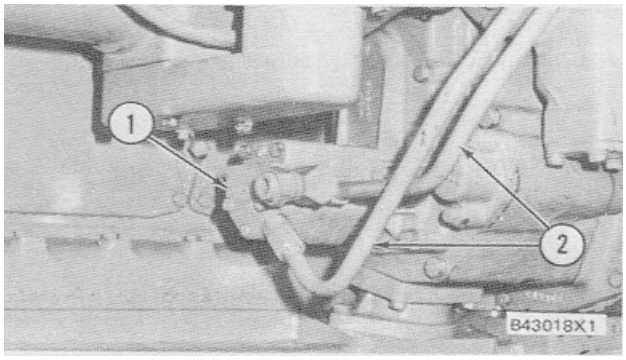
INSTALL FUEL PRIMING PUMP 1258-12

1. Put priming pump (1) and the gasket in position and install the clamp and bolts to hold it.
2. Open the fuel supply line to the engine.



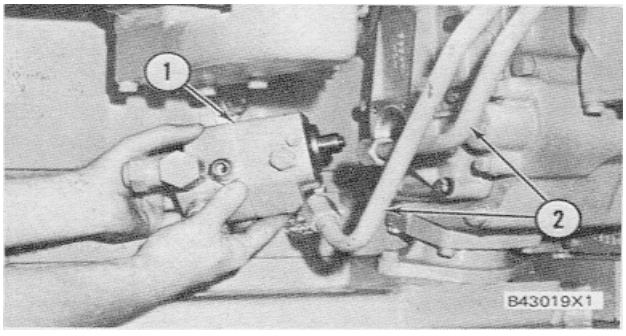
REMOVE FUEL TRANSFER PUMP 1256-11

1. Close the fuel supply line to the engine.
2. Disconnect fuel lines (2) from fuel transfer pump (1).
3. Remove the four bolts to remove fuel transfer pump (1) from the engine.



INSTALL FUEL TRANSFER PUMP 1256-12

1. Make a replacement of the O-ring seal on the fuel transfer pump if necessary. Put clean engine oil on the seal.
2. Put fuel transfer pump (1) in position on the engine oil pump. Make sure the drive coupling for the fuel transfer pump is engaged correctly with the engine oil pump shaft.
3. Install the bolts that hold the fuel transfer pump.
4. Connect fuel lines (2) to fuel transfer pump (1).
5. Open the fuel supply line to the engine and use the fuel priming pump to remove (bleed) the air from the system.



FUEL TRANSFER PUMP

DISASSEMBLE FUEL TRANSFER PUMP **1256-15**

start by:
a) remove fuel transfer pump

1. Pull drive coupling (2) from the pump shaft.

2. Remove O-ring seal (1) from the pump.3x1

3. Remove cap (6), seal washer (5), spring (4) and relief valve poppet (3) from the pump bracket assembly.

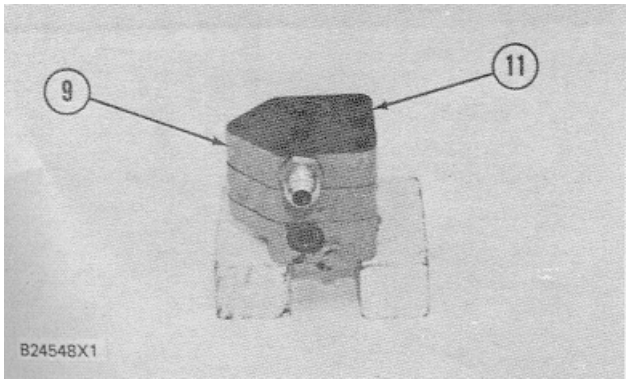
4. Remove bolts (7) and remove pump head (8) from plate (9).

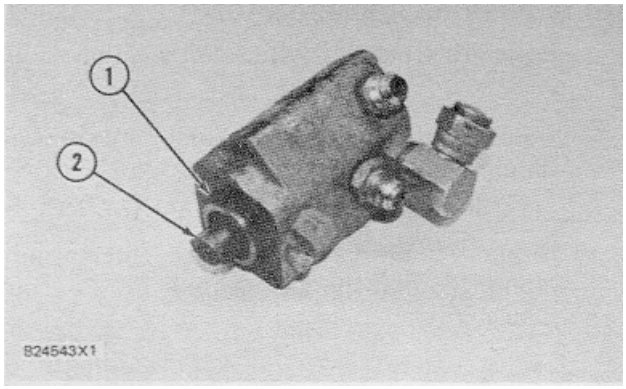
5. If necessary, remove check valve (10) from head (8).

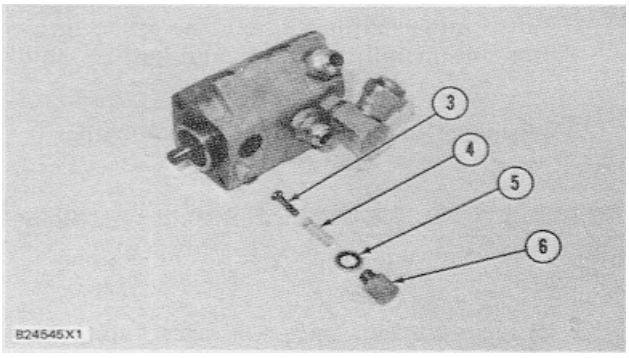
6. Remove plate (9) from the pump casing.

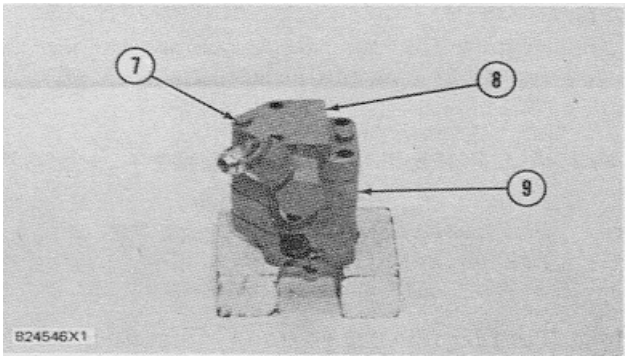
7. Remove gasket (11) and the O-ring seal from' the opposite side of plate (9).

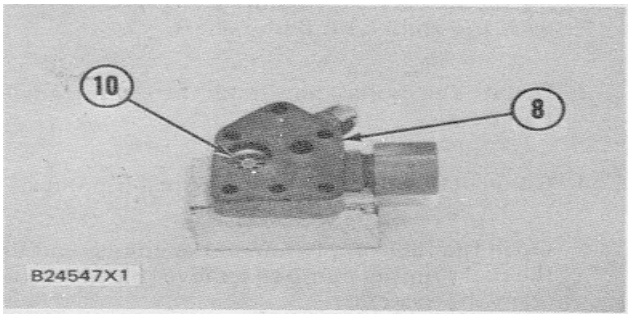
8. If necessary, remove the bearings from plate (9).





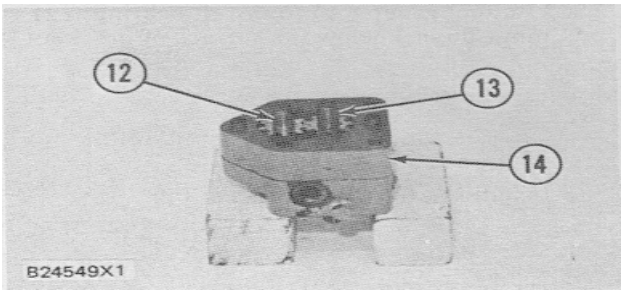






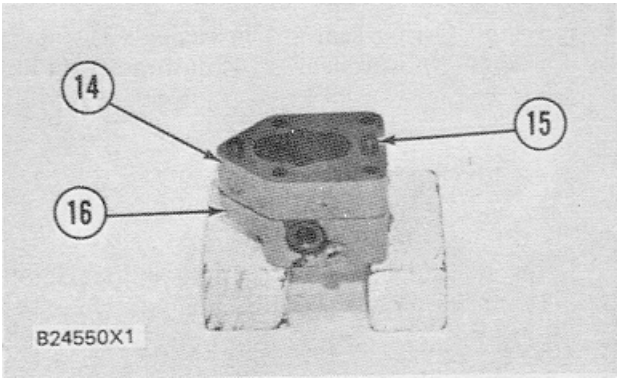
FUEL TRANSFER PUMP

9. Remove gear assembly (12) and shaft assembly (13) from the pump bracket and casing (14).



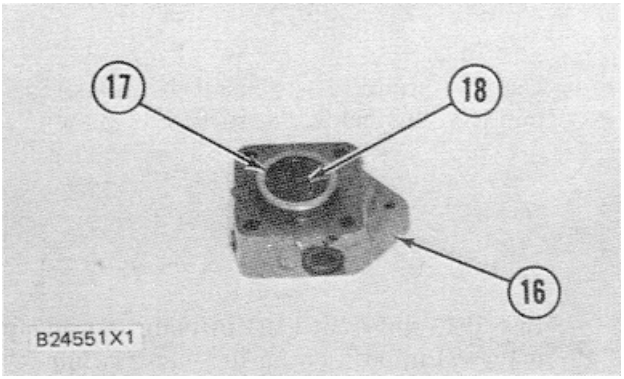
10. Remove casing (14) and sleeves (15) from pump bracket (16).

11. Remove the O-ring seal from casing (14).



12. Remove outer seal (17) and inner seal (18) from bracket (16).

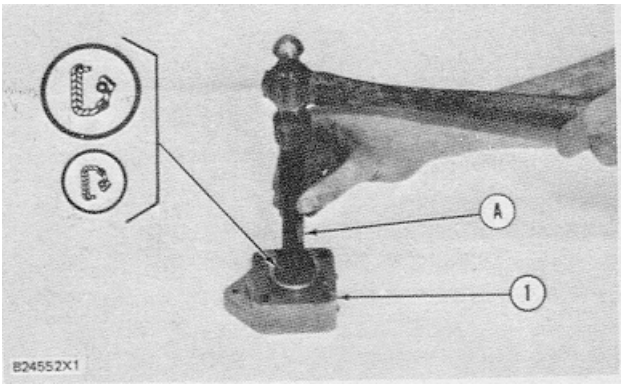
13. If necessary, remove the two bearings from bracket (16).



I

ASSEMBLE FUEL TRANSFER PUMP 1256-16

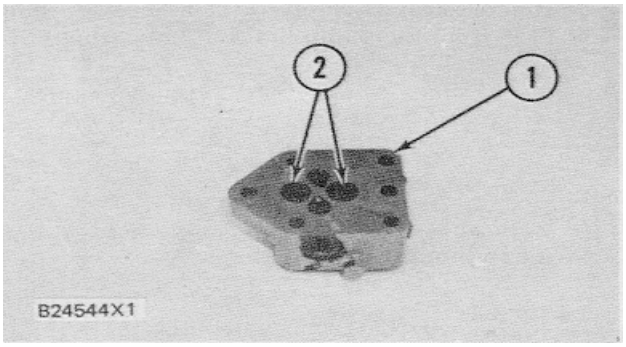
	Tools Needed	A
1P510	Driver Group	1



1. Use tool group (A) to install the inner and outer lip type seals in bracket (1). Make sure the lips of the seals are in the position shown at assembly. Put clean engine oil on the lips of the seals.

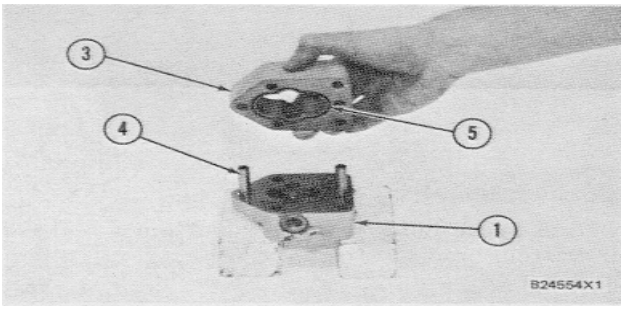
FUEL TRANSFER PUMP

2. Use tool group (A) to install bearings (2) 1.5 mm (.06 in.) below the surface of bracket (1).



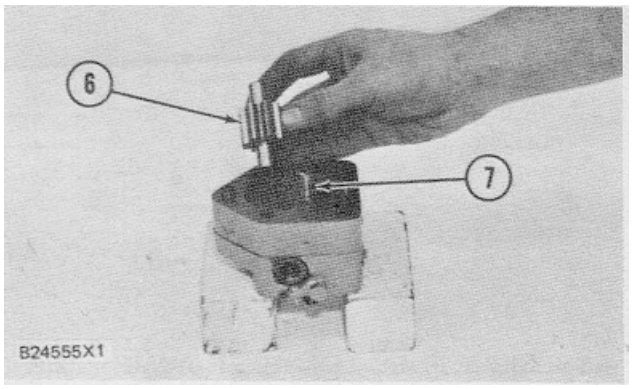
3. Install sleeves (4) in bracket (1).

4. Install O-ring seal (5) in casing (3) and put casing (3) over sleeves (4) on bracket (1).

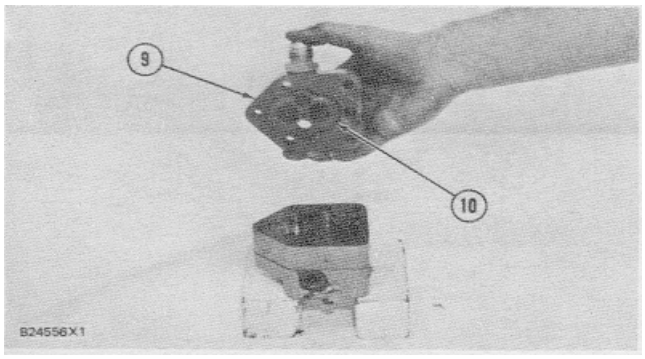


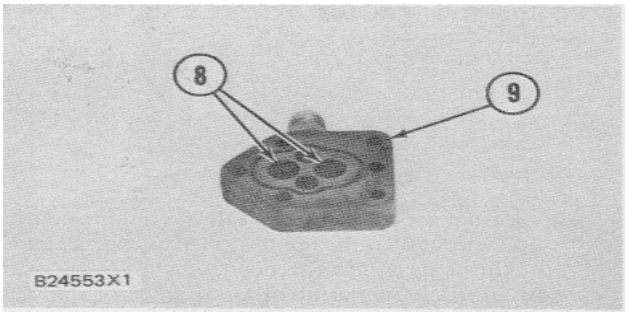
5 Install gear assembly (6) and shaft assembly (7) in the bracket and casing.

6. Use tool group (A) to install bearings (8) 1.5 mm (.06 in.) below the surface of plate (9).



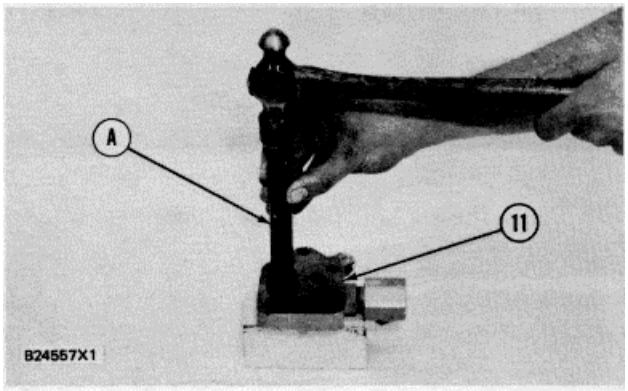
7. Install O-ring seal (10) in plate (9) and put plate (9) in position on the pump casing.



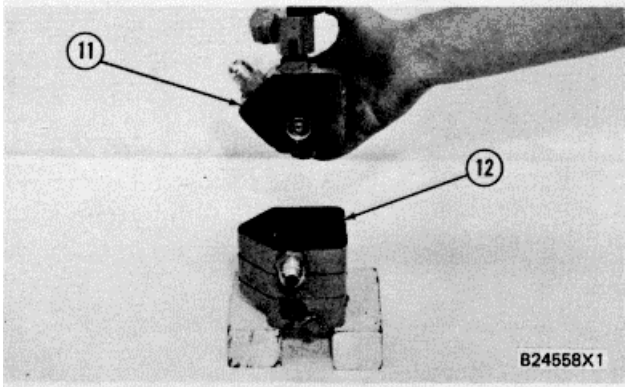


FUEL TRANSFER PUMP

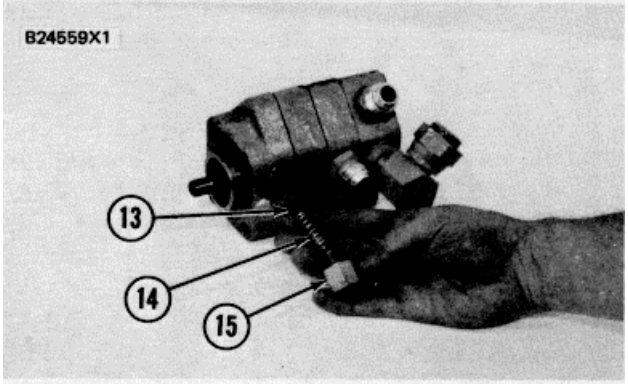
8. Use tool group (A) to install the check valve in head (11) until it makes contact with the shoulder in its bore. Make sure the spring on the check valve is toward the inside before it is installed.



9. Put gasket (12) and head (11) in position on the plate and install the two bolts that hold the pump together.

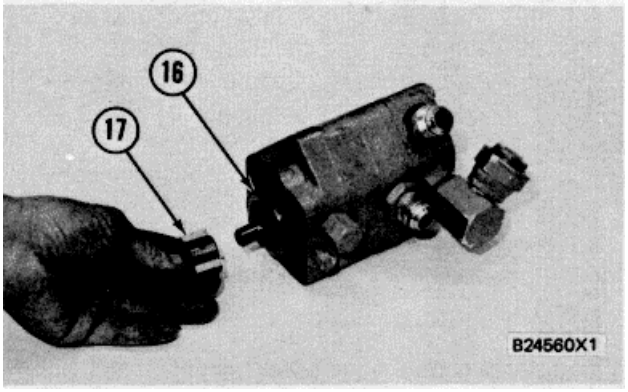


10. Install the relief valve poppet (13), spring (14), the seal washer and cap (15) in the pump.



11. Install O-ring seal (16) around the pump and put clean engine oil on it.

12. Install drive coupling (17) on the pump shaft.
end by:
a) install fuel transfer pump



OIL PUMP

REMOVE OIL PUMP 1304-11

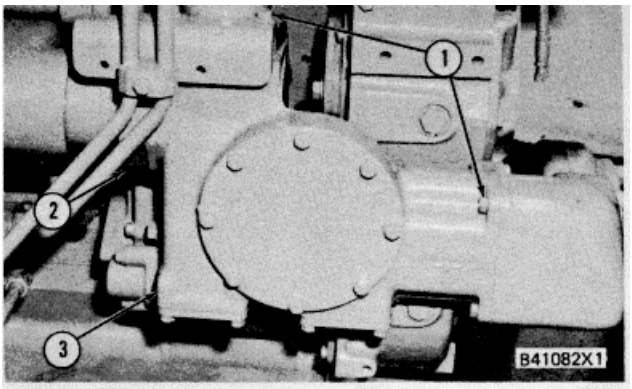
start by:
a) remove fuel transfer pump

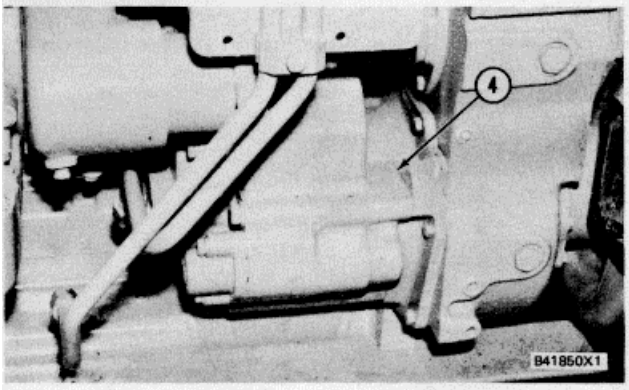
1. Drain the coolant from the cooling system.

2. Drain the oil from the oil pan.

3. Remove all bolts (1) and (2) to remove adapter (3) from the engine.

4. Remove all the bolts and remove oil pump (4) from the engine. The weight of the pump is 39 kg (85 lb.).





INSTALL OIL PUMP 1304-12

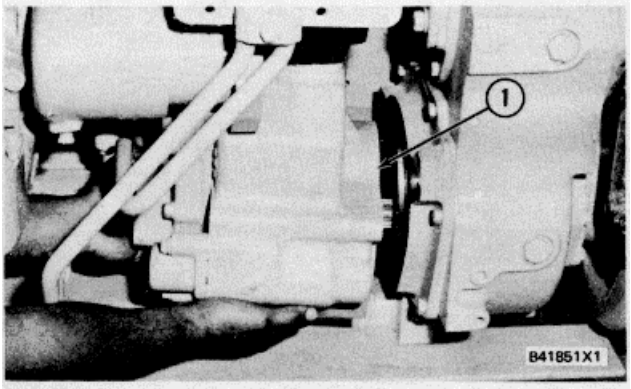
NOTE: The oil pump shaft must turn by hand and the pump must have oil for lubrication before it is installed.

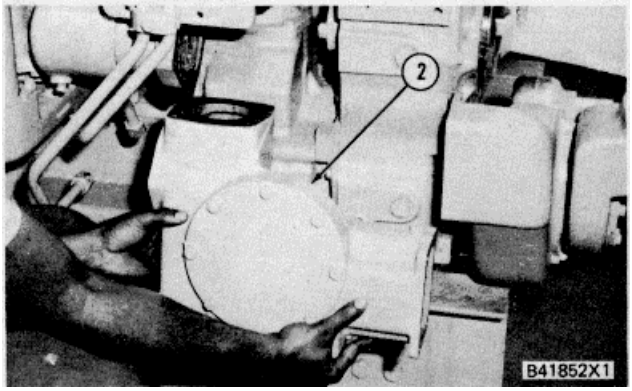
1. Put clean engine oil on the O-ring seals and put oil pump (1) in position. Make sure the splines on the pump shaft are correctly engaged with the splines of the oil pump drive. Install the bolts to hold the oil pump in position.

2. Put the gaskets and adapter (2) in position. Install the bolts to hold the adapter and gaskets in position.

3. Fill the engine with oil to the correct level.'

4. Fill the cooling system with coolant to the correct level.
end by:
a)install fuel transfer pump



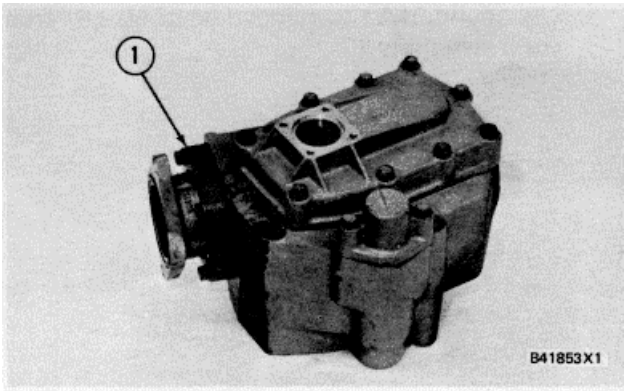


OIL PUMP

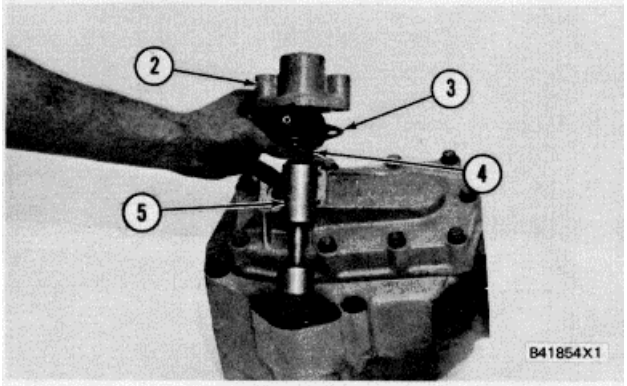
DISASSEMBLE OIL PUMP 1304-15

	Tools Needed	A
1P510	Driver Group	1

start by:
a) remove oil pump

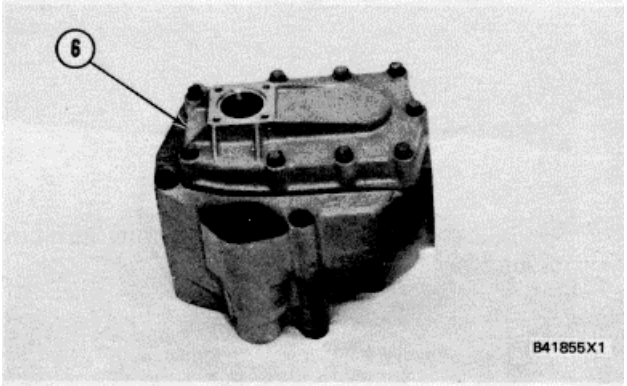


1. Remove adapter assembly (1) from the pump.



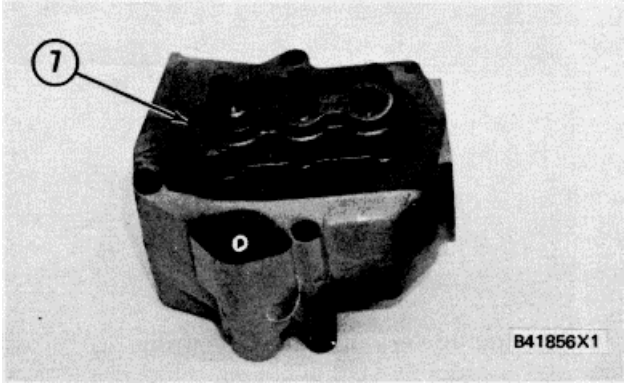
WARNING

Cover (2) has spring tension on it. Loosen the bolts that hold it slowly and the same amount to remove the tension on the cover.



2. Remove the bolts, cover (2), gasket (3), spring (4) and valve spool (5) from the pump.

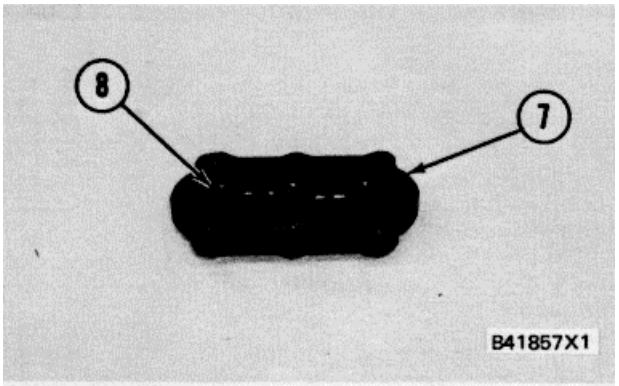
3. Remove cover assembly (6) and the gasket from the pump.



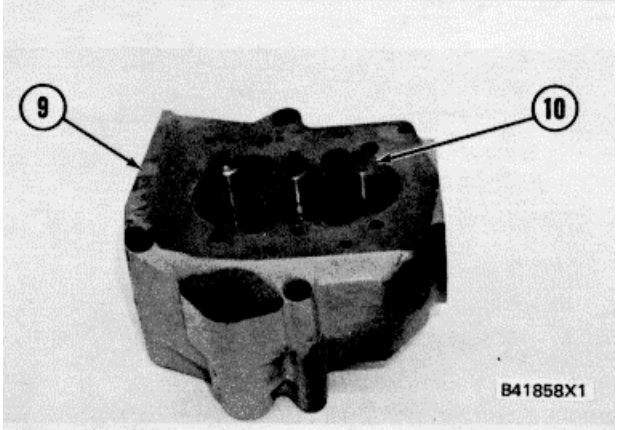
4. Remove cover assembly (7) from the pump.

OIL PUMP

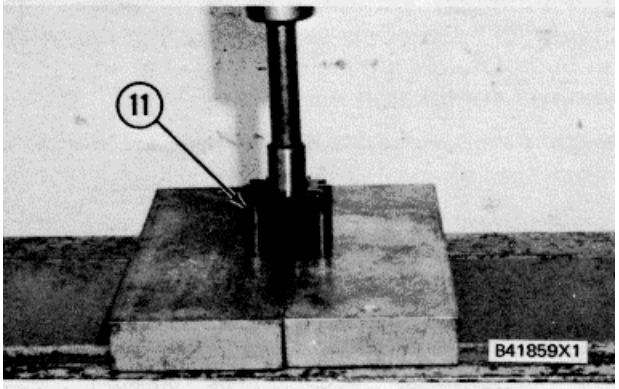
5. Use tooling (A) to remove bearings (8) from cover assembly (7).



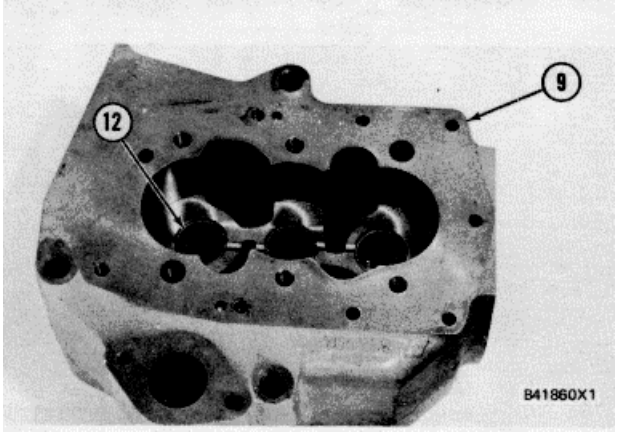
6. Remove shaft assemblies (10) from body assembly (9).



7. Use a press to remove gears (11) from the shaft assemblies.



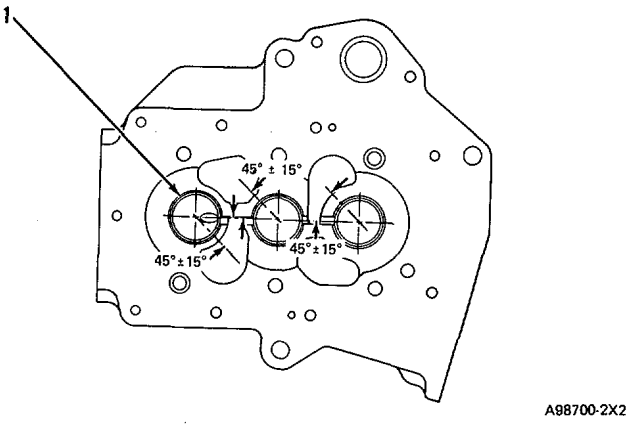
8. Use tooling (A) to remove bearings (12) from body assembly (9).



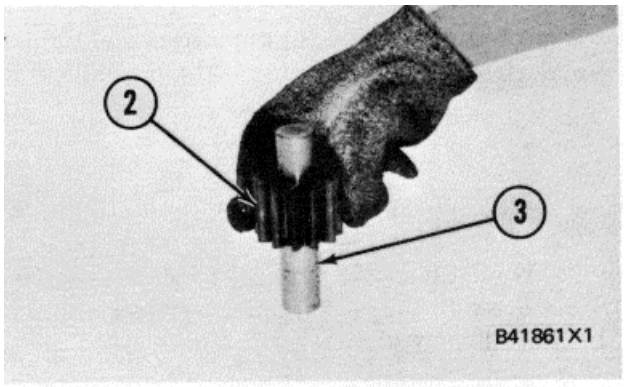
OIL PUMP

ASSEMBLE OIL PUMP 1304-16

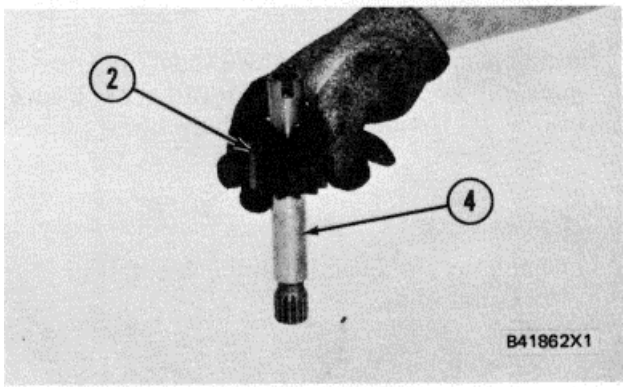
	Tools Needed	A
1P510	Driver Group	1



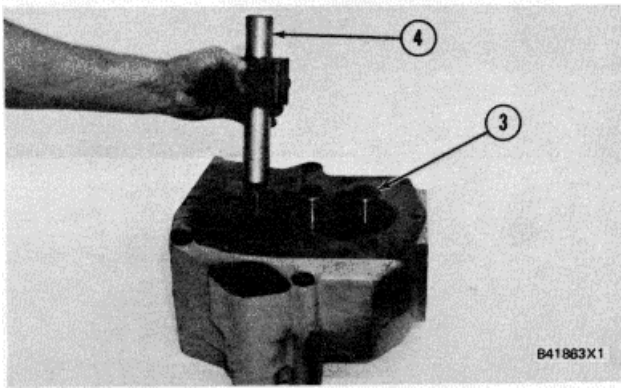
1. Make an alignment of bearings (1) so the joints are 45 ± 15° from a line through the center of the bearing bores as shown.



2. Use tooling (A) to install bearings (1) in the body assembly until they are 1.5 ± 0.5 mm (.059 ±.020 in.) below the gear bore in the body assembly. Check the inside diameter of the bearings after installation. The diameter must be 31.837 ± 0.070 mm (1.2534 ± .0028 in.).



3. Heat gears (2) to a maximum temperature of 316°C (600°F).

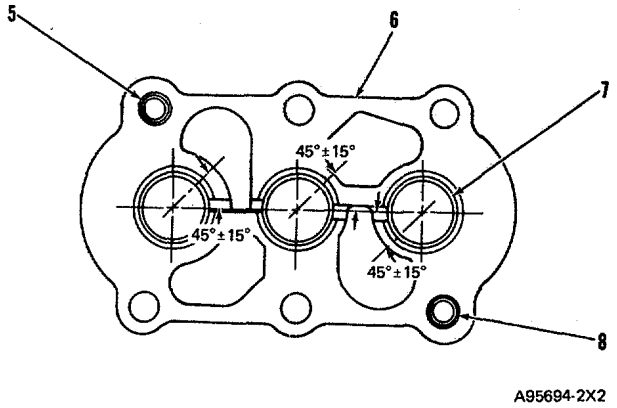


4. Install the gears on shaft assemblies (3) until they are 34.0 ± 0.5 mm (1.34 ± .020 in.) from the cover end of the shaft assemblies to the face of the gears and 47.0 ± 0.5 mm (1.85 ± .020 in.) from the fuel pump drive end of shaft assembly (4).

5. Install shaft assemblies (3) and (4) in the body assembly.

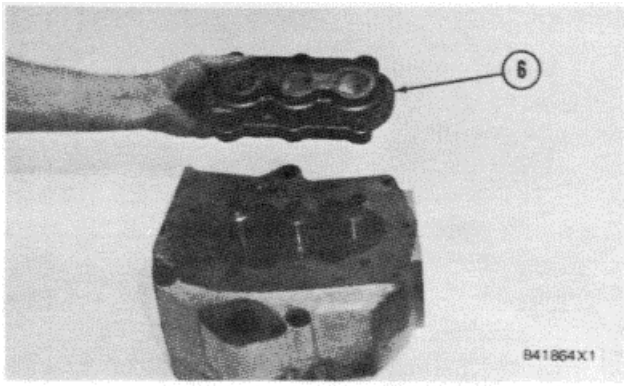
OIL PUMP

6. Make sure dowels (5) and (8) are installed in cover assembly (6) so they extend 6 ± 0.5 mm (.236 ± .02 in.) above the surface of the cover assembly.

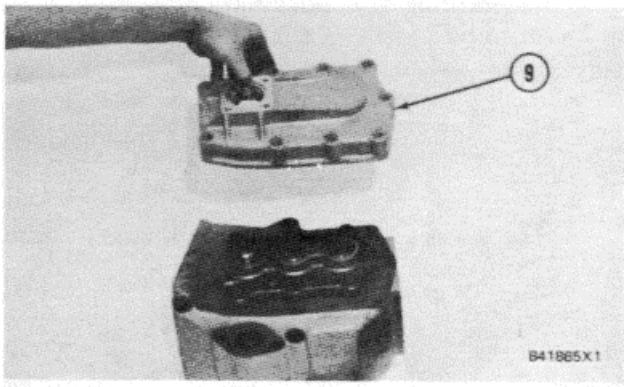


7. Use tooling (A) and install bearings (7) in cover assembly (6) with the joints of the bearings in the positions as shown.

8. Put cover assembly (6) in position and tighten the bolts to hold it to the body assembly.

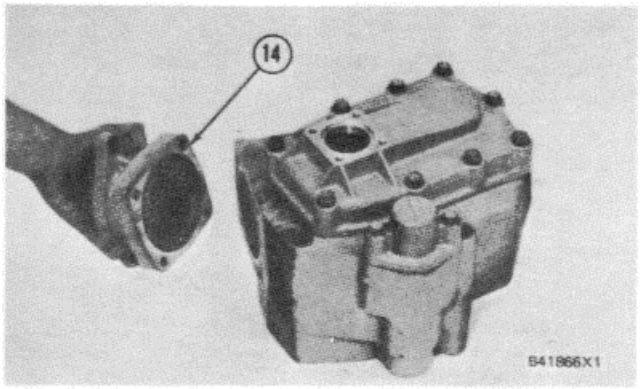


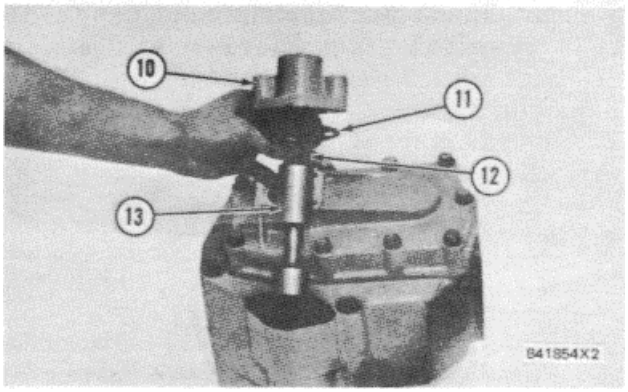
9. Make sure the two pins in cover assembly (9) are installed so they extend 6 ± 1 mm (.236 ± .039 in.) above the surface of the cover assembly. Install the gasket and cover assembly (9) on the pump.



10. Put clean engine oil on valve spool (13). Install valve spool (13), spring (12), gasket (11), cover (10) and the bolts on the pump body.

11. Install the gasket and adapter assembly (14) on the pump body.
end by:
a) install oil pump

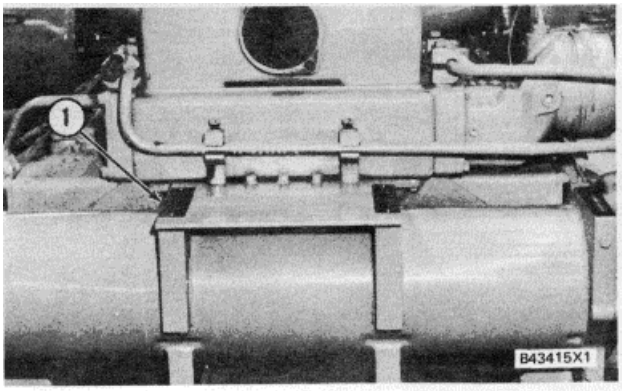




OIL FILTER HOUSING

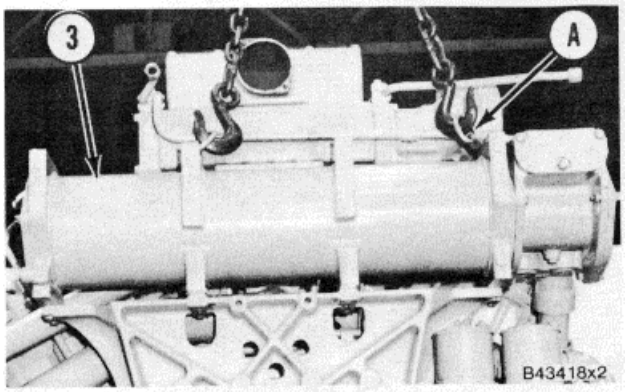
REMOVE OIL FILTER HOUSING 1306-11

Tools Needed		A
6V2156	Link Bracket	2

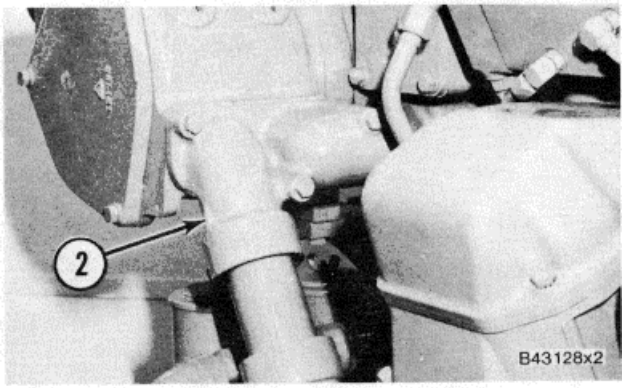


start by:
a) remove fuel filter housing

1. Remove the bolts to remove the clamps and spacers from plate (1). Remove the bolts and remove plate (1) from the engine.



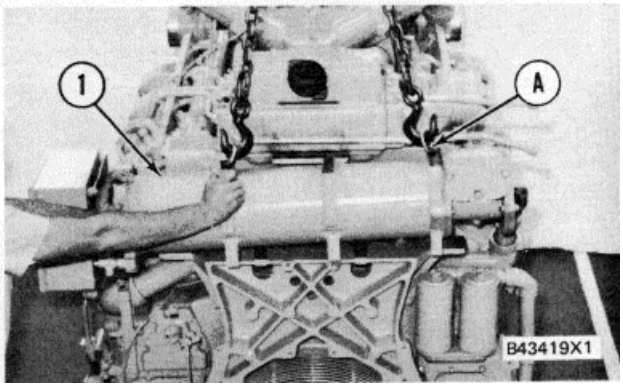
2. Remove the bolts from adapter (2) to disconnect it from the filter housing.



3. Use tooling (A) to fasten a hoist to oil filter housing (3). Remove the bolts that hold the housing to the support and remove housing (3) from the engine. The weight of the oil filter housing is 75 kg (165 lb.).

Install Oil Filter Housing 1306-12

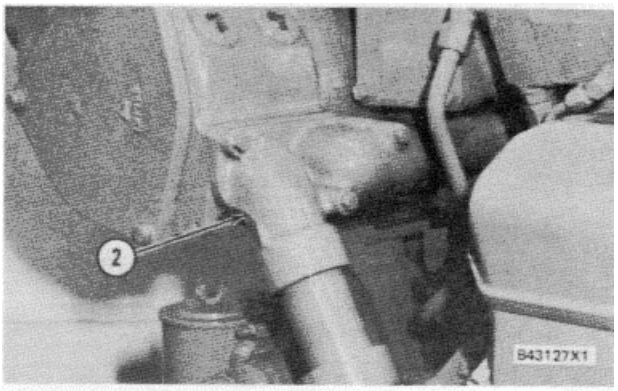
Tools Needed		A
6V2156	Link Bracket	2



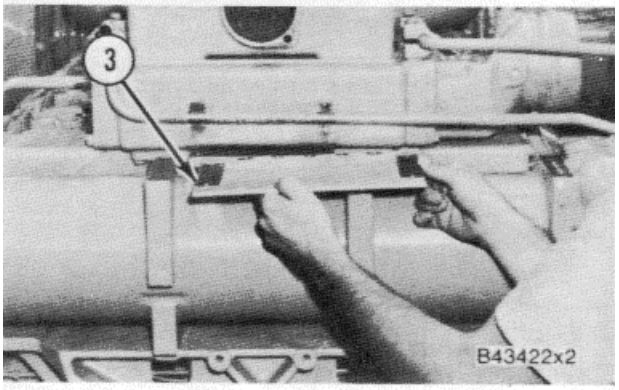
1. Use tooling (A) to fasten a hoist to oil filter housing (1). Put the housing in position on the support and install the bolts to hold it in position.

OIL FILTER HOUSING

2. Install the bolts to connect adapter (2) to the oil filter housing.



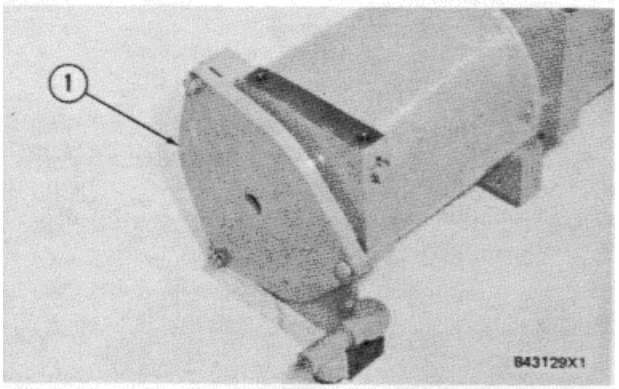
3. Put plate (3) the spacers and clamps in position and install the bolts.



end by:
a) install fuel filter housing

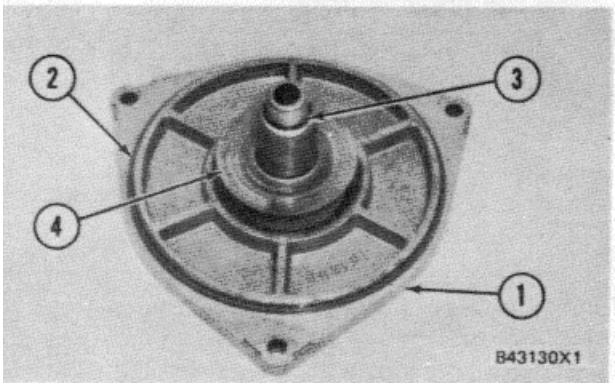
DISASSEMBLE OIL FILTER HOUSING 1306-15

start by:
a) remove oil filter housing



1. Remove the bolts and remove cover (1) from the housing assembly.

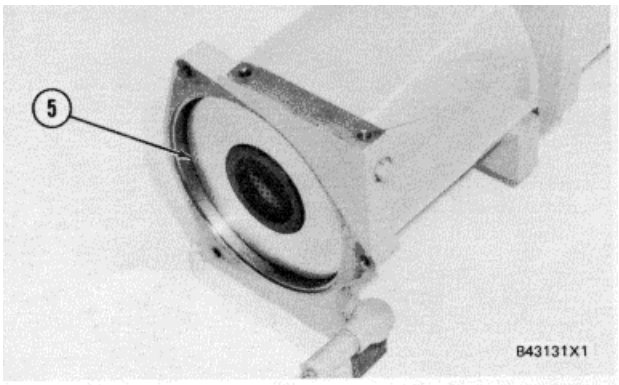
2. Remove O-ring seal (2) from cover (1).



3. Remove ring (3) to remove retainer (4), the spring and the O-ring seal from cover (1).

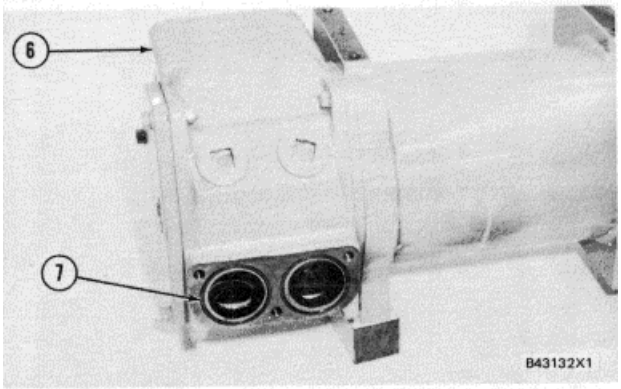
OIL FILTER HOUSING

4. Remove three element assemblies (5) from the housing assembly.



5. Remove O-ring seals (7) from housing (6) and remove the bolts to remove housing (6) from the housing assembly. The weight of housing (6) is 25 kg (55 lb.).

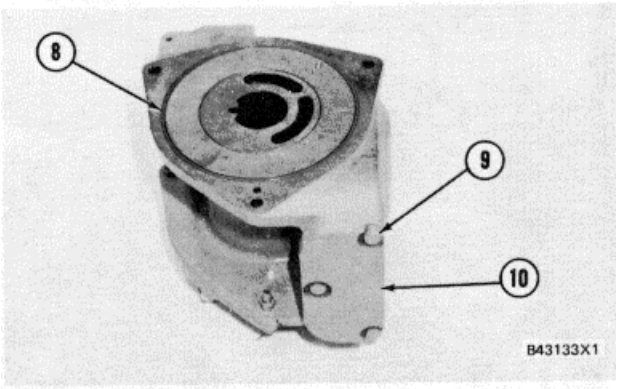
6. Remove O-ring seal (8) from the housing.



⚠ WARNING

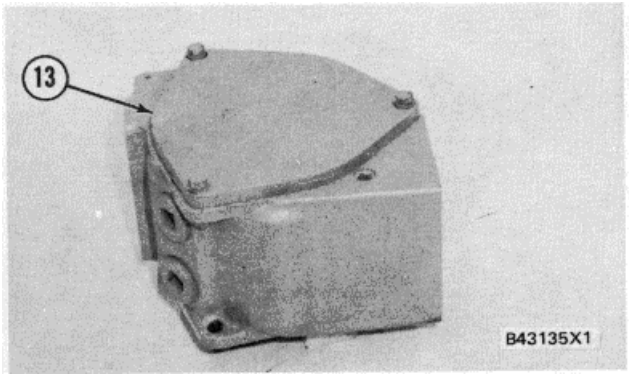
Cover (10) has spring tension behind it. Slowly remove bolts (9) to release the tension and prevent possible personal injury.

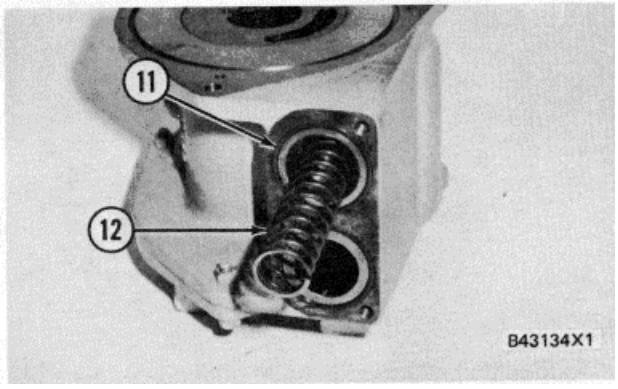
7. Slowly remove bolts (9) to release the spring tension behind cover (10) and remove cover (10) from the housing.



8. Remove 0-ring seals (11), spring (12) and the valve from the housing.

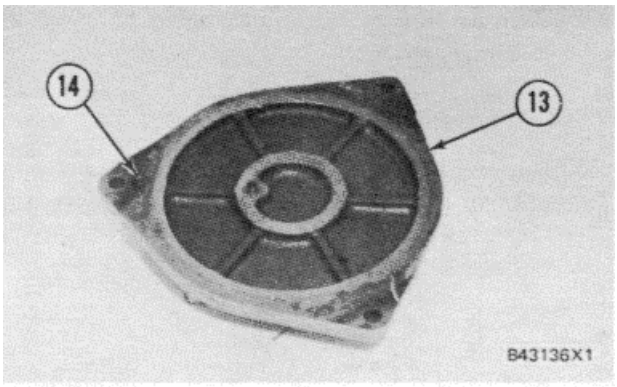
9. Remove the bolts and nuts to remove cover assembly (13) from the housing.



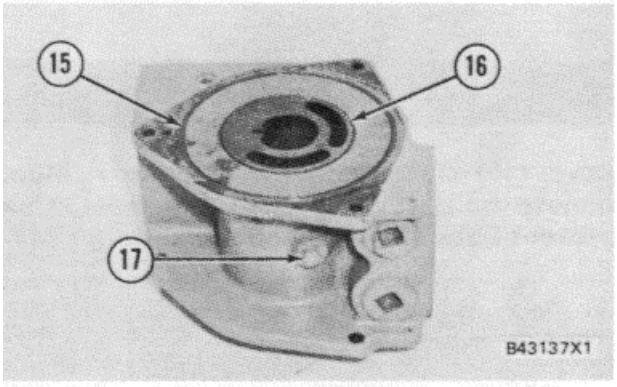


OIL FILTER HOUSING

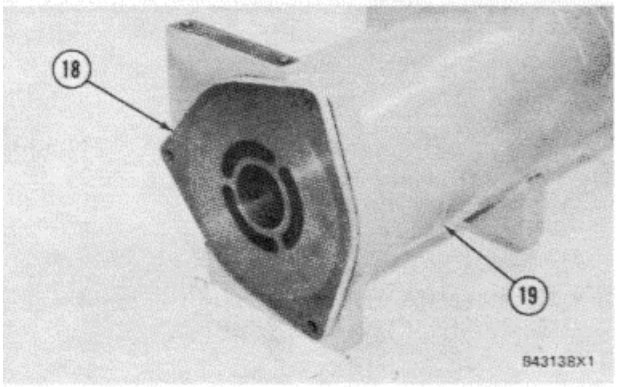
10. If necessary, remove pins (14) from cover assembly (13).



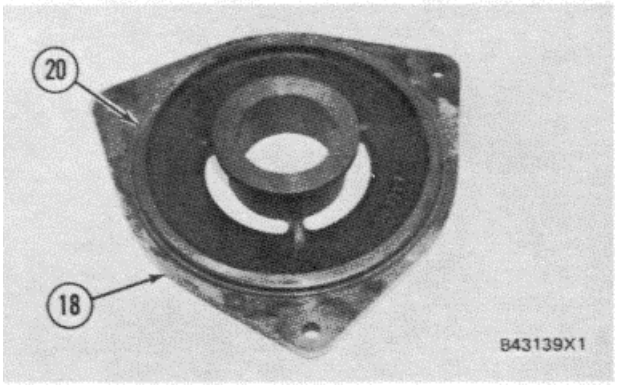
11. Remove O-ring seal (15) from the housing.



12. Remove plug (17) to remove valve (16) from the housing.



13. Remove adapter (18) from housing assembly (19).

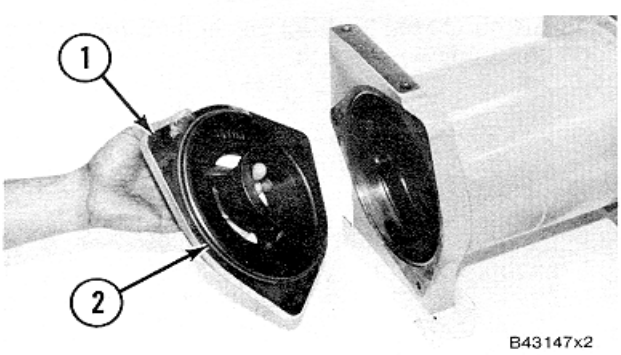


14. Remove O-ring seal (20) from adapter (18).

OIL FILTER HOUSING

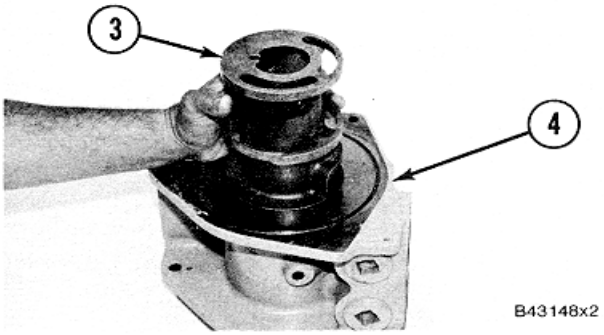
ASSEMBLE OIL FILTER HOUSING 1306-16

1. Install O-ring seal (2) on adapter (1) and put clean engine oil on it. Install adapter (1) in the housing assembly.



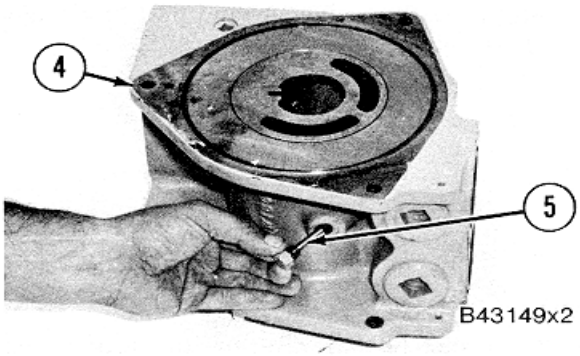
2. Install valve (3) in housing (4) as shown.

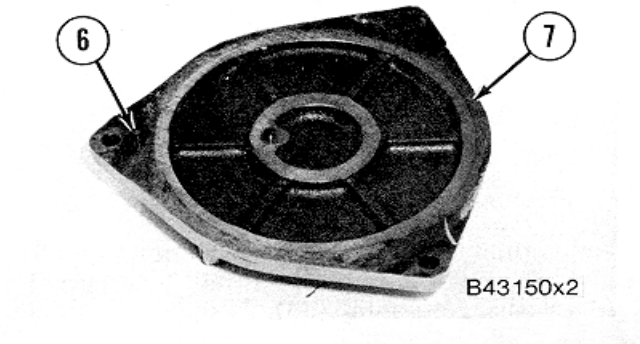
NOTE: If valve (3) has been installed wrong, plug (5) can be installed correctly.



3. Put clean engine oil on the O-ring seal and install plug (5) in housing (4).

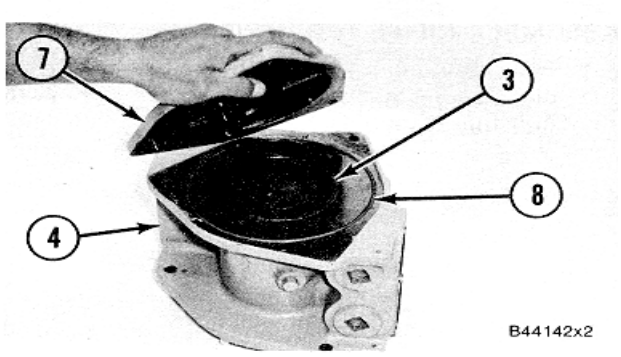
4. If pins (6) were removed, install the new pins in cover (7). Make sure they are 7 ± 0.5 mm (.275 ±.020 in.) above the surface of the cover.



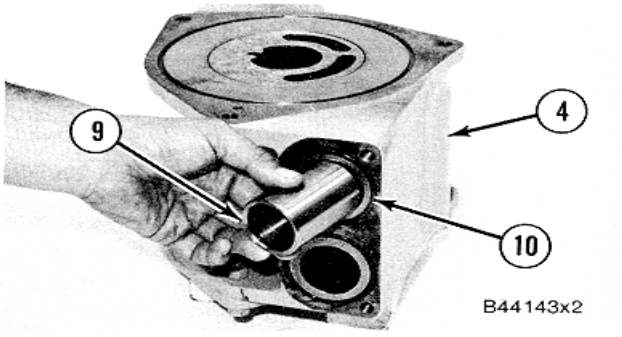


OIL FILTER HOUSING

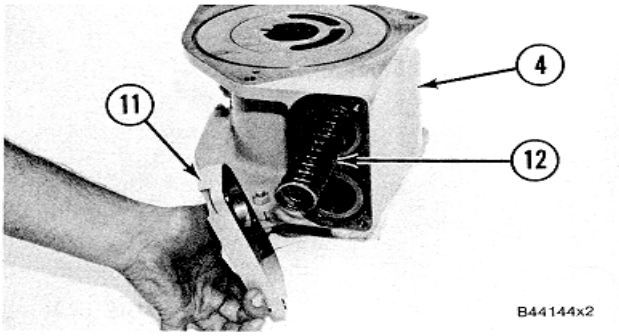
5. Install O-ring seal (8) on the housing and put clean engine oil on it.



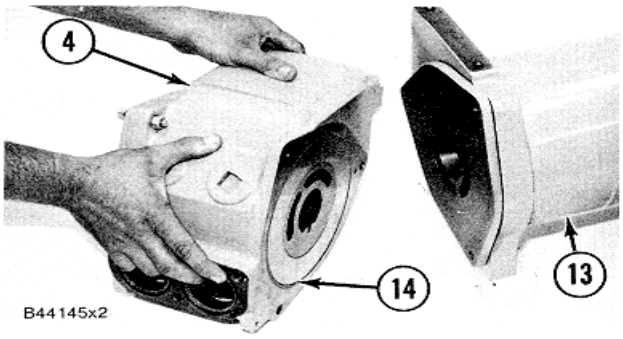
6 Put cover (7) in position on housing (4) and make sure pins (6) are in alignment with the hole in housing (4) and the groove (slot) in valve (3). Install the bolts and nuts to hold the cover in position.



7. Install valve (9) in housing (4). Install O-ring seals (10) in housing (4) and put clean engine oil on the seals.



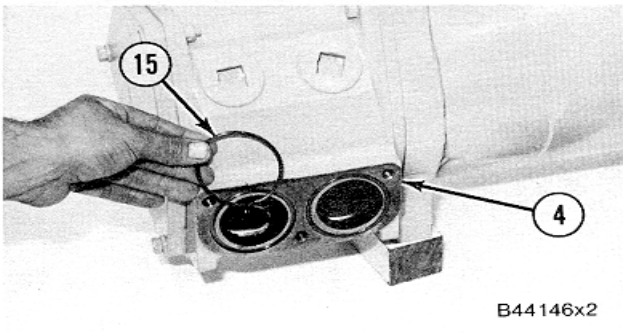
8. Put spring (12) in position and install cover (11) on housing (4).



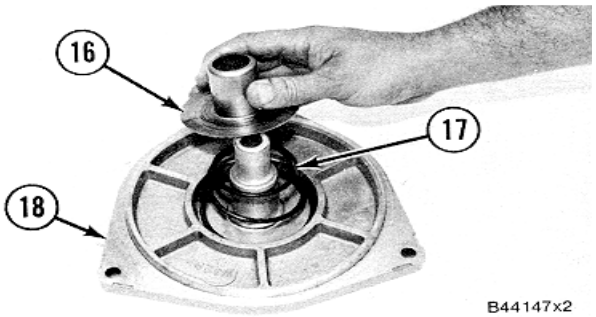
9. Install O-ring seal (14) on housing (4) and put clean engine oil on it. Install housing (4) on housing assembly (13).

OIL FILTER HOUSING

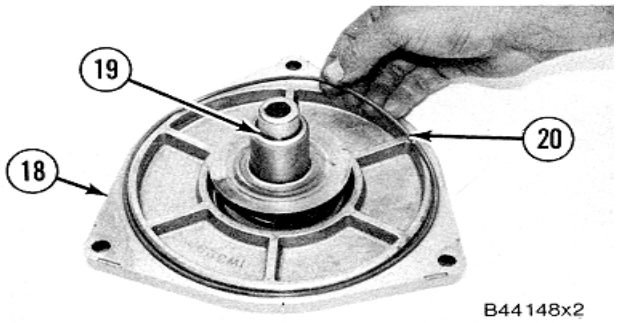
10. Install O-ring seals (15) on housing (4) and put clean engine oil on the seals.



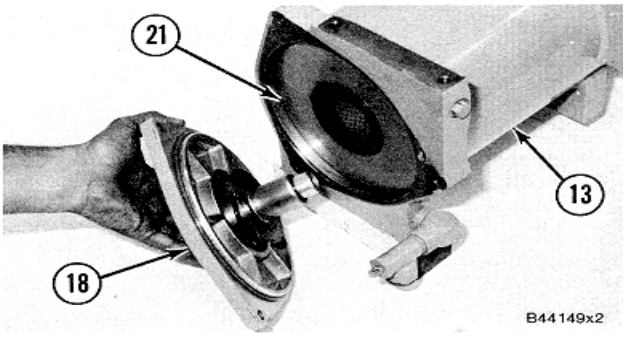
11. Put the O-ring seal, spring (17) and retainer (16) in position on cover (18).



12. Install ring (19) to hold the retainer and spring in position. Install O-ring seal (20) on cover (18) and put clean engine oil on it.



13. Install three element assemblies (21) in housing assembly (13). Install cover (18) on housing assembly (13).



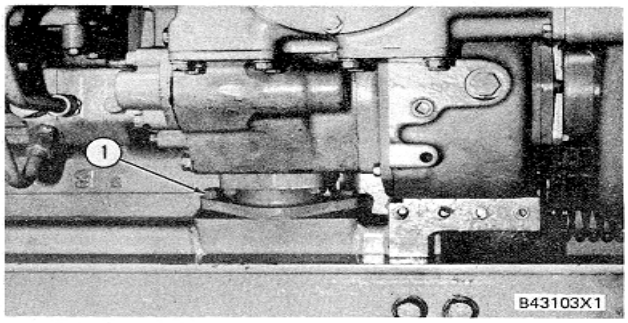
end by:
a) install oil filter housing

OIL PAN

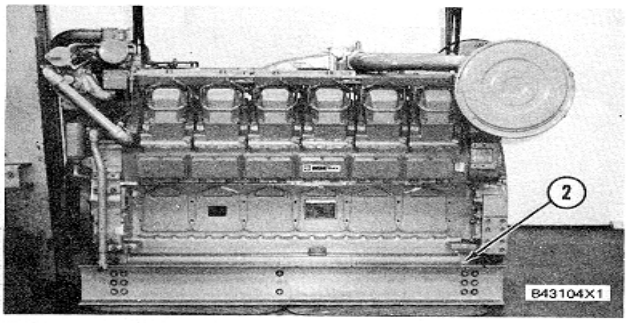
REMOVE OIL PAN 1302-11

1. Drain the oil from the engine.

2. Remove bolts (1) that hold the oil pump adapter to the oil pan.



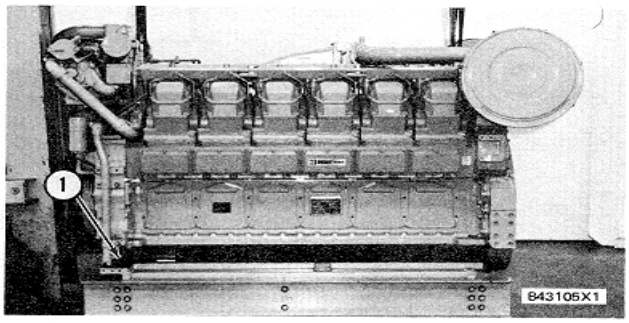
3. Remove the bolts that hold oil pan (2) to the engine and lift the engine off of the oil pan or lower the oil pan away from the engine. The weight of the 3512 oil pan is 295 kg (650 lb.) and the weight of the 3508 oil pan is 240 kg (530 lb.). The weight of the 3512 engine is approximately 5443 kg (12, 000 lb.) and the weight of the 3508 engine is approximately 4445 kg (9800 lb.).



INSTALL OIL PAN 1302-12

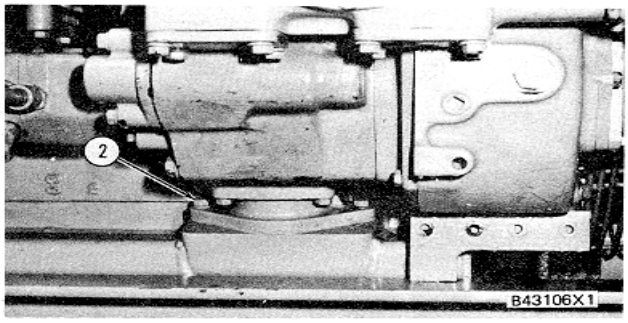
1. Make sure the O-ring seal is installed on the oil pump adapter and put clean engine oil on it.

2. Install four 3/8"-16 NC guide bolts in the pan and put the oil pan gasket in position on the pan.



3. Put the engine in position on the oil pan or put oil pan (1) in position under the engine. Install the bolts that hold the oil pan to the engine.

4. Install bolts (2) that hold the oil pump adapter to the oil pan.

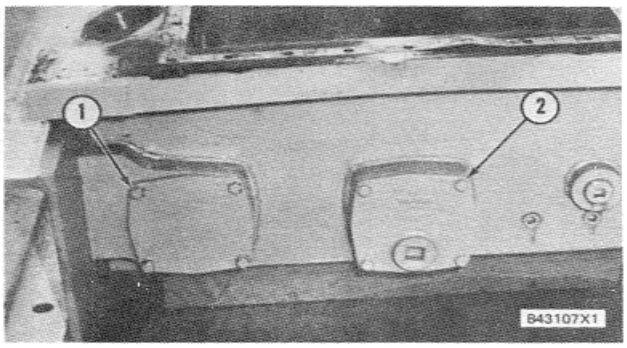


5. Fill the engine with oil to the correct level.

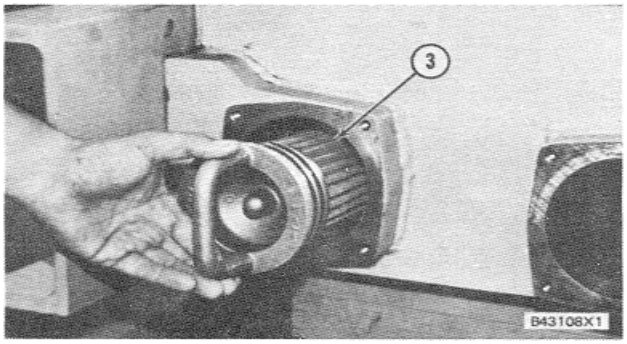
OIL PAN

DISASSEMBLE OIL PAN 1302-15

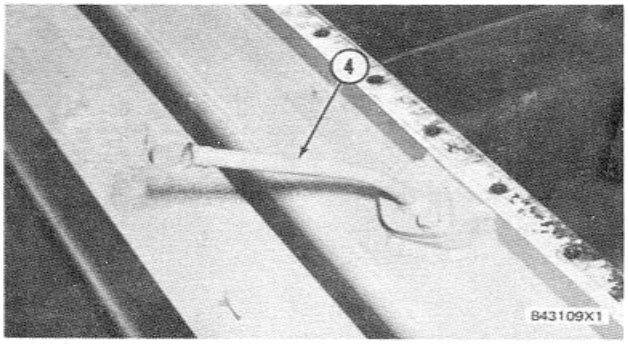
start by:
a) remove oil pan



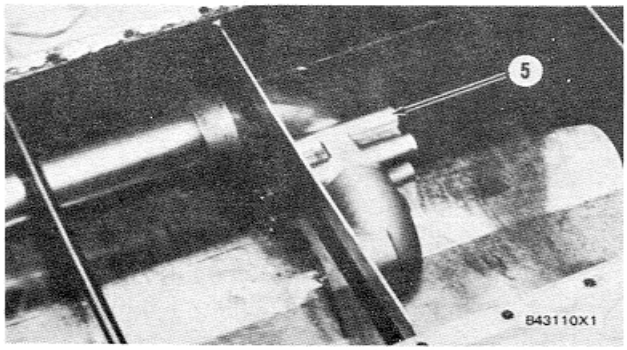
1. Remove covers (1), (2) and the O-ring seals.



2. Remove screen assembly (3) from the oil pan. Remove O-ring seals from the screen assembly.



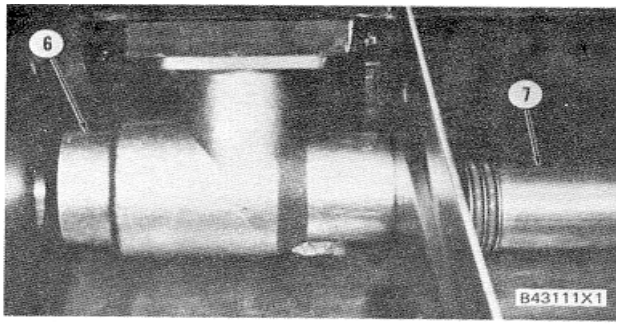
3. Remove the bolts and remove oil level gauge (4) from the oil pan.



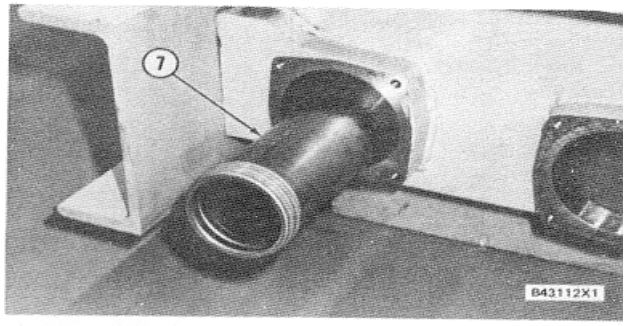
4. Remove the bolts that hold bell (5) to the oil pan. Pull bell (5) off the O-ring seals on the end of the tube assembly and remove bell (5) from the oil pan.

OIL PAN

5. Pull tube assembly (7) from housing (6). Remove the bolts that hold housing (6) in position and remove it from the oil pan. Remove the 0ring seals from the oil pan.

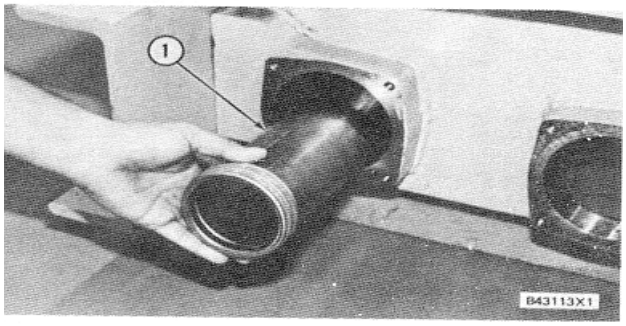


6. Remove tube assembly (7) from the oil pan. Remove the O-ring seals from tube assembly (7).

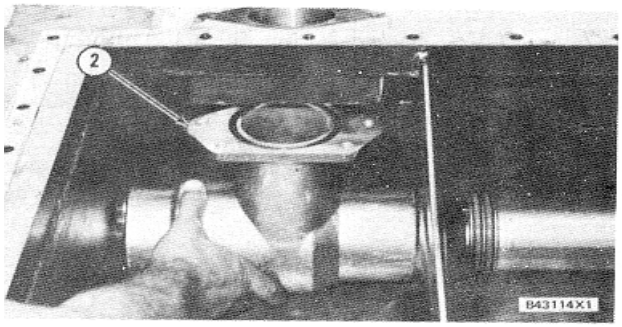


Assemble Oil Pan 1302-16

1. Install the O-ring seals on the ends of tube assembly (1) and put clean engine oil on the seals. Install tube assembly (1) in the oil pan.

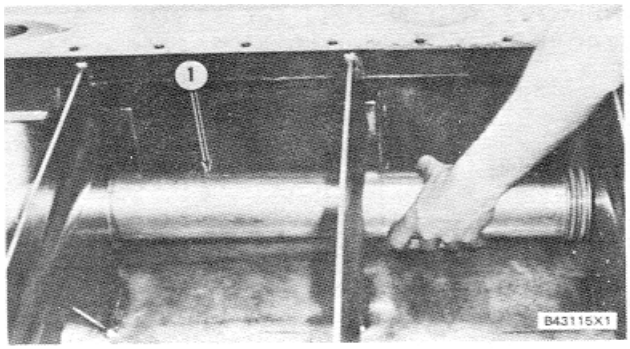


2. Install the O-ring seal in the top of housing (2) and put clean engine oil on it. Put housing (2) in position and install the bolts to hold it in position.

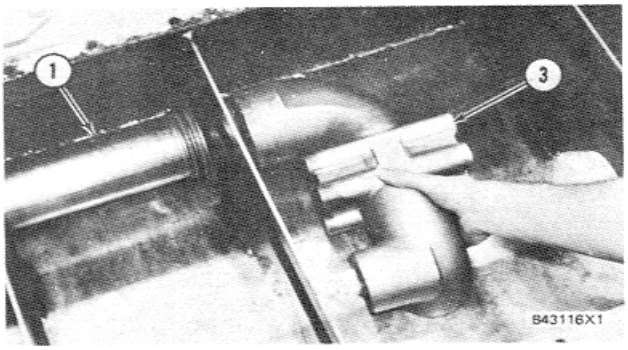


OIL PAN

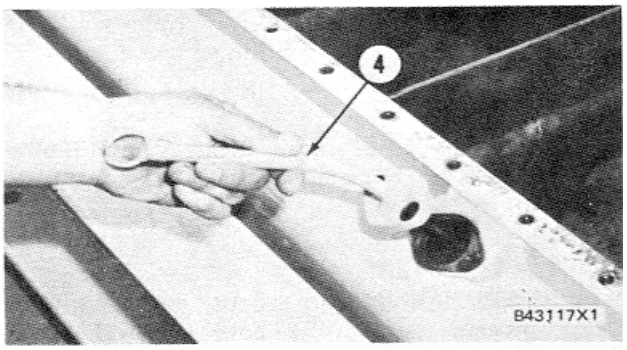
3. Push tube assembly (1) into housing (2).



4. Put bell (3) in position over the end of tube assembly (1) and install the bolts to hold it to the oil pan.

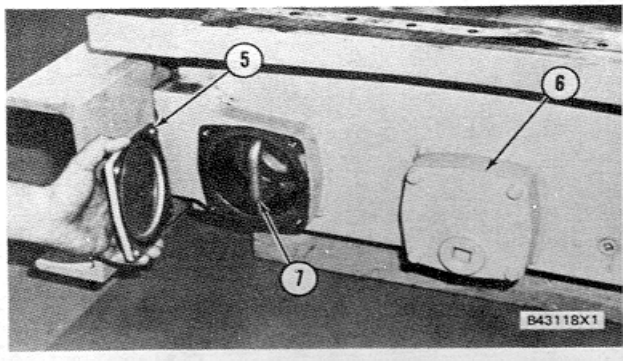


5. Install oil level gauge (4) and the gasket in the oil pan. Install the bolts to hold the gauge in position.



6. Install the O-ring seals on screen assembly (7) and put clean engine oil on the seals. Install screen assembly (7) in the oil pan.

7. Install the O-ring seals on covers (5), (6) and put clean engine oil on the seals. Install covers (5) and (6) on the front of the oil pan.
end by:
a) install oil pan

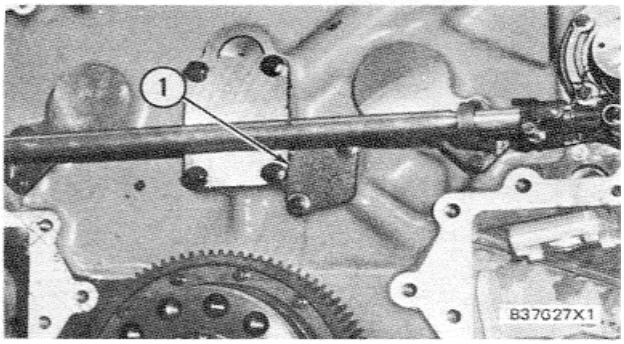


OIL SEQUENCE VALVES

REMOVE AND INSTALL OIL SEQUENCE VALVES

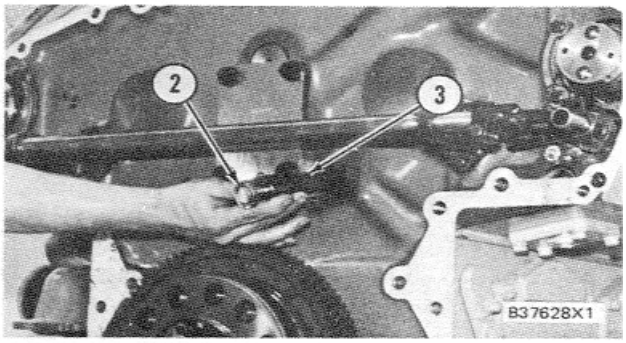
start by:
a) remove front drive housing
b) remove flywheel housing

1. Remove cover (1) from the front of the cylinder block.



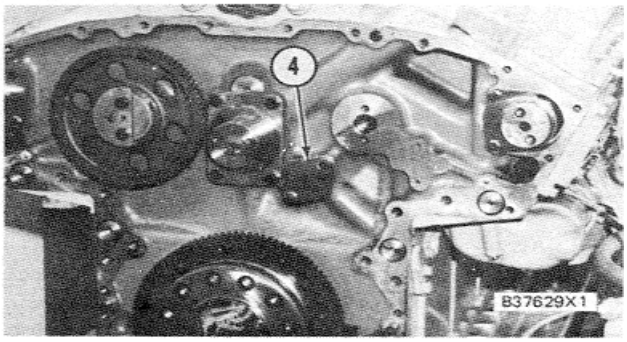
2. Remove plunger assembly (2) and spring (3) from the front of the cylinder block.

3. Remove the gear assembly, idler gear and shaft from over cover (4) on the rear of the cylinder block.



4. Remove cover (4) from the rear of the cylinder block.

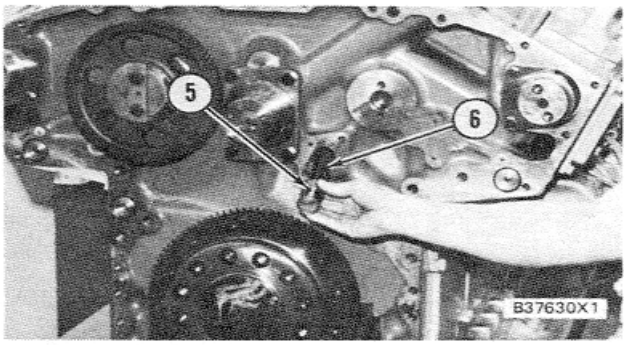
5. Remove plunger assembly (5) and spring (6) from the rear of the cylinder block.



6. Put clean engine oil on spring (6) and plunger assembly (5) and install them as shown in the rear of the cylinder block.

7. Install cover (4). Install the idler gear, shaft and gear assembly over cover (4) on the rear of the cylinder block.

8. Put clean engine oil on spring (3) and plunger assembly (2) and install them in the front of the cylinder block as shown.



9. Install cover (I) to hold the plunger assembly and spring in position.

end by:
a) install flywheel housing
b) install front drive housing

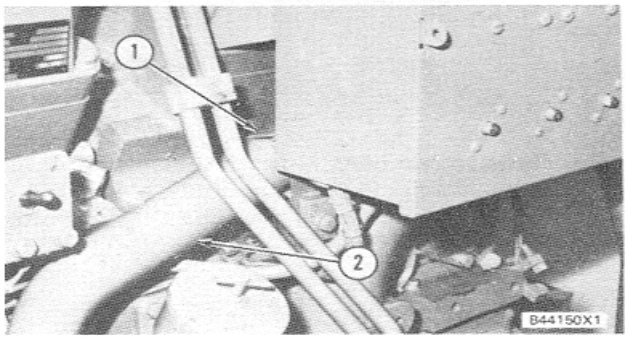
OIL COOLER

REMOVE OIL COOLER 1378-11

1. Drain the coolant from the cooling system.

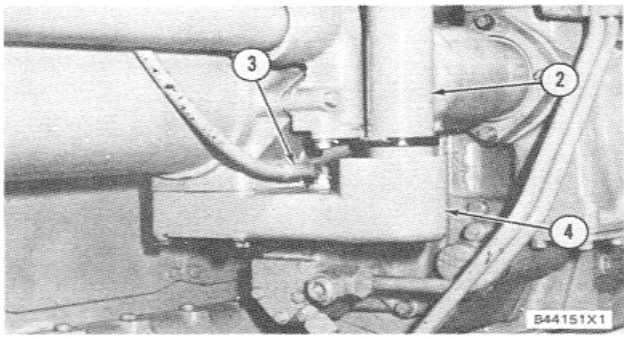
2. Drain the oil from the oil cooler.

3. Remove the bolt and remove clips (1) from oil tube (2).



4. Disconnect oil hose (3) from elbow (4).

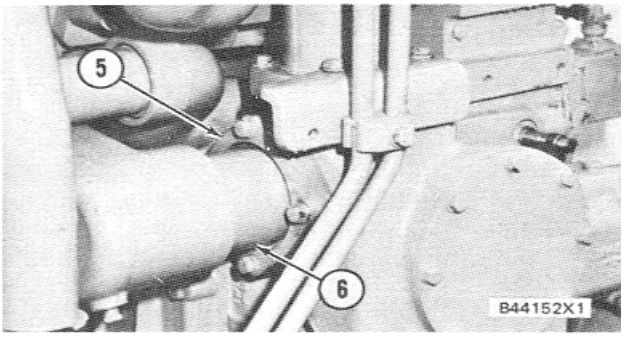
5. Remove the bolts and retainers that hold oil tube (2) to elbow (4) and pull tube (2) out of elbow (4). Remove the bolts and remove elbow (4) from the oil cooler.



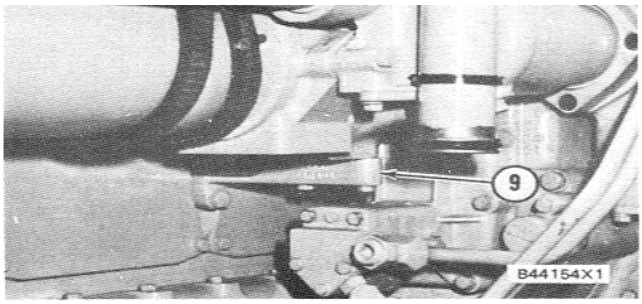
6. Remove the bolts to disconnect flange (5) and tube (6) from the water line adapter.

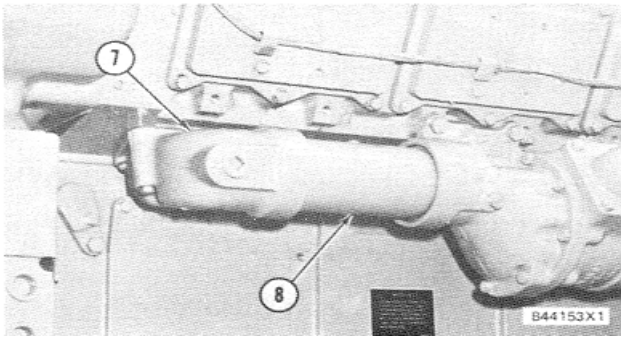
NOTE: Step 7 is for the 3512 Engines.

7. Remove the bolts from elbow (7) and remove elbow (7) and tube (8) as a unit from the oil cooler bonnet.



8. Fasten a hoist to the oil cooler and remove the bolts from bracket (9).





3512 ENGINES

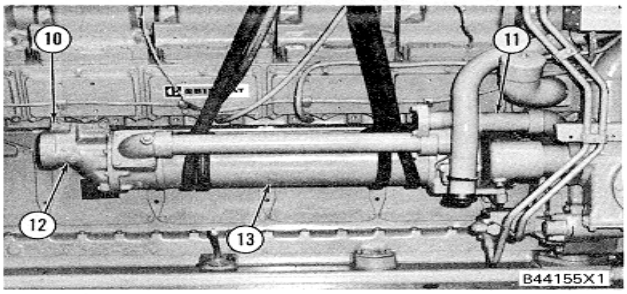
OIL COOLER

NOTE: Step 9 is for the 3512 Engine.

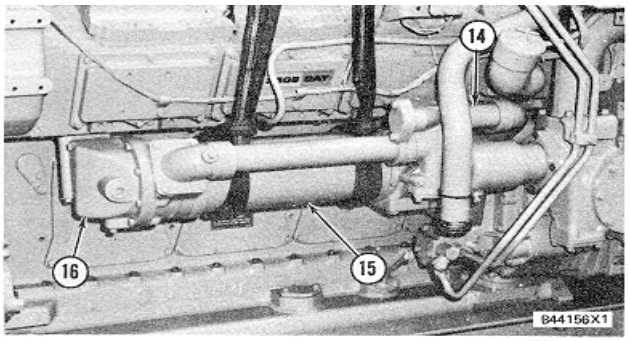
9. Deleted.

NOTE: Step 10 is for the 3508 Engine.

10. Remove the four bolts from bonnet (16) and pull oil cooler (15) from oil tube (14). Remove the cooler from the engine. The weight of cooler (15) is 50 kg (110 lb.).



3512 ENGINES



3512 ENGINES

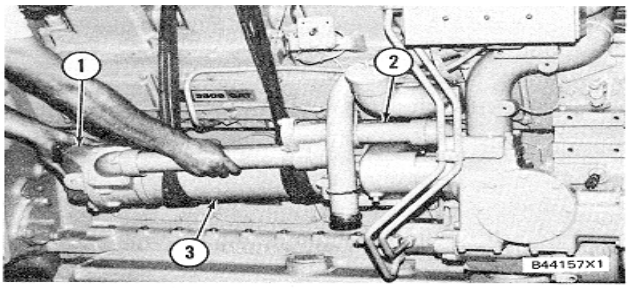
INSTALL OIL COOLER 1378-12

NOTE: Step I is for the 3508 Engine.

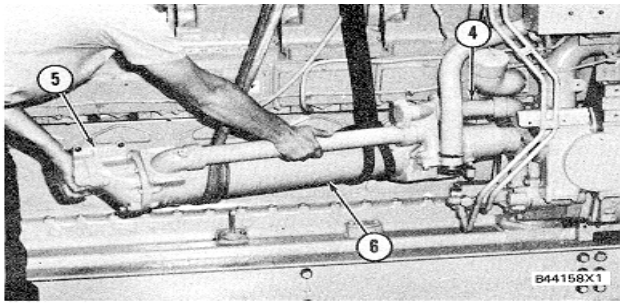
1. Put clean engine oil on the O-ring seal on oil tube (2). Fasten a hoist to oil cooler (3) and put cooler (3) in position on oil tube (2). Make sure the gasket is in place and install the four bolts in bonnet (1) to hold the cooler in position.

NOTE: Step 2 is for the 3512 Engine.

2. Put clean engine oil on the O-ring seal on oil tube (4). Fasten a hoist to oil cooler (6) and put cooler (6) in position on oil tube (4). Install the two bolts in bonnet (5) to hold the cooler in position.



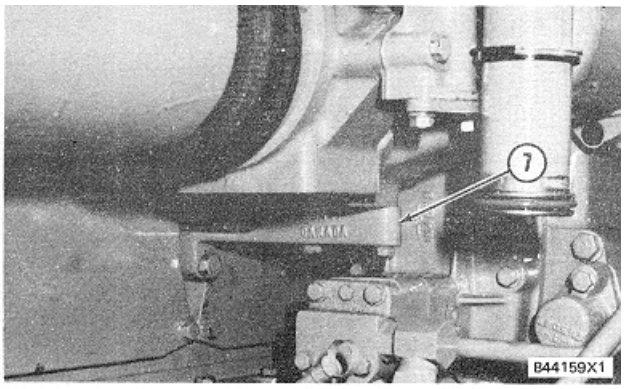
3508 ENGINES



3508 ENGINES

OIL COOLER

3. Install the bolts that hold the oil cooler to bracket (7) and remove the hoist from the oil cooler.

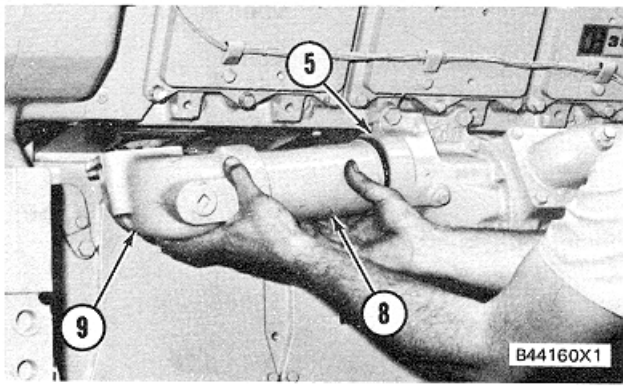


NOTE: Step 4 is for the 3512 Engine.

4. Deleted.

5. Make sure the gasket is in place and install the bolts to hold flange (I I) and tube (10) to the water line adapter.

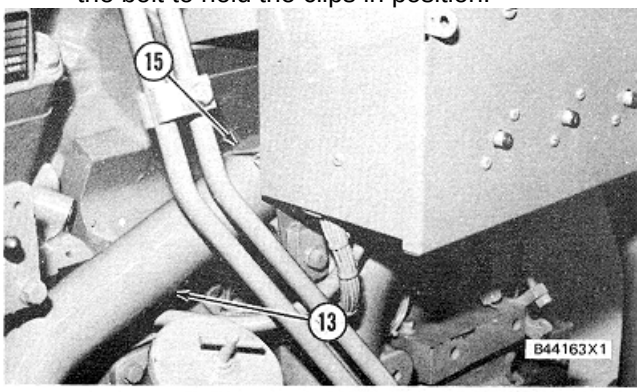
6. Put clean engine oil on the O-ring seal on elbow (14). Put elbow (14) in position on the oil cooler and install the bolts to hold it.

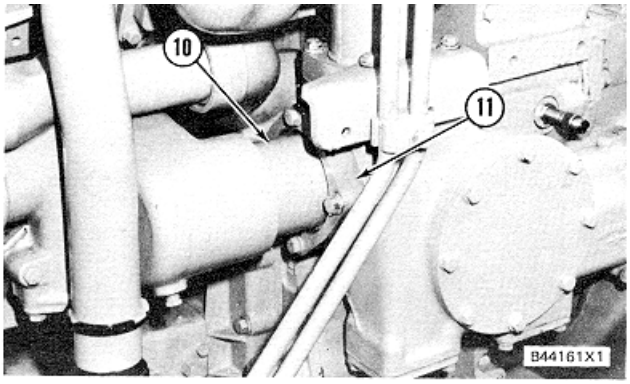


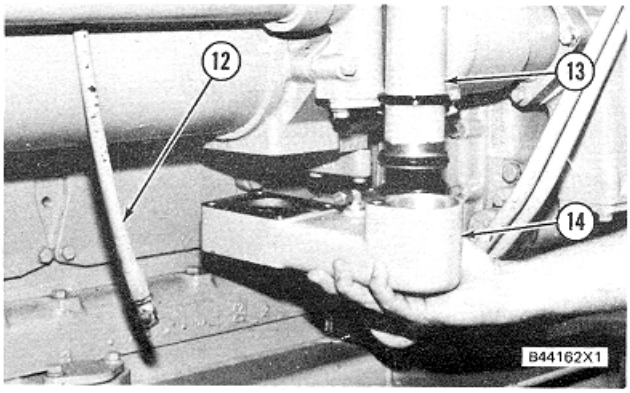
7. Put clean engine oil on the O-ring seal on the end of tube (13). Put tube (13) in position in elbow (14) and install the retainers and bolts to hold the tube.

8. Connect oil hose (12) to elbow (14).

9. Put clips (15) in position on tube (13) and install the bolt to hold the clips in position.







OIL COOLER

DISASSEMBLE OIL COOLER 1378-15

start by:
a) remove oil cooler

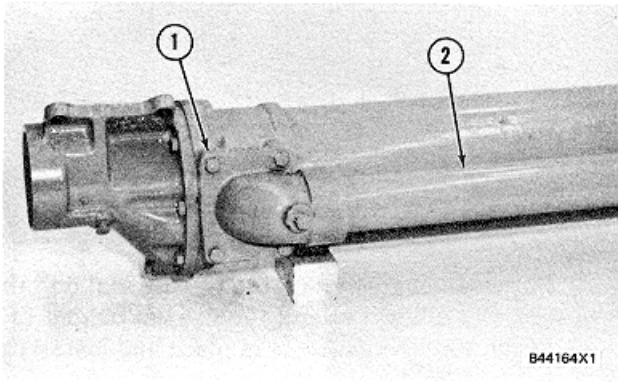
1. Remove the bolts from elbow (1) and remove elbow (1) and tube (2) as a unit from the oil cooler.

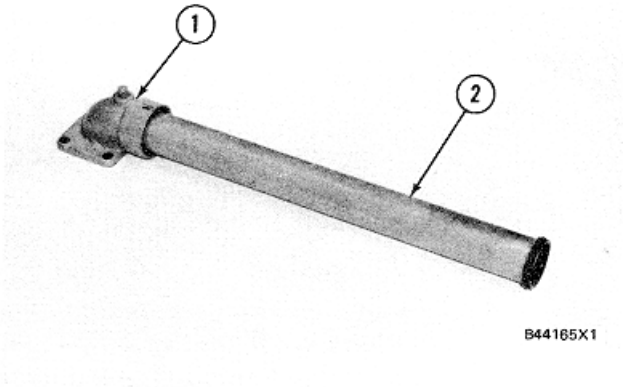
2. Remove tube (2) from elbow (1) and remove the O-ring seals from tube (2) and elbow (1).

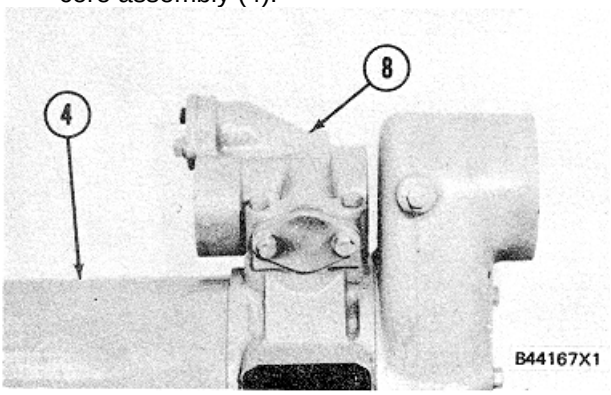
3. Put marks on bonnet (3) and core assembly (4) for correct alignment at assembly. Remove bonnet (3) from core assembly (4).

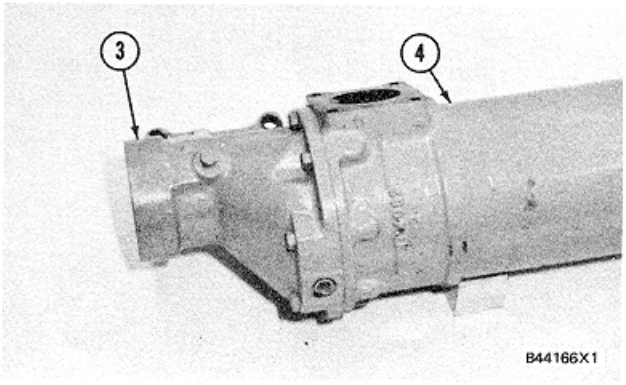
4. Remove flange (7) and tube (6) as a unit from bonnet (5). Remove the O-ring seals from tube (6).

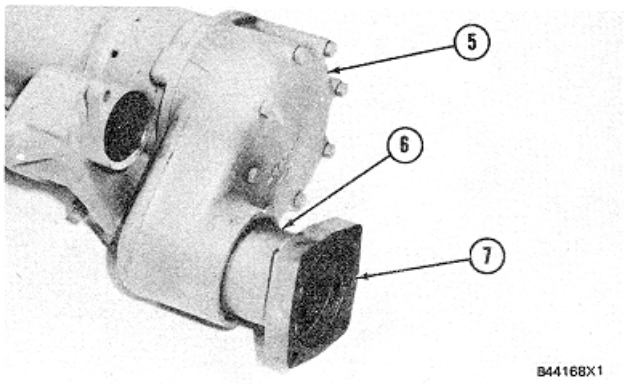
5. Remove the bolts and remove elbow (8) from core assembly (4).





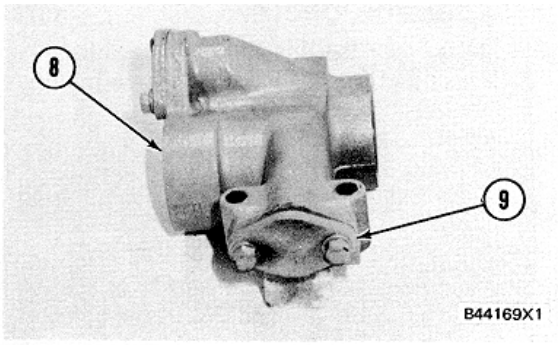




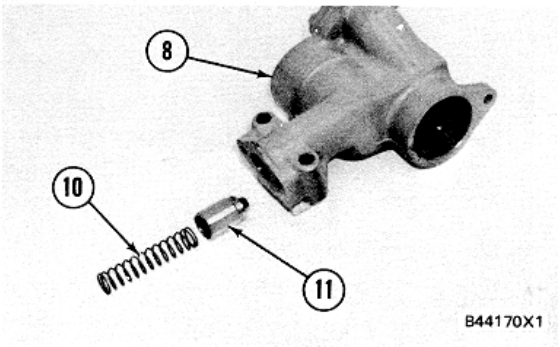


OIL COOLER

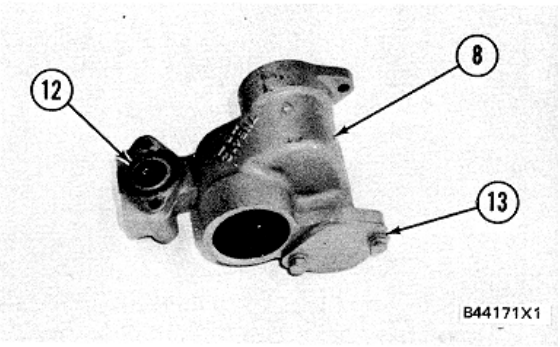
6. Remove the bolts and remove cover (9) from elbow (8). Remove the O-ring seal from cover (9).



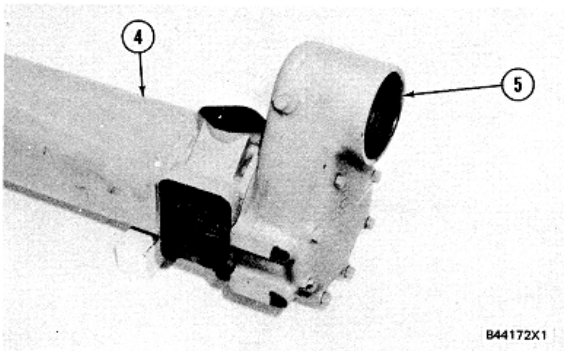
7. Remove spring (10) and plunger (11) from elbow (8).



8. Remove the bolts to remove cover (13) and remove O-ring seals (12) from elbow (8).



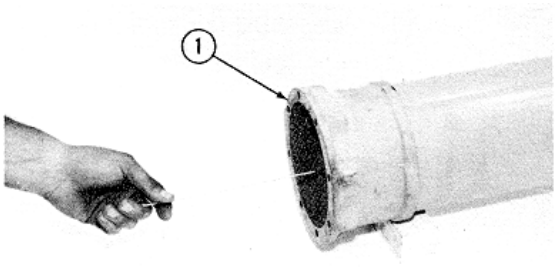
9 Put marks on bonnet (5) and core assembly (4) for correct alignment at assembly. Remove bonnet (5) from core assembly (4).



OIL COOLER

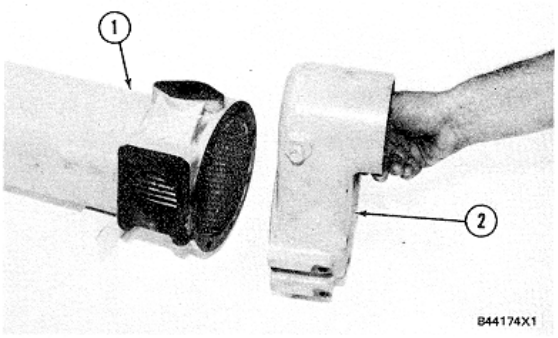
ASSEMBLE OIL COOLER 1378-16

1. Make sure the tubes in core assembly (I) are clean and free of dirt and foreign material.



B44173X1

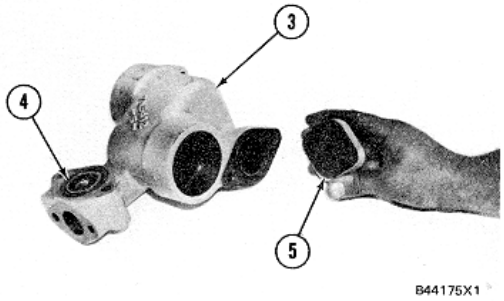
2. Put the gasket and bonnet (2) in position on core assembly (1) and install the bolts.



B44174X1

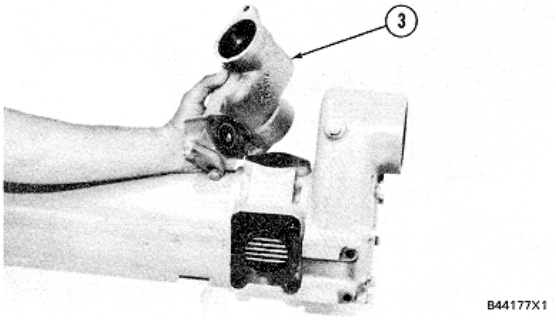
3. Install O-ring seals (4) on elbow (3) and put clean engine oil on the seals. Install cover (5) on elbow (3).

4. Put plunger (7) and spring (8) in position in elbow (3). Install the O-ring seal in cover (6) and put clean engine oil on it. Install cover (6) on elbow (3).

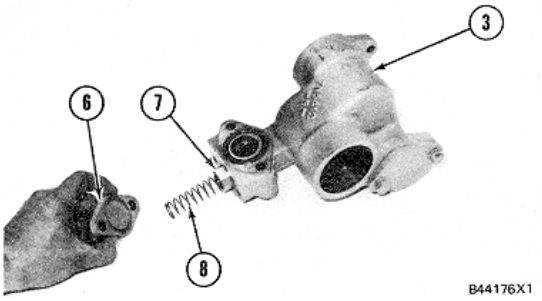


B44175X1

5. Put elbow (3) in position on the core assembly and install the bolts.



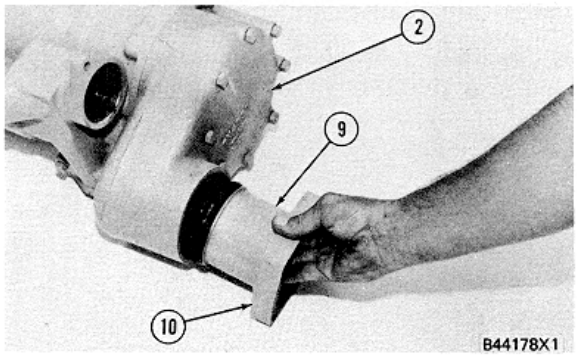
B44177X1



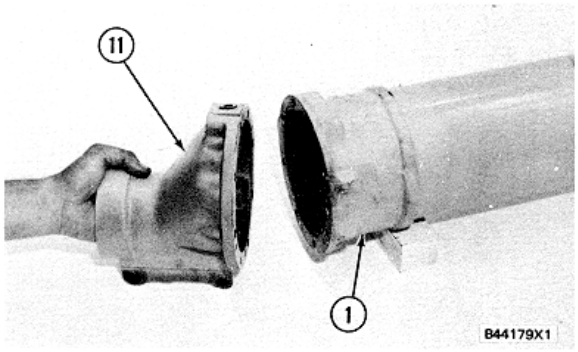
B44176X1

OIL COOLER

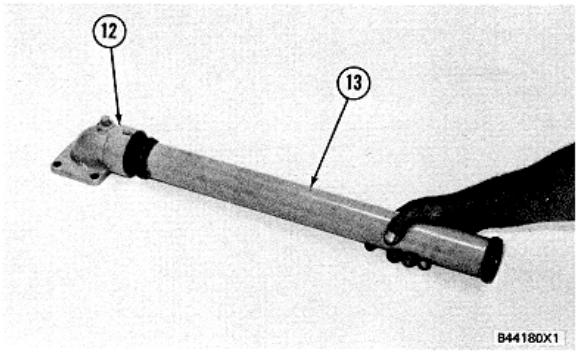
6. Install the O-ring seals on tube (9) and put clean engine oil on the seals. Install tube (9) and flange (10) as a unit in bonnet (2).



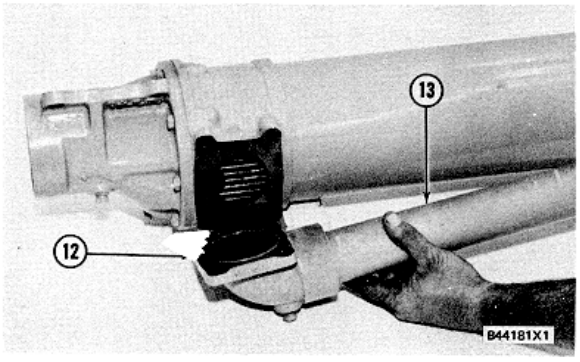
7. Put the gasket and bonnet (11) in position on core assembly (1) and install the bolts.



8. Install the O-ring seals on tube (13) and put clean engine oil on the seals. Install tube (13) in elbow (12).



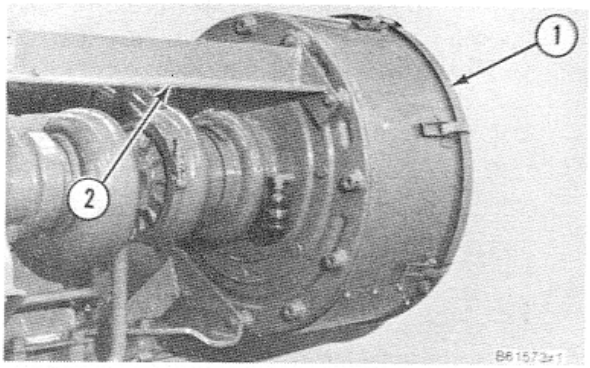
9. Install the O-ring seal on elbow (12) and put clean engine oil on it. Put elbow (12) and tube (13) as a unit in position and install the bolts in elbow (12) to hold the elbow and the tube in position.
end by:
a) install oil cooler



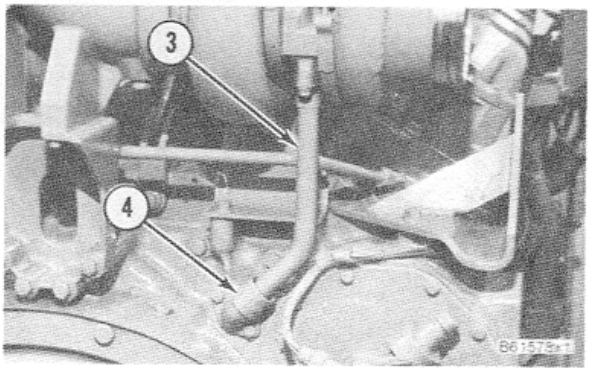
TURBOCHARGERS

REMOVE TURBOCHARGERS 1052-11

1. Remove the bolts to remove support assembly (2) from the air cleaner housing and the engine.

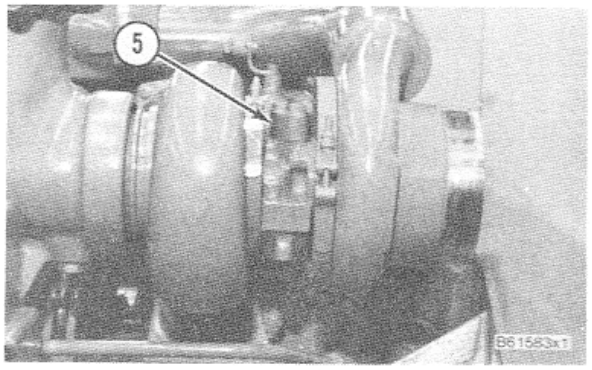


2. Loosen the clamp that holds the air cleaner housing to the turbocharger. Fasten a hoist to air cleaner housing (I) or use two men to remove the housing from the turbocharger. The weight of housing (1) is 29 kg (65 lb.).

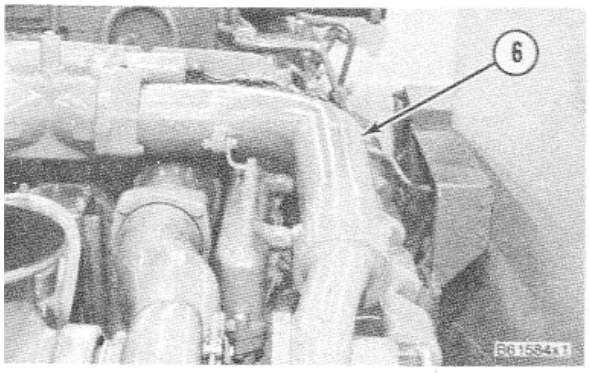


3. Remove turbocharger oil drain tube (3), elbow (4) and the gaskets from the engine. Remove elbow (4) and the O-ring seal from oil drain tube (3).

4. Disconnect oil supply line (5) from the turbocharger.

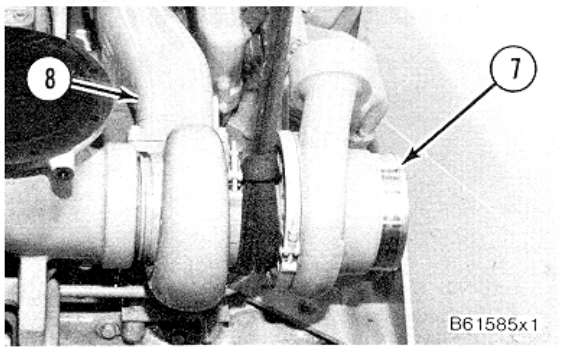


5. Remove turbocharger outlet pipe (6) from the engine. Remove the flange and the O-ring seals from each end of the pipe.

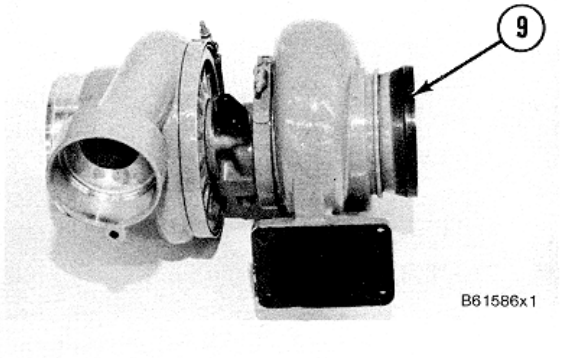


TURBOCHARGERS

6. Fasten a hoist to turbocharger (7) and remove the bolts that hold it to exhaust manifold (8). Pull turbocharger (7) and the coupling from the exhaust elbow and remove these as a unit from the engine. The weight of the 3508 Turbocharger is 45 kg (100 lb.) and the 3512 Turbocharger is 20 kg (45 lb.).



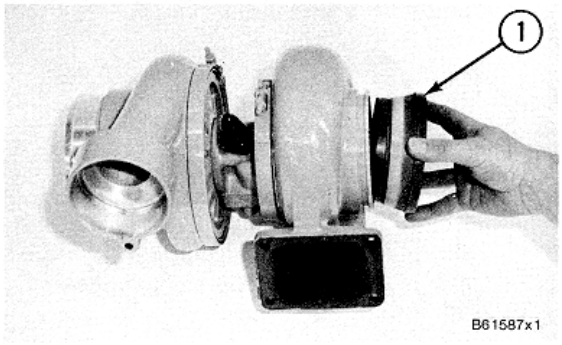
7. Remove coupling (9) from the turbocharger turbine housing.



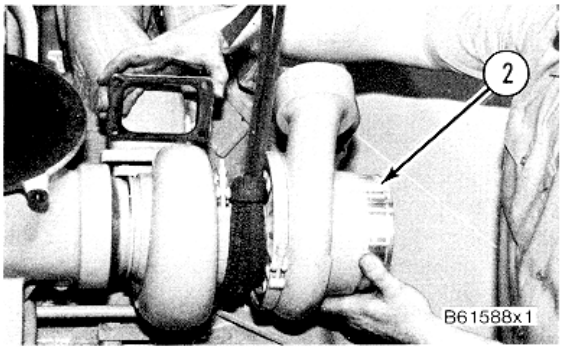
8. Do Steps 1 through 7 for the other turbocharger.

Install Turbochargers 1052-12

1. Install coupling (I) in the turbocharger turbine housing.

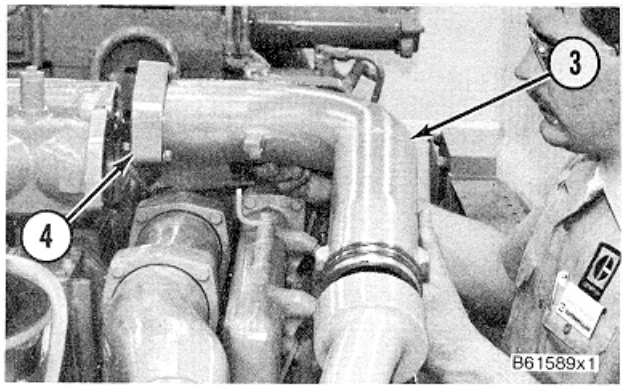


2. Fasten a hoist to turbocharger (2) and put it and the gasket in position. Put 5P3931 Anti- seize Compound on the threads of the nuts and bolts that hold the turbocharger to the exhaust manifold. Install the bolts and nuts and tighten the nuts to a torque of 54 + 5 N.m (40 + 4 lb. ft.).



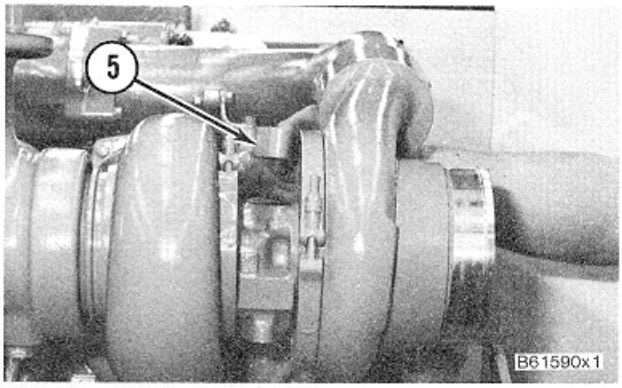
TURBOCHARGERS

3. Install the O-ring seals on both ends of pipe (3) and put clean engine oil on the seals. Install flange (4) on the pipe and install pipe (3) on the engine.

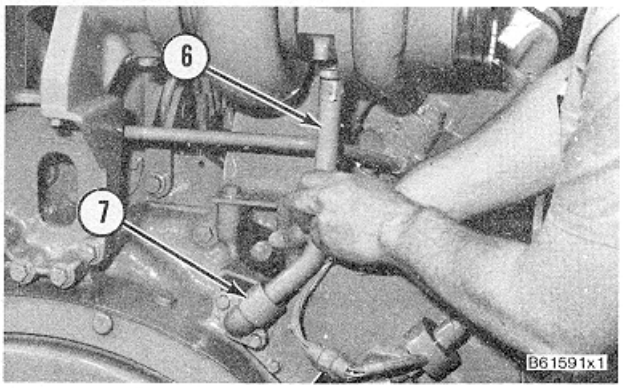


4. Make sure the gasket is in position and connect oil supply line (5) to the turbocharger.

5. Install the O-ring seal on drain tube (6) and put clean engine oil on it. Install elbow (7) on the drain tube.

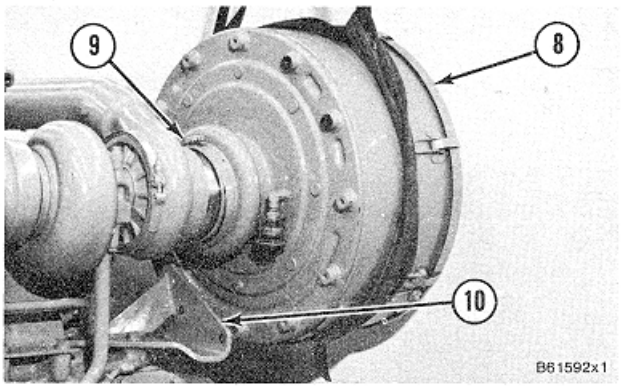


6. Install the gaskets, elbow (7) and turbocharger oil drain tube (6) on the engine.



7. Fasten a hoist to air cleaner housing (8) and put it in position on the turbocharger compressor housing. Install the bolts that hold housing (8) to bracket (10) and tighten clamp (9).

8. Install the support assembly between the air cleaner housings.



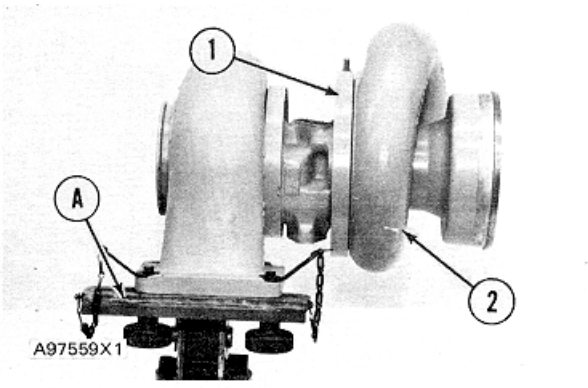
9. Do Steps I through 8 for the other turbocharger.

TURBOCHARGERS (3508)

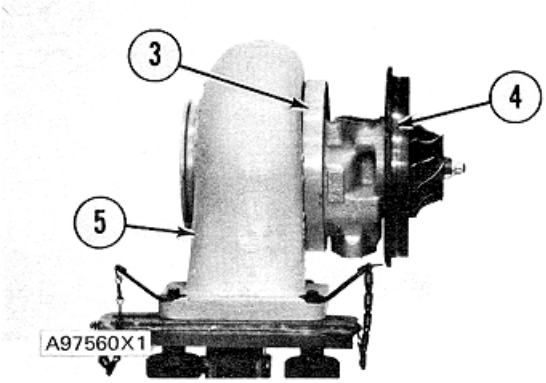
DISASSEMBLE TURBOCHARGERS (AIRESEARCH TV61 AND TW61)

Tools Needed		A	B	C	D	E	F
9S6363	Turbocharger Fixture Group	1					
9S6343	Fixture Assembly		1				
8S9946	Holder			1			
5S9566	T-Wrench				1		
5P6518	Fixture Group					1	
FT745	Modified Pliers						1

start by:
a) remove turbochargers



1. Install the turbocharger on tool (A) as shown. Put marks on the three housings of the turbo- charger for correct installation and alignment at assembly.

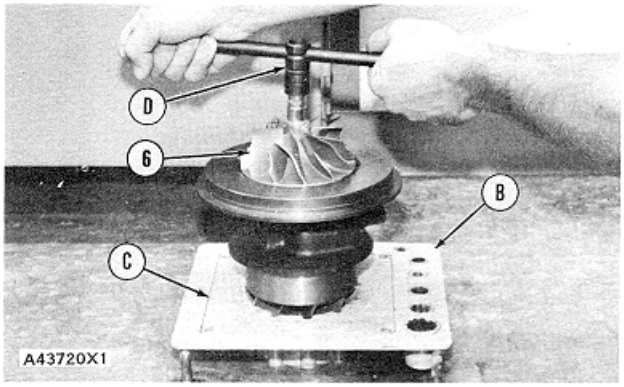


2. Loosen clamp (1) and remove compressor housing (2) and the clamp from the cartridge assembly.

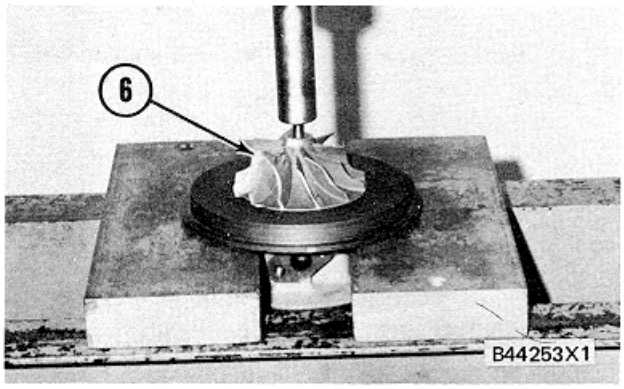
3. Loosen clamp (3) and remove cartridge assembly (4) from turbine housing (5).

NOTICE

To prevent a bent shaft, do not put a side force on the turbine shaft when the compressor wheel nut is loosened.



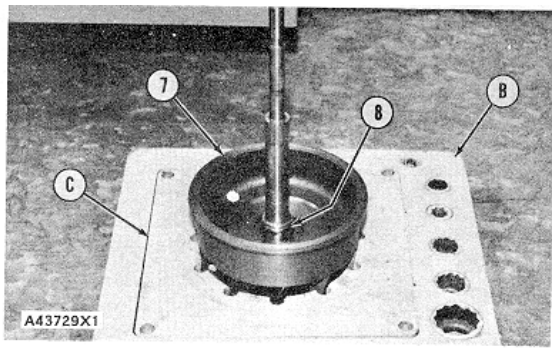
4. Install tool (C) in tool (B) and put the cartridge assembly in tool (C) as shown. Use tool (D) to remove the nut that holds compressor wheel (6).



5. Use a press to push the turbine shaft out of compressor wheel (6) and the cartridge housing. Remove compressor wheel (6) from the cartridge housing.

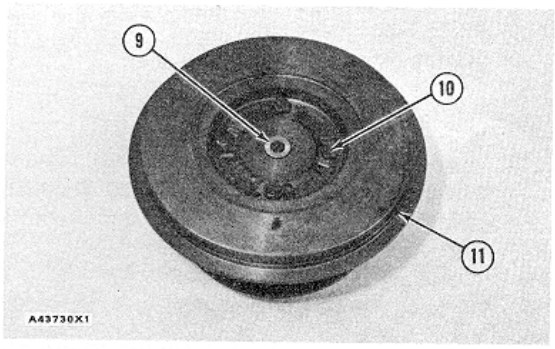
TURBOCHARGERS (3508)

6. Put the turbine shaft in tool (C). Remove seal ring (8) and shroud (7) from the shaft.

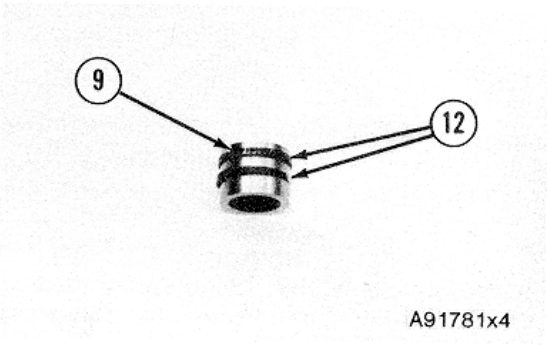


7. Use tool (E) to make sure the turbocharger shaft is straight. See SPECIAL INSTRUCTION Form No. SMHS6998.

8. Bend the tabs of the locks from bolts (10) and remove the bolts and locks.

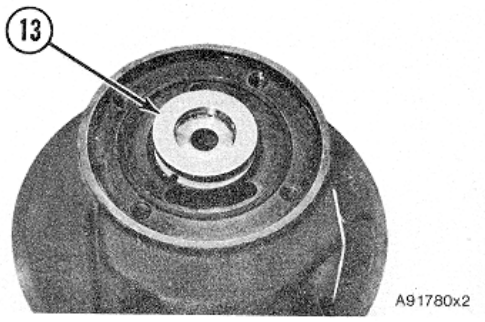


9. Remove backplate assembly (I1) from the cartridge housing. Remove spacer (9) from back- plate assembly (11).



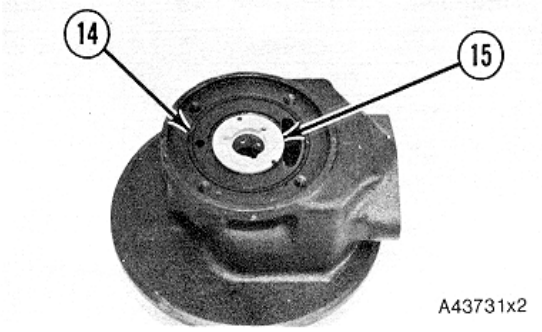
10. Remove seal rings (12) from spacer (9).

11. Remove thrust collar (13) from the cartridge housing.



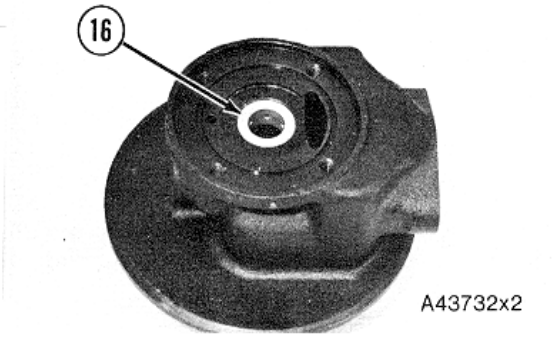
TURBOCHARGERS (3508)

12. Remove seal ring (14) and thrust bearing (15) from the cartridge housing.



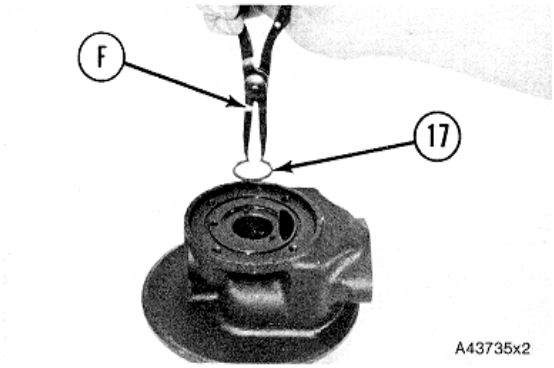
NOTE: If the bearings are to be used again, put identification on them as to their location for correct assembly.

13. Remove bearing (16) and the washer below the bearing from the cartridge housing.



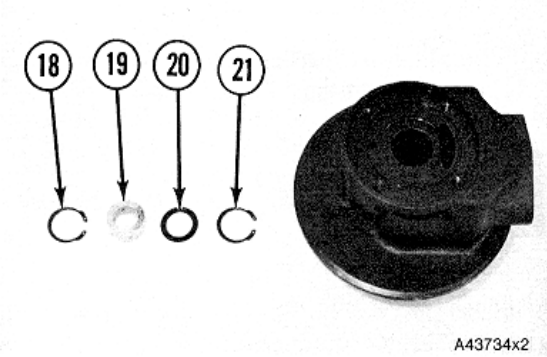
14. Use tool (F) to remove snap rings (17) and (18) from the cartridge housing.

15. Remove bearing (19) and washer (20) from the cartridge housing.



16. Use tool (F) to remove snap ring (21) from the cartridge housing if necessary.

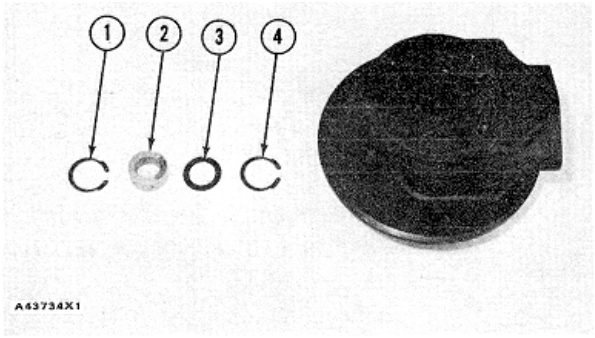
17. Check all the parts of the turbocharger for damage. If the parts have damage, use new parts for replacement. See SPECIAL INSTRUCTION Form No. SMHS6854 for TURBOCHARGER RECONDITIONING. Also see GUIDELINE FOR REUSABLE PARTS Form No. SEBF8018.



TURBOCHARGERS (3508)

ASSEMBLE TURBOCHARGERS (AIRESEARCH TV61 AND TW61) 1052-16

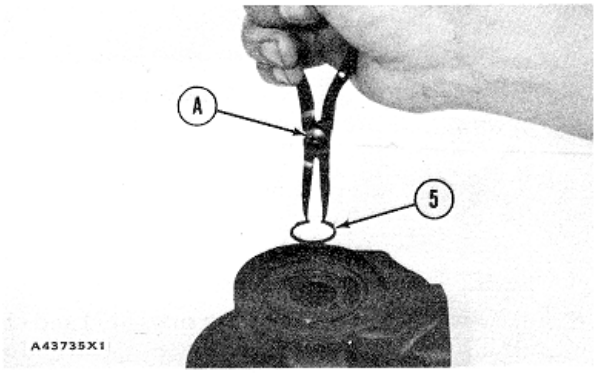
Tools Needed		A	B	C	D	E
FT745	Modified Pliers	1				
9S6343	Fixture Assembly		1			
8S9946	Holder			1		
8S2328	Dial Test Indicator Group				1	
9S6363	Turbocharger Fixture Group					1



1. Make sure all of oil passages in the turbocharger cartridge housing, backplate assembly and bearings are clean and free of dirt and foreign material.

2. Put clean engine oil on all parts of the cartridge at assembly.

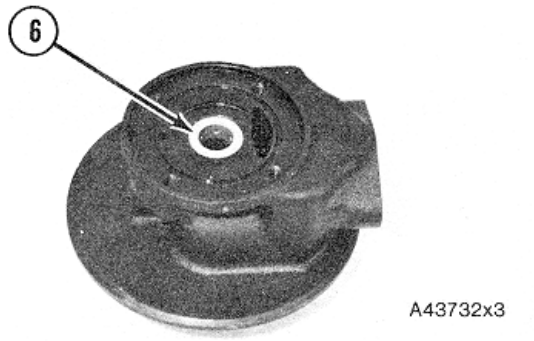
NOTE: Make sure the round edge of the snap rings are toward the bearings when the snap rings are installed.



3. If necessary, use tool (A) to install snap ring (1) in the turbine end of the cartridge housing.

4. Install washer (2) and bearing (3). Use tool (A) to install snap ring (4) to hold the washer and bearing in the cartridge housing.

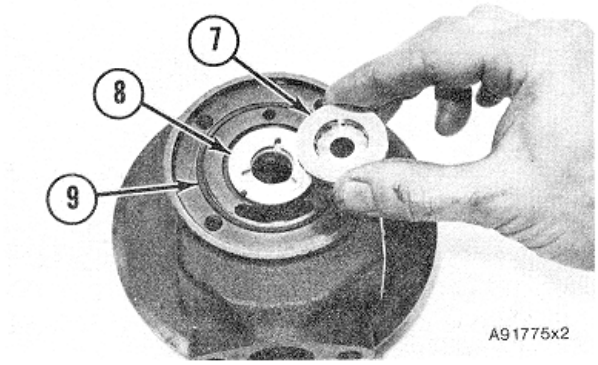
5. Use tool (A) to install snap ring (5) in the cartridge housing.



6. Install the washer and bearing (6) until the washer makes contact with snap ring (5).

7. Install thrust bearing (8) over the dowels in the cartridge housing. Make sure the grooves in bearing (8) are toward the outside as shown.

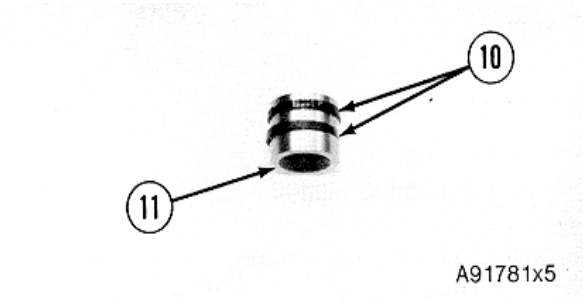
8. Install seal ring (9) in the groove of the cartridge housing.



9. Put thrust collar (7) in position on the thrust bearing with the counterbore for the spacer up.

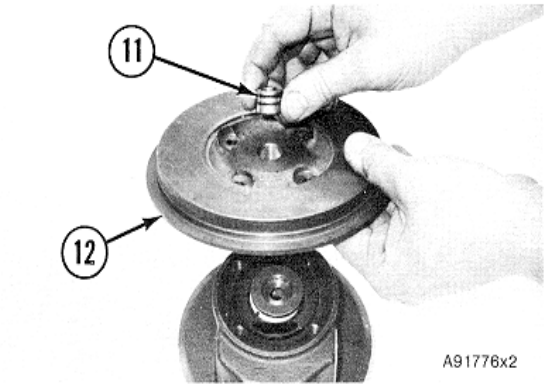
TURBOCHARGERS (3508)

10. Install seal rings (10) on spacer (11) so the gaps in the rings are 180° apart.



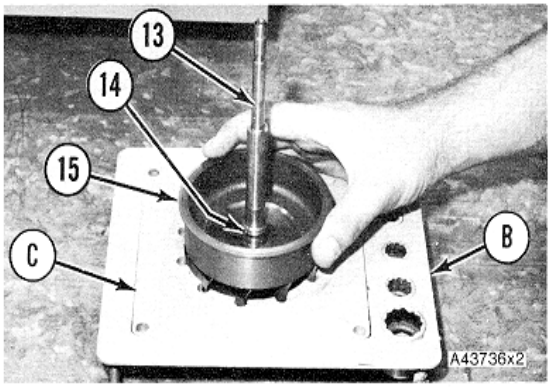
11. Install spacer (11) in backplate assembly (12) with the chamfer end of the spacer toward the cartridge housing.

12. Make sure the oil passage in the cartridge housing and the backplate assembly are in alignment. Put the backplate assembly (12) in position on the cartridge housing.



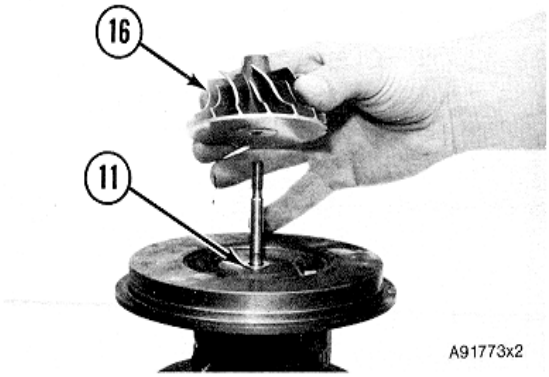
13. Install the locks and bolts to hold backplate assembly (12) to the cartridge housing. Tighten the bolts to a torque of 10 ± 1.1 N•m (90 ± 10 lb. in.) and bend the tabs of the locks on the bolts.

14. Install tool (C) in tool (B). Put the turbine shaft in position in tooling (C). Put 6V2055 High Vacuum Grease in the groove for seal ring (14). Make sure the grease fills the groove approximately one half or more of the groove depth for the complete circumference of the groove to help make a carbon dam under the seal ring. Install seal ring (14) and shroud (15) on turbine shaft (13).



15. Install the cartridge housing on the turbine shaft while spacer (11) is held in position. Make sure the seal ring on the turbine is fitted correctly in the cartridge housing.

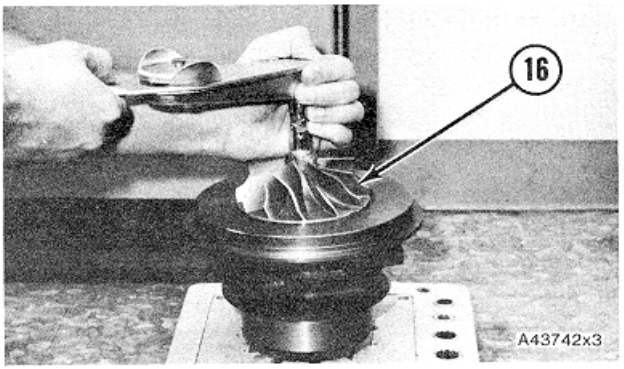
16. Put compressor wheel (16) in position on the turbine shaft.



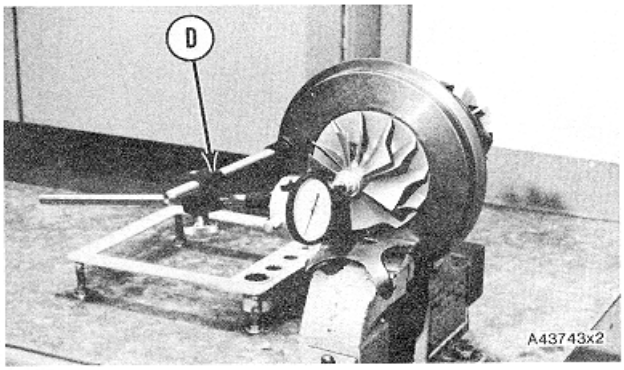
TURBOCHARGERS (3508)

NOTICE
Do not put a side force on the turbine shaft when the nut is tightened or a bent shaft will be the result.

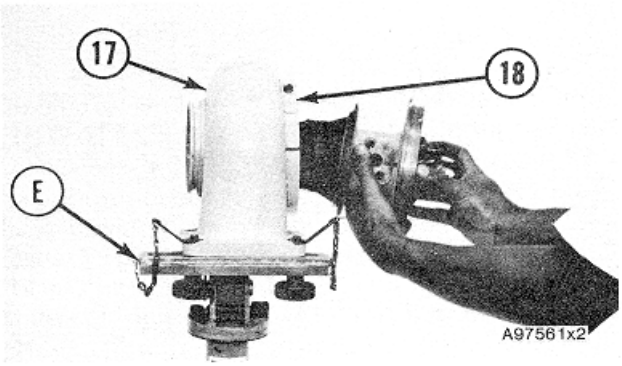
17. Put a small amount of oil on the turbine shaft threads and the compressor wheel face that will be under the nut. Install the nut and tighten it to a torque of 13.6 N•m (120 lb. in.) to push the compressor wheel (16) on the shaft. Loosen the nut and tighten it again to 3.4 N•m (30 lb. in.). Tighten the nut 1200 of a turn more.



18. Put the cartridge housing in a vise as shown. Check the shaft end play with tool group (D). The shaft end play must be 0.08 mm to 0.25 mm (.003 to .010 in.).



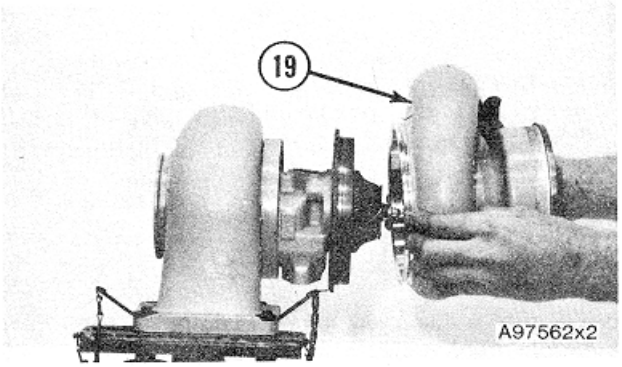
19. Install turbine housing (17) on tool group (E) as shown. Put the cartridge and clamp (18) in position in turbine housing (17). Make sure the marks on the housing and cartridge are in alignment and tighten clamp (18) to a torque of 13.6 ± 1.1 N•m (120 ± 10 lb. in.). Lightly hit all around the clamp with a soft faced hammer and again tighten clamp nut to same torque.



20. Install clamp and compressor housing (19) on the cartridge in the correct position. Move clamp into position and tighten the nut to a torque of 13.6 ± 1.1 N•m (120 ± 10 lb. in.). Lightly hit all around the clamp with a soft faced hammer and again tighten clamp nut to the same torque.

end by:

a) install turbochargers

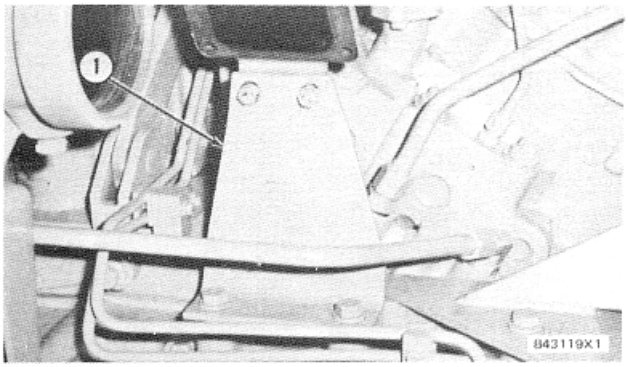


EXHAUST MANIFOLDS

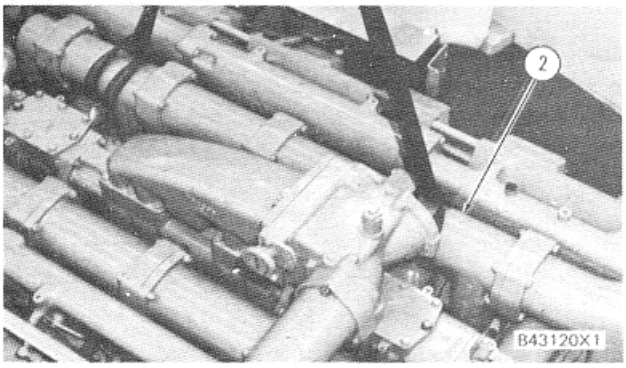
REMOVE EXHAUST MANIFOLDS 1059-11

start by:
a) remove turbochargers
b) remove air intake shutoff (3508)

1. Remove bracket (1) that holds the rear of the exhaust manifold in position.



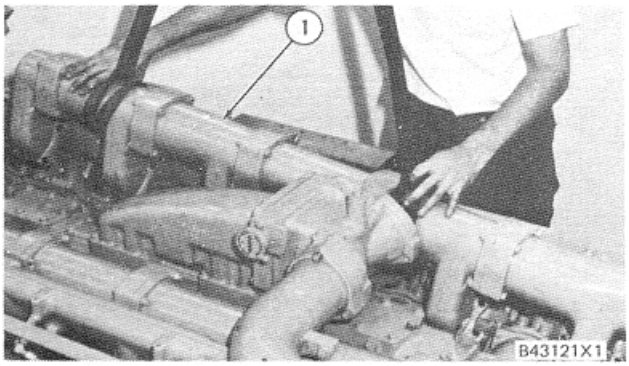
2. Fasten a hoist to exhaust manifold (2) and remove the bolts that hold it to each cylinder head. Remove the exhaust manifold from the engine. The weight of the 3512 exhaust manifold is 56 kg (125 lb.). The weight of the 3508 exhaust manifold is 49 kg (110 lb.).



INSTALL EXHAUST MANIFOLDS 1059-12

1. If the exhaust manifold was disassembled, put 5P3931 Anti-Seize Compound on the threads of the bolts and nuts at assembly.

2. Fasten a hoist and put exhaust manifold (1) and the gaskets in position on the engine.

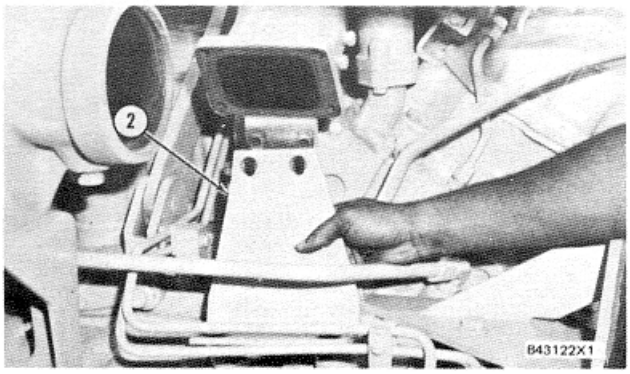


NOTE: The gaskets can be fastened to the exhaust manifold ports with tag wire or short 3/8"-16 NC studs can be used as guide bolts for alignment at assembly.

3. Put 5P3931 Anti-Seize Compound on the threads of the bolts and install them to hold the exhaust manifolds to the cylinder heads. Tighten the bolts to a torque of 45 $\pm$ 7 N-m (32 $\pm$ 5 lb. ft.).

4. Install bracket (2) to hold the rear of the exhaust manifold in position. start by:

a) install turbochargers
b) install air intake shutoff (3508)

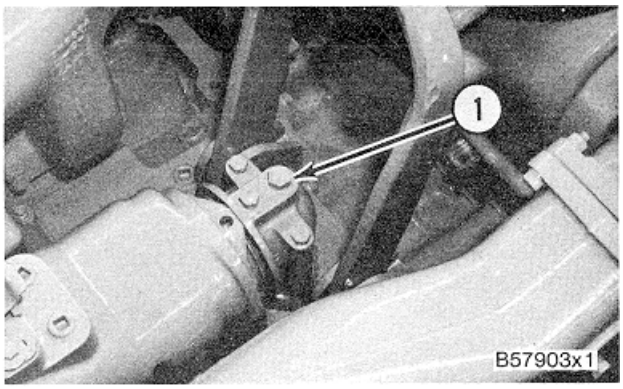


AFTERCOOLER

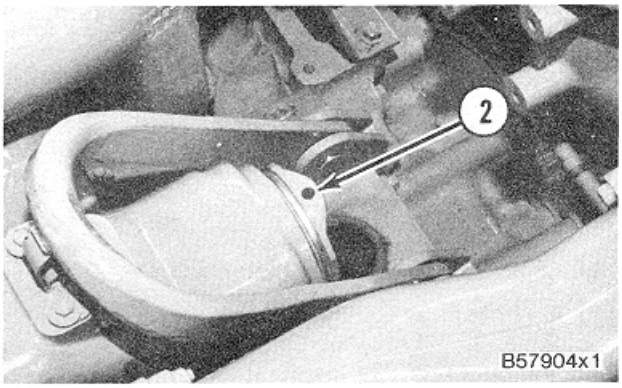
REMOVE AFTERCOOLER 1063-11

Tools Needed	A
6V2156 Link Bracket	2

start by:
a) remove air intake shutoff

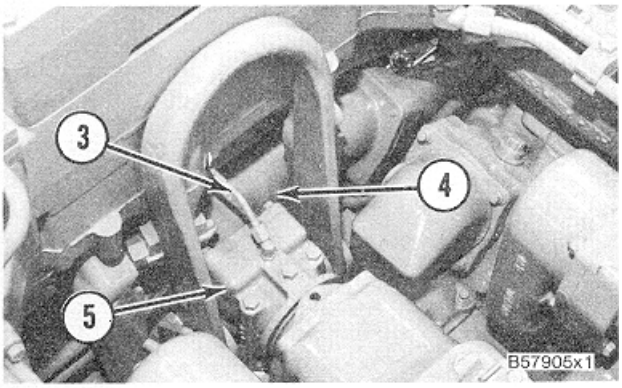


1. Drain the coolant from the cooling system.



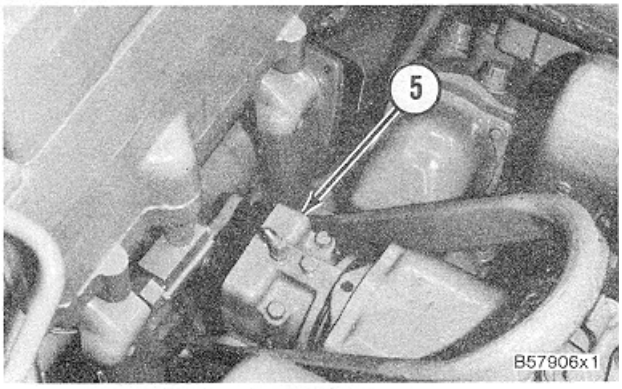
2. Remove the two bolts to remove elbow (1) and a sleeve from the rear of the aftercooler housings.

3. Remove adapter (2) from the rear of aftercooler housings.



4. Disconnect tube assembly (3) from adapter (5) and the water temperature regulator housing. Remove the tube assembly from the engine.

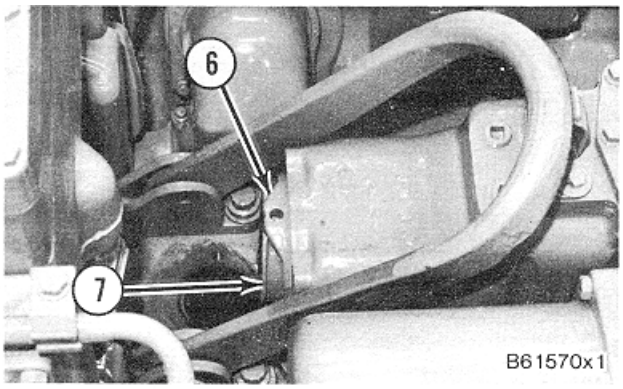
5. Remove all the bolts that hold elbow (4) in position and disconnect elbow (4) from adapter (5).



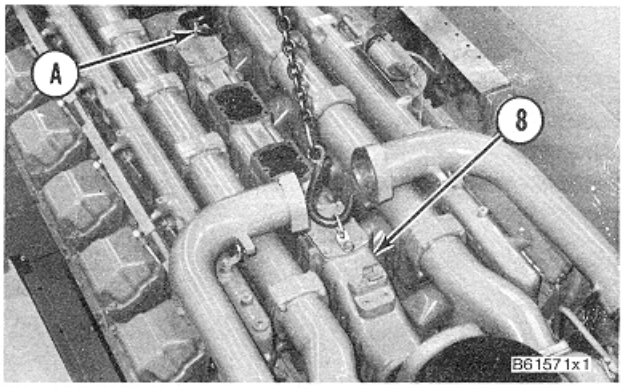
6. Remove the two bolts and remove adapter (5) from the front of the aftercooler housings.

AFTERCOOLER

7. Remove sleeve (7) from adapter (6) and remove adapter (6) from the front of the aftercooler housings.



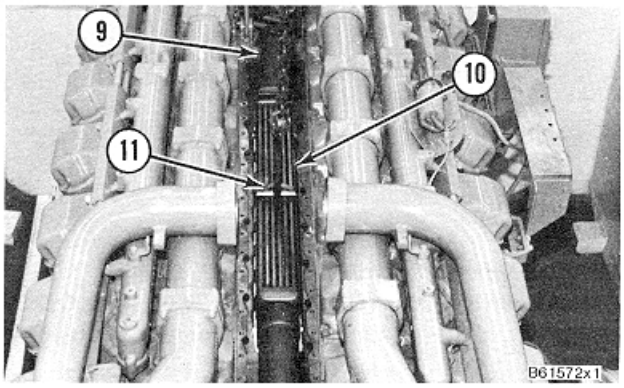
8. Fasten a hoist to aftercooler housings (8) with tooling (A). Remove the bolts to remove aftercooler housings (8) from the engine. The weight of the 3508 Aftercooler Housings is 28 kg (62 lb.) and the 3512 Aftercooler Housings is 66 kg (145 lb.).



NOTICE

Be careful when the aftercooler core is removed because the lower rear part of the core is held in position by a connector and O-ring seals.

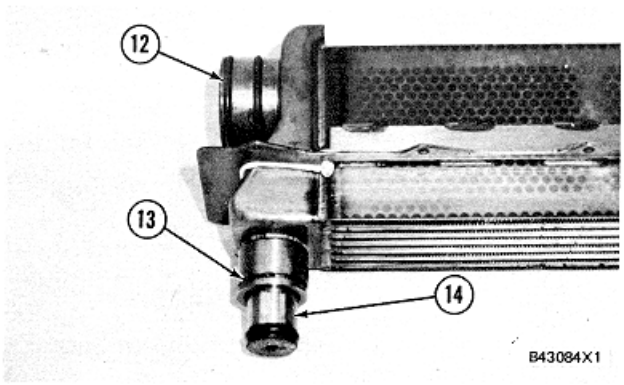
9. Fasten a hoist to strap (11) and remove the bolts and two plates that hold aftercooler core (10) in position. Remove aftercooler core (10) from the engine. The weight of the 3512 Aftercooler Core is 39 kg (85 lb.). The weight of the 3508 Aftercooler Core is 29 kg (65 lb.).



NOTE: The 3512 and 3508 Engines use the same aftercooler core but the 3508 Engines do not have pipes (9) at the ends of the core or the two plates to hold the core in position.

10. Remove pipes (9) from the ends of the aftercooler core and remove the O-ring seals from the tubes.

11. Remove O-ring seals (12) from each end of the aftercooler core. Remove ring (13) to remove connector (14) from the aftercooler core. Remove the O-ring seals from the connector.

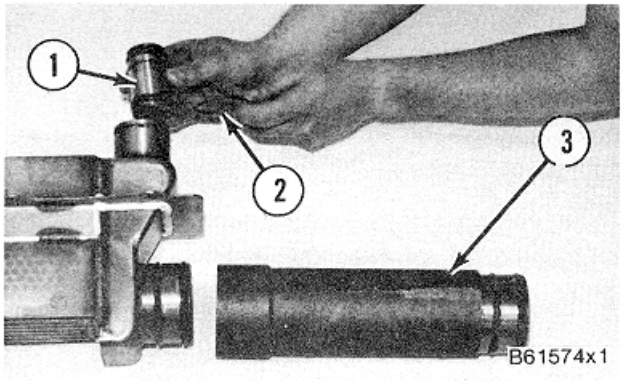


AFTERCOOLER

INSTALL AFTERCOOLER 1063-12

Tools Needed	A
6V2156 Link Bracket	2

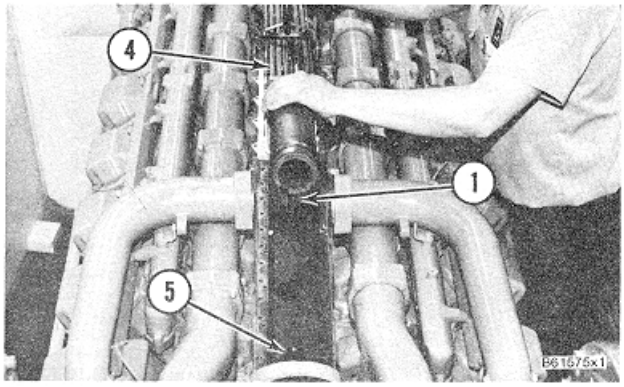
NOTE: Clean and inspect all of the O-ring seals and gaskets. Make a replacement of any worn or damaged seals and gaskets.



1. Install the O-ring seals on connector (1) and put clean engine oil on the seals. Put connector (I) in position and install ring (2) to hold the connector in position.

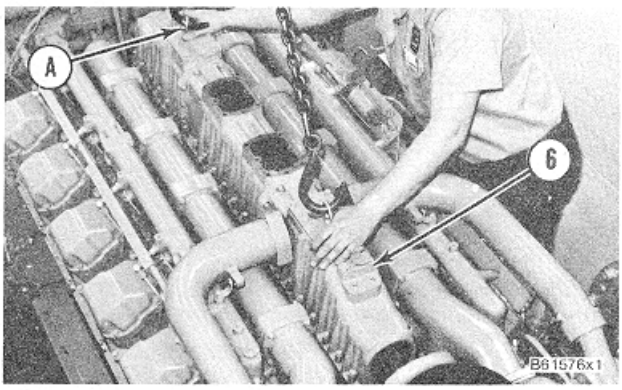
2. Install the O-ring seals on the ends of the aftercooler core and put clean engine oil on the seals.

3. Install the O-ring seals on pipes (3) and put clean engine oil on the seals. Install pipes (3) on the ends of the 3512 Aftercooler Core only.



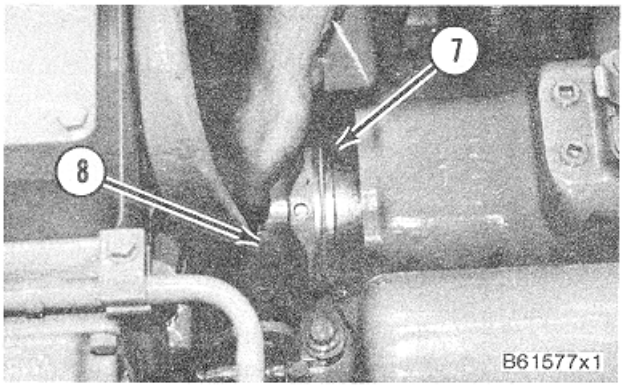
4. Fasten a hoist to aftercooler core (4) as shown and put it in position on the engine. Make sure connector (I) is correctly engaged with adapter (5) in the cylinder block. Install the bolts and plates to hold the core in position. The 3508 Engines do not use the plates.

5. If the aftercooler housings were taken apart and new gaskets installed, cut the gaskets even with the bottom of the housings.



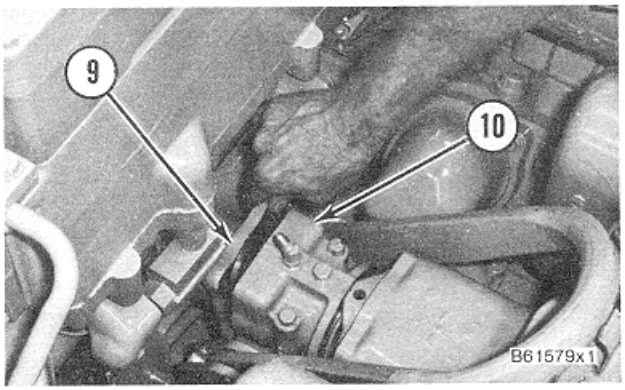
6. Fasten a hoist to aftercooler housings (6) with tooling (A). Put housings (6) and the gasket in position and install the bolts to hold the housings in position. Tighten the bolts to a torque of 55 ± 7 N•m (40 ± 5 lb. ft.).

7. Put clean engine oil on the O-ring seal on adjuster (7). Install adapter (7) and sleeve (8) in the front of the aftercooler housings and over the end of the pipe.

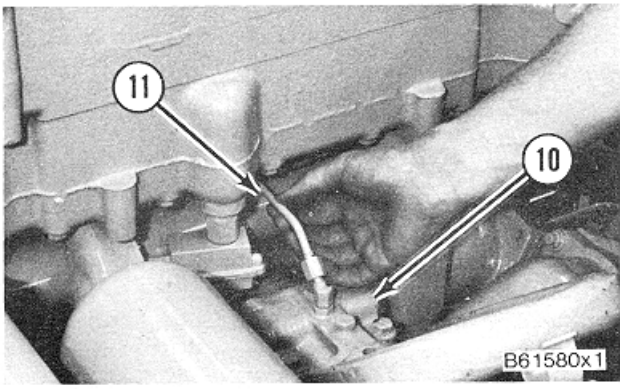


AFTERCOOLER

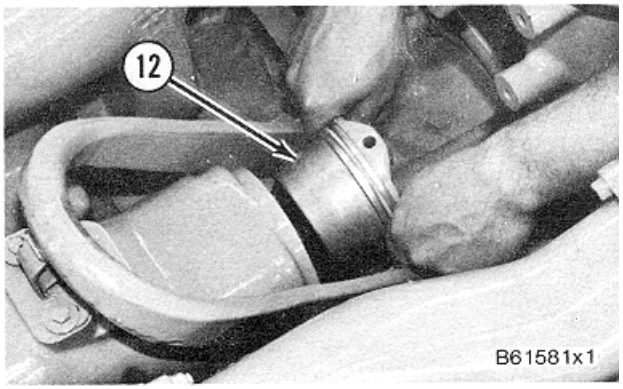
8. Put clean water on the O-ring seal and put adapter (10) and the gasket in position in the front of the aftercooler housings. Install the bolts to the adapter.



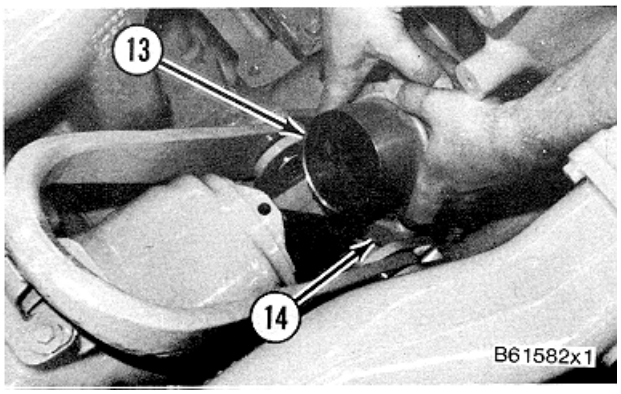
9. Put clean water on the O-ring seal and push elbow (9) into adapter (10). Put the gasket in position between elbow (9) and the tube. Install the bolts to hold elbow (9) in position.



10. Install tube assembly (11) on the regulator housing and adapter (10).



11. Put clean engine oil on the O-ring seal and install adapter (12) in the rear of the aftercooler housings and over the end of the pipe.



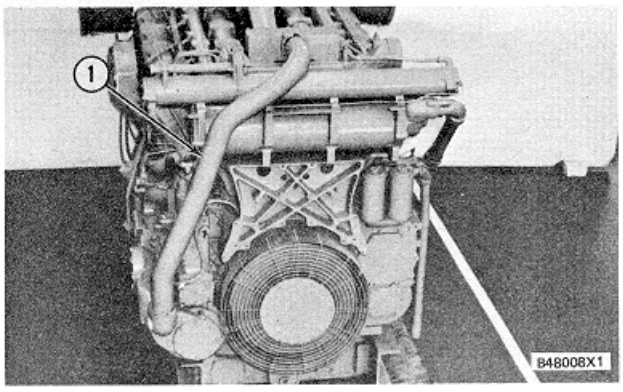
12. Put clean water on the O-ring seal on elbow (14). Install sleeve (13) and elbow (14) in the rear of the aftercooler housings. Make sure sleeve (13) is over the end of the pipe and install the bolts to hold elbow (14).

end by:
a) install air intake shutoff

GOVERNOR

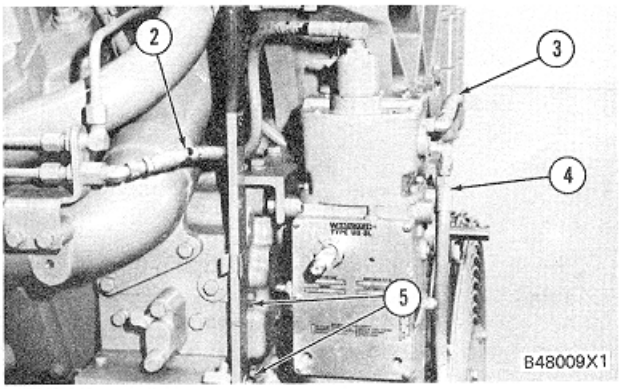
REMOVE GOVERNOR 1264-11

1. Drain the coolant from the cooling system.



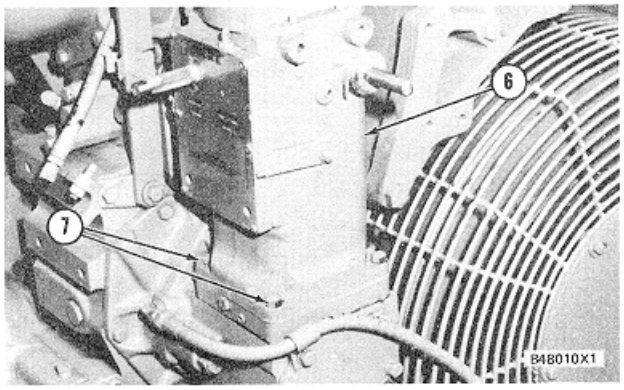
2. Remove the bolts and retainers to remove tube (1) from the engine.

3. Disconnect hose assemblies (3) and (4) from the governor. Disconnect hose assembly (2) from the engine and remove it from the governor.



4. Remove bolts (5) that hold the governor fastener group to the engine.

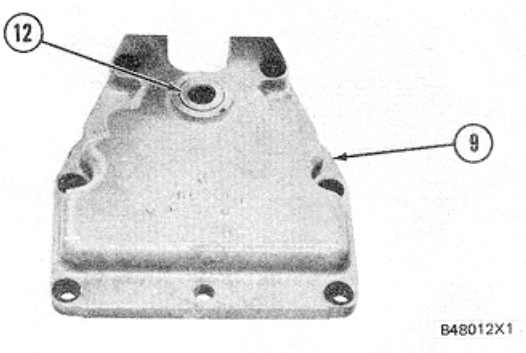
5. Remove bolts (7) to remove governor (6) and the fastener group as a unit from the engine. The weight of the unit is 23 kg (50 lb.).

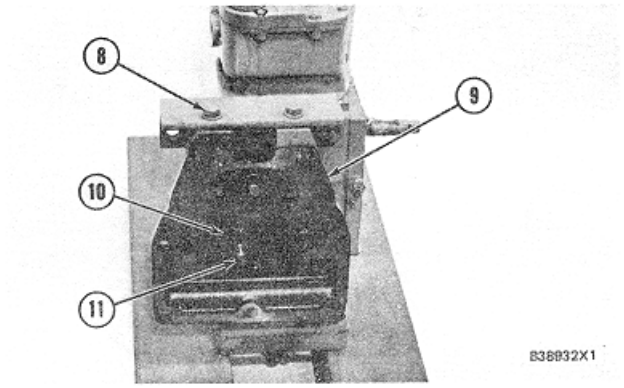


6. Remove the bolt and remove lever assembly (10) from the governor output shaft. If necessary, remove pin (11) from the lever assembly.

7. Remove bolts (8) and remove cover (9) from the governor.

8. Remove seal (12) and the washer from cover (9).





GOVERNOR

INSTALL GOVERNOR 1264-12

	Tools Needed	A
1P510	Driver Group	1

1. Install the washer in cover (1) and use tool group (A) to install the seal in cover (1). Make sure the lip of the seal is toward the engine as shown and put clean engine oil on the seal.

2. Make sure two bolts (3) are in position and put cover (1) in position on the governor. Install.48013X1 bolts (2) to hold the cover in position.

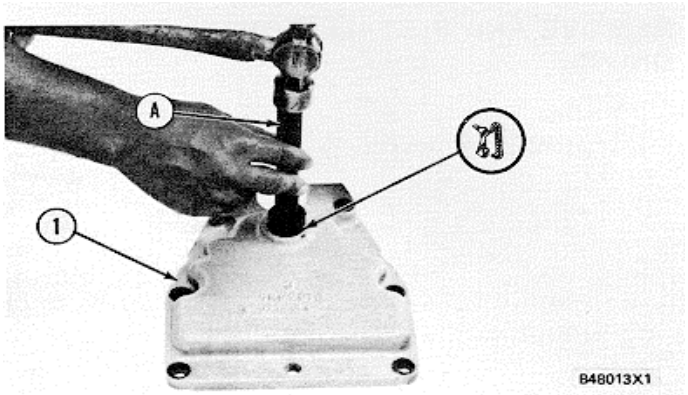
3. If pin (5) was removed, use a press to install the new pin until it is 18 ± 1 mm (.71 ± .04 in.) above the surface of the lever assembly as shown. Put lever assembly (4) in position on the governor output shaft and install the bolt to hold it.

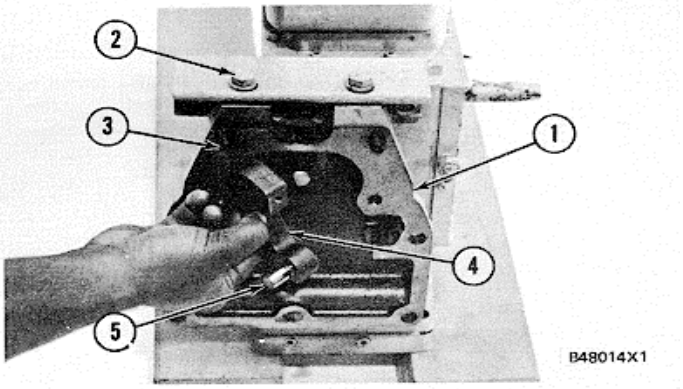
4. Put the gaskets for the governor and the fastener group in position on the engine. Fasten a hoist or use two men to put governor (6) and the fastener group as a unit in position on the engine. Make sure the pin on lever assembly (4) engages in the groove (slot) of the lever for the fuel control. Make sure the splines on the governor input shaft are engaged correctly in the governor drive and install the bolts to hold the governor and fastener group in position.

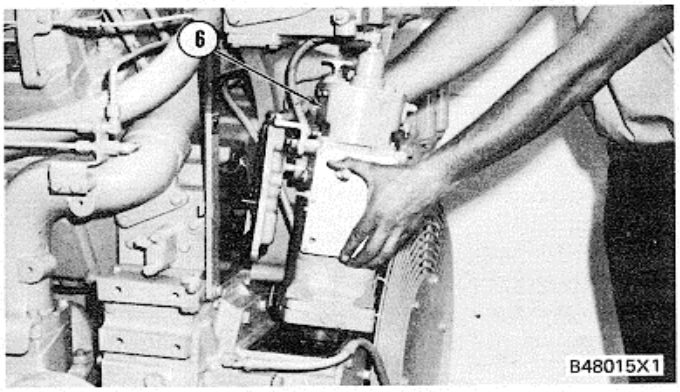
5. Install hose assembly (7) on the governor and connect it to the engine. Connect hose assemblies (8) and (9) to the governor.

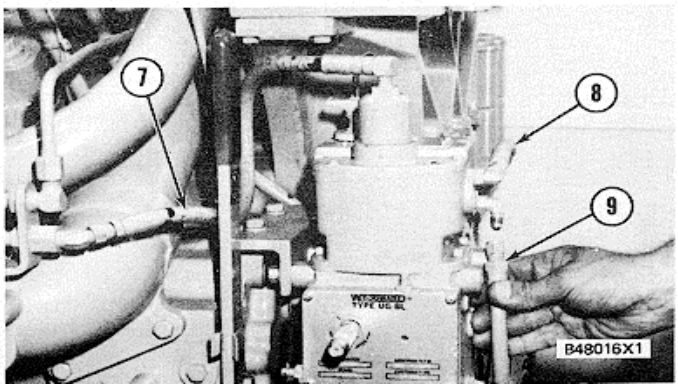
6. Put clean engine oil on the O-ring seals and' install tube (10) on the engine. Install the bolts and retainers to hold the tube in place.

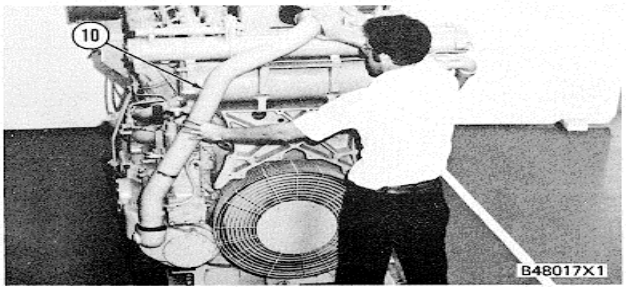
7. Fill the cooling system with coolant to the correct level.









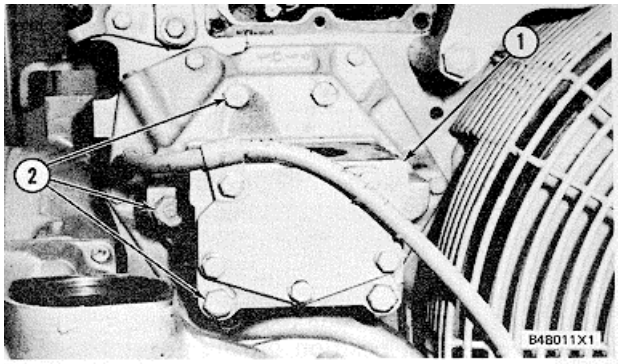


GOVERNOR DRIVE

REMOVE AND INSTALL GOVERNOR DRIVE 1288-10

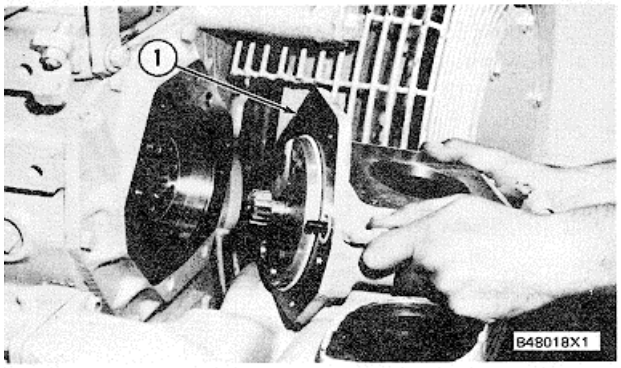
start by:
a) remove governor

1. Remove bolts (2) and pull governor drive (1) from the front drive housing.



2. Make sure the O-ring seals are in position on the front of governor drive (1) and put clean engine oil on the seals.

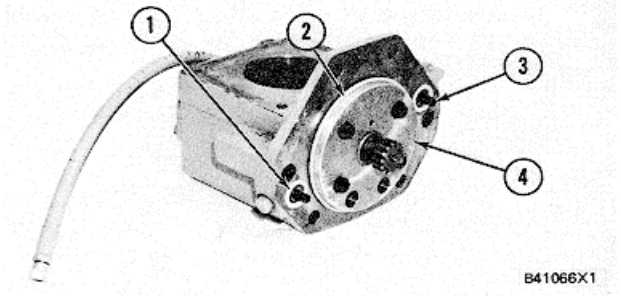
3. Put governor drive (1) in position and install bolts (2) to hold it to the front drive housing.
end by:
a) install governor401X



DISASSEMBLE GOVERNOR DRIVE 1288-15

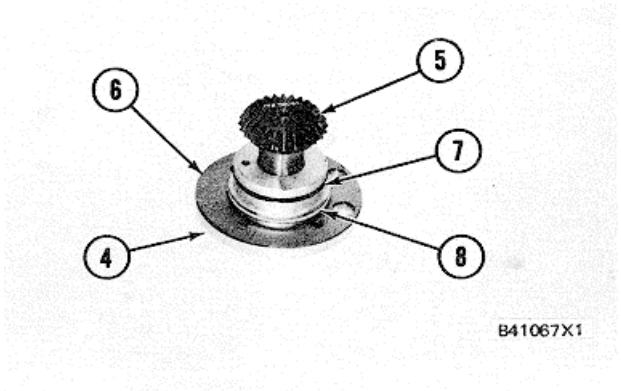
start by:
a) remove governor drive

1. Remove O-ring seals (1), (2) and (3) from the front of the governor drive housing.



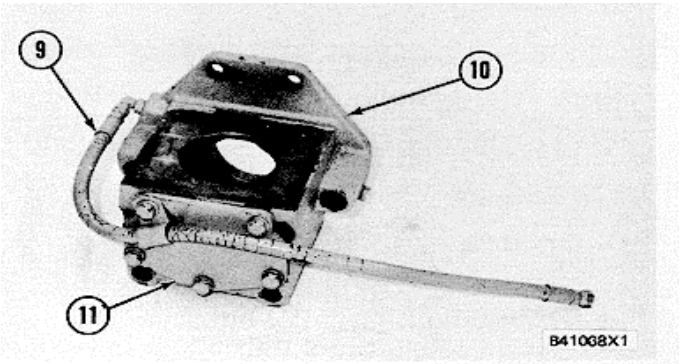
2. Remove the bolts that hold adapter (4) in position and pull adapter (4) from the housing.

3. Remove pinion (5), shims (6), seals (7) and (8) from adapter (4). Make a measurement of the.4-0 thickness of shims (6) and put identification on them for assembly purposes.

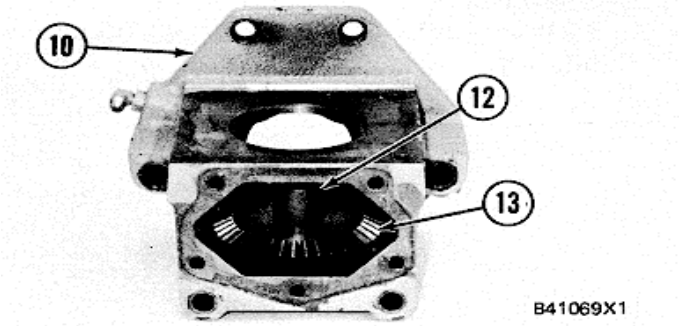


GOVERNOR DRIVE

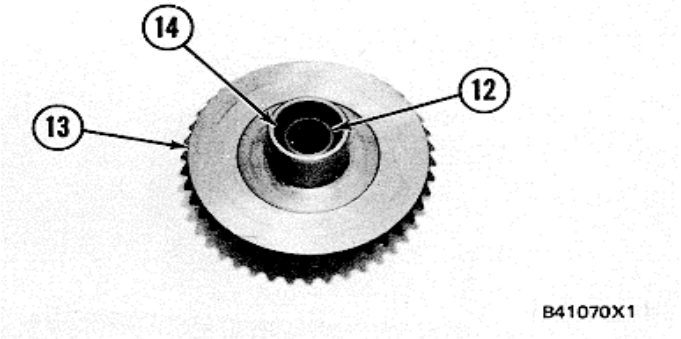
4. Remove hose assembly (9), cover (11) and the gasket from governor drive housing (10).



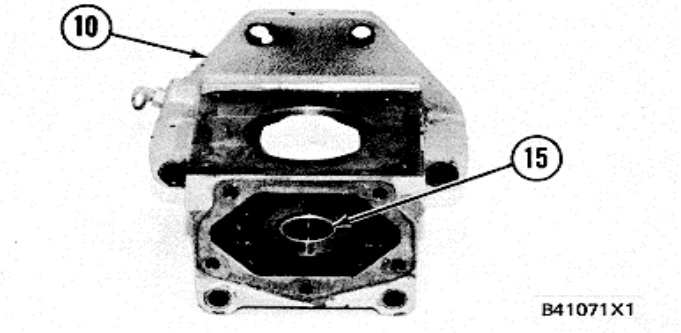
5. Remove gear (13) and coupling (12) from housing (10) as a unit.



6. Remove ring (14) to remove coupling (12) from gear (13).



7. If necessary, remove bearing (15) from housing (10).

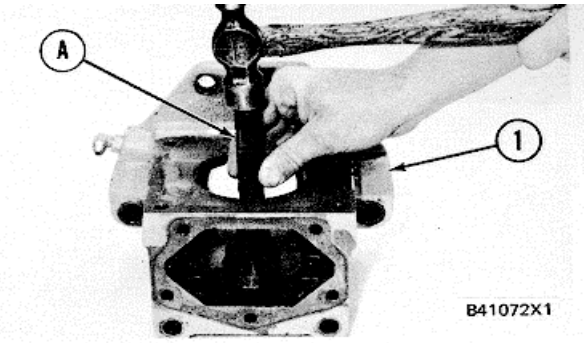


GOVERNOR DRIVE

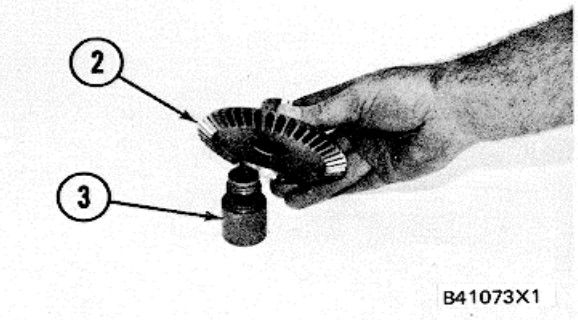
ASSEMBLE GOVERNOR DRIVE 1288-16

	Tools Needed	A	B
1P510	Driver Group	1	
8S2328	Dial Test Indicator Group	1	

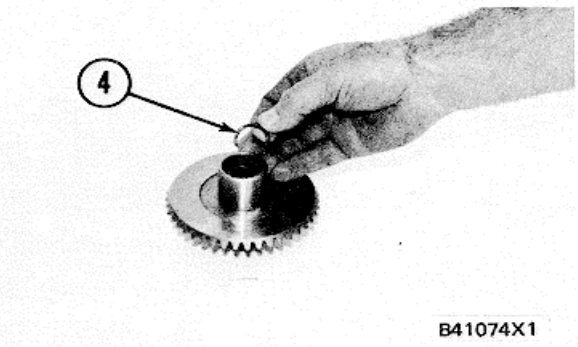
1. Make an alignment of the oil hole in the bearing with the drilled oil passage in governor drive housing (1). Use tool group (A) and install the bearing in housing (1) until it is 1.0 ± 0.5 mm (.039 ± .020 in.) below the inside surface of the housing.



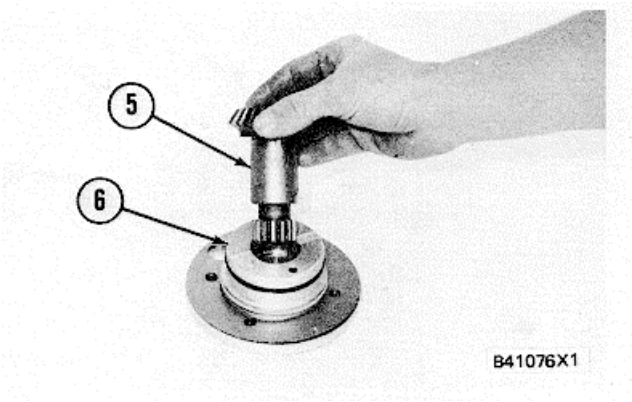
2. Put coupling (3) in position in gear (2) and install ring (4) to hold the gear and coupling as a unit.

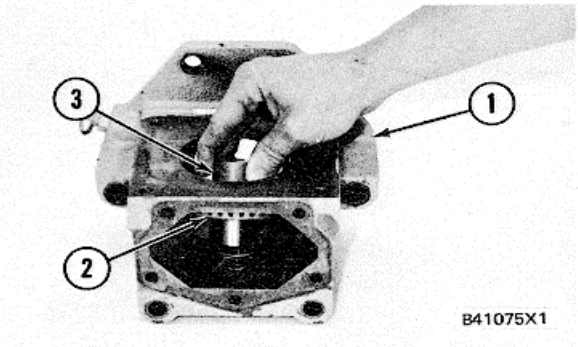


3. Install coupling (3) and gear (2) as a unit in housing (1).



4. Install pinion (5) in adapter (6).





GOVERNOR DRIVE

5. Put adapter (6) and shims (7) of the original thickness in position and install the bolts to hold the unit together.

6. Make an adjustment of the gear clearance (backlash) between gear (2) and the pinion as follows:

   a) Install tool group (B) on gear (2) as shown to check the gear clearance (backlash) at four locations around gear (2) 90° apart.

   b) Hold the pinion in position and push down" while gear (2) is moved back and forth. Make a record of the indications on tool group (B) and use the lowest indication as the correct gear clearance (backlash) value. The correct gear clearance (backlash) is 0.100 + 0.050 or 0.025 mm (.0039 + .0020 or .0010 in.).

   c) Add or subtract shims (7) as necessary until the gear clearance (backlash) is correct.

7 Remove tool group (B), the adapter and pinion from the housing.

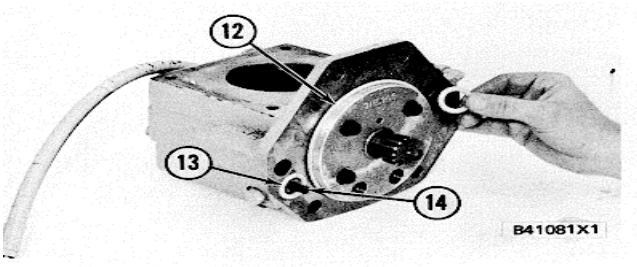
8. Connect hose assembly (8) to housing (1). Put the gasket and cover (9) in position and install the bolts and washers to hold them to housing (1).

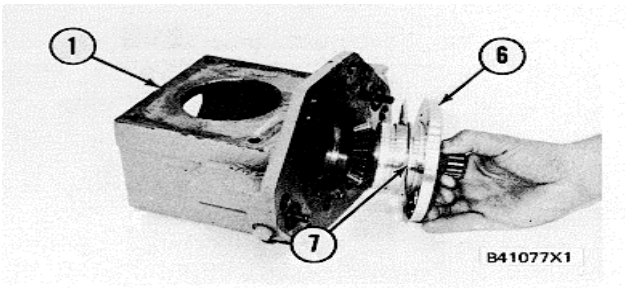
9. Install seals (10) and (11) on adapter (6) and put clean engine oil on them.

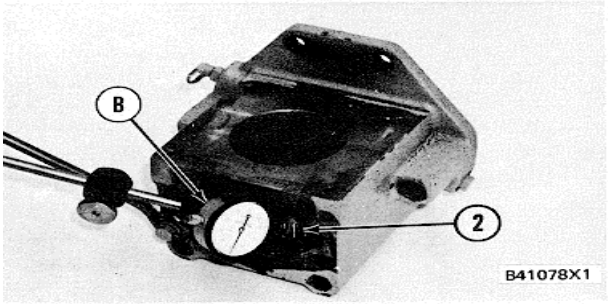
10. Install the correct amount of shims (7) and adapter (6) with the pinion in housing (1) and tighten the bolts.

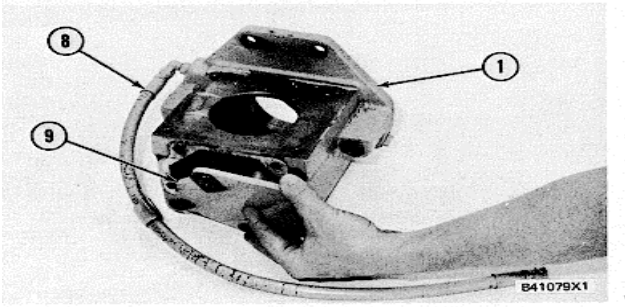
11. If necessary, make a replacement of pins (14).(Make sure the pins are 14 ±1 mm (.55 ±.04 in.) above the surface of the housing.

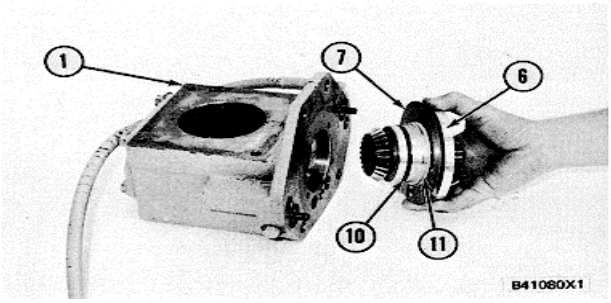
12. Install O-ring seal (12) and seals (13) on the front of the housing. Put clean engine oil on the seals.
end by:
   a) install governor







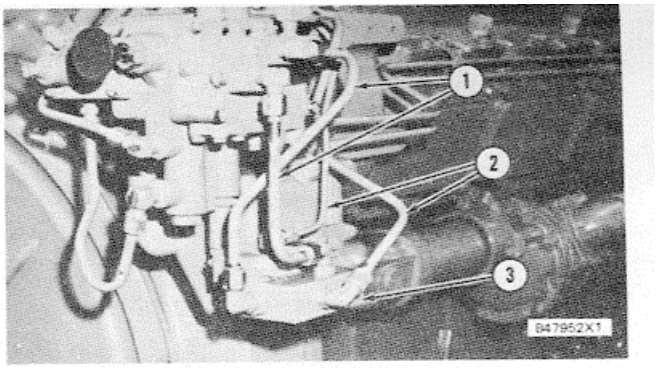




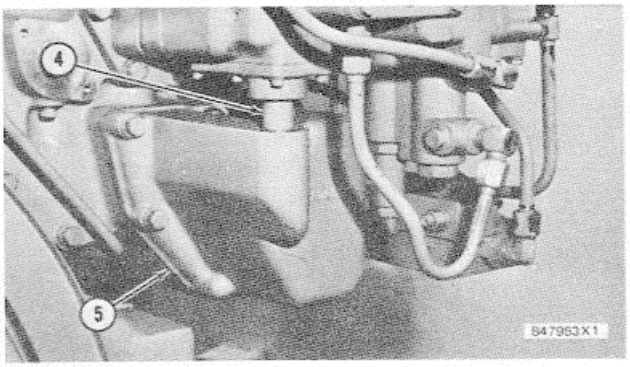
HYDRAMECHANICAL SHUTOFF CONTROL

REMOVE HYDRAMECHANICAL SHUTOFF CONTROL

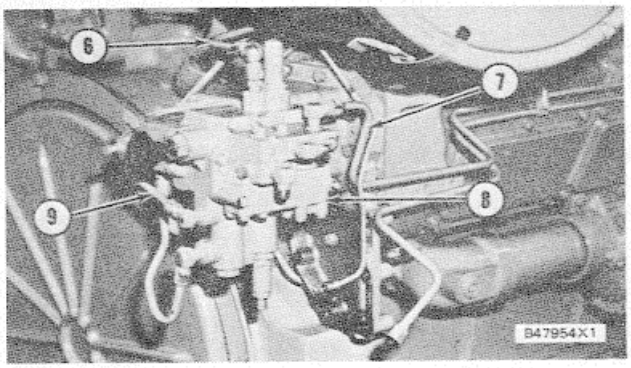
1. Disconnect tube assemblies (2) from diverter valve (3) and disconnect tube assemblies (1) from the shutoff control.



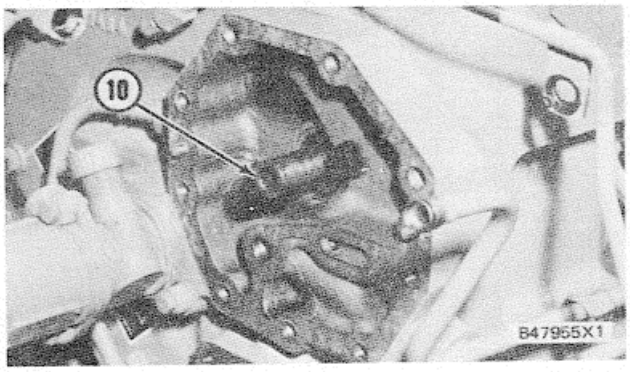
2. Remove the bolts to remove cover (5), tube (4) and the diverter valve as a unit from the shutoff drive housing assembly and the shutoff control.



3. Disconnect tube assemblies (6), (7) and (9) from the shutoff control. Remove the bolts and hydramechanical shutoff control (8) from the shutoff drive housing assembly.



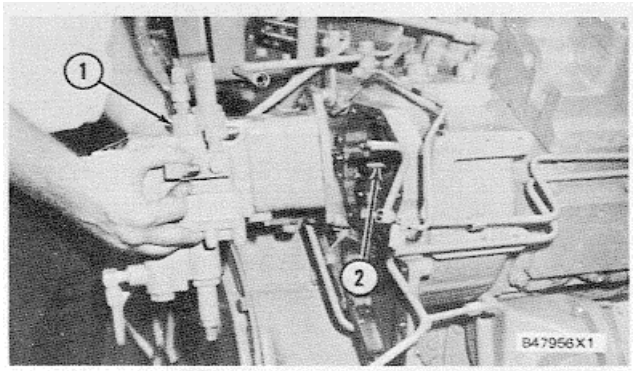
4. Remove coupling (10) from the end of the shut off drive gear.



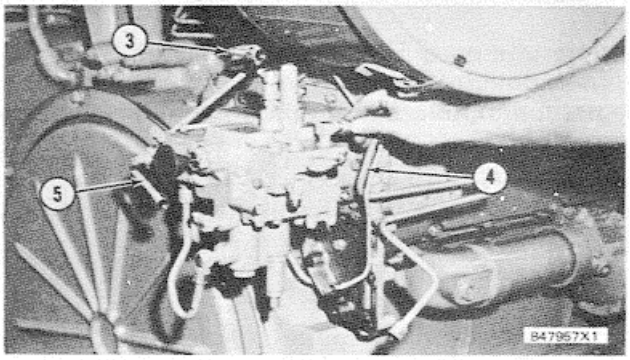
HYDRAMECHANICAL SHUTOFF CONTROL

INSTALL HYDRAMECHANICAL SHUTOFF CONTROL

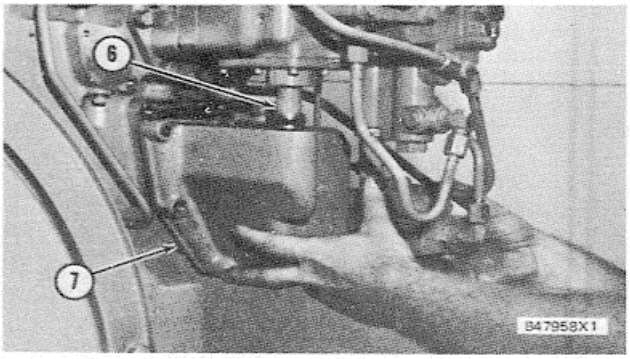
1. Install coupling (2) on the end of the shutoff drive gear.



2. Put hydramechanical shutoff control (1) and the gasket in position on the shutoff drive housing assembly. Make sure the shaft of the shutoff control is correctly engaged with the coupling and install the bolts to hold the shutoff control in position.

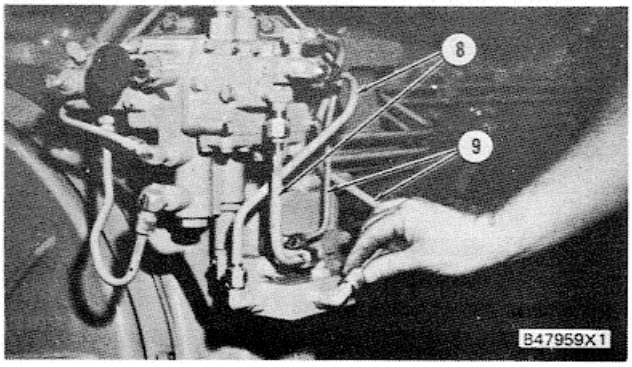


3. Connect tube assemblies (3), (4) and (5) to the shutoff control.



4. Put clean engine oil on the O-ring seals and install tube (6) in the bottom of the shutoff control. Put cover (7) and the diverter valve as a unit in position on tube (6) and the shutoff drive housing assembly. Install the bolts to hold these in position.

5. Connect tube assemblies (8) to the shutoff control and connect tube assemblies (9) to the diverter valve.



HYDRAMECHANICAL SHUTOFF CONTROL

DISASSEMBLE HYDRAMECHANICAL SHUTOFF CONTROL

	Tools Needed	A	B	C
1P1855	Pliers	1		
1P1853	Pliers		1	
1P510	Driver Group			1

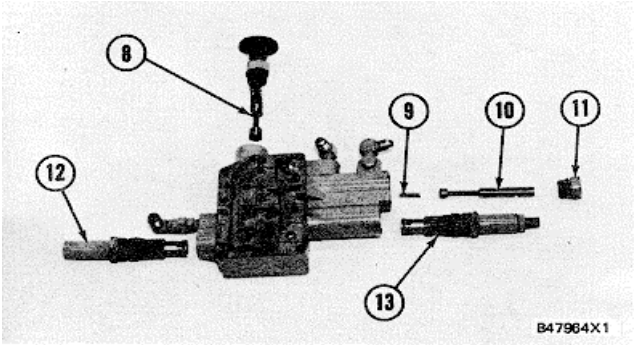
start by:
a) remove hydramechanical shutoff control

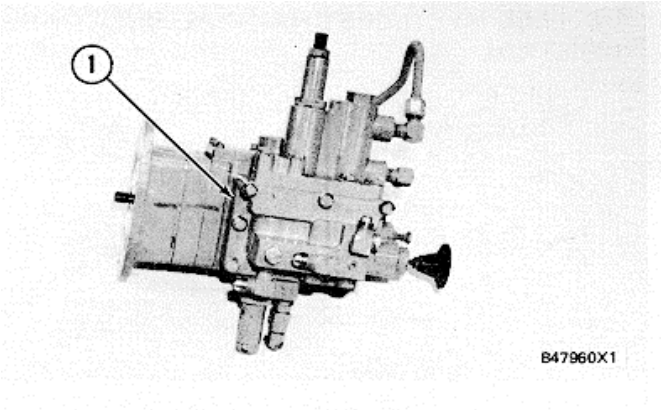
1. Remove the bolts and remove actuator valve (1) from the pressure control valve.

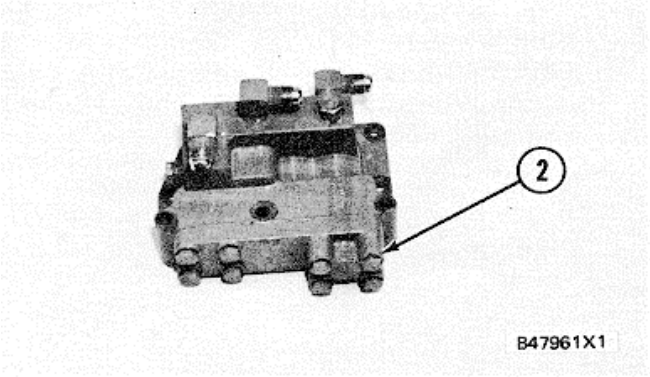
⚠ WARNING

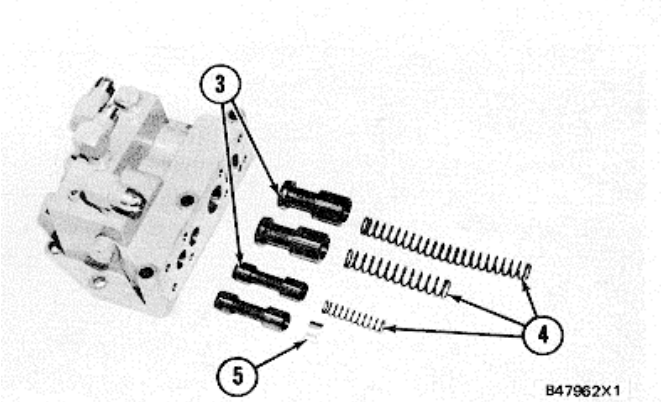
There is spring pressure on cover (2). To prevent possible personal injury slowly release the bolts that hold cover (2) until all the pressure is removed.

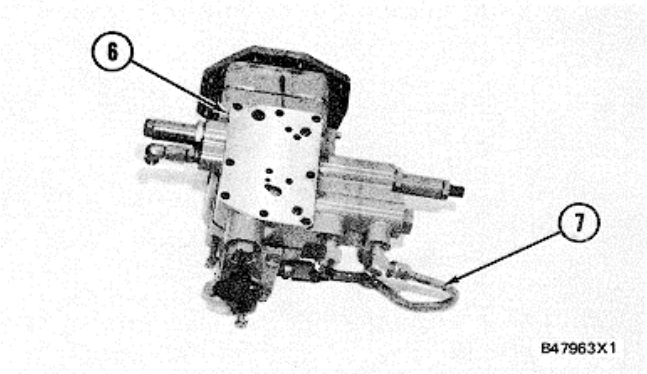
2. Remove the bolts and remove cover (2) from the actuator valve body.
3. Remove springs (4), spacer (5) and valve assemblies (3) from the valve body.
4. Remove tube assembly (7) from the shutoff control.
5. Remove pressure control valve (6) from the shutoff control.
6. Put identification marks on valve assemblies (12) and (13) for assembly purposes. Remove rack shutoff valve (12) and air inlet shutoff valve (13) from the pressure control body assembly. Remove three O-ring seals from each valve.
7. Remove plug (11) to remove pilot valve (10), and spring (9) from the pressure control body assembly.
8. Remove manual shutoff valve (8) as a unit from the pressure control body assembly.





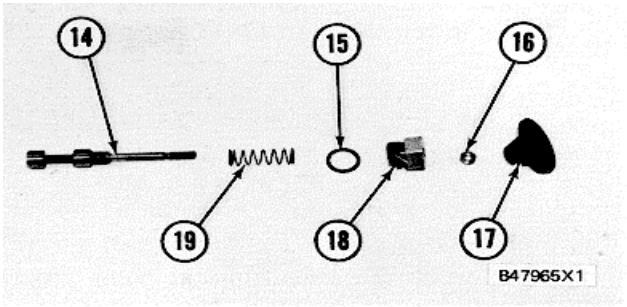




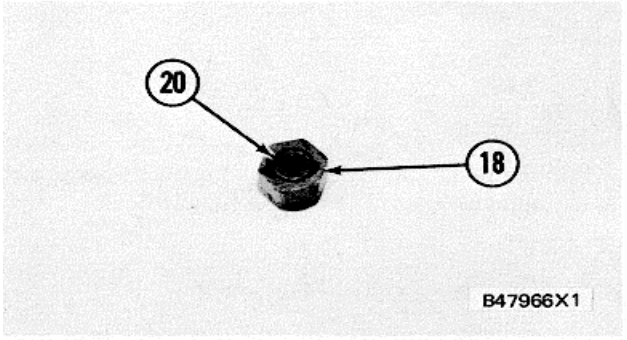


HYDRAMECHANICAL SHUTOFF CONTROL

9. Loosen nut (16) to remove knob (17) and nut (16) from valve (14). Remove adapter (18) and spring (19) from valve (14). Remove O-ring seal (15) from adapter (18).

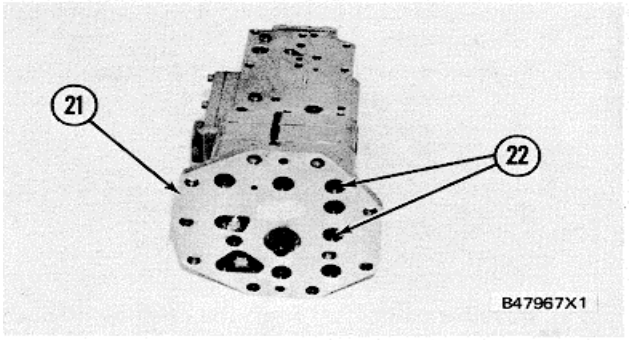


10. Remove seal (20) from adapter (18).



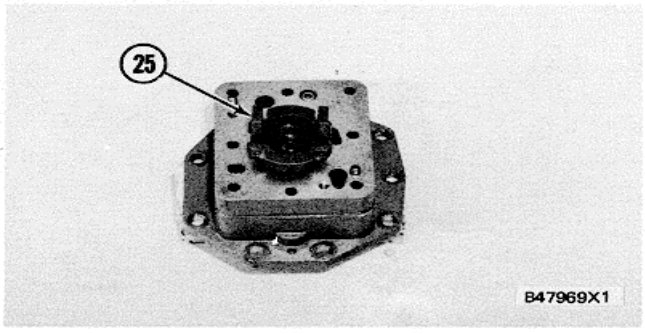
11. Remove eight bolts (22) to remove gerotor pump group (21) from the shutoff control housing assembly.

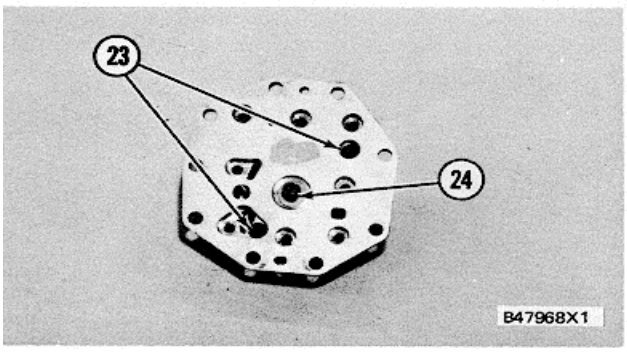
12. Use tool (A) to remove ring (24) and the washer from the carrier assembly shaft.



NOTE: Do not remove bolts (23) at this time.

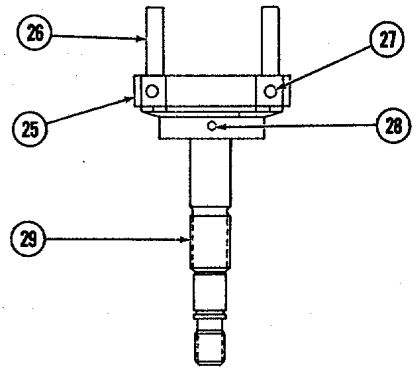
13. Remove carrier assembly (25) from the gerotor pump group.





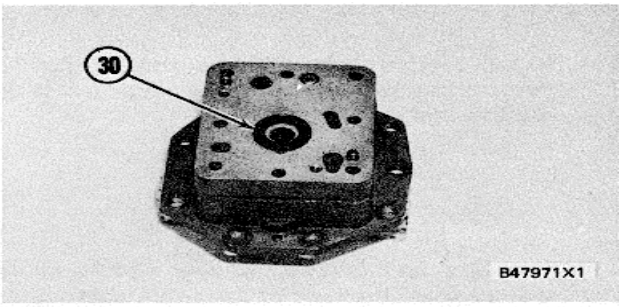
HYDRAMECHANICAL SHUTOFF CONTROL

14. Remove dowels (27) to remove weights (26) from carrier (25). Remove pin (28) and use a press to remove shaft (29) from carrier (25).



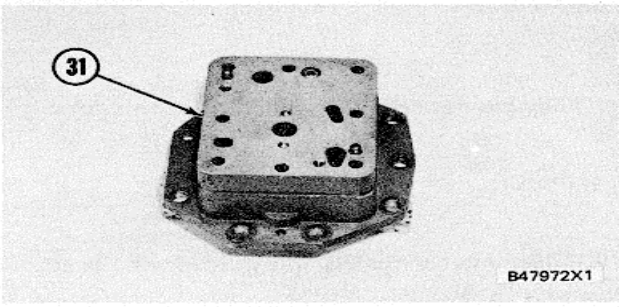
B47970X1

15. Remove washer (30) from the pump group.



B47971X1

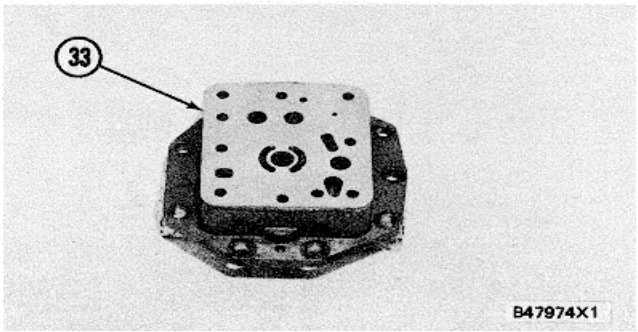
16. Remove the two bolts (23) to remove cover assembly (31) from the plate.



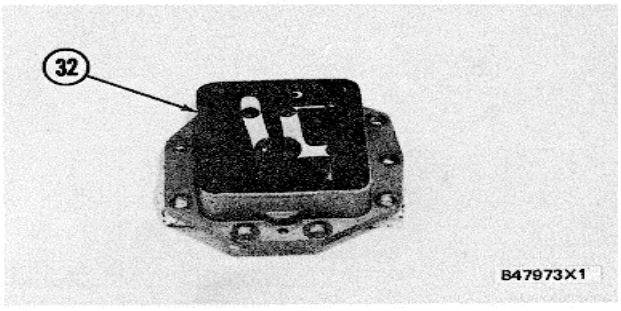
B47972X1

17. Remove gasket (32) from the plate.

18. Remove plate (33) from the housing assembly.



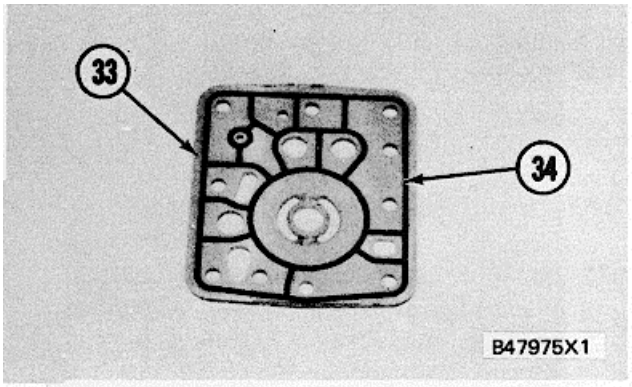
B47974X1



B47973X1

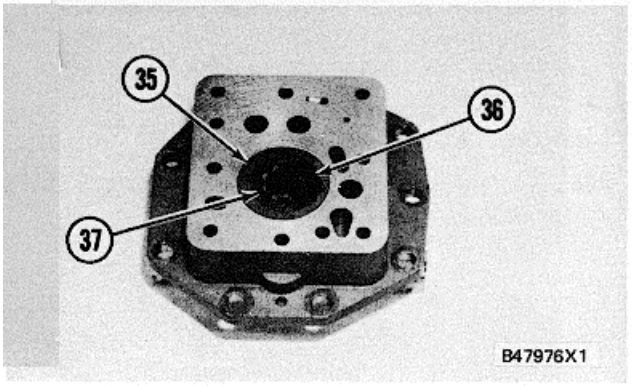
HYDRAMECHANICAL SHUTOFF CONTROL

19. Remove seal (34) from plate (33).



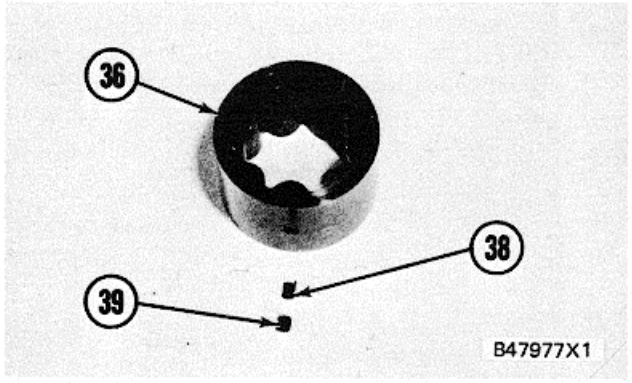
NOTE: Carefully remove driven gear (36) from sleeve (35) so brush (39) and spring (38) do not become lost.

20. To remove the gerotor assembly, remove drive gear (37), driven gear (36) and sleeve (35) from the housing assembly.

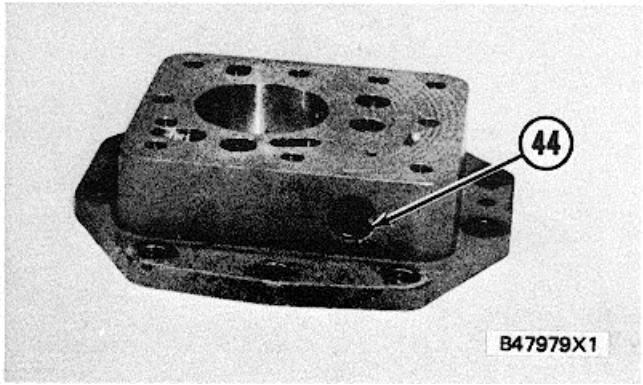


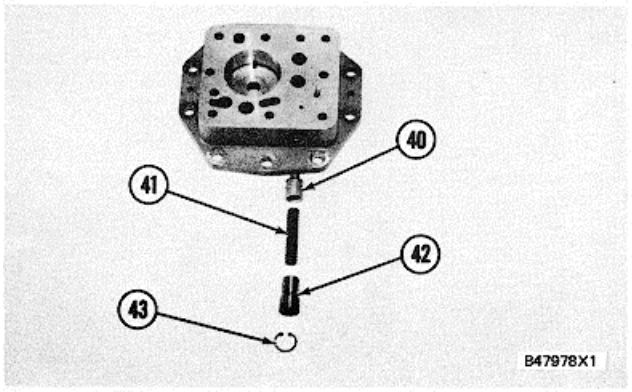
21. Remove brush (39) and spring (38) from driven gear (36).

22. Use tool (B) to remove snap ring (43) and remove seat (42), spring (41) and plunger assembly (40) from the housing assembly.



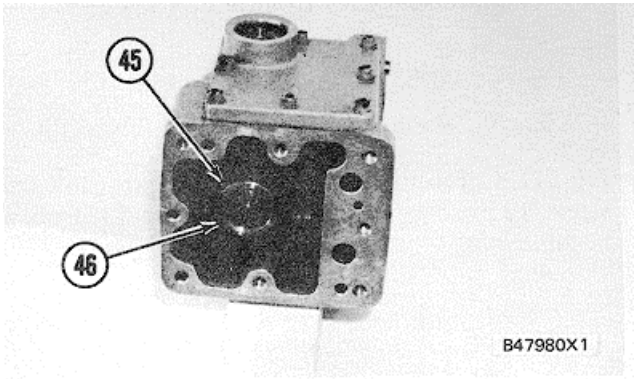
23. Remove O-ring seal (44) from the housing assembly.



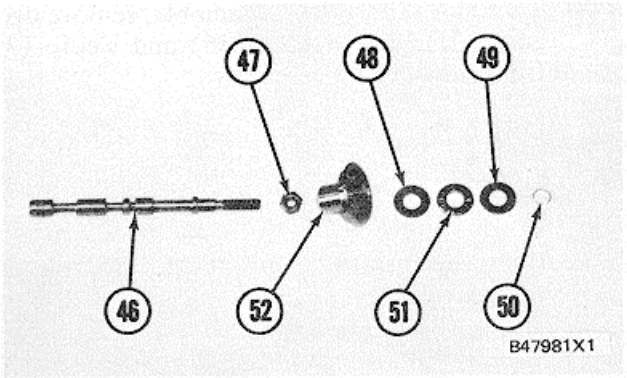


HYDRAMECHANICAL SHUTOFF CONTROL

24. Remove speed sensing valve (46), spring (45) and the seat from the housing assembly guide.

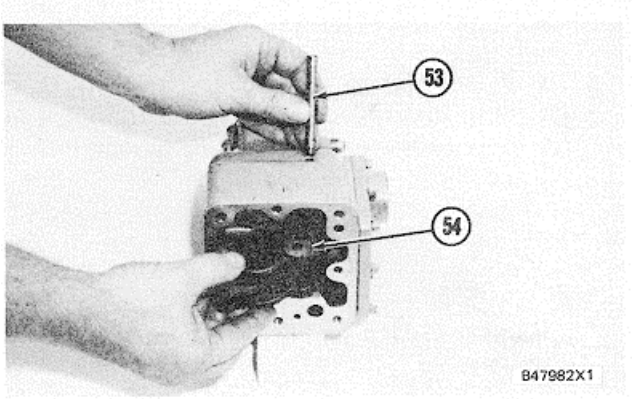


25. Remove ring (50) to remove race (49), bearing (51) and race (48) from seat (52). Loosen nut (47) to remove seat (52) and nut (47) from speed sensing valve (46).

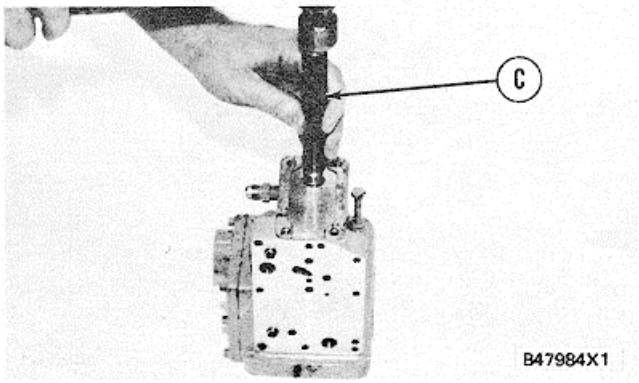


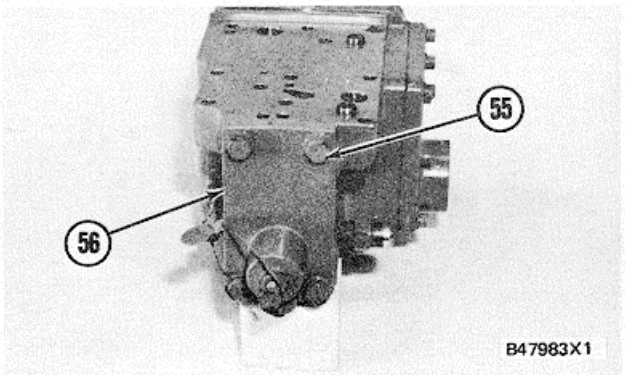
26. Remove shaft (53) to remove lever (54) from the housing assembly.

27. Remove the wire seal and bolts (55) to remove cover (56), the two seats and the spring from the housing assembly.

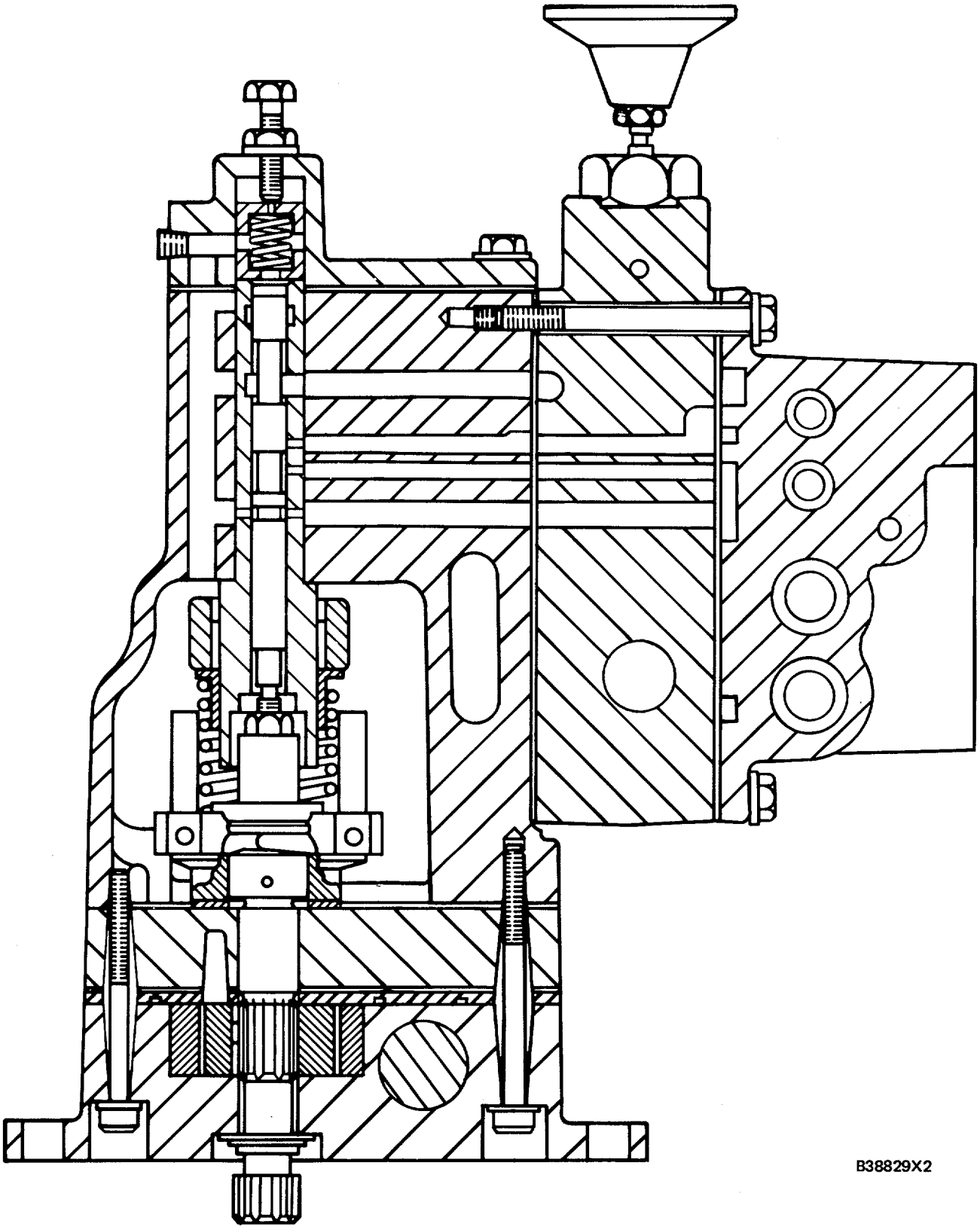


28. Use tool group (C) to remove the guide from the housing assembly.





HYDRAMECHANICAL SHUTOFF CONTROL



B38829X2

HYDRAMECHANICAL SHUTOFF CONTROL

ASSEMBLE HYDRAMECHANICAL SHUTOFF CONTROL

	Tools Needed	A	B	C
1P510	Driver Group	1		
1P1853	Pliers		1	
1 1P1855	Pliers			1

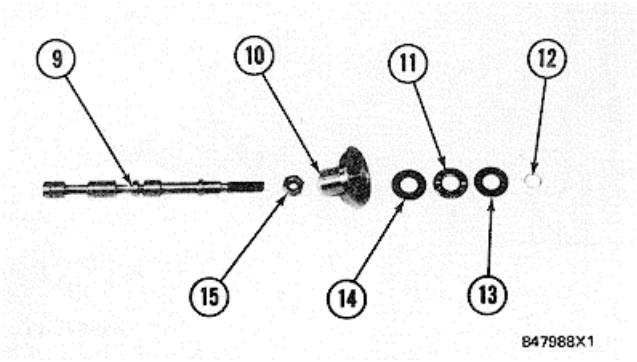
1. If necessary, make a replacement of dowels (2) and make sure they are 3.0 ± 0.5 mm (.118. ± .020 in.) above the surface of the housing assembly.

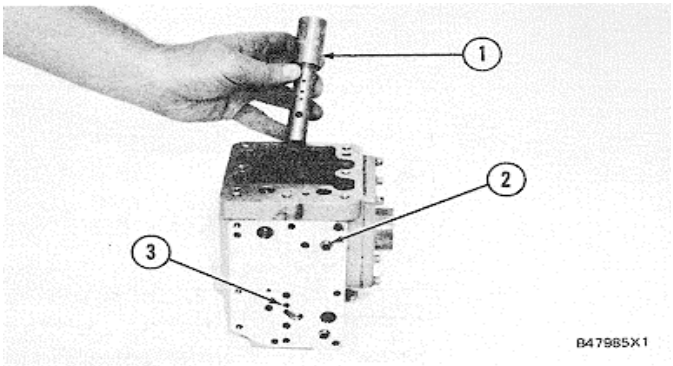
2. Put guide (I) in position in the housing assembly and make sure the dash mark on the end of, the guide is in alignment with hole (3). Use tool group (A) to install guide (I) in the housing assembly.

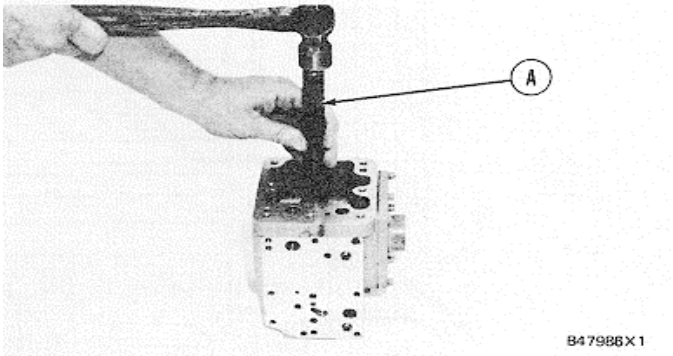
3. Put lever (5) in position in the housing assembly as shown and install shaft (4) to hold lever (5) in position. Make sure the end of the shaft is, a even (flush) ± 0.25 (.010 in.) with the housing assembly.

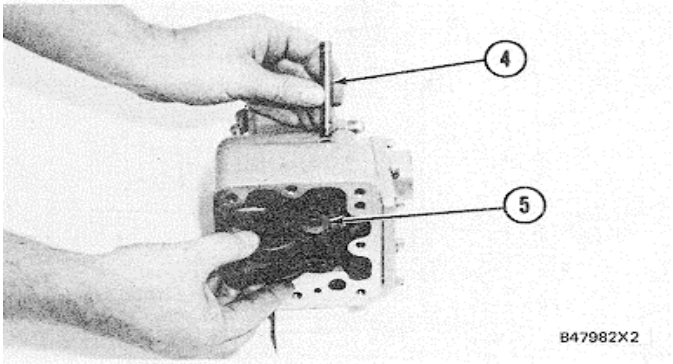
4. Put the seat, spring (7) and seat (6) in position in cover (8) and put cover (8) and the gasket in position on the housing assembly. Install the bolts to hold the cover in position.

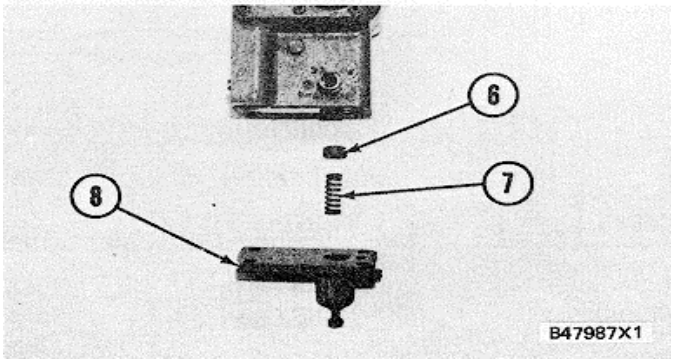
5. Install nut (15) and seat (10) on speed sensing valve (9). Make sure the dimension between the end of the valve and the nut face of the seat is 117.21 ± 0.25 mm (4.614 ± .010 in.) and tighten the nut. Put race (14), bearing (11) and race (13) in position on seat (10) and install ring (12) to hold these in position.





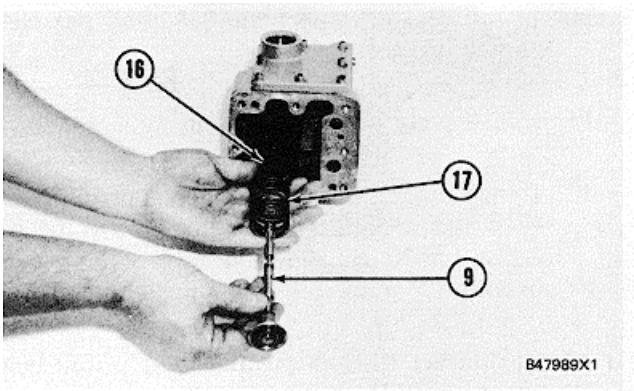




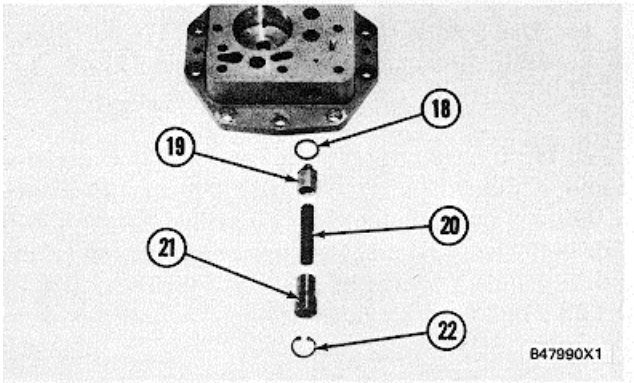


HYDRAMECHANICAL SHUTOFF CONTROL

6. Install seat (16), spring (17) and speed sensing valve (9) on the housing assembly guide.



7. Put clean engine oil on O-ring seal (18) and put 0-ring seal (18), plunger assembly (19), spring (20) and seat (21) in position in the housing assembly. Use tool (B) to install snap ring (22) to hold the plunger assembly, the spring and seat in position.

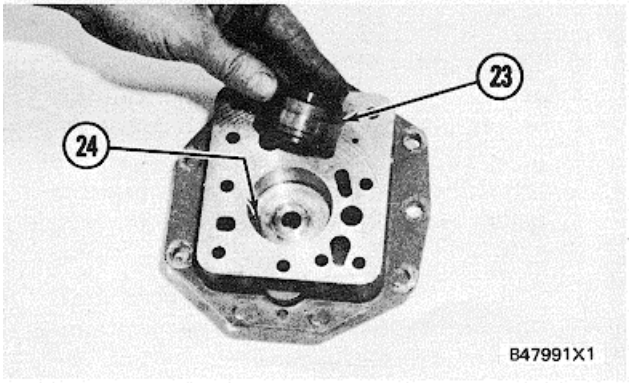


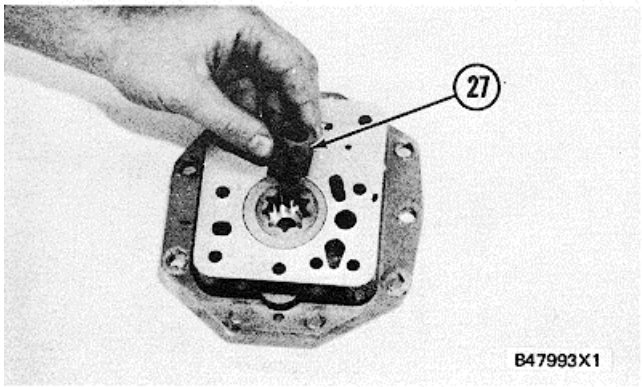
8. If necessary, make a replacement of pin (24) and make sure pin (24) is 3.96 + 0.50 mm (.156 + .020 in.) above the bottom surface of the bore.

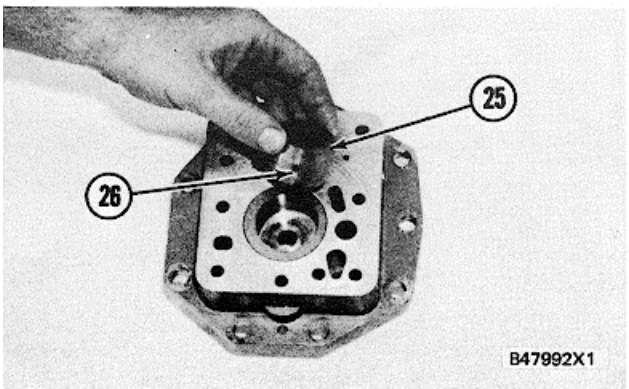
9. Install the gerotor assembly as follows:

10.

a) Install sleeve (23) and make sure the groove (slot) on sleeve (23) is in alignment with pin (24).
b) Put the spring and brush (26) in position in the driven gear (25). Install driven gear (25) in the sleeve.
c) Install drive gear (27) in the driven gear.







HYDRAMECHANICAL SHUTOFF CONTROL

10. Install seal (29) on plate (28) and put clean engine oil on it.

11. Install plate (28) on the housing assembly.

12. If necessary, make a replacement of dowels (31) and make sure they are 6.5 + 0.5 mm (.256 + .020 in.) above the surface of the cover assembly.

13. Put gasket (32) in position and install-cover assembly (30) on the plate.

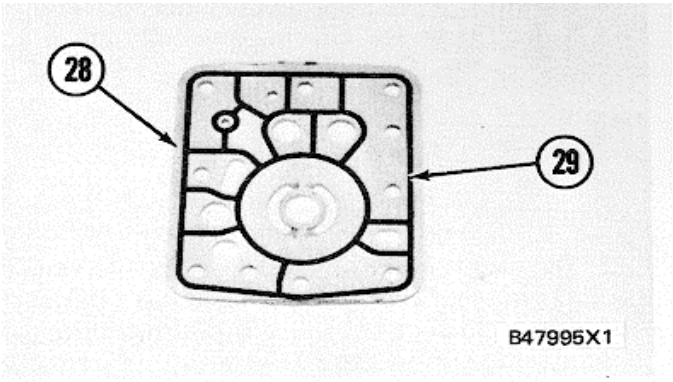
14. Use a press to install shaft (37) in carrier (35) until dimension (X) is 84.08 + 0.25 mm (3.310 ± .010 in.).

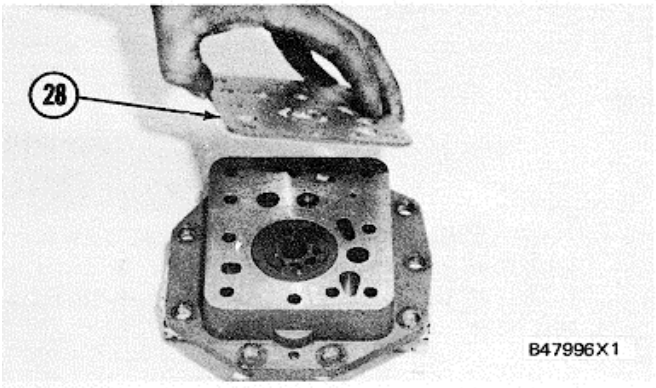
NOTE: If either or both the shaft and the carrier are new, a hole 3.175 ± 0.051 0.000 mm (.125 ± .002 .000 in.) in diameter must be drilled through either or both the shaft and the carrier at location (Z) and dimension (Y) must be 5.0 + 0.5 (.197 + .020 in.). This must be done before Step 15 can be done.

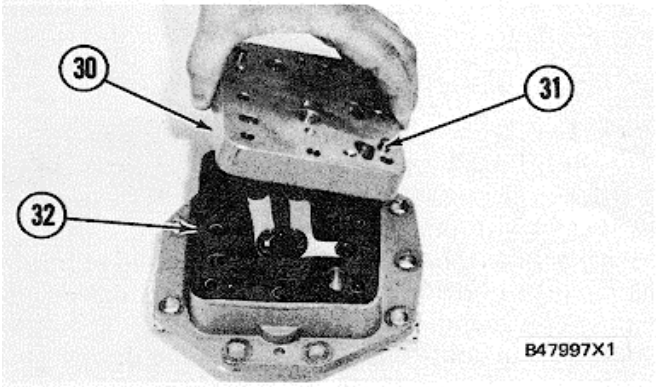
15. Install pin (36) to hold the shaft and carrier in position.

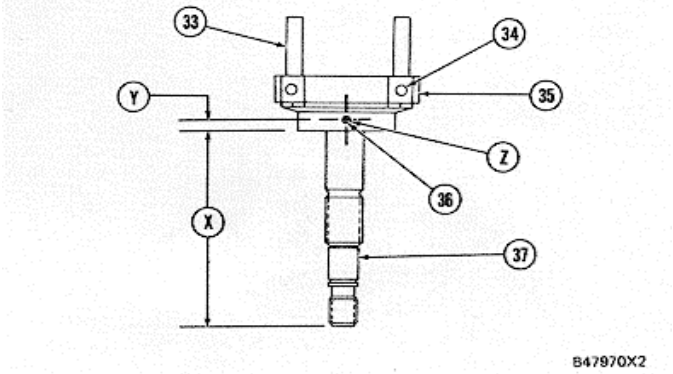
16. Put weights (33) in position on carrier (35) and install dowels (34) to hold the weights. Each weight must move freely on its dowel and must have 0.02 to 0. 18 mm (.001 to .007 in.) end play after assembly. Put marks (counter punch) four places around both ends of the dowels.

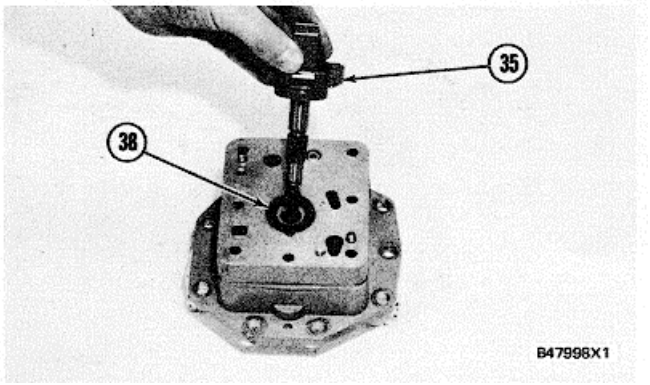
17. Install washer (38) on the cover assembly and put carrier assembly (35) in position in the gerotor pump group.











HYDRAMECHANICAL SHUTOFF CONTROL

18. Put the washer in position and use tool (C) to install snap ring (39) on the carrier assembly shaft.

19. Install two bolts (40) to hold the gerotor pump group together as a unit.

20. Put gerotor pump group (41) in position on the housing assembly. Make sure the speed sensing valve is correctly engaged with the carrier assembly and install the eight bolts to hold the pump in position.

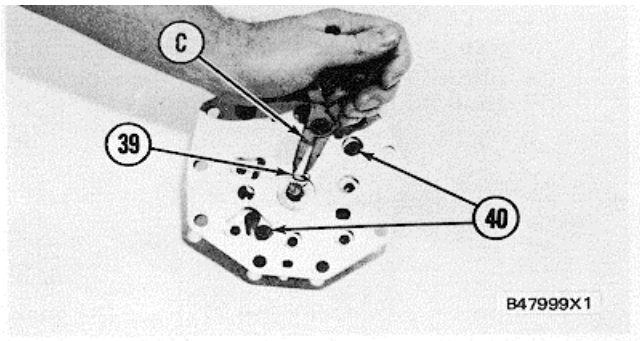
21. If necessary, make a replacement of dowels (45) and make sure they are 3.0 ± 0.5 mm (.1 18 ± .020 in.) above the surface of the valve body.

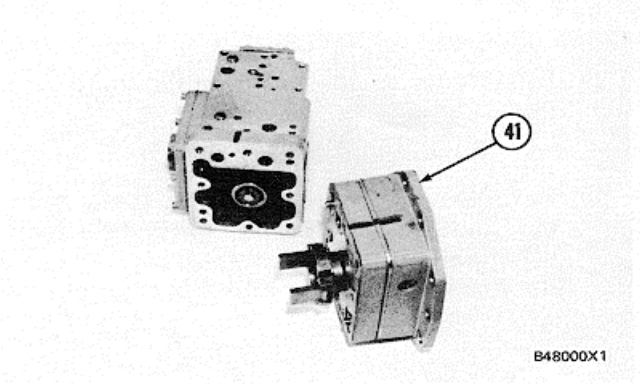
22. Put spring (44) and pilot valve (43) in position in the valve body. Put clean engine oil on the 0ring seal and install plug (42) to hold the spring and pilot valve in position.

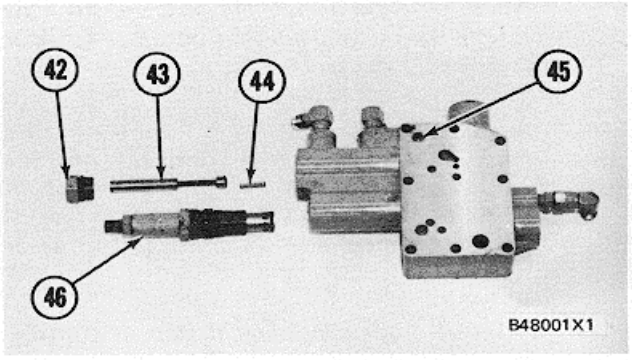
23. Install three O-ring seals on air inlet shutoff valve (46) and put clean engine oil on the seals. Install valve (46) in the valve body and tighten it to a torque of 58 ± 4 N•m (43 ± 3 lb. ft.).

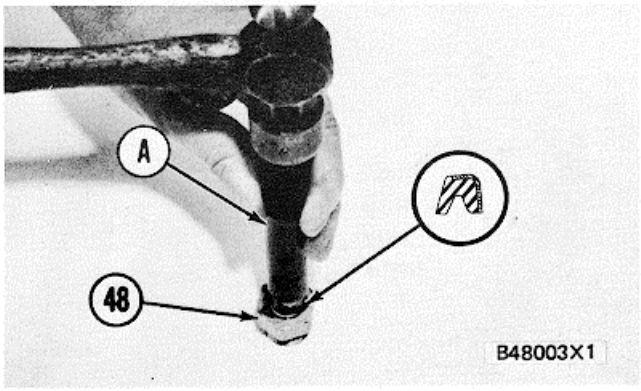
24. Install three O-ring seals on rack shutoff valve (47) and put clean engine oil on the seals. Install valve (47) in the valve body and tighten it to a torque of 58 ± 4 N•m (43 ± 3 lb. ft.).

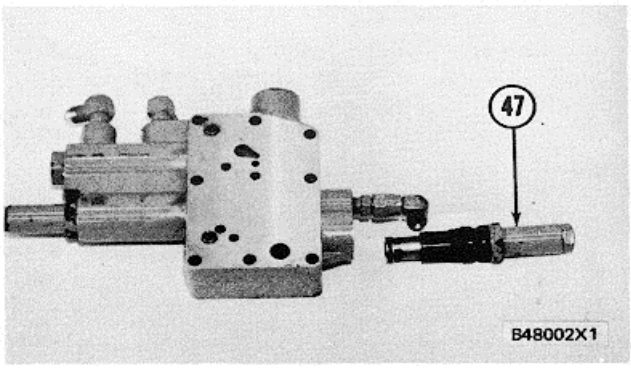
25. Install the seal in adapter (48) with tool group (A). Make sure the lip of the seal is toward the valve body as shown.











HYDRAMECHANICAL SHUTOFF CONTROL

26. Install O-ring seal (50) on adapter (48) and put clean engine oil on it. Install spring (53), adapter (48), nut (51) and knob (52) on manual shutoff valve (49). Tighten the nut to hold the knob on the valve.

27. Install manual shutoff valve (49) as a unit in the valve body.

28. Put pressure control valve (55) and the gasket in position on the shutoff control.

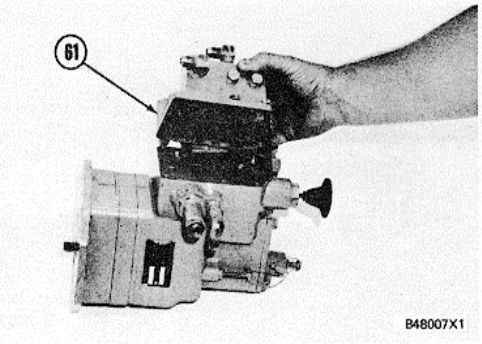
29. Install tube assembly (54) on the shutoff control.

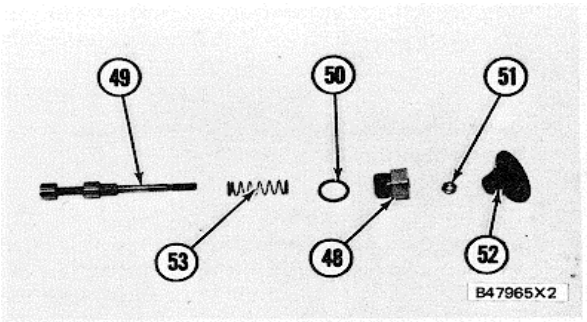
30. Put four valve assemblies (56), three springs (57) and spacer (60) in position in the actuator valve body. Install gasket (58), cover (59) and the bolts to hold the valves, the springs and spacer in position.

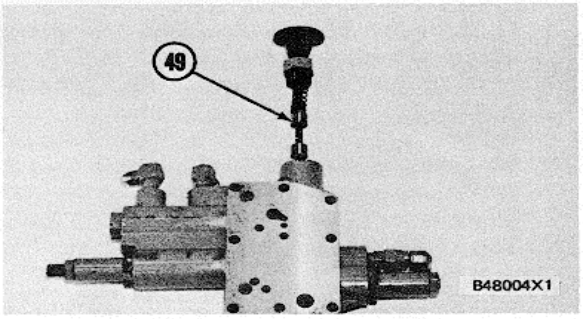
31. Put the gasket, actuator valve (61) and the bolts in position on the pressure control valve. Tighten the bolts to hold the actuator valve and the pressure control to the shutoff control.

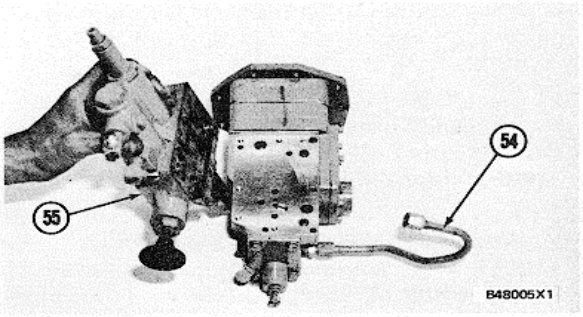
32. See CATERPILLAR FUEL INJECTION TEST BENCH, Form No. SEHS7465 Section IV, X for the correct procedure to adjust the hydramechanical shutoff control after assembly.

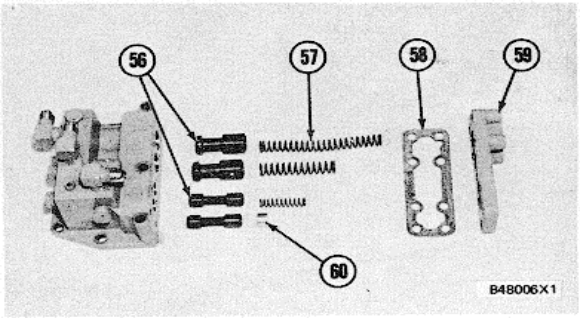
end by:
a) install hydramechanical shutoff control.









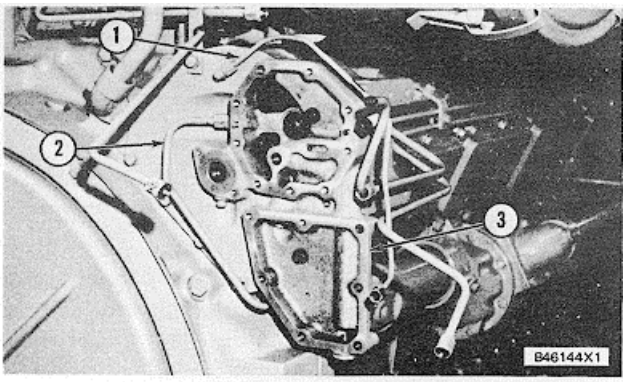


HYDRAMECHANICAL SHUTOFF DRIVE

REMOVE HYDRAMECHANICAL SHUTOFF DRIVE

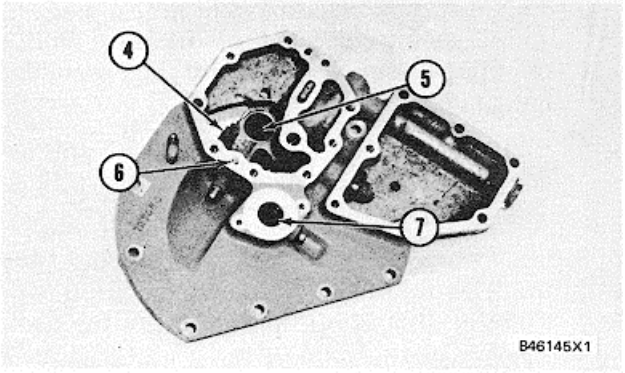
Tools Needed		A
1P 1855	Pliers	1

start by:
a) remove hydramechanical shutoff control
b) remove tachometer drive



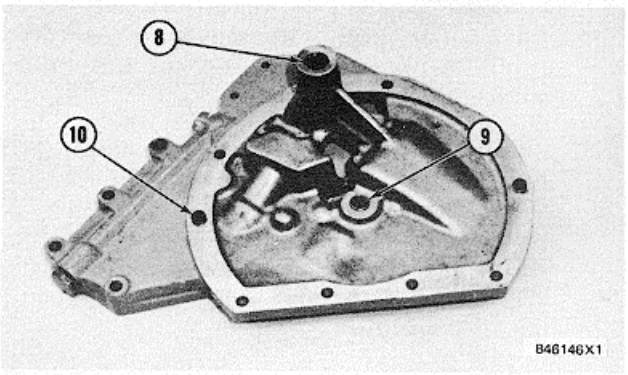
1. Remove tube assemblies (1) and (2) from the shutoff drive housing assembly and the engine.

2. Remove the bolts and remove shutoff drive housing assembly (3) from the flywheel housing.



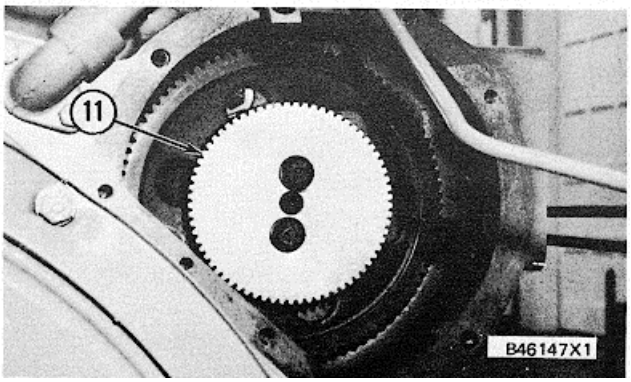
3. Use tool (A) to remove snap ring (5) and the washer from the end of drive gear (4). Remove drive gear (4) from the housing assembly.

4. If necessary, remove dowels (6) from the housing assembly.



5. Remove bearing (9) and seal (7) from the housing assembly. The bearing can be used to push the seal out of the bore.

6. Remove two bearings (8) from the drive gear bore.



7. If necessary, remove dowels (10) from the housing assembly.

8. Remove gear assembly (11) from the end of the crankshaft.

HYDRAMECHANICAL SHUTOFF DRIIVE

INSTALL HYDRAMECHANICAL SHUTOFF DRIVE

	Tools Needed	A	B
1P510	Driver Group	1	
1P 1855	Pliers		1

1. If necessary, make a replacement of dowels (1) in gear assembly (2). The dowels must extend 9.5 ± 0.5 mm (.374 ± .020 in.) from the gear. Put gear assembly (2) in position on the end of the camshaft and install the bolts to hold it. Tighten the bolts evenly to a torque of 100 ± 15 N•m (75 ± 10 lb. ft.). Hit the gear assembly with a hammer and tighten the bolts again to the same torque. Do this until the torque does not change.

2. If dowels (5) were removed, install the new dowels until they extend 6.0 ± 0.5 mm (.236 ± .020 in.) from the housing assembly.

3. Use tool group (A) to install two bearings (4) in the drive gear bore until they are 1.5 ± 0.5 mm (.059 ± .020 in.) from the ends of the bore.

4. Put drive gear (3) in position in the housing assembly.

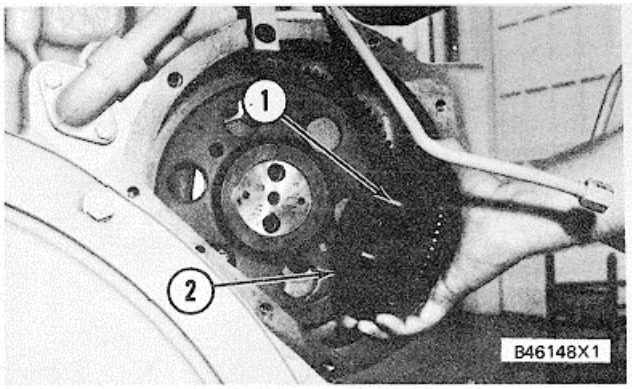
5. Put washer (8) in position and use tool (B) to install snap ring (7) to hold the washer and drive gear in position.

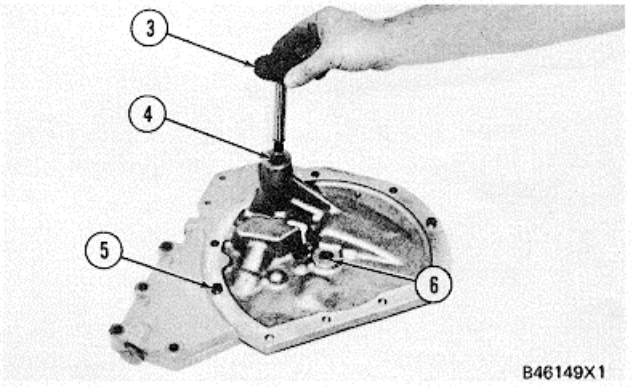
6. Use tool group (A) to install bearing (6) in the housing assembly until it is 26 ± 1 mm (1.02 ± .04 in.) below surface (X). Use tool group (A) and install seal (10) to the bottom of the bore. Make sure the lip of the seal is toward the engine as shown and put clean engine oil on the lip.

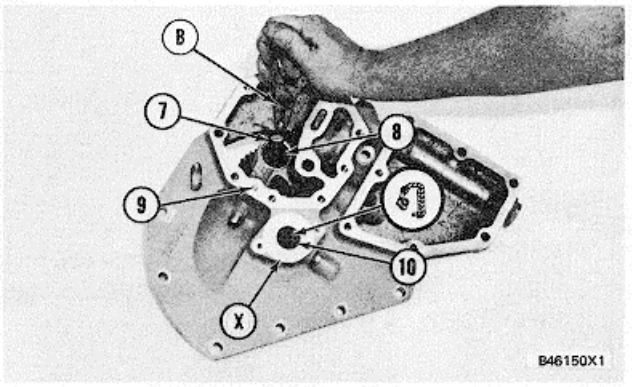
7. If dowels (9) were removed, install the new dowels until they extend 6.0 ± 0.5 mm (.236 ± .020 in.) from the housing.

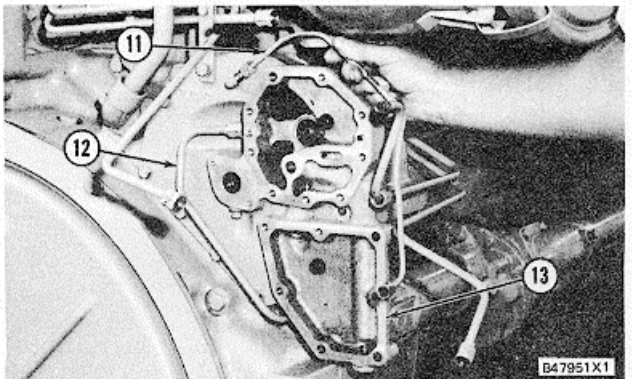
8. Install shutoff drive housing assembly (13) and the bolts to hold it on the flywheel housing. Make sure the teeth of drive gear (3) are correctly engaged with the teeth of gear assembly (2).

9. Install tube assemblies (11) and (12) on the X housing assembly and the engine.
end by:
   a) install hydramechanical shutoff control
   b) install tachometer drive







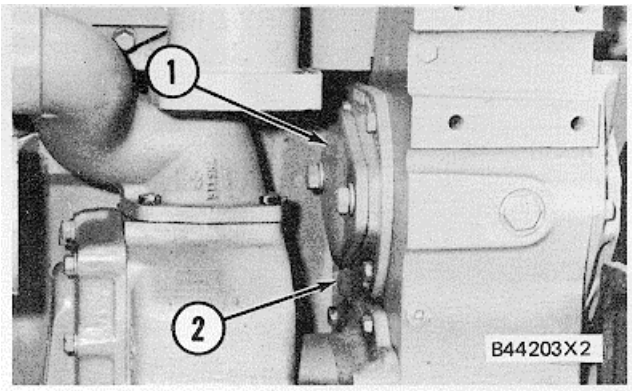


ACCESSORY DRIVE (FRONT)

REMOVE ACCESSORY DRIVE (FRONT) 1207-11

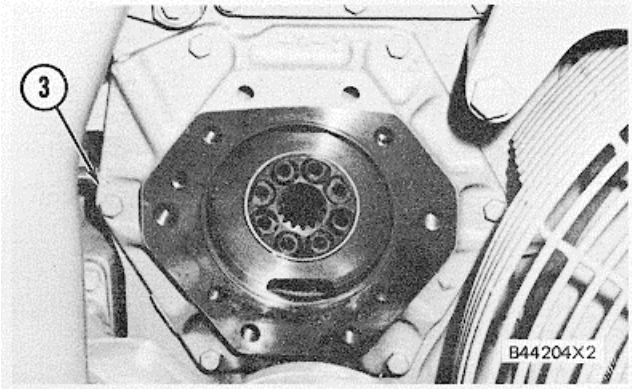
start by:
a) remove governor drive
b) remove alternator (if so equipped)

1. Remove the bolts and remove cover (1) from adapter assembly (2).



2. Use two 1/2"-13 NC forcing screws to remove adapter assembly (2) from the front drive housing.

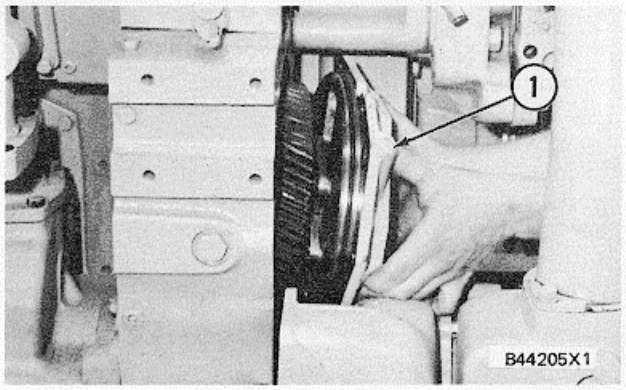
3. Remove the bolts and remove adapter assembly (3), the drive gear and shaft as a unit from the front drive housing.



INSTALL ACCESSORY DRIVE (FRONT) 1207-12

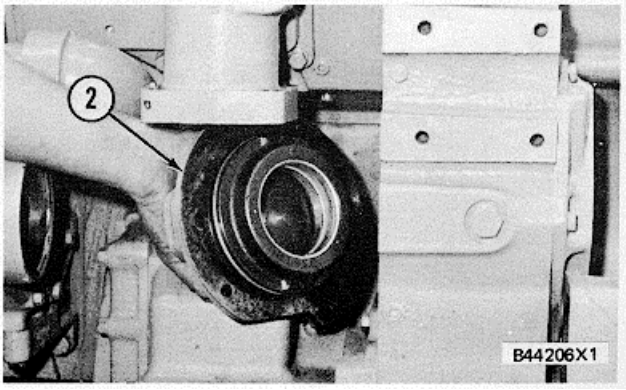
1. Make sure the two O-ring seals are in position on adapter assembly (1) and put clean engine oil on them.

2. Install the drive shaft, gear and adapter assembly (1) in the front drive housing. Make sure the teeth of the accessory drive gear are correctly engaged with the teeth of the oil and water pump drive gear and install the bolts to hold adapter assembly (1) in position.



3. Make sure the two O-ring seals are installed on adapter assembly (2) and put clean engine oil on the seals. Put clean oil on the lip of the seal and bearing in adapter assembly (2) and install the adapter assembly. Tighten the bolts to hold adapter assembly (2) in position.

4. Install the cover on adapter assembly (2).
end by:
a) install governor drive
b) install alternator (if equipped)



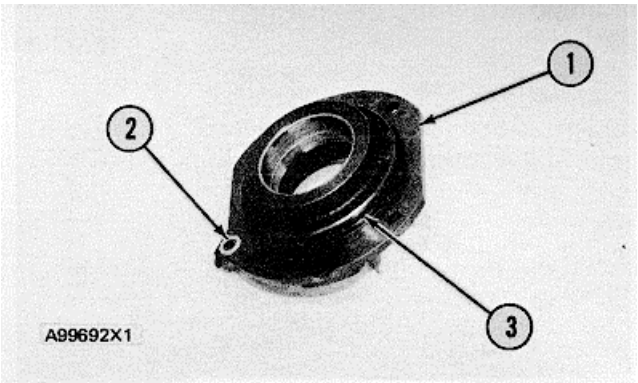
ACCESSORY DRIVE (FRONT)

DISASSEMBLE ACCESSORY DRIVE (FRONT) 1207-15

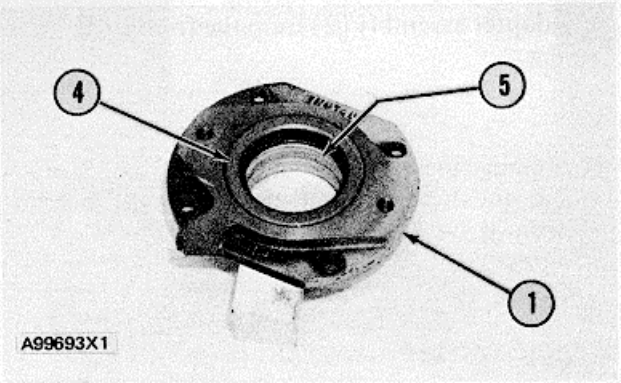
	Tools Needed	A
1P520	Driver Group	1

start by:
a) remove accessory drive (front)

1. Remove O-ring seals (2) and (3) from the adapter.

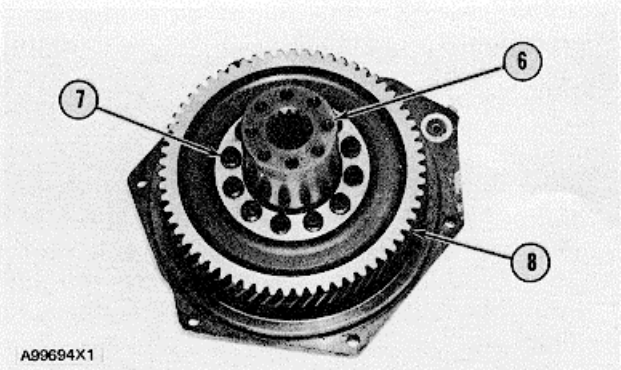


2. Remove seal (4) from adapter (1). Use a press and tool group (A) to remove bearing (5) from adapter (1).



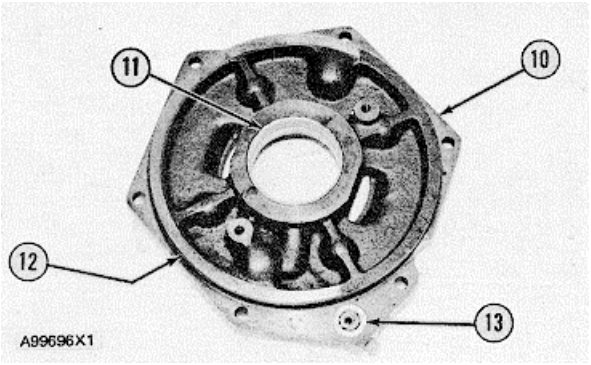
3. Remove bolts (7) to remove gear (8) from shaft (6).

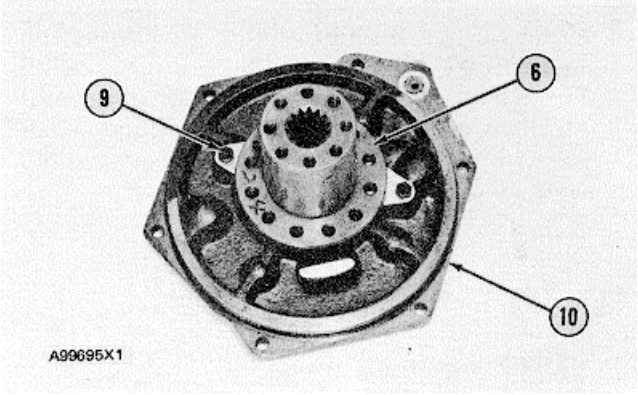
4. Remove bolts (9) and the retainer washer to remove shaft (6) from adapter (10).



5. Remove O-ring seals (12) and (13) from adapter (10).

6. Use a press and tool group (A) to remove bearing (11) from adapter (10)



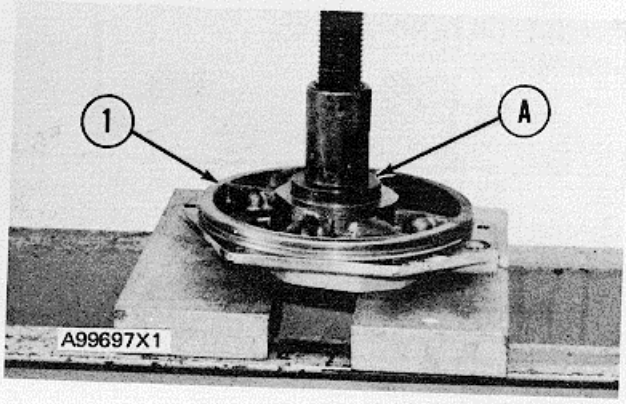


ACCESSORY DRIVE (FRONT)

ASSEMBLE ACCESSORY DRIVE (FRONT) 1207-16

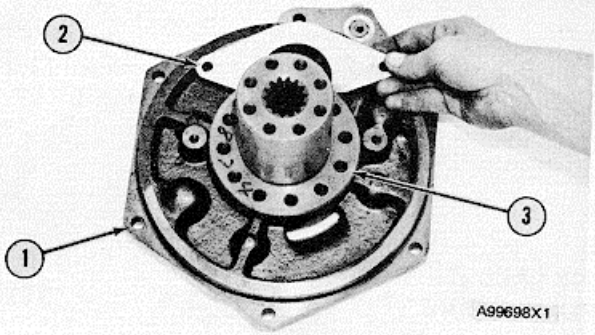
	Tools Needed	A
1P520	Driver Group	1

1. Make an alignment of the oil hole in the bearing and the oil hole in adapter (1). Use a press and tool group (A) and install the bearing in adapter (1). Check the bore in the bearing after assembly. The bore in the bearing must be 75.000 ± 0.055 mm (2.9528 ± .0022 in.).



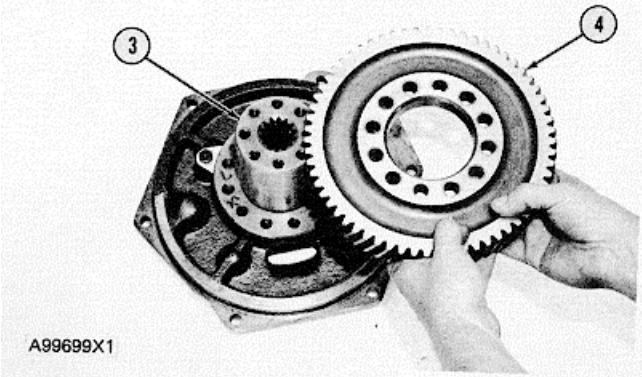
2. Install the two O-ring seals in adapter (1).

3. Put clean engine oil on the bearing and install shaft (3) in adapter (1). Install retainer washer (2) to hold the shaft and adapter together.



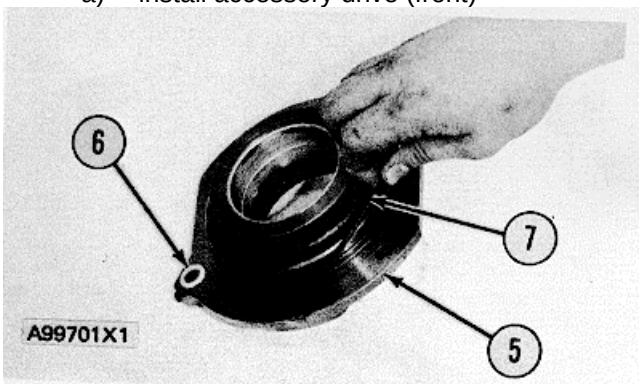
4. Put gear (4) in position on shaft (3) and install the bolts to hold them together.

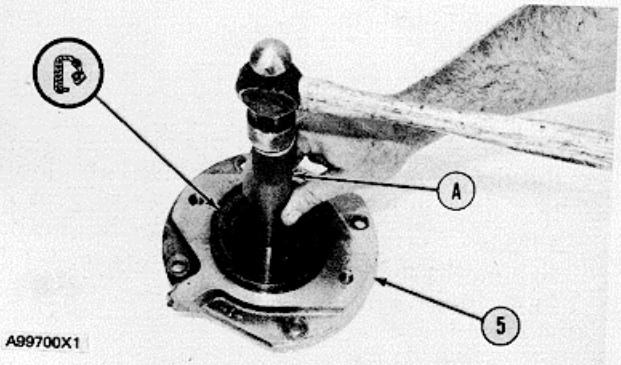
5. Make an alignment of the oil hole in the bearing and the oil hole in adapter (5). Use a press and tool group (A) and install the bearing in adapter (5). Check the bore in the bearing after assembly. The bore in the bearing must be 75.000 ± 0.055 mm (2.9528 ±.0022 in.).



6. Use tool group (A) to install the seal in adapter (5). Make sure the lip of the seal is toward the bearing as shown.

7. Install 0-ring seals (6) and (7) on adapter (5) and put clean engine oil on them.
end by:
a) install accessory drive (front)



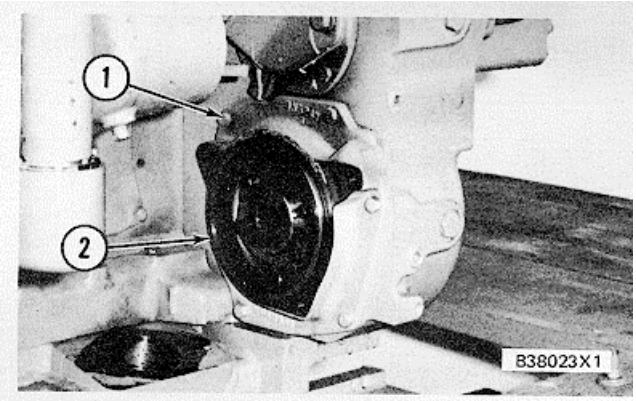


OIL AND WATER PUMP DRIVE

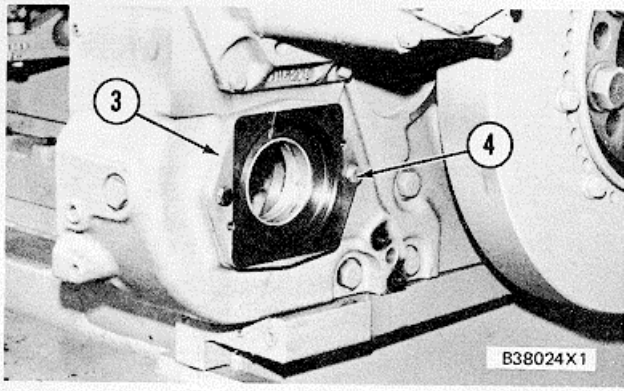
REMOVE OIL AND WATER PUMP DRIVE 1313-11

start by:
a) remove oil pump
b) Remove water pump

1. Remove bolts (1) and pull adapter assembly (2) and the gears from the front drive housing as a unit. The weight of the unit is 23 kg (50 lb.).



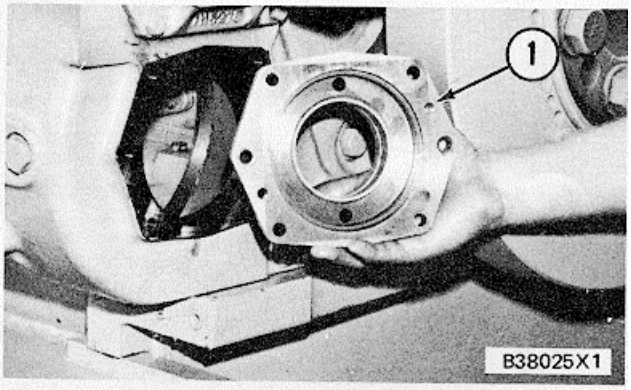
2. Remove bolts(4) and pull adapter assembly(3) from the front drive housing.



INSTALL OIL AND WATER PUMP DRIVE 1313-12

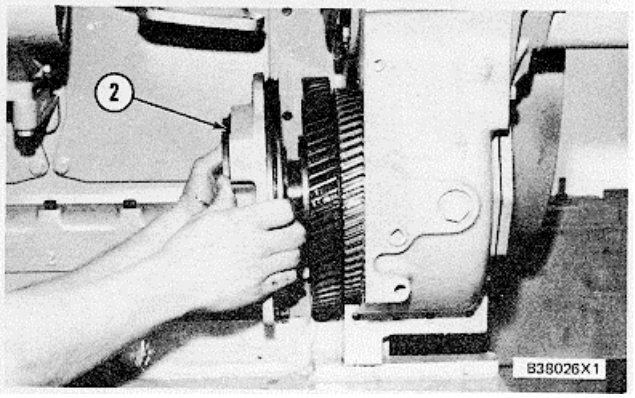
1. Make sure the O-ring seal is installed in the groove of adapter assembly (1) and put clean engine oil on it.

2. Put adapter assembly (1) in position and install the bolts to hold it to the front drive housing.



3. Make sure the 0-ring seals are installed on the grooves of adapter assembly (2) and have clean engine oil on them.

4. Put the gears and adapter assembly (2) in position as a unit. Make sure the drive gear is engaged correctly with the idler gear and tighten the bolts to hold adapter assembly (2) in position.
end by:
a) install oil pump.
b) install water pump

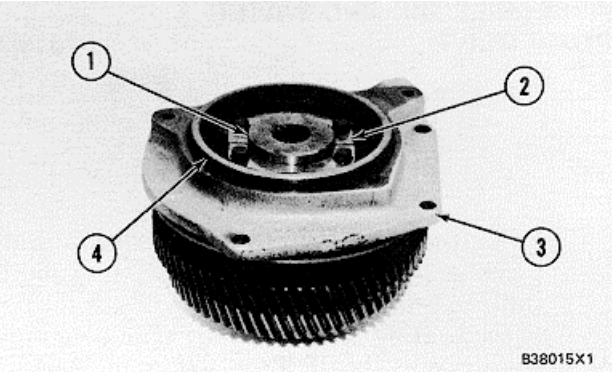


OIL AND WATER PUMP DRIVE

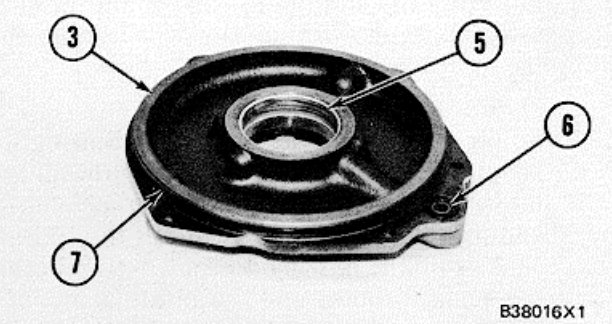
DISASSEMBLE OIL AND WATER PUMP DRIVE 1313-15

	Tools Needed	A
1P520	Driver Group	1

start by:
a) remove oil and water pump drive

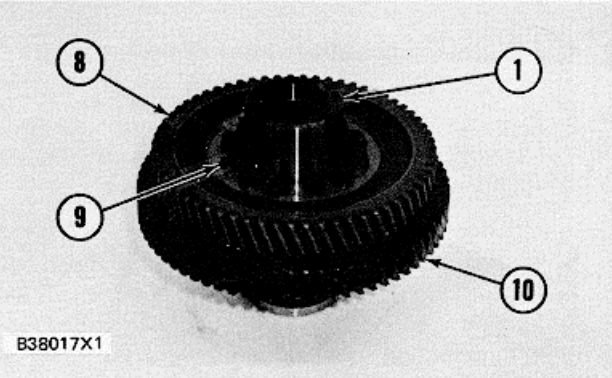


1. Remove oil pump O-ring seal (4) from adapter (3).



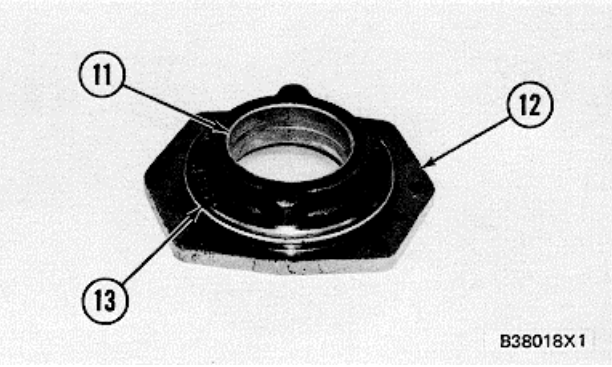
2. Remove washers (2). Remove adapter (3) from shaft assembly (1).

3. Remove O-ring seals (6) and (7) from adapter (3).



4. Use a press and tool group (A) to remove bearing (5) from adapter (3).

5. Remove bolts (9) to remove gears (8) and (10) from shaft assembly (1).



6. Remove O-ring seal (13) from the water pump adapter assembly (12).

7. Use a press and tool group (A) to remove bearing (11) from adapter assembly (12).

OIL AND WATER PUMP DRIVE

ASSEMBLE OIL AND WATER PUMP DRIVE 1313-16

	Tools Needed	A
1P520	Driver Group	1

1. Lower the temperature of the bearing for water pump adapter (1). Use tool group (A) and install the bearing in adapter (1). Check the bore in the bearing after assembly. The bore in the bearing must be 75.00 ± 0.06 mm (2.953 ± .002 in.). Install O-ring seal (2) on adapter (1).

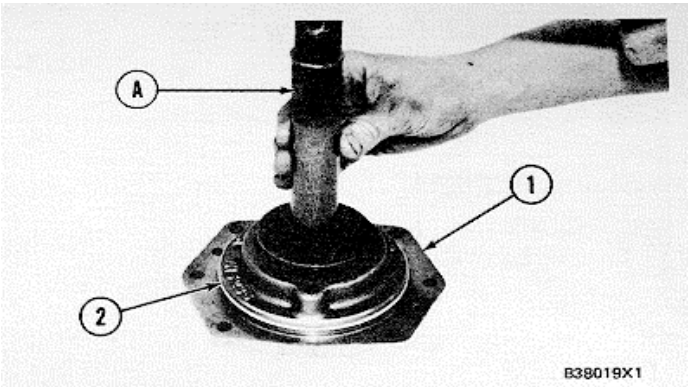
2. Put gears (3) and (4) in position on the shaft assembly as shown and install the bolts to hold the unit together.

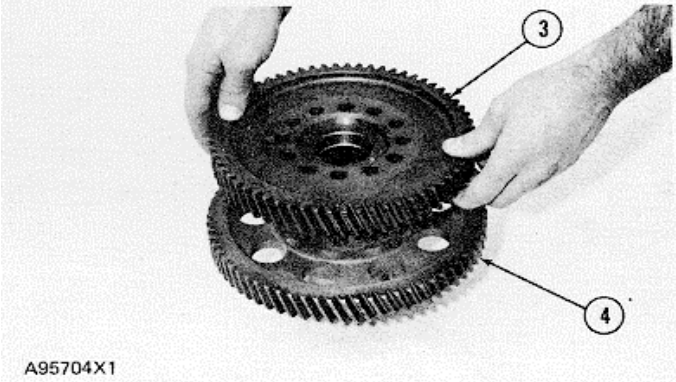
3. Lower the temperature of the bearing for adapter (5). Make an alignment of the oil hole in the bearing with the oil hole in adapter (5) and use tool group (A) to install the bearing. Make sure the bearing does not extend beyond the surface shown and the inside diameter is 75.00 ± 0.06 mm (2.953 ± .002 in.) after installation.

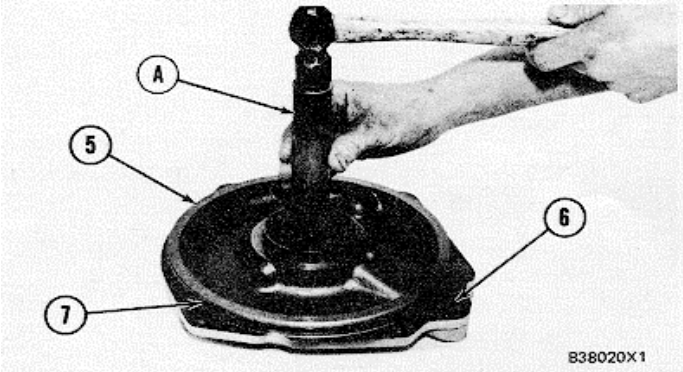
4. Install O-ring seals (6) and (7) on adapter (5).

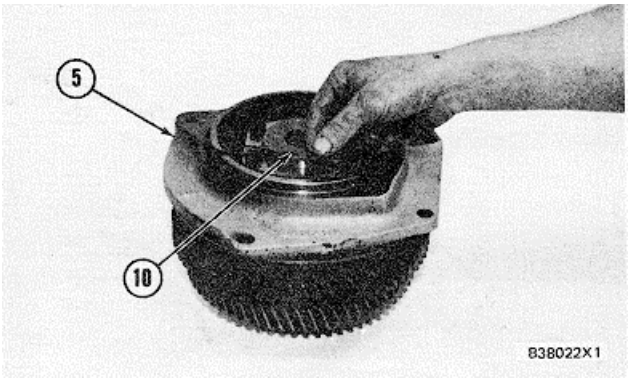
5. Put adapter (5) in position on shaft assembly (8) and install washers (9) to hold the unit together.

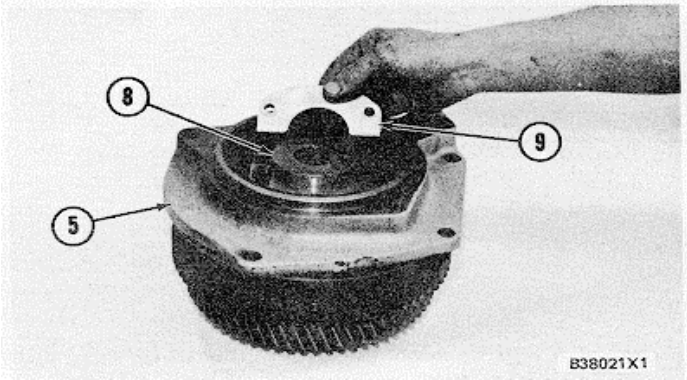
6. Install the oil pump O-ring seal (10) on adapter (5).
end by:
a) install oil and water pump drive











CRANKSHAFT VIBRATION DAMPER

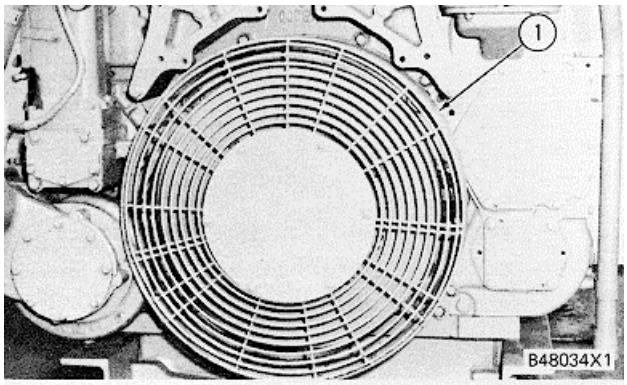
REMOVE CRANKSHAFT VIBRATION DAMPER 1205-11

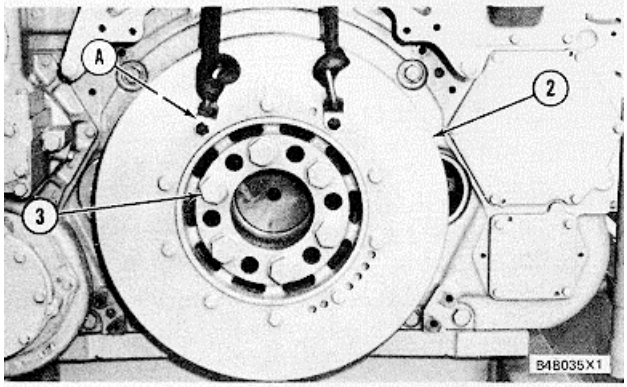
	Tools Needed	A
5P9736	Link Bracket	2

1. Remove the bolts and remove damper guard (1) from the engine.

2. Remove two bolts (3) and install two 1"-14 NF guide bolts 11 in. long. Fasten a hoist to vibration damper (2) with tooling (A) and remove the remainder of bolts (3). Remove vibration damper (2) from the engine. The weight of the damper is 81 kg (180 lb.).

3. If necessary, remove the bolts and remove the damper from the adapter. The weight of the damper is 52 kg (115 lb.) and the weight of the, adapter is 29 kg (65 lb.).





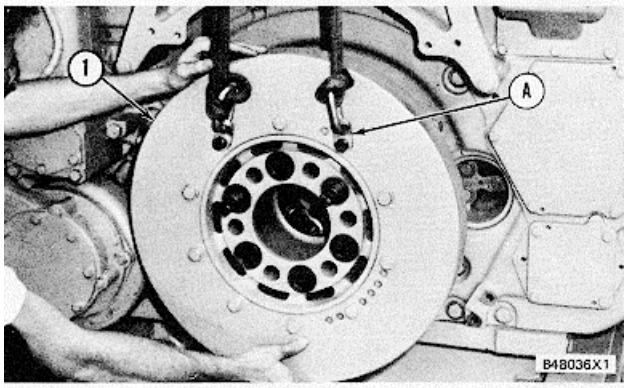
INSTALL CRANKSHAFT VIBRATION DAMPER 1205-12

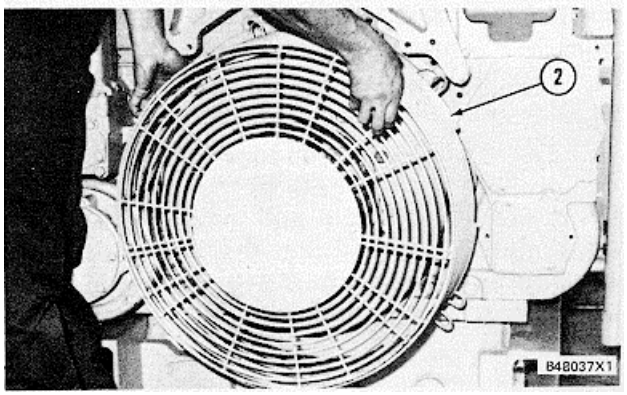
	Tools Needed	A
5P9736	Link Bracket	2

1. If the damper was removed from the adapter, put the damper on the adapter and install the bolts to hold the unit together.

2. Install two 1"-14 NF guide bolts 11 in. long in the end of the crankshaft. Fasten a hoist to vibration damper (1) with tooling (A). Put the damper in position on the guide bolts and make sure the mark on the damper is in alignment with the mark on the end of the crankshaft a Install four of the bolts to hold the damper in position and remove tooling (A). Remove the guide bolts and install the remainder of the bolts.

3. Put damper guard (2) in position and install the bolts to hold it in position on the engine.





CRANKSHAFT FRONT SEAL AND WEAR SLEEVE

REMOVE CRANKSHAFT FRONT SEAL AND WEAR SLEEVE 1160-11

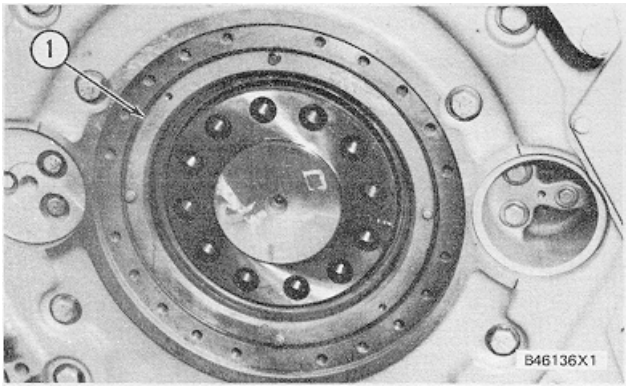
	Tools Needed	A	B
5P7409	Distorter	1	
6V3143	Distorter Adapter		1

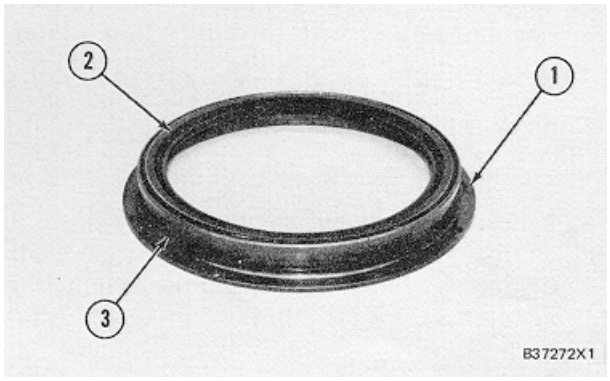
start by:

a) remove crankshaft vibration damper

NOTE: Any time the crankshaft seal is removed from the wear sleeve, a new sleeve and seal must be installed as a unit. If the seal is put back on the sleeve, the seal will leak.

1. Remove the bolts from adapter (1) and install two 5/16"- 13 NC forcing screws in the adapter to remove it from the drive housing.
2. Remove O-ring seal (3) and crankshaft seal (2) from adapter (1).
3. Install tool (B) in adapter bore as shown.
4. Install tool (A) between tool (B) and wear sleeve (4). Turn tool (A) until the edge of the tool makes a flat plate (crease) in the wear sleeve. Do this several places around the wear sleeve until the sleeve can be removed from the end of the crankshaft by hand.





INSTALL CRANKSHAFT FRONT SEAL AND WEAR SLEEVE 1160-12

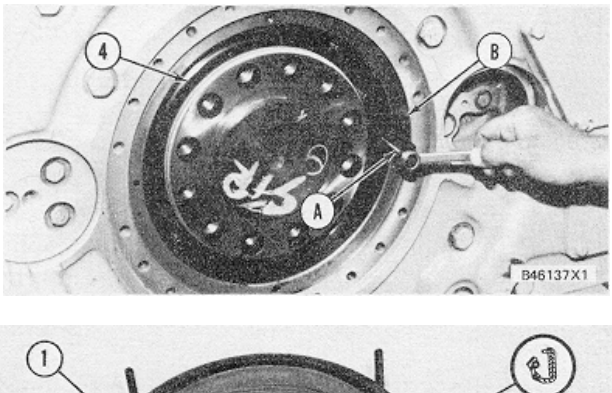
	Tools Needed	A	B	C	D	E	F	G
6V4002	Forcing Bracket	2						
6V4001	Forcing Ring		1					
1B4330	Nut (5/ 16"-18 NC)		4					
6V4003	Locator				1			
2N5006	Bolt (1"-14 NF x 2.5 in. long)				2			
	Guide Bolts (5/ 16"-18 NC x 4 in. long)				2			
6V4977	Installer						1	
9S8858	Nut							1

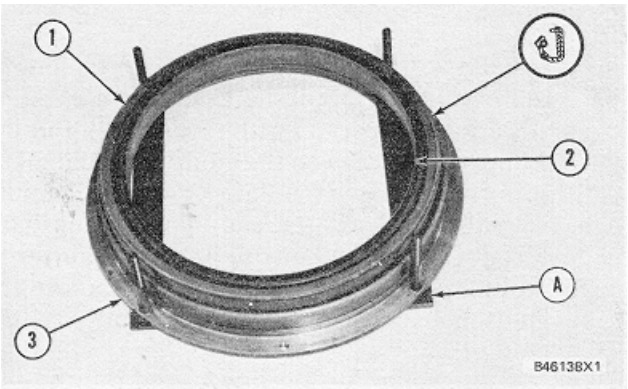
NOTE: Any time the crankshaft seal is removed from the wear sleeve, a new sleeve and seal must be installed as a unit. If the seal is put back on the sleeve, the seal will leak.

1. Install adapter (3) on tooling (A) as shown.

NOTICE

If the crankshaft seal and wear sleeve come apart during installation, the seal and sleeve become scrap and a new seal and sleeve must be used as a replacement.





NOTE: The front seal and wear sleeve can not be exchanged with the rear seal and wear sleeve. There are grooves in the sealing lip of the seals that direct the oil back into the crankcase as the crankshaft turns. An exchange of front and rear seals would pump the oil out of the crankcase.

2. Put crankshaft seal (1) and wear sleeve (2) as a unit in position on adapter (3). Make sure the lip of the seal is up as shown.

CRANKSHAFT FRONT SEAL AND WEAR SLEEVE

3. Install tool (B) over the studs of tooling (A). Install nuts (C) and tighten the nuts evenly until the seal is against the bottom of the adapter bore.

4. Remove nuts (C), tool (B) and tooling (A) from the adapter.

NOTE: Do not put engine oil on the lip of the seal during installation. Lubrication of the seal at installation can be a wrong indication for linkage at a later time.

5. Put clean engine oil on the O-ring seal and, install the seal on the adapter.

6. Install tooling (D) on the end of the crankshaft.

7. Install guide bolts (E) in the drive housing. Put adapter (3) in position on guide bolts (E) and over tooling (D). Make sure the wear sleeve makes contact with the end of the crankshaft.

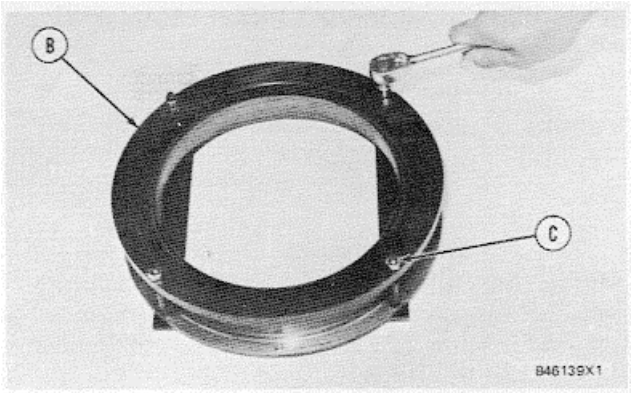
8. Install tool (B) over the small outside diameter of tool (F) until tool (B) is against the shoulder on tool (F).

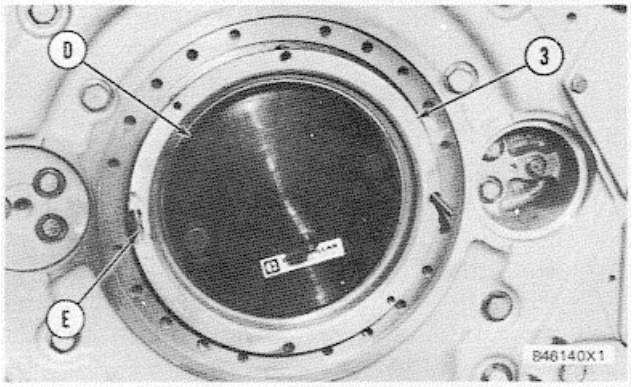
9. Install tooling(B) and(F) as a unit on the guide bolts and over the locator.

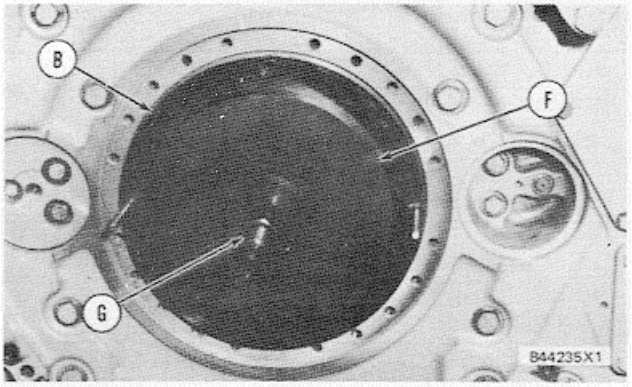
10. Put clean engine oil on the face of nut (G) and, install nut (G) on the locator. Tighten nut (G) until the wear sleeve and adapter are in position.

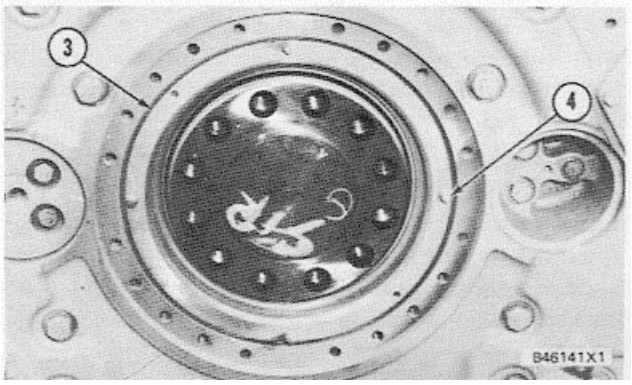
11. Remove the tooling from the engine.

12. Install bolts (4) to hold adapter (3) in position.
end by:
a) install crankshaft vibration damper









CRANKSHAFT REAR SEAL AND WEAR SLEEVE

REMOVE CRANKSHAFT REAR SEAL AND WEAR SLEEVE 1161-11

	Tools Needed	A	B
5P7409	Distorter	1	
6V3143	Distorter Adapter		1

start by:

a) remove flywheel

NOTE: Any time the crankshaft seal is removed from the wear sleeve, a new sleeve and seal must be installed as a unit. If the seal is put back on the sleeve, the seal will be damaged.

1. Remove the bolts from adapter (1) and install two 5/16"- 18 NC forcing screws in the adapter to remove it from the drive housing.
2. Remove O-ring seal (3) and crankshaft seal (2) from adapter (1).
3. Install tool (B) in adapter bore as shown.
4. Install tool (A) between tool (B) and wear sleeve (4). Turn tool (A) until the edge of the tool makes a flat place (crease) in the wear sleeve. Do this several places around the wear sleeve until the sleeve can be removed from the end of the crankshaft by hand.

INSTALL CRANKSHAFT REAR SEAL AND WEAR SLEEVE 1161-12

	Tools Needed	A	B	C	D	E	F	G
6V4002	Forcing Bracket	2						
6V4001	Forcing Ring		1					
1B4330	Nut (5/16"-18 NC)			4				
6V4003	Locator				1			
2N5006	Bolt (1"-14 NF x 2.5 in. long)				2			
	Guide Bolts (5/16"-18 NC x 4 in. long)					2		
6V4977	Installer						1	
9S8858	Nut							1

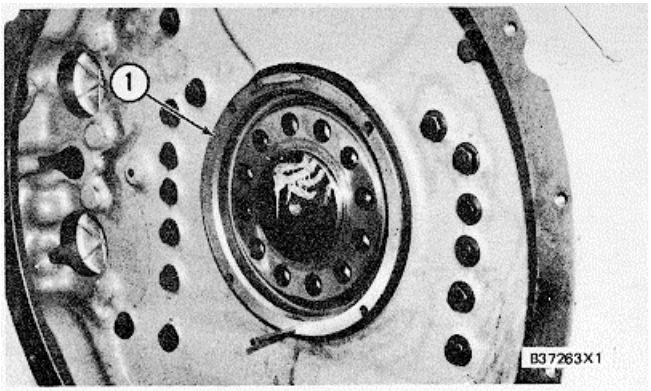
NOTE: Any time the crankshaft seal is removed from the wear sleeve, a new sleeve and seal must be installed as a unit. If the seal is put back on the sleeve, the seal will be damaged.

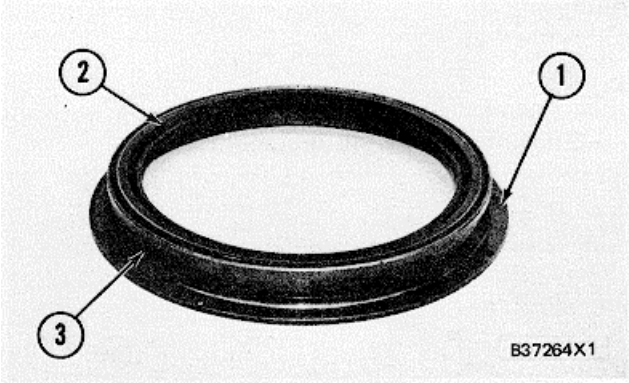
1. Install adapter (3) on tooling (A) as shown.

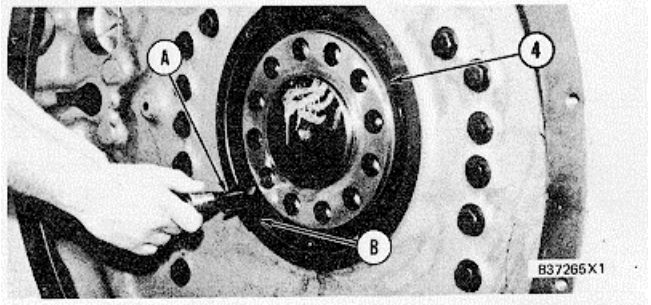
NOTICE

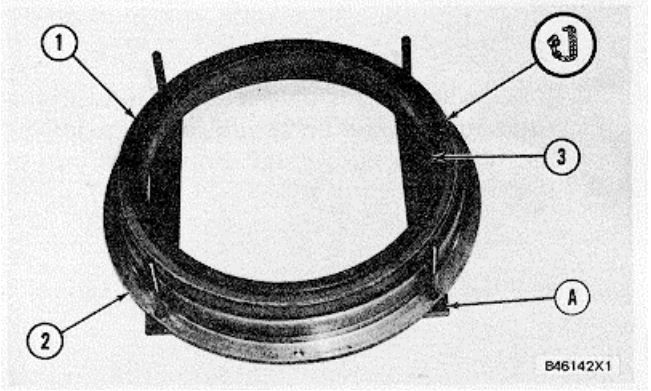
If the crankshaft seal and wear sleeve come apart during installation, the seal and sleeve become scrap and a new seal and sleeve as a unit must be used as a replacement.

NOTE: The rear seal and wear sleeve can not be exchanged with the front seal and wear sleeve. There are grooves in the sealing lip of the seals that direct the oil back into the crankcase as the crankshaft turns.







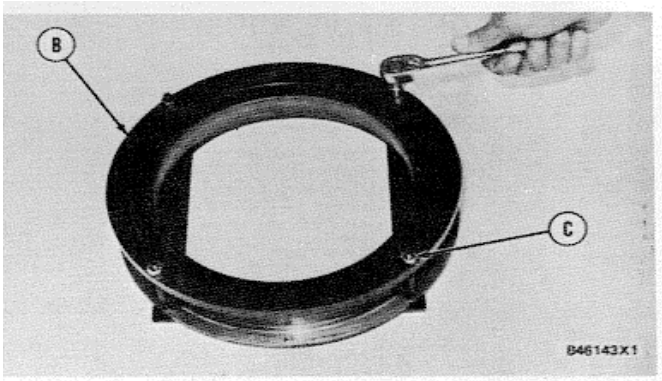


An exchange of front and rear seals can cause the oil to come out of the crankcase.

2. Put crankshaft seal (1) and wear sleeve (2) as a unit in position on adapter (3). Make sure the lip of the seal is up as shown.

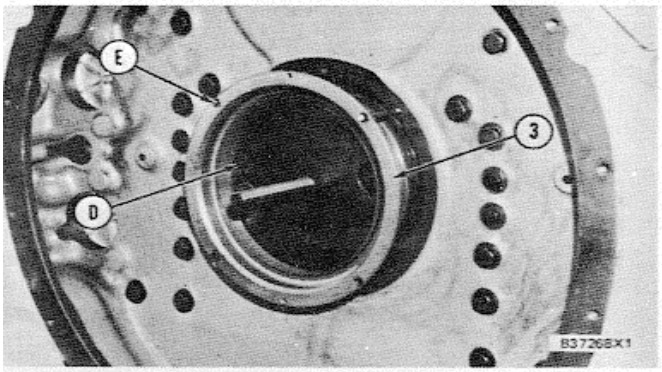
CRANKSHAFT REAR SEAL AND WEAR SLEEVE

3. Install tool (B) over the studs of tooling (A). Install nuts (C) and tighten the nuts evenly until the seal is against the bottom of the adapter bore.



4. Remove nuts (C), tool (B) and tooling (A) from the adapter.

NOTE: Do not put engine oil on the lip of the seal during installation. Lubrication of the seal at installation can be a wrong indication for linkage at a later time.

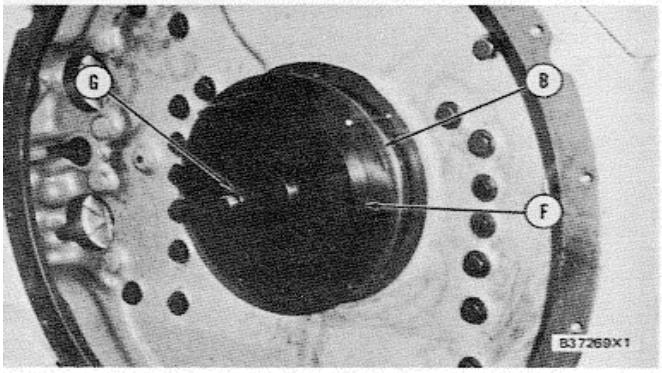


5. Put clean engine oil on the O-ring seal and, install the seal on the adapter.

6. Install tooling (D) on the end of the crankshaft.

7. Install guide bolts (E) in the drive housing. Put adapter (3) in position on guide bolts (E) and over tooling (D). Make sure the wear sleeve makes contact with the end of the crankshaft.

8. Install tool (B) over the small outside diameter. of tool (F) until tool (B) is against the shoulder on tool (F).

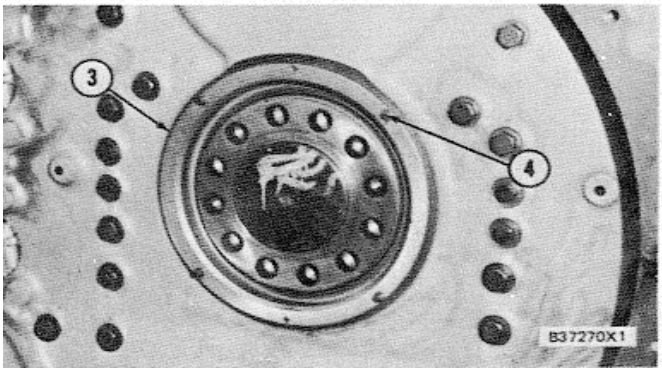


9. Install tooling (B) and (F) as a unit on the guide bolts and over locator.a8'" "A

10. Put clean engine oil on the face of nut (G) and install nut (G) on the locator. Tighten nut (G) until the wear sleeve and adapter are in position.

11. Remove the tooling from the engine.

12. Install bolts (4) to hold adapter (3) in position.
end by:
a) install flywheel



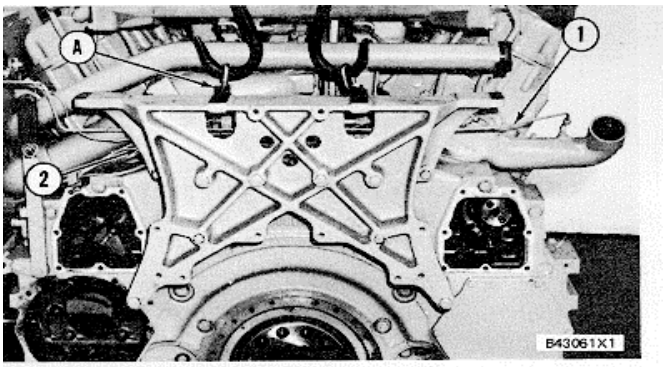
FRONT DRIVE HOUSING

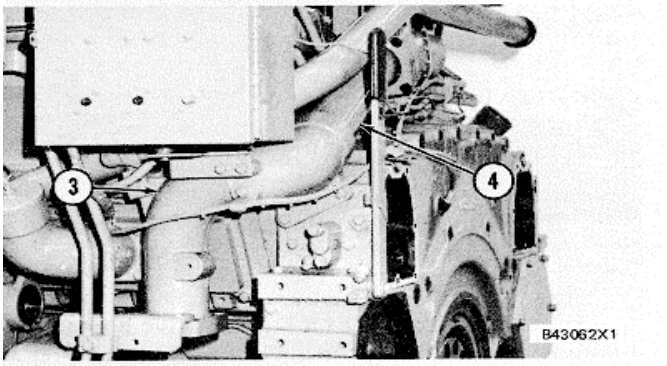
REMOVE FRONT DRIVE HOUSING 1151-11zit

	Tools Needed	A	B	C
6V2156	Link Bracket	2		
1P74	Slide Hammer and Puller		1	
8B7557	Threaded Adapter		1	
1P520	Drive Group			1

start by:
a) remove oil filter housing
b) remove crankcase breather
c) remove front crankshaft seal and wear sleeve
d) remove accessory drive (front)
e) remove governor drive.

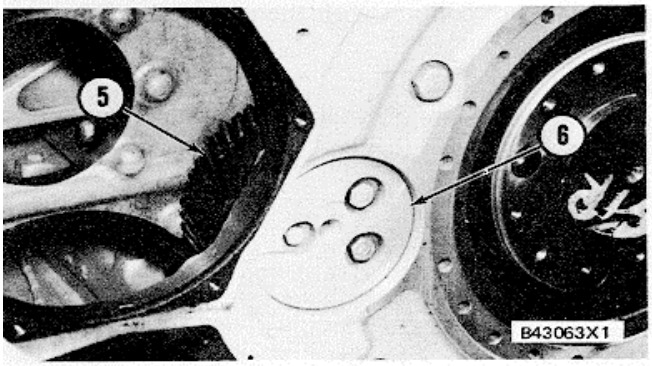
NOTE: Make sure there is a new front crankshaft seal and wear sleeve before the front drive housing is removed. Anytime the front seal is removed from the wear sleeve, a new seal and sleeve must be installed.





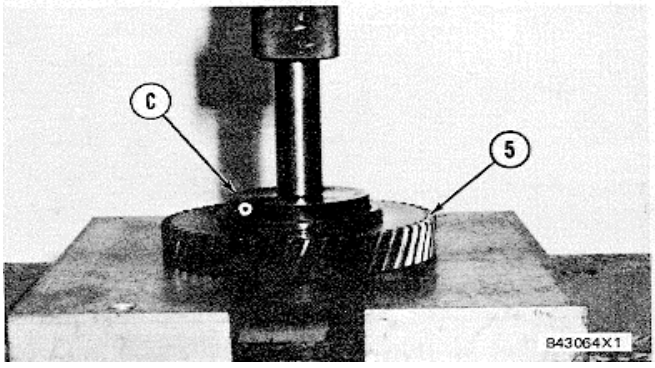
1. Remove oil tube (I) from the engine.

2. Fasten a hoist to support (2) with tooling (A) and remove support (2) from the drive housing. The weight of the support is 102 kg (225 lb.).



3. Remove elbow (3) and tube (4) as a unit from the engine.

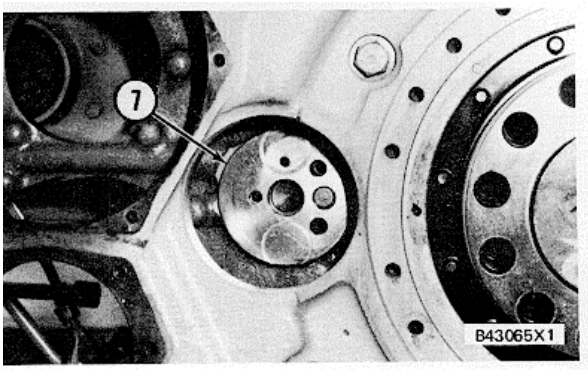
4. Remove the bolts and use tooling (B) to remove shaft (6) and idler gear (5) from the drive housing.



5. If necessary, use tooling (C) to remove the bearing from idler gear (5).

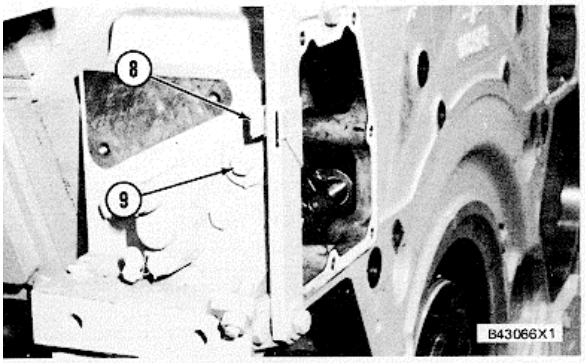
FRONT DRIVE HOUSING

6. Remove washer (7) from the inside of the drive housing.

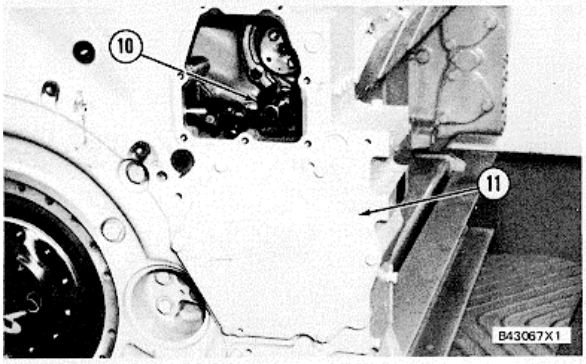


7. Remove bolt (9) and washer to remove clip (8) from the drive housing.

8. Remove cover (11) from the drive housing



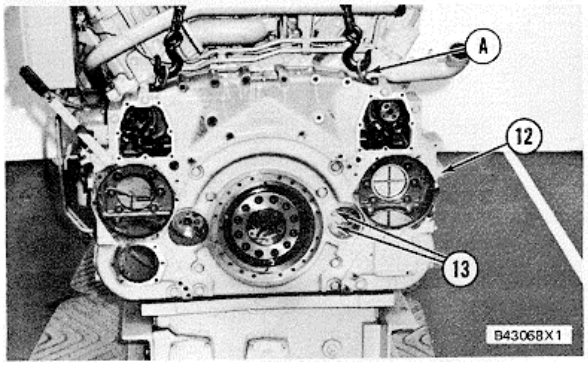
9. Remove all of the bolts that hold the oil pan to the engine. Install 3/8"-16 NC guide bolts in each side of the oil pan. Fasten a hoist to the engine and lift the engine approximately 12E mm (0.5 in.) off of the oil pan. Put two 50 mm.-66 wide x 100 mm long x 6 mm thick (2 in. wide x 4 in. long x l/4 in. thick) plates in position between the cylinder block and the oil pan on each side of the engine. Lower the engine on the plates and remove the hoist. The weight of the 3512 2 Engine is approximately 5443 kg (12, 000 lb.). The weight of the 3508 Engine is 4445 kg (9800 lb.).



NOTICE.

Fuel control linkage (10) must be moved for clearance to pull the front drive housing from the engine or damage to parts can be the result.

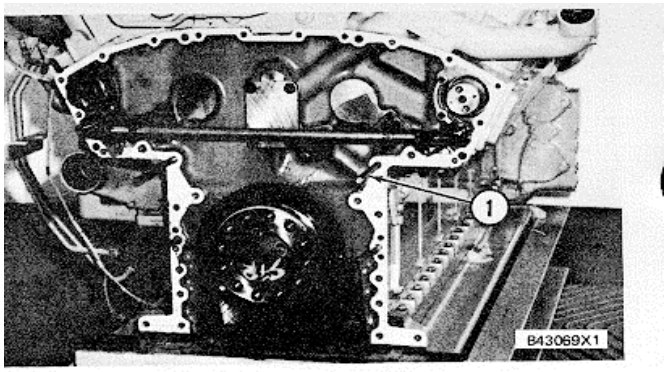
10. Fasten a hoist to front drive housing (12) with tooling (A). Remove bolts (13) and the remainder of the bolts that hold housing (12) in_ 1 position. Remove front drive housing (1 2) from the engine. The weight of the housing is 209 kg (460 lb.).:



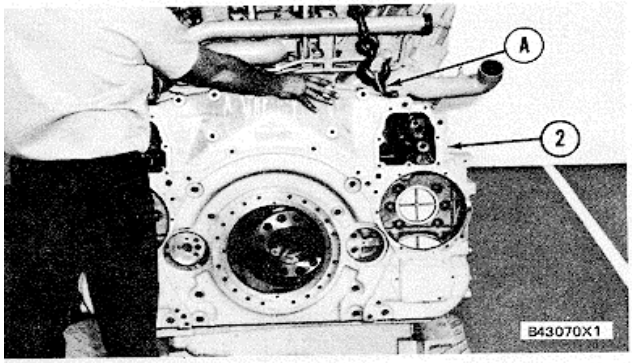
FRONT DRIVE HOUSING

INSTALL FRONT DRIVE HOUSING 1157-12

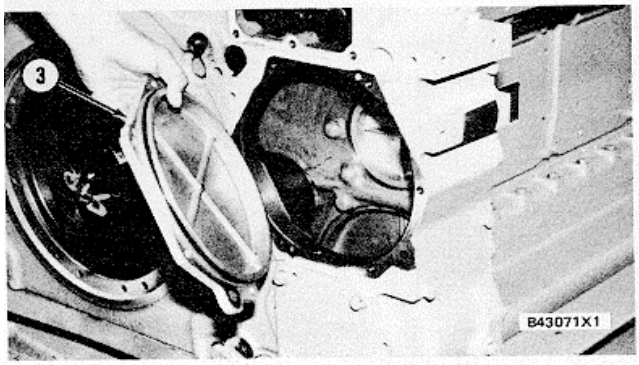
	Tools Needed	A	B
6V2156	Link Bracket	2	
1P520	Drive Group		1



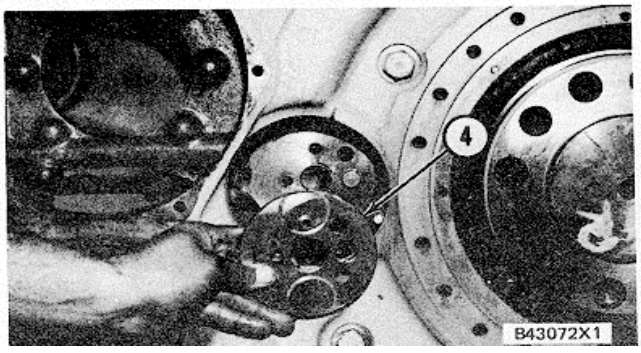
1. Put the housing gasket in position on the front of the cylinder block. Install two 5/8"-11 NC guide bolts (1) in the cylinder block.



2. Fasten a hoist to front drive housing (2) with tooling (A). Put housing (2) in position on the guide bolts and install the bolts to hold it in position. Remove the guide bolts and install the remainder of the bolts. Tighten all of the bolts evenly and cut the housing gasket even with the bottom of the cylinder block.



3. Fasten a hoist to the engine and lift the engine enough to remove the plates between the cylinder block and the oil pan. If the oil pan gasket damaged, the engine will have to be removed from the oil pan to make a replacement of the gasket. Lower the engine on the oil pan and remove the guide bolts of the oil pan. Install all of the bolts that hold the oil pan to the engine.

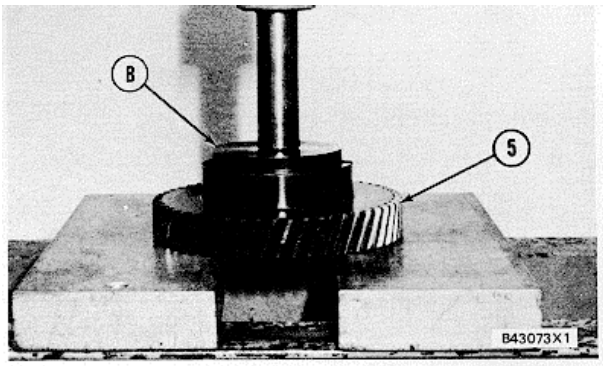


4. Put clean engine oil on the O-ring seals and install cover (3) on the drive housing.

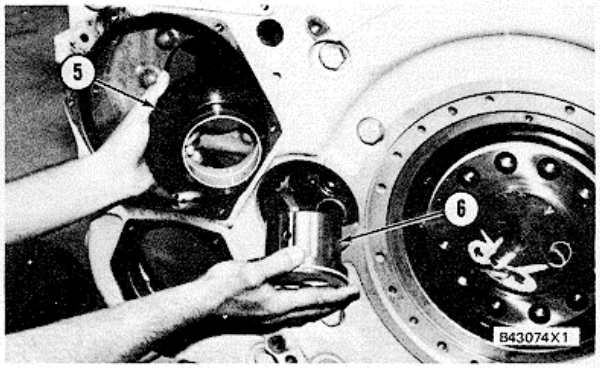
5. Put washer (4) in position inside the drive housing.

FRONT DRIVE HOUSING

6. Use tooling (B) and a press to install the bearing in idler gear (5). Check the bore in the bearing after assembly. The bore in the bearing must be 90.00 + 0.06 mm (3.543 ± .002 in.).

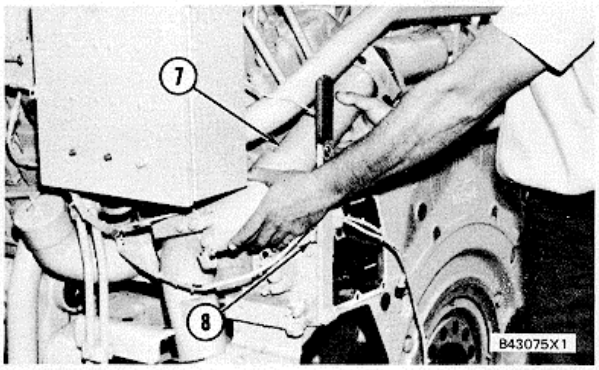


7. Put clean engine oil on the O-ring seal on shaft (6). Install idler gear (5) and shaft (6) in the front drive housing.



8. Make sure the gasket and seals are in position and install aftercooler water line (7) on the engine. Install clip (8) on the drive housing.

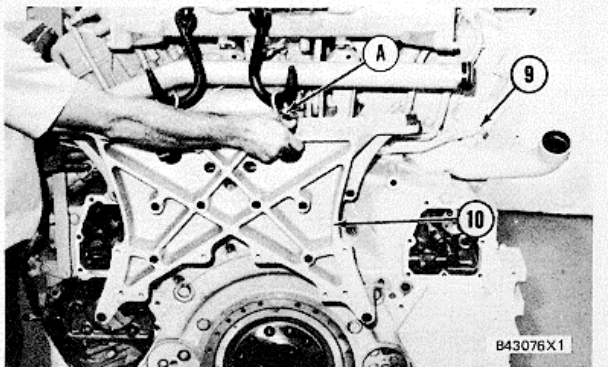
9. Install oil tube (9) on the engine.-4.



10. Fasten a hoist to support (10) with tooling (A)' and put it in position on the front drive housing. Install the bolts to hold the support in position.

NOTE: Anytime the front crankshaft seal and wear sleeve are removed a new seal and wear sleeve must be installed.
end by:

a) install oil filter housing
b) install crankcase breather
c) install front crankshaft seal and wear sleeve
d) install accessory drive (front)
e) install governor drive



FLYWHEEL

REMOVE FLYWHEEL1156-11

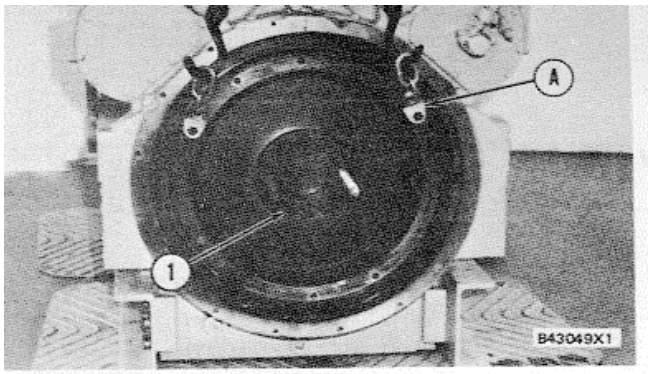
	Tools Needed	A
6V2157	Link Bracket	2’

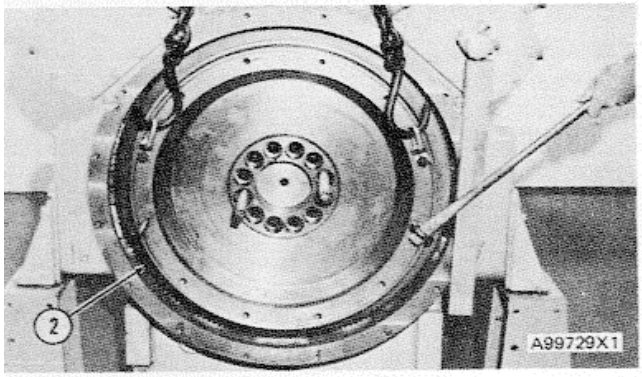
1. Fasten a hoist to the flywheel with tooling (A).

2. Remove flywheel (2) from the engine. The NF guide bolts 11 in. long in their place. Remove the remainder of bolts (I).

3. If necessary, install a 5/8"- 1 NC forged eye-bolts in each side of the flywheel and use a pry bar to remove the flywheel from the pilot on theW5 crankshaft.

4. Remove flywheel (2) from the engine. The weight of the 3512 Flywheel is 167 kg (370 lb.). The weight of the 3508 Flywheel is 126 kg (280 lb.).





TYPICAL EXAMPLE

INSTALL FLYWHEEL 1156-12

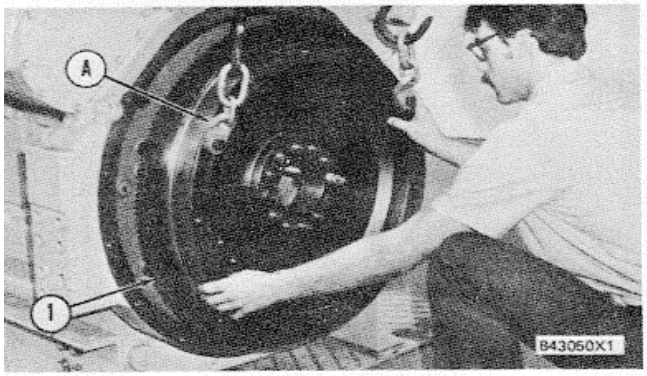
	Tools Needed	A
6V2157	Link Bracket	2

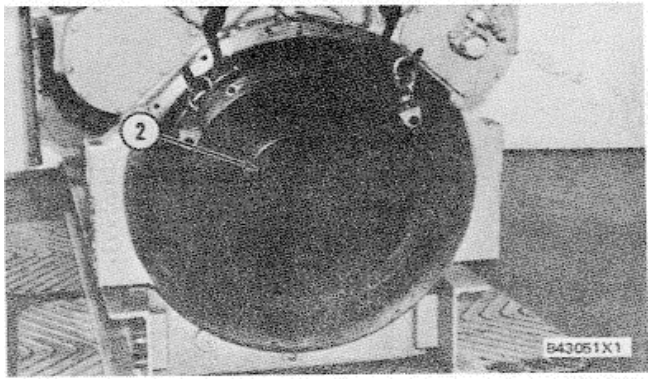
1. If the flywheel ring gear has damage, a replacement can be made as follows:
   a) Heat the ring gear to a maximum temperature of 316° C (6000 F) and install it on the., flywheel so the chamfer of the gear teeth will be toward the starter pinion when the flywheel is installed.

2. Install two 1"-14 NF guide bolts 11 in. long in the end of the crankshaft.

3. Fasten a hoist to flywheel (1) with tooling (A) and put it in position on the guide bolts. Make sure the mark on the flywheel is in alignment with the mark on the crankshaft.

4. Put clean engine oil on the threads of bolts (2) and install them to hold the flywheel in place. Tighten bolts (2) to a torque of 1 *150* + 30 N-m (848 ± 22 lb. ft.).





FLYWHEEL HOUSING

REMOVE FLYWHEEL HOUSING 1157-11

	Tools Needed	A	B
8B7548	Puller Assembly	1	
8B7559	Threader Adapter	2	
8B7561	Step Plate	1	
8H684	Ratchet Box Wrench	1	
5P9736	Link Bracket		1

start by
a) remove exhaust elbow'
b) remove tachometer drive
c) remove crankshaft rear seal and wear sleeve

NOTE: Make sure there is a new rear crankshaft seal and wear sleeve before the housing is removed. Anytime the seal is removed from the wear sleeve a new sleeve and seal must be installed.

1. Remove brackets (1) and (2) from the engine.

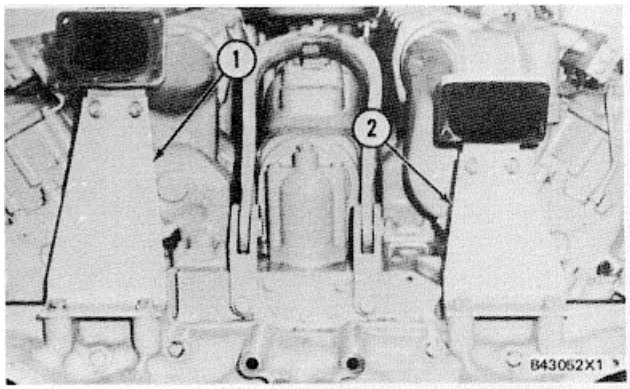
2. Use tooling (A) to remove the camshaft drive gears from the camshafts.

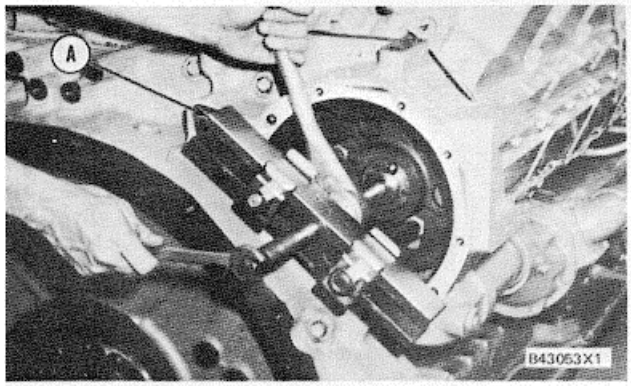
3. Drain the oil from the oil pan.

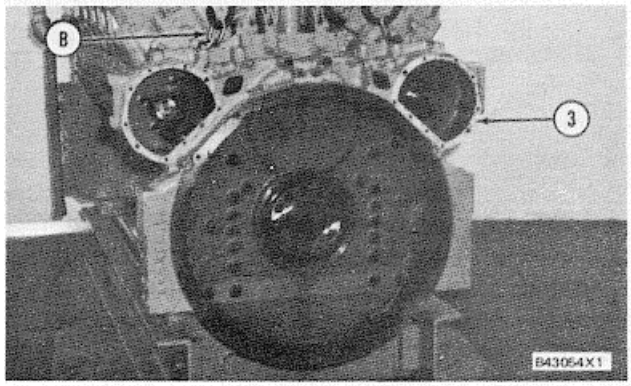
4. Remove all of the bolts that hold the oil pan to., the engine. Install two 3/8"-16 NC guide bolts in each side of the oil pan. Fasten a hoist to the engine and lift the engine approximately 12 mm (0.5 in.) off of the oil pan. Put two 50 mm wide x 100 mm long x 6 mm thick(2 in. wide x 4 in. long x l/4 in. thick) plates in position between the cylinder block and the oil pan on each side of the engine. Lower the engine. Lower the engine on the plates and remove the hoist. The weight of the 3512 Engine is approximately 5443 kg (12, 000 lb.). The weight of the 3508, Engine is 4445 kg (9800 lb.).

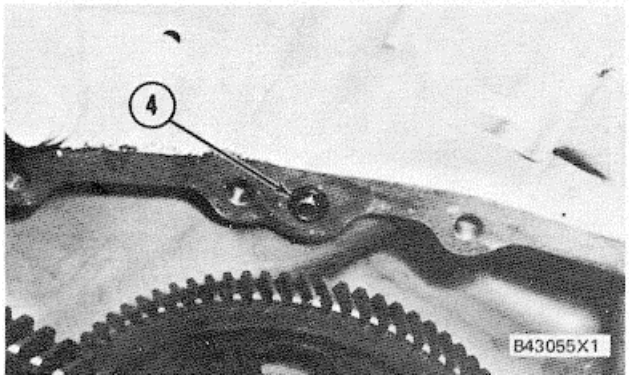
5. Use tooling (B) to fasten a hoist to the flywheel housing. Remove the bolts and remove flywheel housing (3) from the engine. The weight of the housing is 245 kg (540 lb.).

6. Remove O-ring seal (4) from the engine block.









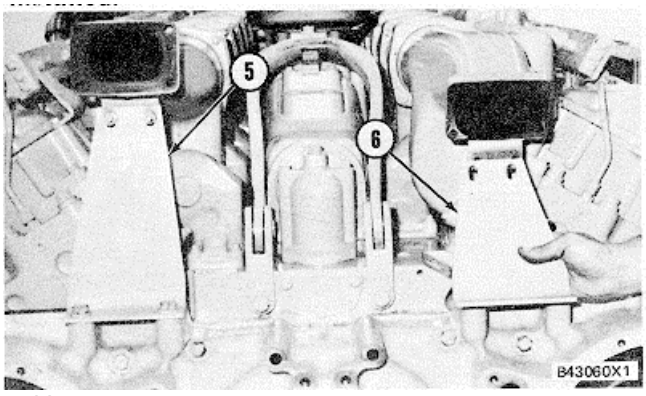
FLYWHEEL HOUSING

INSTALL FLYWHEEL HOUSING1157-12

	Tools Needed	A
5P9736	Link Bracket	2

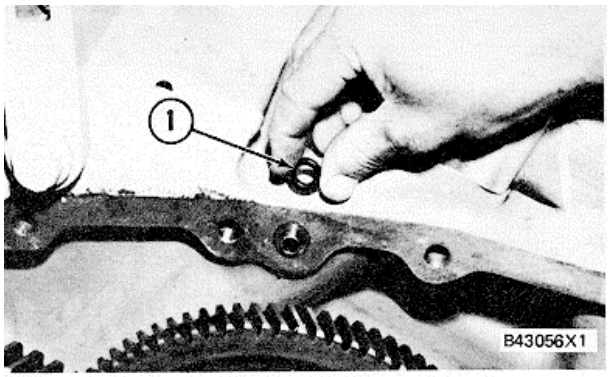
1. Install O-ring seal (1) on the engine block and put clean engine oil on it.
2. Put the flywheel housing gasket in position on the rear of the engine block.
3. Install two 5/8"-11 NC guide bolts (2) in the, engine block.
4. Fasten a hoist to flywheel housing (3) with_43056 tooling (A) and put the housing in position on the guide bolts. Install the bolts to hold the housing in position and tighten the bolts evenly. Remove the guide bolts and install the remainder of the bolts.
5. Cut the flywheel housing gasket even with the bottom of the cylinder block.-!_w
6. Fasten a hoist to the engine and lift the engine enough to remove the plates between the cylinder block and the oil pan. If the oil pan gasket is damaged, the engine will have to be removed from the oil pan to make a replacement of the gasket. Lower the engine on the oil pan and 430 remove the guide bolts from the oil pan. Install all of the bolts that hold the oil pan to the engine.
7. Put camshaft drive gears (4) in position on the ends of the camshafts. Install the plate and tachometer drive adapter assembly to hold the gears in position. Tighten the bolts evenly to a torque of 100 + 15 N-m (75 + 11 lb. ft.). Hit the plate and adapter assembly with a hammer*3* and tighten the bolts again to the same torque. Do this until the torque does not change.
8. Install brackets (5) and (6) on the engine.

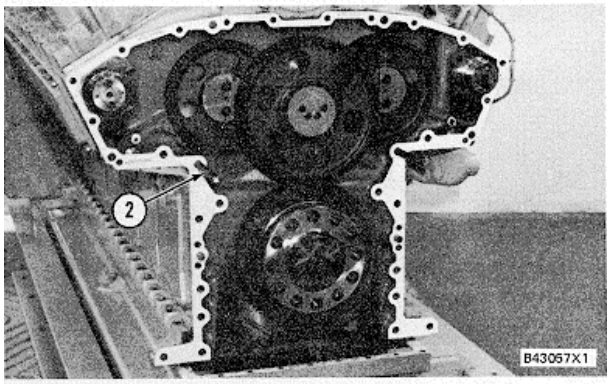
NOTE: Any time the rear crankshaft seal and wear sleeve are removed, a new seal and sleeve must be installed.

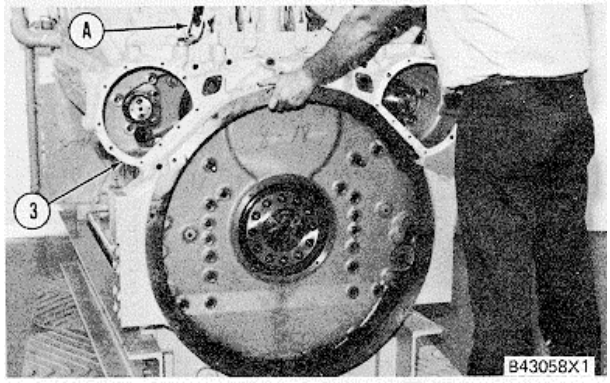


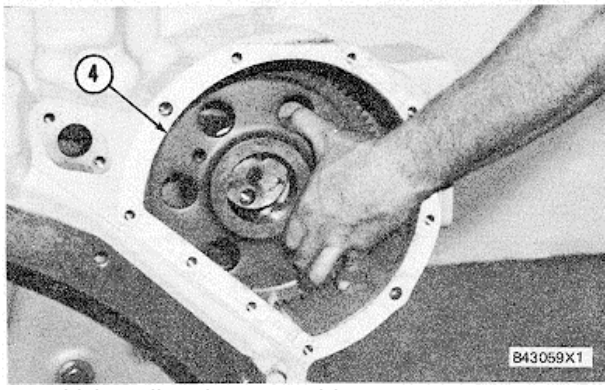
end by:

a) install exhaust elbow









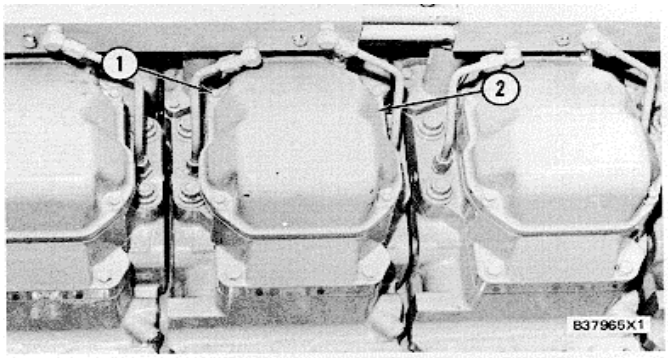
b) install tachometer drive

c) install crankshaft rear seal and wear sleeve’

VALVE COVERS, ROCKER SHAFTS AND PUSH RODS

REMOVE VALVE COVERS1107-11

1. Remove bolts (1) and remove valve cover (2) from the valve cover base.

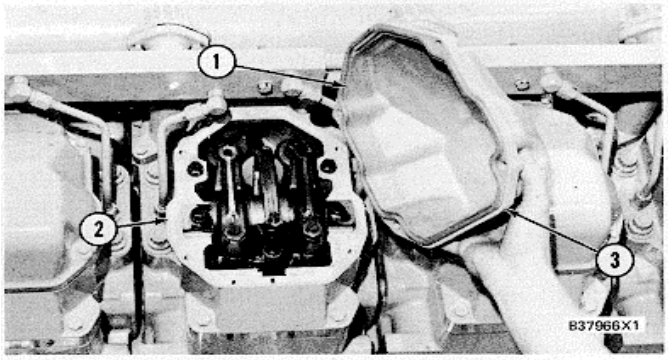


2. If necessary, remove the seal from valve cover, (2).

INSTALL VALVE COVERS 1107-12

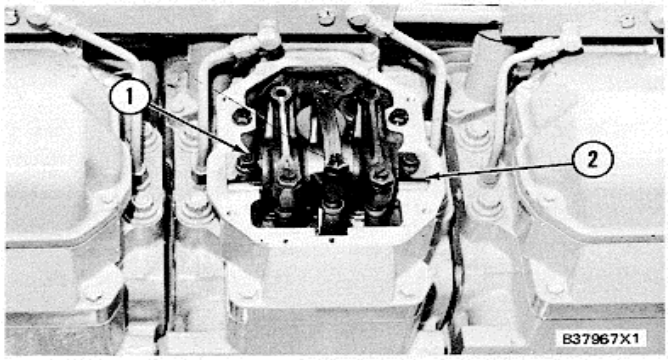
1. Make sure seal (I) is installed in the groove of valve cover (3). Cut new seals to fit at assembly.

2. Put valve cover (3) in position on valve cover base (2) and install the four bolts to hold it. Tighten the bolts to a torque of 14 + 3 N•m (10 + 2 lb. ft.).



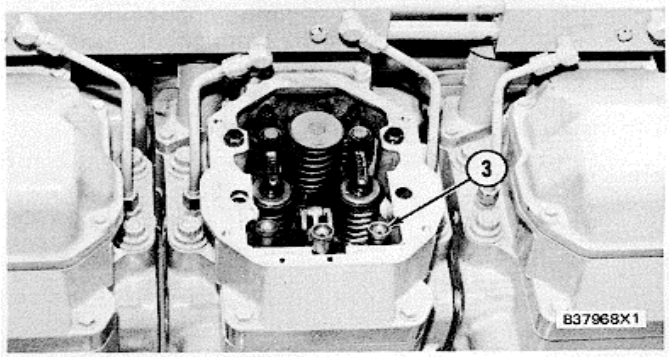
REMOVE ROCKER SHAFTS AND PUSH RODS 1102 & 1208-11

start by:
a) remove valve covers



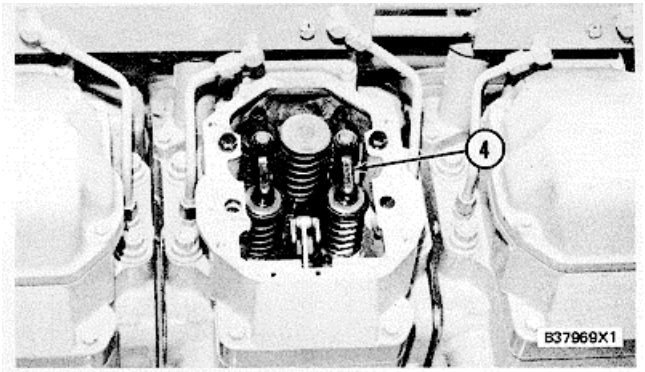
1. Remove bolts (1) and lift shaft (2) and the rocker arms off the valve cover base and the push rods.

2. Remove push rods (3) from the valve lifters and valve cover base.



ROCKER SHAFTS AND PUSH RODS

3. Remove bridge assemblies (4) from the dowels.

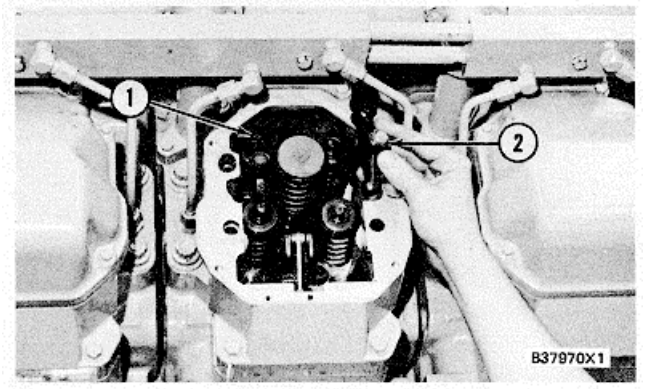


INSTALL ROCKER SHAFTS AND PUSH RODS 1102 & 1208-12

1. Loosen the adjustment nuts and screws (1) on valve bridges (2)

2. Put clean engine oil on the bridge dowels, the inside diameter of valve bridges (2) and on the top pad of the valve bridge. Install valve bridges (2) on the bridge dowels as shown.'

3. While bridges (2) are pushed straight down with a force of 25 + 20 N (5.6 + 4.5 lb.) on the top contact surface, turn adjustment screw (1) : until it makes contact with the valve stem. Turn : screw (1) another 200 to 300. This will straighten the dowel in the guide and make compensation for clearance (slack) in the threads.

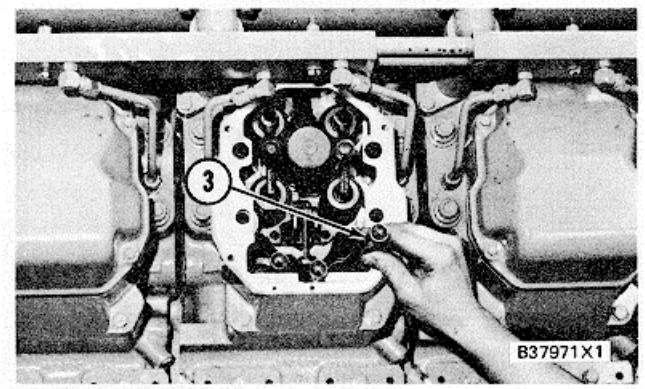


4. Hold adjustment screw (1) in position and, tighten the nut around screw (I) to a torque of. 30 _ 4 N•m (22 ± 3 lb. ft.).B3797

5. Put push rods (3) in position in the valve lifters and valve cover base.

NOTICE

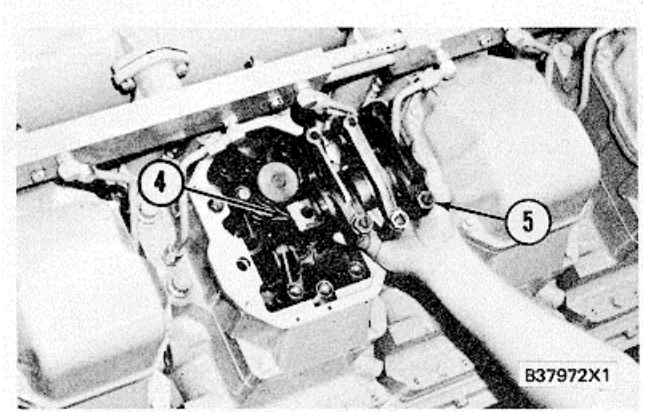
Make sure the crankshaft and camshafts are in time with each other and that adjustment screws (5) are turned all the way out before the rocker shaft bolts are tightened or damaged to, the valves or pistons can be the result. See INSTALL CAMSHAFTS for the procedure to time the engine.



6. Put the rocker arms and shaft (4) in position on the valve cover. Make sure the rocker shafts and push rods are in alignment and install the bolts to hold shaft (4).

7. Make an adjustment of the valves to have a clearance of 0.40 mm (.016 in.) for intake and 0.76 mm (.030 in.) for exhaust. See VALVE CLEARANCE SETTING in TESTING" AND ADJUSTING section for the complete procedure.

   a) install valve covers.



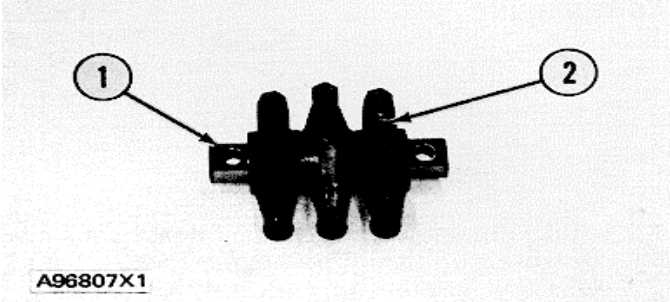
ROCKER SHAFT ASSEMBLIES

DISASSEMBLE ROCKER SHAFT ASSEMBLIES 1102-15

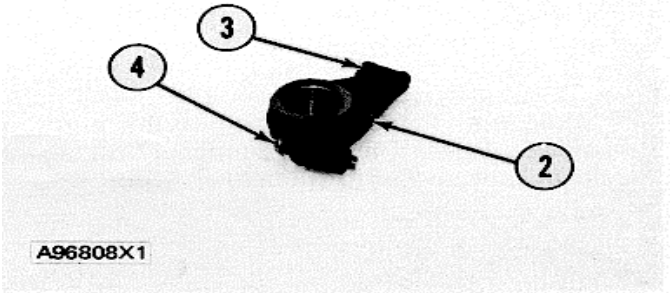
	Tools Needed	A
1P510	Driver Group	1

start by:
a) remove rocker shafts and push rods

1. Slide shaft assembly (1) out of rocker arms (2). If necessary, remove the dowel from shaft assembly (1).

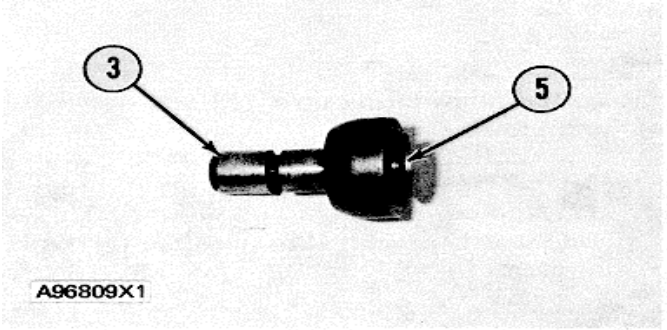


2. Remove adjustment screw (4) and the nut from rocker arm (2).



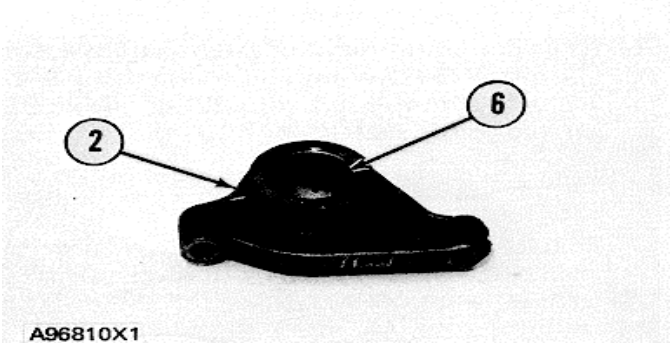
3. Use a hammer and punch to push socket (3) out(of rocker arm (2).

4 Remove the ring that holds button (5) in socket (3) and remove the button from the socket.



5. Use tool group (A) to remove bearing (6) from rocker arm (2).

6. Do Steps 2 through 5 for the other two rocker arms.



ROCKER SHAFT ASSEMBLIES

ASSEMBLE ROCKER SHAFT ASSEMBLIES 1102-16-

	Tools Needed	A
1P510	Driver Group	1

1. Make an alignment of the oil hole (slot) in the bearing with the oil passage in rocker arm (1). Use tool group (A) to install the bearing in rocker arm (1) with the joint in the bearing toward the top of the rocker arm. The bore in the bearing must be 37.140 ± 0.015 mm (1.4622 ± .0006 in.) after assembly.

2. Make an alignment of the scribe mark on socket (2) with the mark on rocker arm (1) and install the socket in the rocker arm.

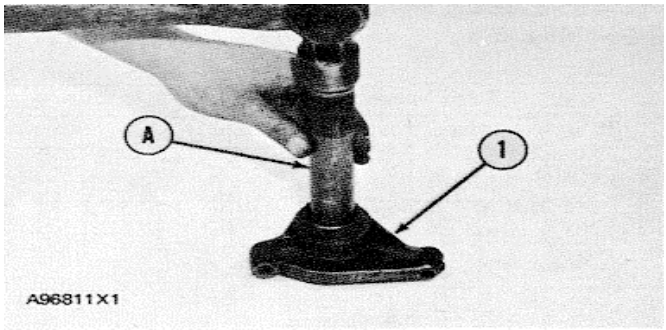
3. Put button (3) in socket (2) and install ring (4) to hold the unit together.

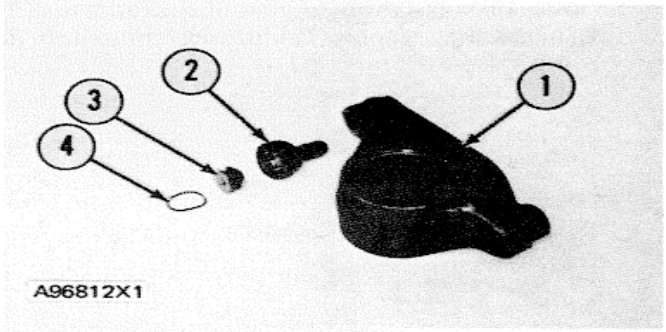
4. Install adjustment screw (5) and nut (6) on rocker arm (1).

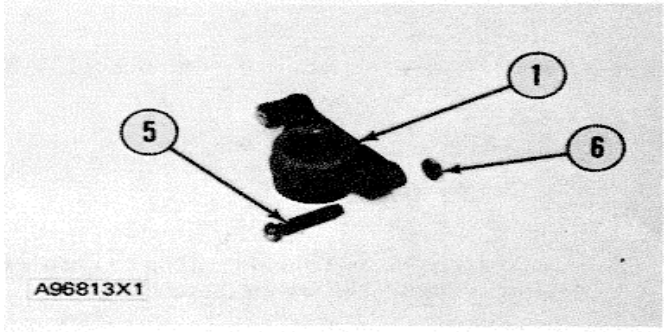
5. Do Steps I through 4 for the other two rocker arms.

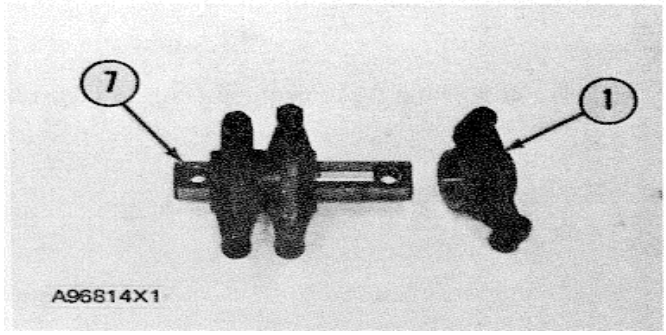
6. If the dowel was removed from shaft assembly (7), install the new dowel in the shaft until it is 7.7 ± 0.5 mm (.303 ± .020 in.) above the-surface of the shaft.

7. Put clean engine oil on the rocker arm bearings and shaft assembly (7). Install rocker arms (1) on shaft assembly (7).
end by:
a) install rocker shafts and push rods









FUEL INJECTORS

REMOVE FUEL INJECTORS 1251-11

start by:
a) remove rocker shafts and push rods

1. Close the fuel supply to the engine.

2. Remove inlet fuel tube (1) and outlet fuel tube (2) from the cylinder head. Put caps on the fuel openings.

NOTE: Step 2 must be done to prevent fuel leakage into the combustion chambers and the crankcase.

3. Remove locknut (4) and the washer. Disconnect lever assembly (3) from the control rod.

4. Remove bolts and remove lever assembly (3) from the cylinder head.

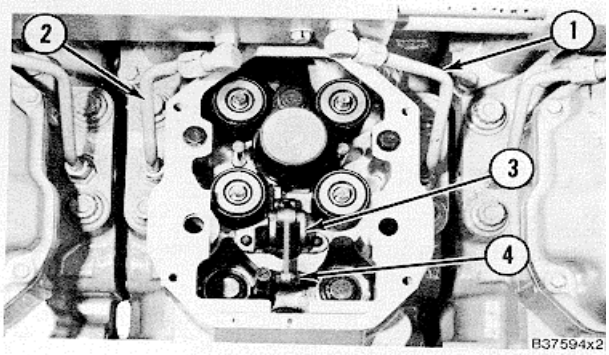
5. Remove bolt (6) and clamp (5) that hold the fuel injector in position.

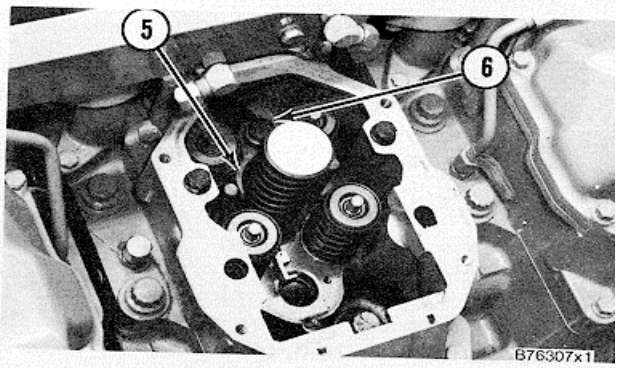
NOTICE
Do not put a force on the fuel injection rack or cause damage to it when the injectors are removed from the cylinder head.

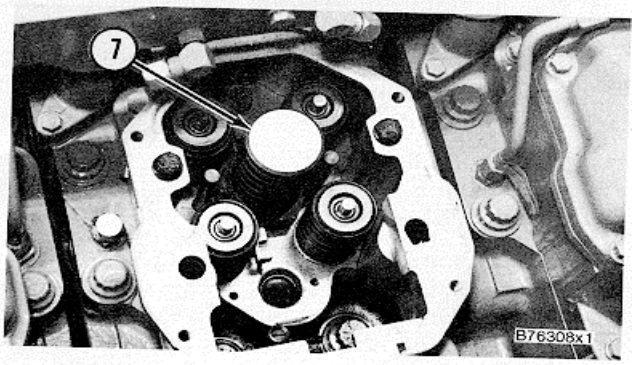
6. Use a pry bar and loosen injector (7) from the cylinder head. Pull injector (7) out of the cylinder head and remove it from the engine.

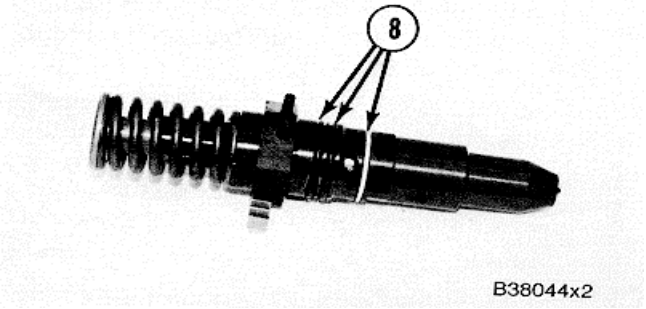
7. Remove O-ring seals (8) from the injector.

8. If necessary, remove the plug for clamp (5) from the cylinder head.









FUEL INJECTORS

INSTALL FUEL INJECTORS 1251-12

Tools Needed		A
6V4062	Injector Spring Compressor	1

1. Use tool (A) as shown to make sure the fuel injection rack will move freely by its own weight when injector (1) is turned a total of. 180° in both directions. Check the rack movement with the injector spring under compression. in several positions.

NOTE: To prevent a carbon deposit between the injector and the injector bore, make sure the injector body (especially the tapered area) and the injector bore are clean and free of foreign material.

2. Make sure the three O-ring seals (2) are installed on injector (1) and put clean engine oil on the seals and in the bore for the injector.

3. Make sure the plug that the anvil of clamp (5) sets on is installed in the top of the cylinder head.

NOTICE

Do not tap or hit on the injector follower to install the injector. Damage and failure of the injector can be the result.

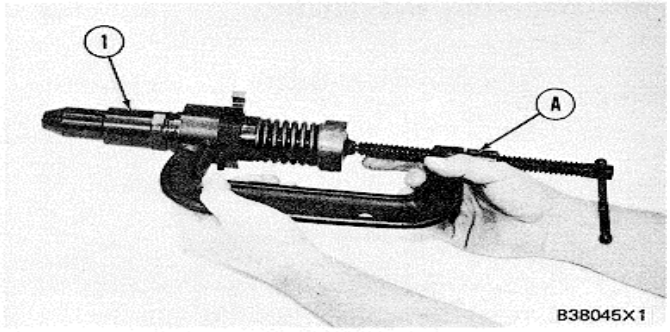
4. Put injector (1) in position in the cylinder head. Install clamp (5) and tighten the bolt and washer to push injector (1) all the way into its bore. Tighten the bolt to a torque of 65 ± 7 N•m (48 ± 5 lb.ft.).

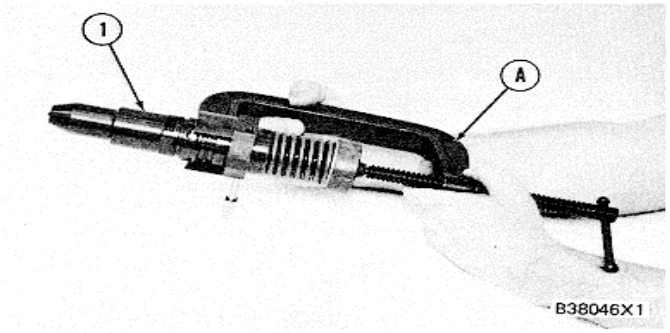
5. Check to make sure the fuel injection rack moves freely by hand in the injector after the injector is installed.

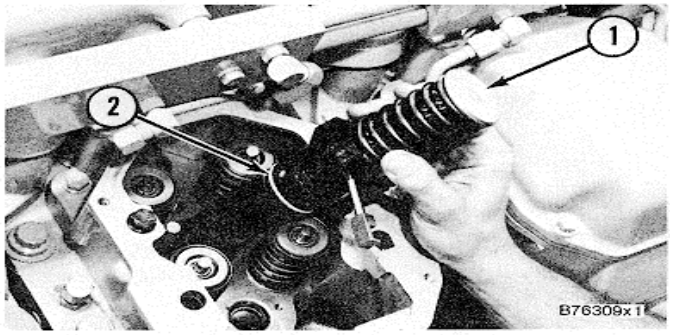
6. Put lever assembly (6) in position. Connect the lever assembly to control rod (7) and make sure lever assembly (6) is engaged correctly with the fuel injection rack. Install the two bolts to holdB7. the lever assembly in place.

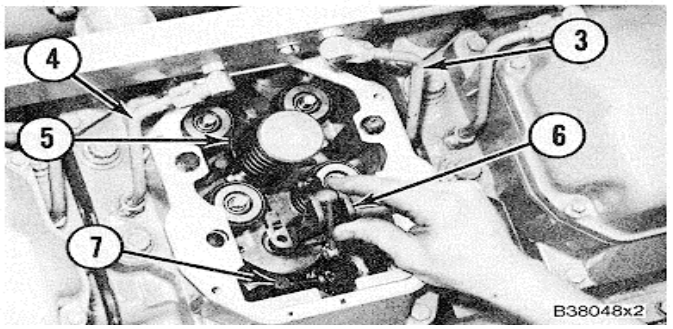
7. Remove the caps from the fuel openings and install inlet fuel tube (3) and outlet fuel tube (4) on the cylinder head. Open the fuel supply to the engine.

8. See TESTING AND ADJUSTING section for the correct adjustment of the fuel injection of the fuel injection control group. Make sure the control group can move to the fuel off position with the governor linkage disconnected.
end by:
a) install rocker shafts and push rods





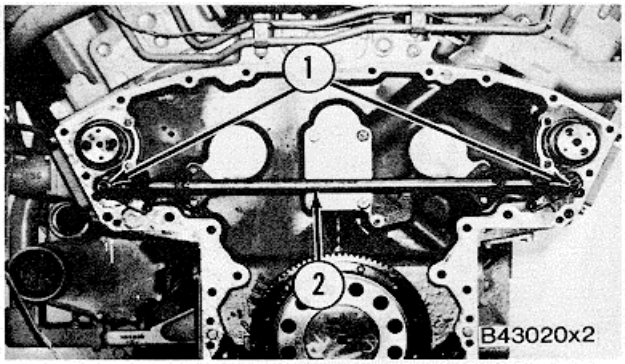




FUEL INJECTION CONTROL LINKAGE

REMOVE FUEL INJECTION CONTROL LINKAGE 1269

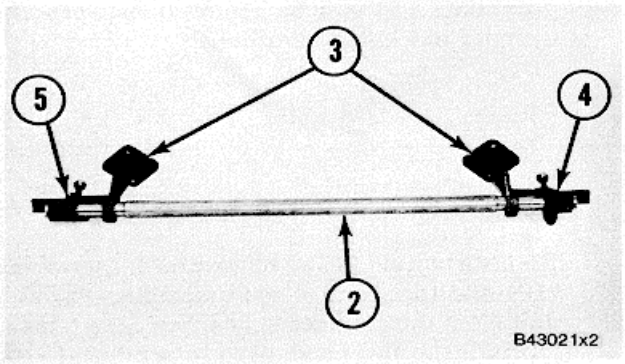
Tools Needed	A	B
1P510 Driver Group	1	
9S9082 Engine Turning Pinion		1



start by:

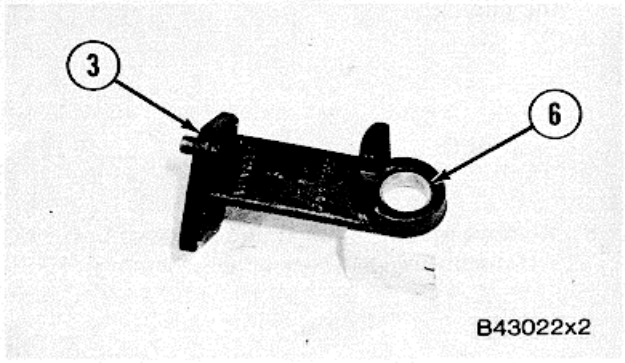
a) remove rocker shafts and push rods

b) remove front drive housing



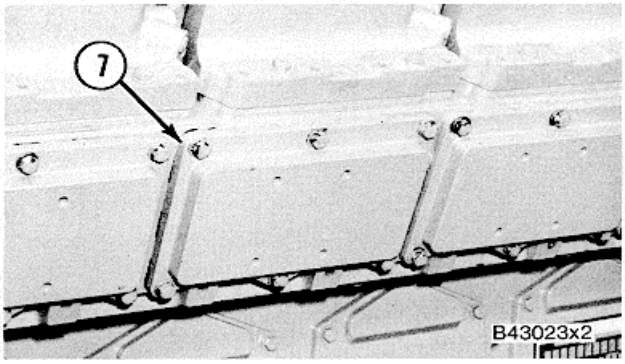
1. Remove the bolts that hold the brackets for shaft (2) to the front of the cylinder block. Disconnect the levers on shaft (2) from the levers on shafts (1) and remove shaft (2) from(the engine.

2. Remove levers (4) and (5) and brackets (3) from shaft (2).



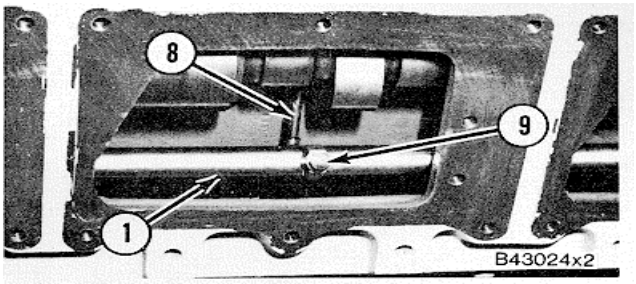
3. Remove bearings (6) from brackets (3) with tool group (A).

4. Remove access covers (7) from over the camshafts.



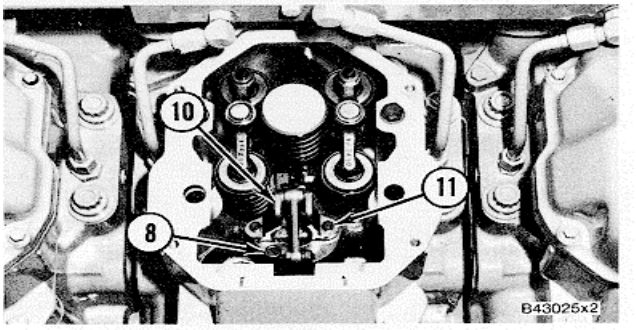
FUEL INJECTION CONTROL LINKAGE

5. Remove bolts (9) and the caps that hold the levers of rod assemblies (8) to the fuel control rod.

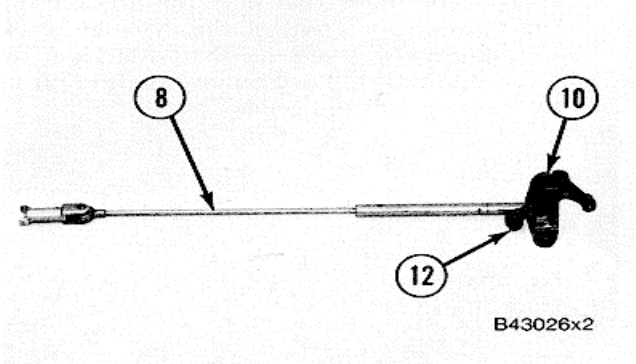


6. If necessary, remove the cover from the front right side of the flywheel housing and use tool (B) to turn the engine flywheel until the camshaft is moved in a position so the levers of rod assemblies (8) can be removed between the cylinder block and camshaft.

7. Remove bolts (11) and remove lever assemblies (10) and fuel control rod assemblies (8) as a unit from the cylinder heads. See Step 6 if the levers on the lower ends of rod assemblies (8) do not have enough clearance to be removed from the engine.

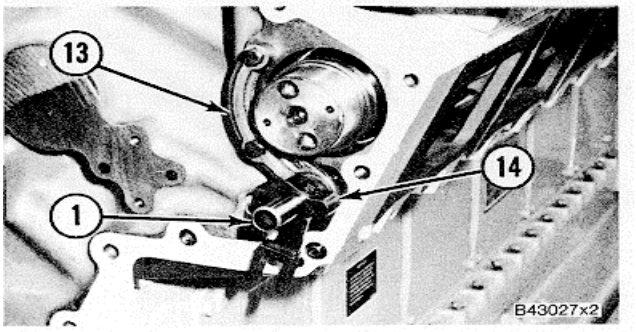


8. Remove locknut (12) and the washer to remove rod assembly (8) from lever assembly (10).



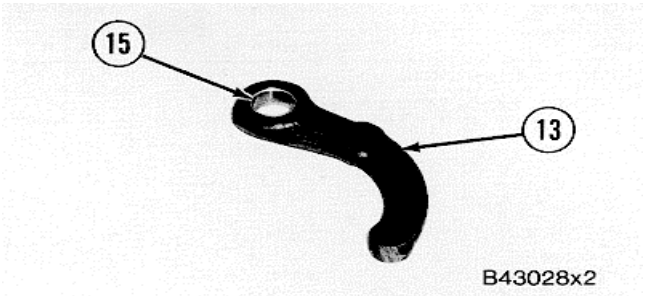
9. Remove levers (14) from control shafts (1).

10. Remove the bolts and supports(13) from each side of the engine.

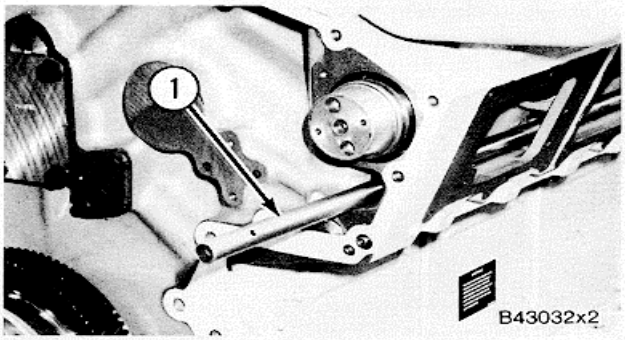


FUEL INJECTION CONTROL LINKAGE

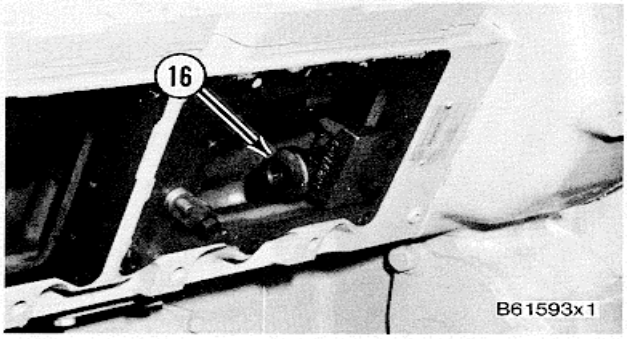
11. If necessary, remove bearings (15) from supports (13) with tool group (A).



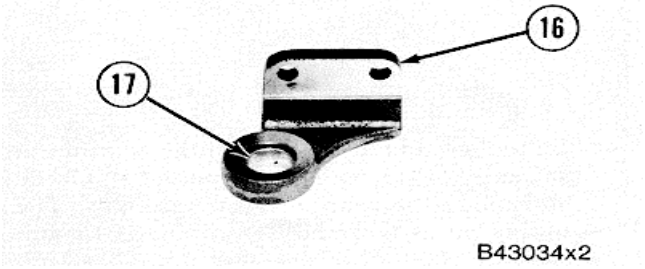
12. Pull control shaft (1) out of each side of the engine block.



13. Remove the bolts and remove two bracket assemblies (16) on each side of the 3512 Engine. The 3508 Engine has only one bracket assembly (16) on each side.



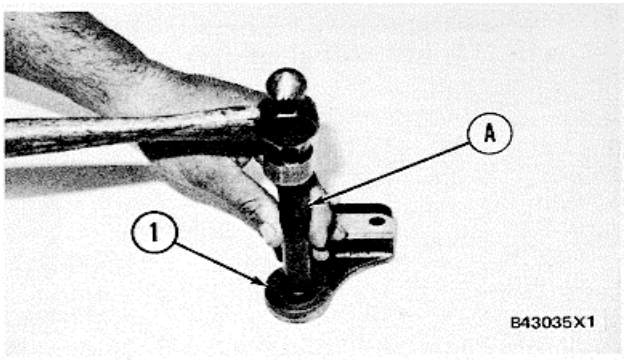
14. If necessary, use tool group (A) to remove bearings (17) from bracket assemblies (16).



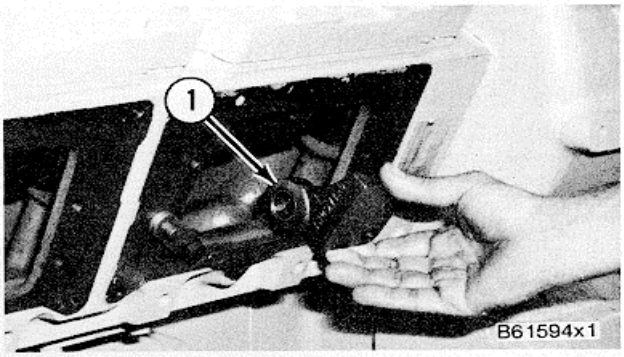
FUEL INJECTION CONTROL LINKAGE

INSTALL FUEL INJECTION CONTROL LINKAGE 1269-12

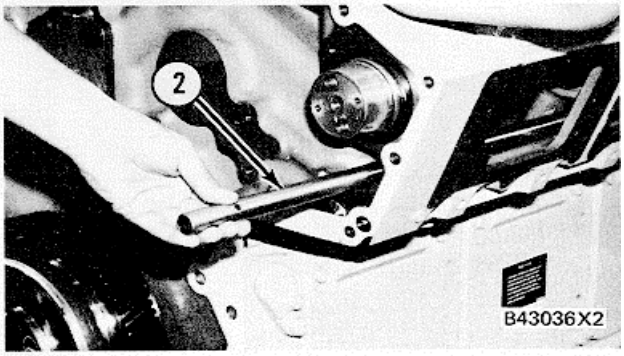
Tools Needed	A	B
1P510 Driver Group	1	
9S9082 Engine Turning Pinion		1



1 Use tool group (A) to install the bearings in bracket assemblies (1) until they are in the center of their bores. Check the bore in the bearings after assembly. The bearing bores must be 21.925 ± 0.015 mm (.8632 ± .0006 in.).

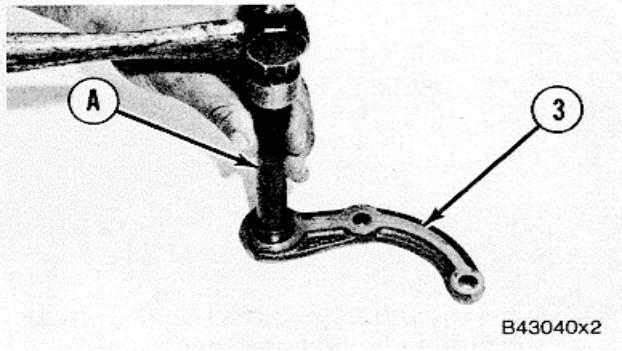


2. Install two bracket assemblies (1) on each side of the 3512 Engines. Install one bracket assembly (1) on the 3508 Engines.



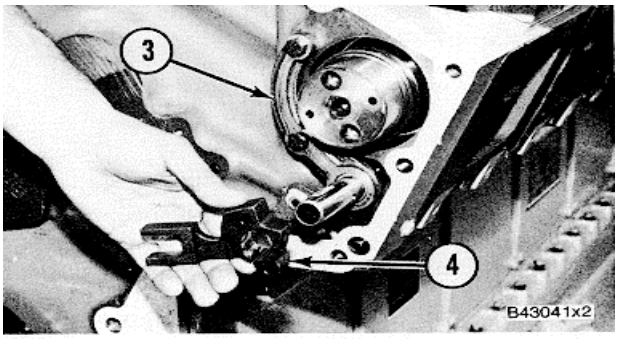
3. Install control shaft (2) on each side of the engine block.

4. Use tool group (A) and install the bearings in the center of the bores in supports (3). Check the bore in the bearings after assembly. The bearing bores must be 21.925 ± 0.015 mm (.8632 ± .0006 in.).

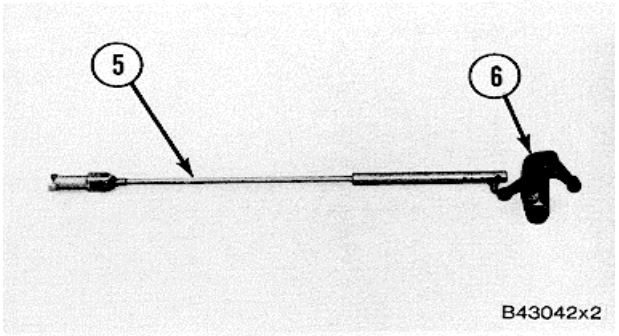


FUEL INJECTION CONTROL LINKAGE

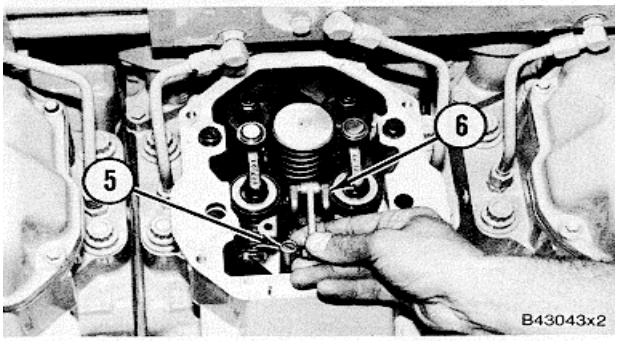
5. Install supports (3) to hold the front of the control shafts. Install levers (4) on each of the control shafts.



6. Connect lever assembly (6) to rod assembly (5).

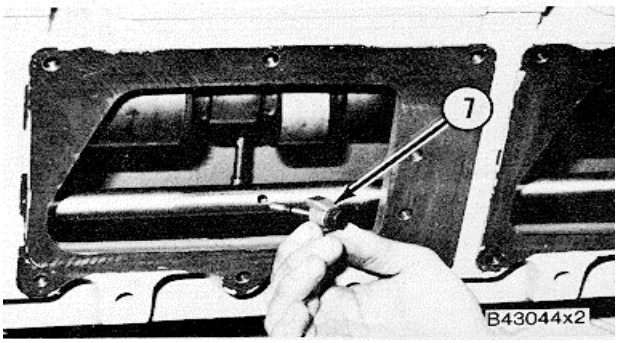


7. Install lever assembly (6) and rod assembly (5) as a unit in each cylinder head. If necessary, use tool (B) to turn the engine flywheel until the camshaft moves enough to permit the lever of the rod assembly to move into position.



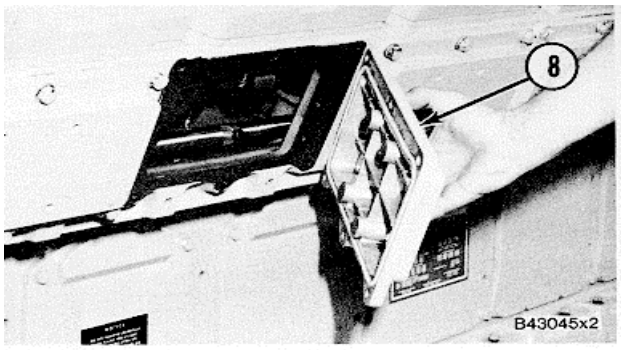
8. Make sure lever assembly (6) is engaged correctly with the fuel injection pump rack and install the two bolts to hold it in place.

9. Make sure the lever for the fuel control and assembly is in position on the control shaft and install the bolt and cap (7).

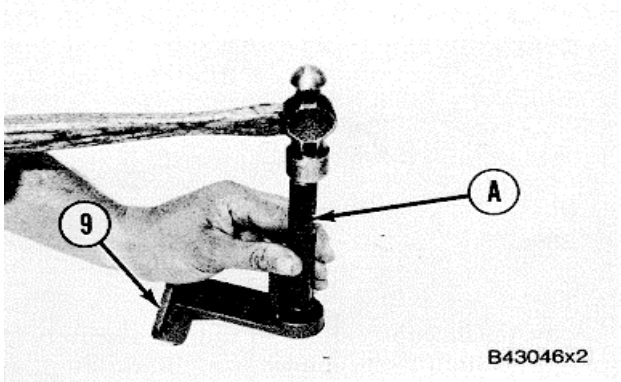


FUEL INJECTION CONTROL LINKAGE

10. Install access covers (8) and seal over the camshafts and control rods.

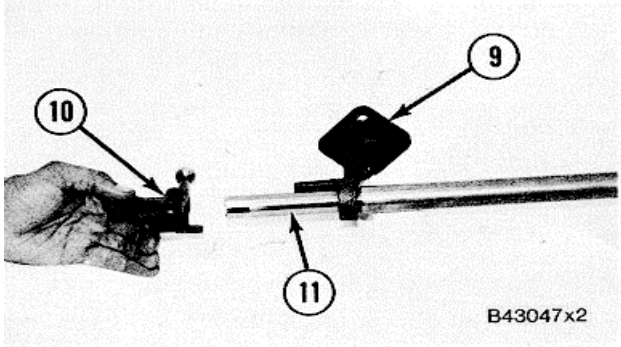


11. Use tool group (A) and install the bearings in the center of the bores in front control shaft brackets (9). Check the bore in the bearings after assembly. The bearing bores must be 21.925 + 0.015 mm (.8632 ± .0006 in.). If necessary, make a replacement of the pins in brackets (12). The pins must extend 8.0 + 0.5 mm (.315 ± .020 in.) above the surface of brackets (9).

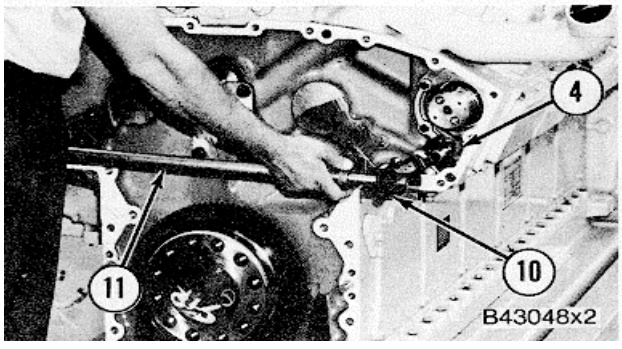


12. Install brackets (9) and levers (10) on the ends of front control shaft (11).

13. Put shaft (11) in position on the front of the engine. Make sure levers (10) and (4) are engaged correctly and install the bolts to hold the brackets and shaft (11) to the engine.



NOTE: After assembly the control shafts must turn freely by hand and the linkage must return to the **"SHUTOFF"** position when it is turned and released. See **TESTING AND ADJUSTING** section for the correct adjustment of the fuel injection control group.



end by:

a) rocker shafts and push rods

b) front drive housing

CYLINDER HEADS

REMOVE CYLINDER HEADS 1101-11

	Tools Needed	A	B
9S9082	Engine Turning Pinion	1	
6V2156	Link Bracket	2	

start by:
a) remove rocker shafts and push rods

1. Drain the coolant from the cooling system.

2. Shut off the fuel supply to the engine.

3. Remove fuel lines (2) from the cylinder head and fuel line manifold (1). Remove the bolts and remove fuel line manifold (1) and the bracket from the cylinder head.

4. Remove the access cover from over the camshaft and remove bolt (4) and cap (5) that hold fuel rod assembly (3) to the fuel control shaft.

5. Remove bolts (7) and remove lever assembly " (6) and fuel rod assembly (3) as a unit. If necessary remove the cover from the front right side of the flywheel housing and use tool (A) to turn the engine flywheel until the camshaft is moved in a position so the lever of rod assembly (3) can be removed between the engine block and camshaft.

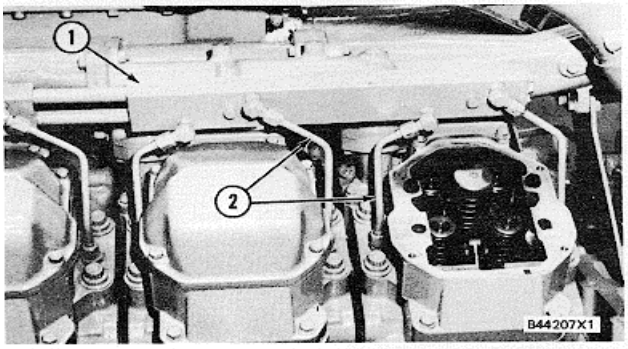
6. Remove the bolts and remove valve cover base (10) and the gasket from the cylinder head.

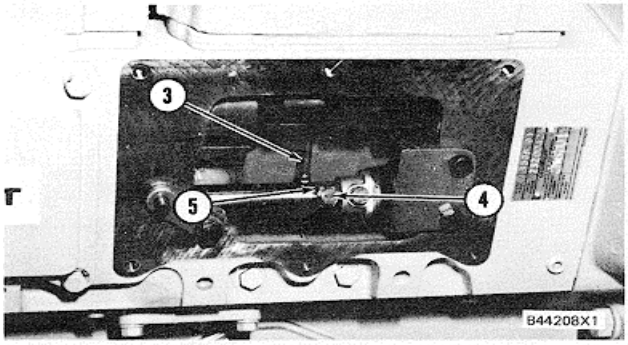
7. Remove bolt (8) and clamp (11) from the fuel injector.

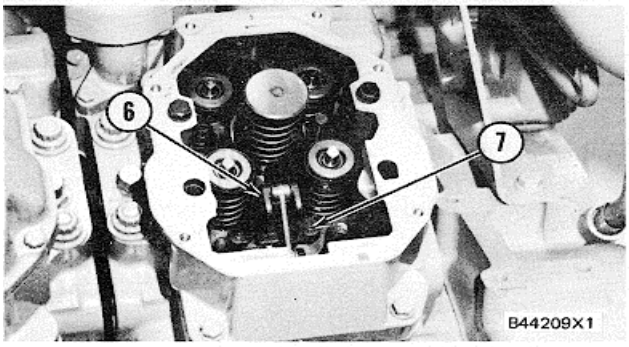
NOTICE

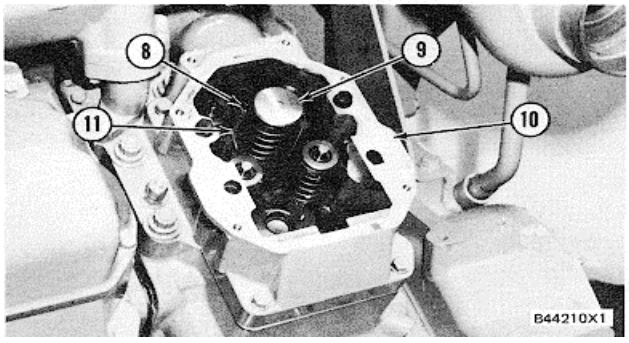
Do not put a force on the fuel injection rack or cause damage to it when the injectors are removed.

8. Use a pry bar to loosen fuel injector (9) and remove the injector from the cylinder head.



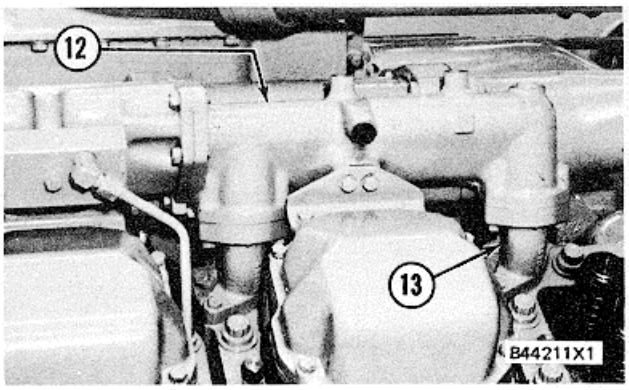




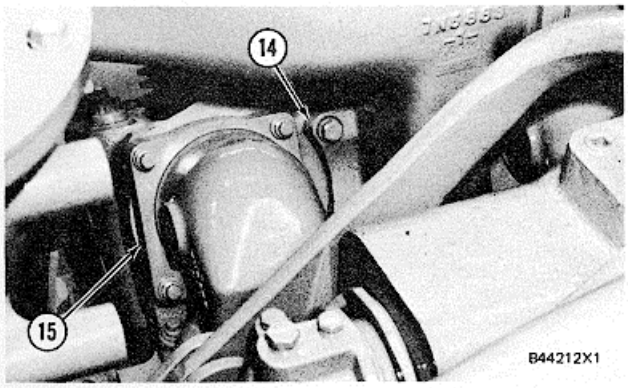


CYLINDER HEADS

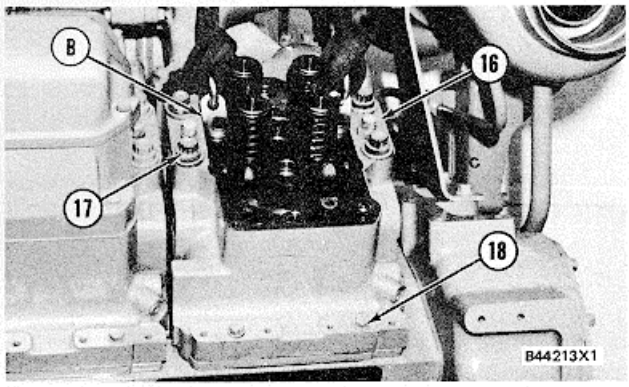
9. Remove a section of water manifold (12) and elbows (13) from the cylinder head



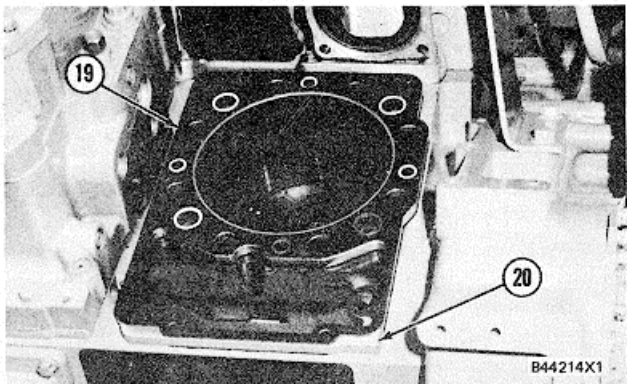
10. Remove the bolts that hold air inlet elbow (15) and exhaust manifold (14) to the cylinder head.



11. Fasten a hoist to cylinder head (16) with tooling. Remove bolts (17) and (18) to remove cylinder head (16) from the engine. The weight of the head is 45 kg (100 lb.).



12. Remove head gasket (19) and the seals from the spacer plate. Remove spacer plate (20) and the gasket from the cylinder block.



CYLINDER HEADS

INSTALL CYLINDER HEADS 1101-12

	Tools Needed	A	B
6V2156	Link Bracket	2	
9S9082	Engine Turning Pinion		1

NOTE: A new spacer plate gasket must be installed when the cylinder head is removed. See REMOVE AND INSTALL SPACER PLATE.

1. Thoroughly clean the spacer plate and bottom surface of the cylinder head. Install a new spacer plate gasket and the spacer plate on the cylinder block. Install a new head gasket and seals on the spacer plate. Do not use any adhesives.

2. Put the gaskets for the exhaust manifold and air inlet elbow in position. Use heavy grease or 5N5561 Silicone Lubricant to hold the gaskets in position.

3. Fasten a hoist to the cylinder head with tooling (A). Put the cylinder head into position on the spacer plate.

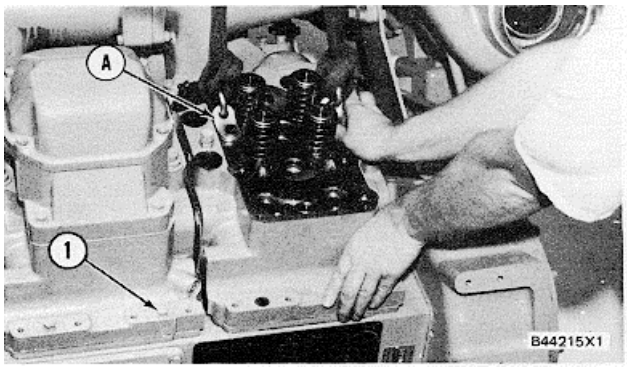
4. Put clean engine oil on the threads of the cylinder head bolts. Install the cylinder head bolts and washers. Tighten the bolts in the following sequence:
   a) Tighten all of the bolts in the following sequence: a) Tighten all of the bolts to a torque of 30 ± 5 N•m (22 ± 4 lb. ft.).
   b) Tighten bolts 1 through 8 in number sequence to a torque of 270 ± 35 N•m (200 ± 25 lb. ft.).
   c) Tighten bolts 1 through 8 in number sequence to a torque of 450 ± 20 N•m (330 ± 15 lb. ft.).

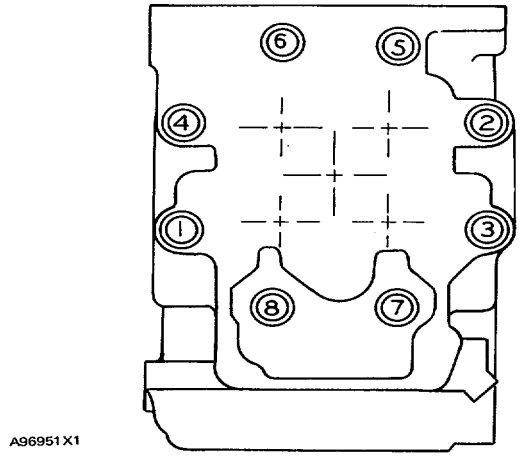
5. Install bolts (I) and the washers to hold the cylinder head to the engine.

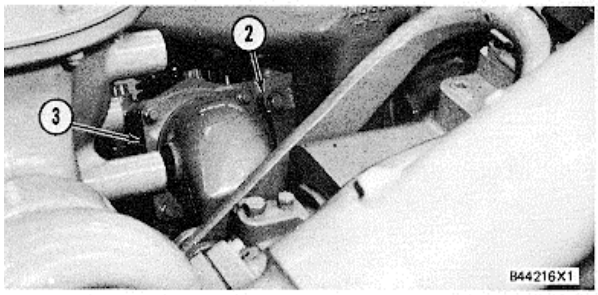
6. Put 5P3931 Anti-Seize Compound on the threads of the bolts for exhaust manifold (2) and install the bolts and washers to hold manifold (2) to the cylinder head.

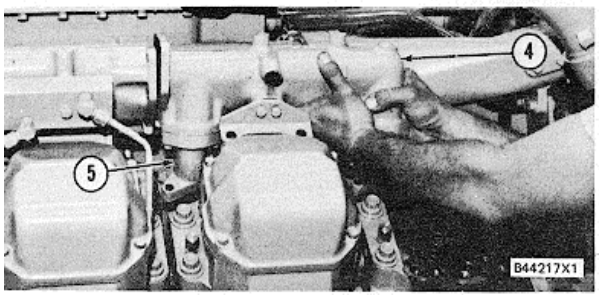
7. Install the bolts and washers to hold air inlet elbow (3) to the cylinder head.

8. Put the gaskets, water manifold (4) and elbows (5) in position as a unit and install the bolts.









CYLINDER HEADS

9. Make sure the three O-ring seals are installed on injector (6) and put clean engine oil on them and in the bore for the injector.

NOTICE

Do not tap or hit on the injector follower to install the injector. Damage and failure to the injector can be the result.

10. Put injector (6) in position. Install the clamp, washer and bolt. Tighten the bolt to push injector (6) all the way in its bore. Tighten the bolt to a torque of 65 + 7 N•m (48 + 5 lb. ft.).

11. Check to make sure the fuel injection rack moves freely by hand in the injector after the injector is installed.

12. Make sure the O-ring seals are installed around the three dowels in the bottom of valve cover base (7). Put the gasket and base (7) in position and install the bolts to hold them to the cylinder head.

13. Put fuel control rod assembly (9) and lever assembly (8) in position in the cylinder head. If necessary, use tool (B) to turn the engine fly 44219Xl wheel until the camshaft moves enough to permit the lever of rod assembly (9) to move into position.

14. Make sure lever assembly (8) is engaged correctly with the fuel injection rack and install the two bolts and washers to hold it in place.

15. See TESTING AND ADJUSTING section for the correct adjustment of the fuel injection control group.

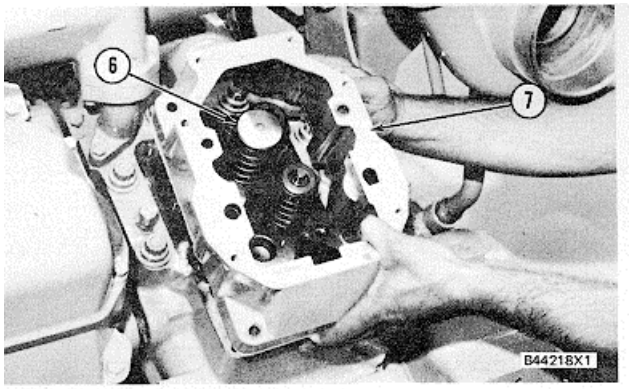
16. Make sure the lever for the fuel control and assembly is in position on control shaft (10) and install the bolt and cap (11).

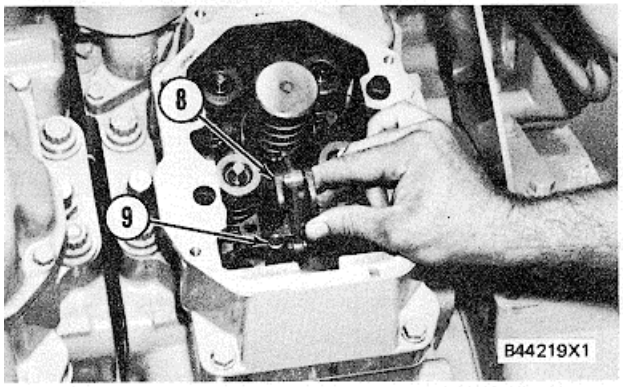
17. Install the access cover and seal over the camshaft and control shaft (10).

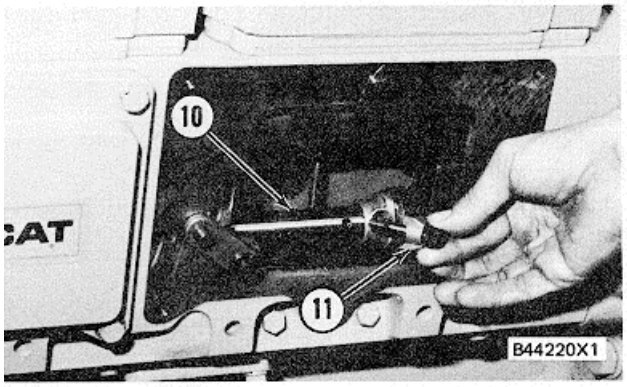
18. Make sure the 0-ring seals for the fuel manifold and lines are installed and have clean engine oil on the seals. Install fuel manifold (12) and fuel lines (13) on the engine.

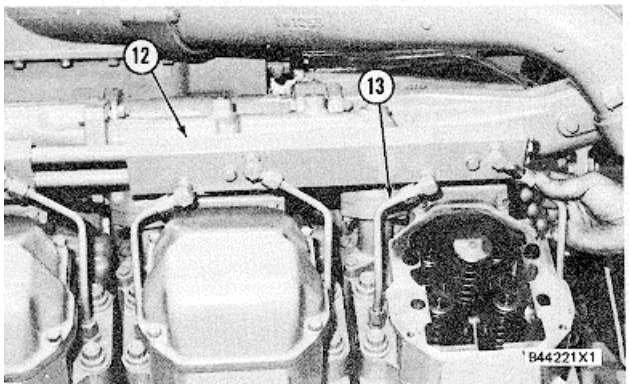
19. Turn the fuel supply to the engine.

20. Fill the cooling system with coolant to the correct level.
end by:
   a) install rocker shafts and push rods









VALVES

REMOVE VALVES 1105-11

	Tools Needed	A	B
5S1330	Compressor Assembly	1	
8S2263	Valve Spring Tester		1

start by:
a) remove cylinder heads

1. Use tool (A) to put valve springs (1) under compression.

2. Remove locks (2) from the valve stem.

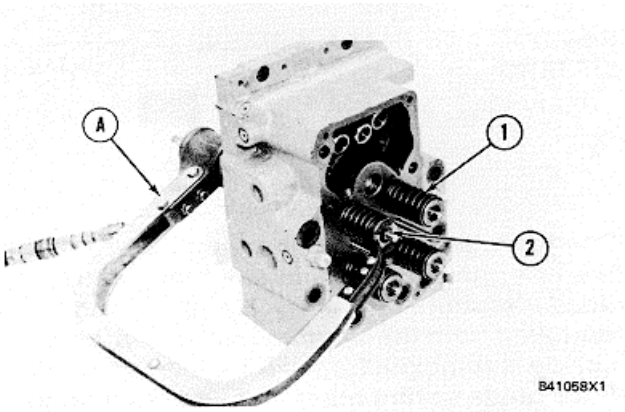
3. Release the tension on springs (1) with tool (A) and remove tool (A), the rotor coil assembly, springs (1) and washer from the valve stem and guide.

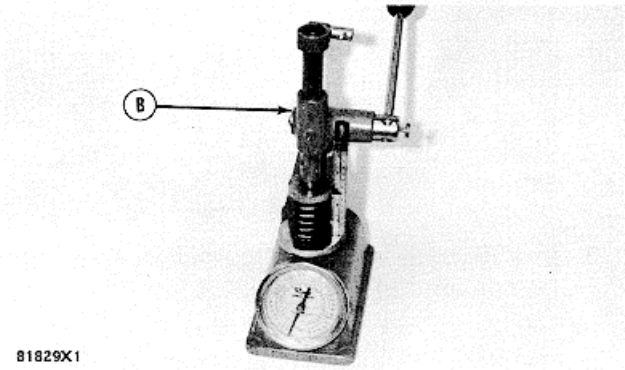
4. Remove the valves from the cylinder head.

NOTE: If the valves can be used again, put identification on them as to their location for installation purposes.

5. Check the valve spring force with tool (B). See SPECIFICATIONS for the correct spring force values.

6. Do Steps I through 5 again for the remainder of the valves.





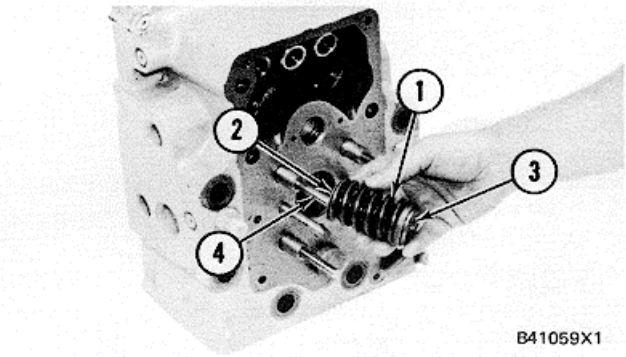
INSTALL VALVES 1105-12

	Tools Needed	A
5S1330	Compressor Assembly	1

1. Put clean engine oil on the valve stem and install valve (4) in the cylinder head.

2. Put washer (2), the inner spring, outer spring (I) and rotocoil assembly (3) over the valve stem and valve guide.

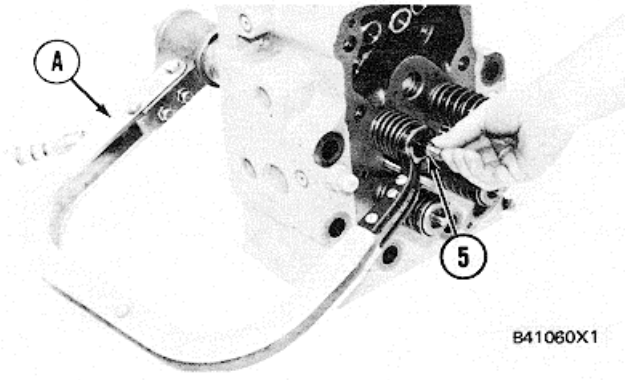
3. Put the valve springs under compression with tool (A) and install locks (5).



⚠ WARNING

The locks can be thrown from the valve when the spring compressor is released if they are not in their correct position on the valve stem. To prevent possible personal injury be sure to stay away from in front of the valve retainer and springs.

4. Remove tool (A) and hit the top of the valve with a plastic hammer to be sure the locks are in their correct position on the valve stem.



5. Do Steps 1 through 4 again for the remainder of valves.

end by:
a) install cylinder heads

VALVE LIFTERS, BRIDGE DOWELS

REMOVE AND INSTALL VALVE LIFTERS 1209-10

start by:
a) remove cylinder heads

NOTICE

The lifter guide springs can be assembled on the lifter assembly or installed in the cylinder head lifter bore only once. If a lifter assembly is removed from the cylinder head or a lifter guide spring is removed from a lifter assembly, a new lifter guide spring must be installed at assembly.

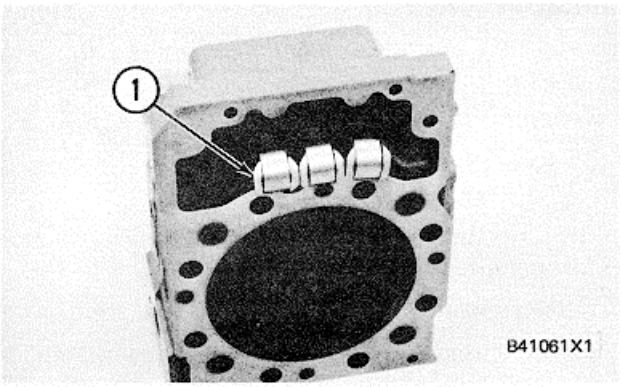
1. Pull lifter assemblies (1) out of the cylinder head lifter bore.

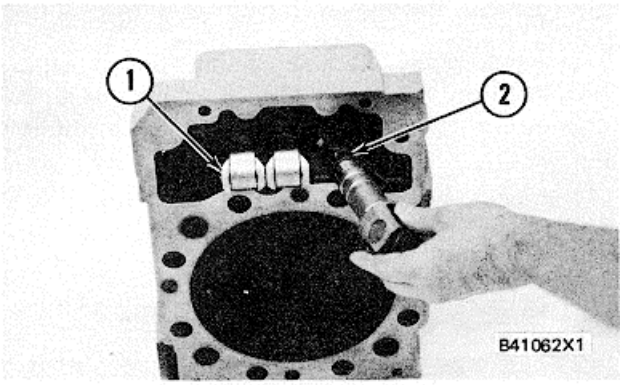
2. Remove the guide springs from the lifter assemblies.

3. Install guide spring (2) on each of the lifter assemblies (i1).

4. Put lifter assemblies (I) in a container of clean engine oil before they are installed. Install lifter assemblies (1) in the lifter bore of the cylinder head.

end by:
a) install cylinder heads





REMOVE AND INSTALL BRIDGE DOWELS

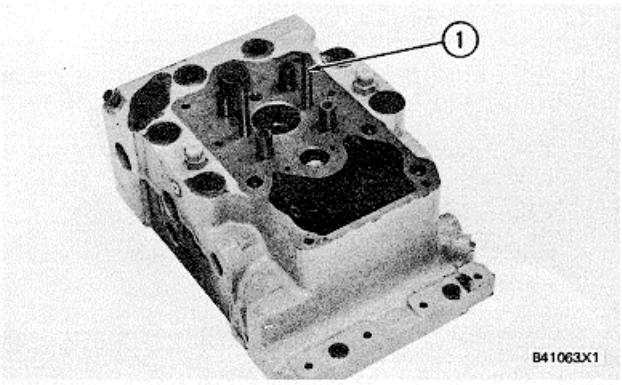
	Tools Needed	A	B
5P944	Dowel Puller Group	1	
5P942	Extractor	1	
6V4009	Dowel Driver		1

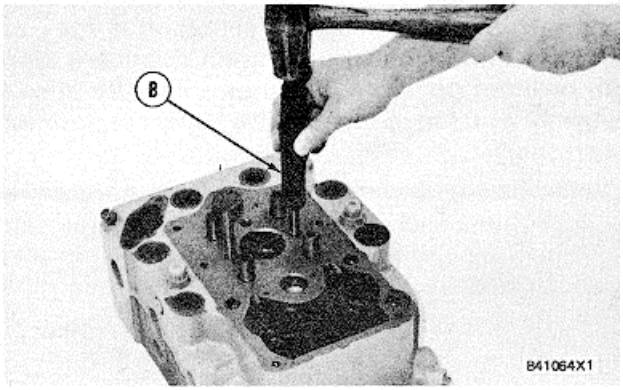
start by:
a) remove valves

1. If necessary, use tooling (A) to remove bridge dowels (1) from the cylinder head.

2. Use tool (B) and a hammer to install dowels (1) in the cylinder head. The dowels must extend 66.5 ± 0.5 mm (2.62 ± .02 in. above the head surface.

end by:
a) install valves





VALVE SEAT INSERTS, VALVE GUIDES

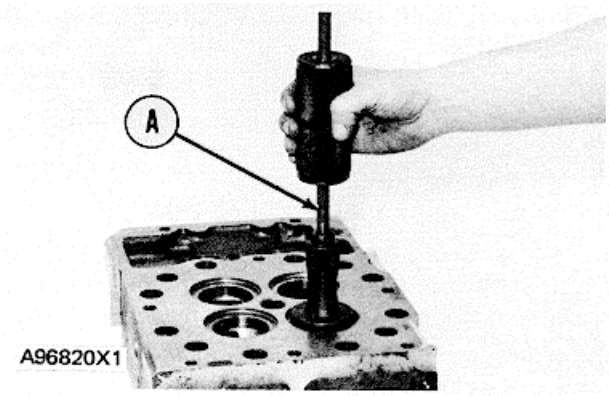
REMOVE VALVE SEAT INSERTS 1103-11

	Tools Needed	A
9S3095	Handle Assembly	1
6V4008	Extractor	1

start by:
a) remove valves

1. Remove the valve seat inserts from the cylinder head with tooling (A).

2. Clean and remove any burrs from the valve seat bores.



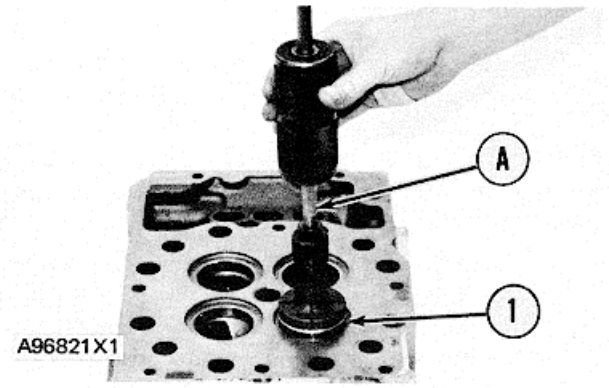
INSTALL VALVE SEAT INSERTS 1103-12

	Tools Needed	A
9S3095	Handle Assembly	1
6V4008	Extractor	1

1. Lower the temperature of valve seat inserts (1) and install them with tooling (A).

NOTICE

Do not make the diameter of the extractor larger when the insert is installed or damage to the insert and cylinder head can be the result.



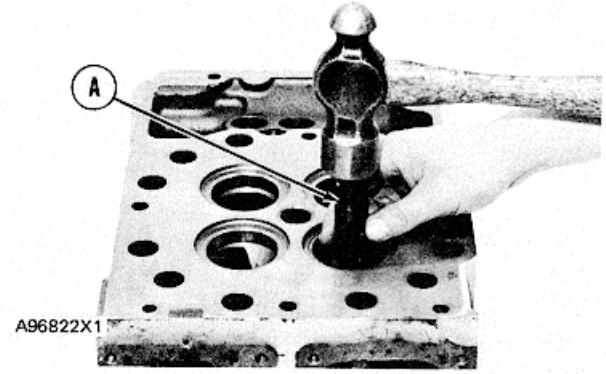
2. Grind valve seat inserts (1) as to the values given in SPECIFICATIONS.
end by:
a) install valves

REMOVE VALVES GUIDES 1104-11

	Tools Needed	A
7M3975	Driver	1

start by:
a) remove valves

1. Use tool (A) and a hammer to push the valve guides out of the cylinder head as shown.

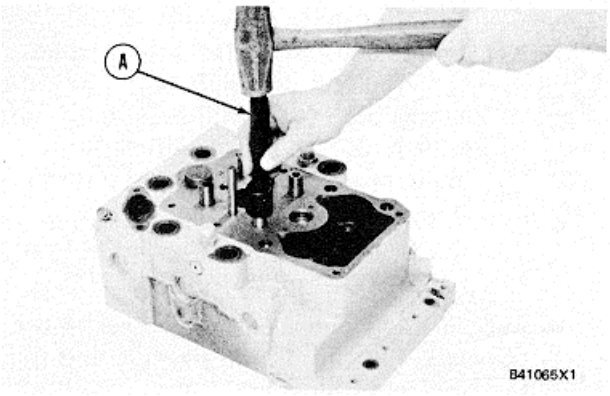


INSTALL VALVE GUIDES 1104-12

	Tools Needed	A
7M3975	Driver	1
5P1729	Bushing	1

1. Put clean engine oil on the outside diameter of the valve guides.

2. Use tooling (A) and install the valve guides until they extend 26 mm (1.024 in.) from the surface of the cylinder head. See SPECIFICATIONS for the correct values for the inside diameters of new and used valve guides.
end by:
a) install valves



CONNECTING ROD BEARINGS

REMOVE AND INSTALL CONNECTING ROD BEARINGS 1219-10

	Tools Needed	A
9S9082	Engine Turning Pinion	1

start by:

a) remove piston cooling jets

1. Use tool (A) and turn the engine flywheel to move the connecting rod cap bolts into a position for removal.

2. Remove bolts (I) to remove bearing caps (2) from the crankshaft and connecting rod. Remove the lower half of the bearings from caps (2).

3. Push the connecting rods away from the crankshaft and remove the upper halves of the bearings from the rods.

NOTE: Install rod bearings dry when the clearance checks are made. Put clean engine oil on the rod bearings for final assembly.

4. Clean the surfaces where the bearing halves fit. Install bearing halves (3) in the rods and caps (2). Put 5P960 Multipurpose Type Grease on the bolt threads and contact surfaces of the bolts and caps.

5. Make a check of the bearing clearance with Plastigage. Put caps (2) in position on the connecting rods and make sure the number on the side of the cap is next to and respective with the number on the side of the connecting rod. Tighten the bolts in the number sequence shown as follows:

NOTICE

Do not use an impact wrench to tighten the bolts the additional 90 ± 50 of a turn more.

NOTE: Bolts (6) and (7) are on the end of the rod cap opposite the end that has the location pin for correct installation.

a) Tighten bolts No. 4 and 5 to a torque of 90 ± 5 N•m (65 ± 4 lb. ft.).

b) Tighten bolts No. 6 and 7 to a torque of 90 ± 5 N•m (65 ± 4 lb. ft.).

c) Tighten bolts No. 6 and 7 again to a torque of 90 ± 5 N•m (65 ± 4 lb. ft.).

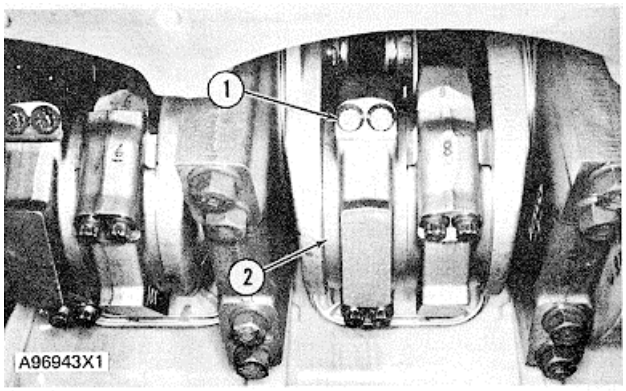
d) Tighten each bolt 90 ± 50 of a turn more.

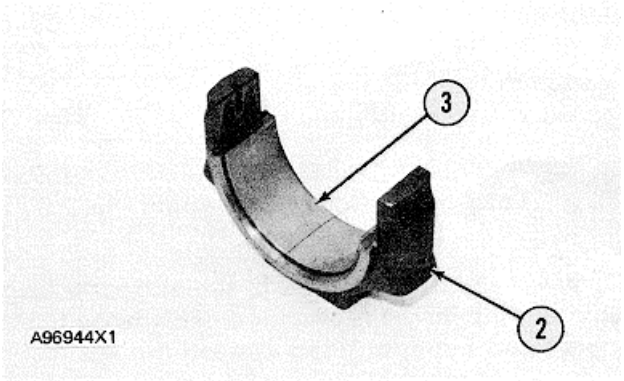
6. Remove the cap and measure the Plastigage. The rod bearing clearance must be 0.107 to 0.218 mm (.0042 to .0086 in.).

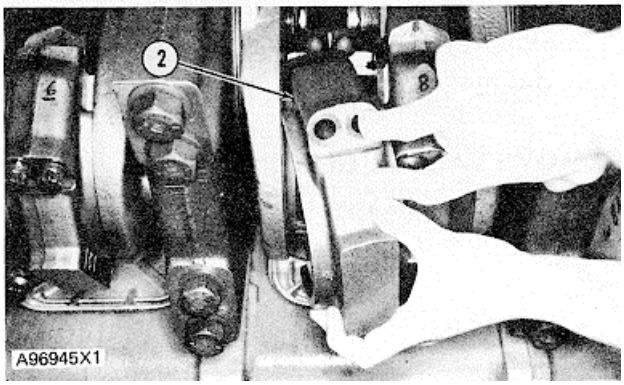
7. Put clean engine oil on both halves of the rod bearings. Put caps (2) in position and tighten the bolts as in Step 5.

end by:

a) install piston cooling jets







FRONT BALANCER GROUP (3508)

REMOVE FRONT BALANCER GROUP 1220-11

	Tools Needed	A	B
9S9082	Engine Turning Pinion	1	
1P520	Driver Group		1

start by:
a) remove front drive housing

1. Remove the bolts that hold the brackets for shaft (2) to the front of the cylinder block. Disconnect the levers on shaft (2) from the levers on shafts (I) and (3) and remove shaft (2) from the engine.

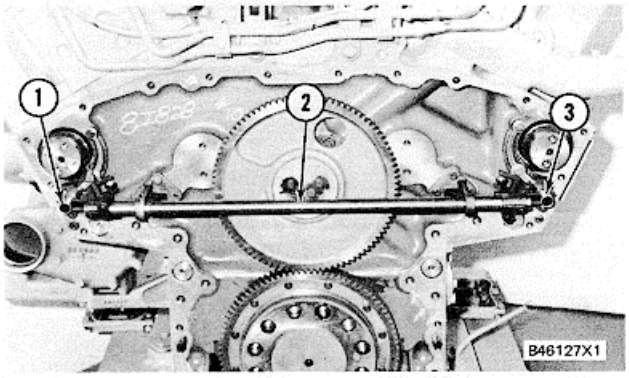
2. Use tool (A) to make an alignment of the marks on balancer gear (4) and crank gear (6) according to the rotation of the engine as shown.

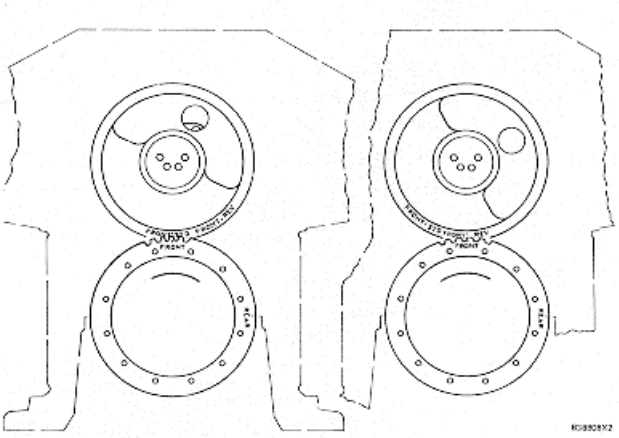
3. Remove the bolts and remove plate (5) from balancer gear (4). Remove balancer gear (4) from the shaft.

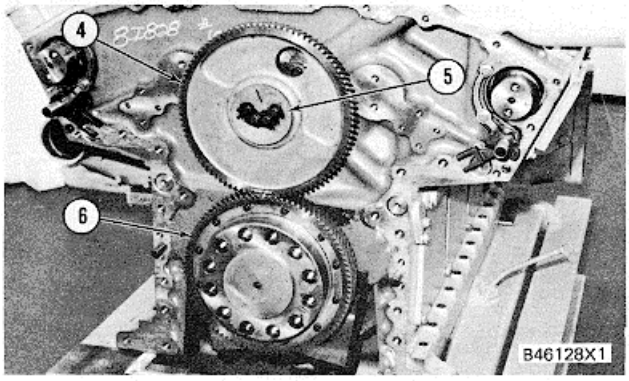
4. Use tool group (A) and a press to remove bearing (7) from balancer gear (4).

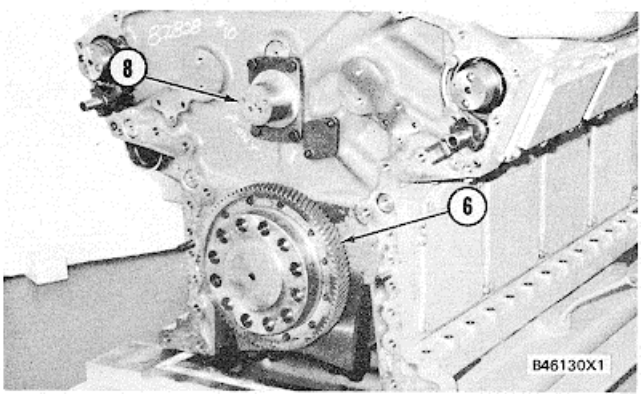
5. Remove shaft (8) from the end of the cylinder block.

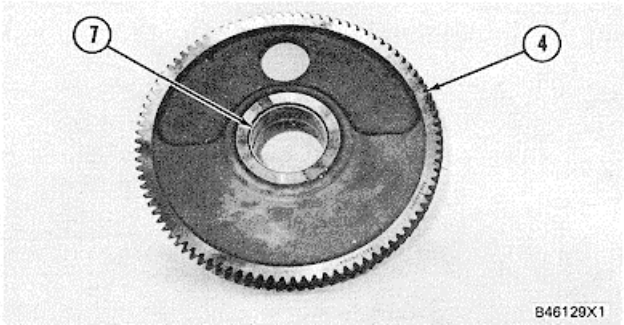
6. Remove crank gear (6) from the end of the crankshaft.











FRONT BALANCER GROUP (3508)

INSTALL FRONT BALANCER GROUP

	Tools Needed	A
1P520	Driver Group	1

1. Put crank gear (2) in position on the end of the crankshaft and install the bolts.

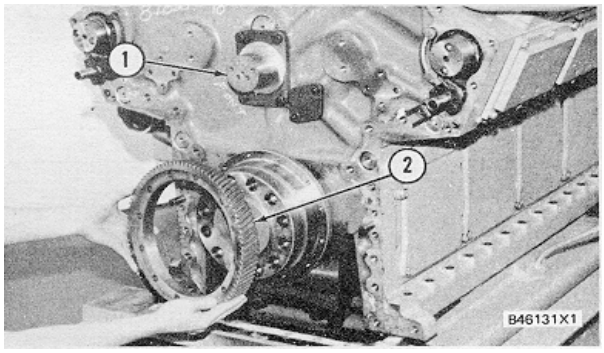
2. Install shaft (1) on the end of the cylinder block.

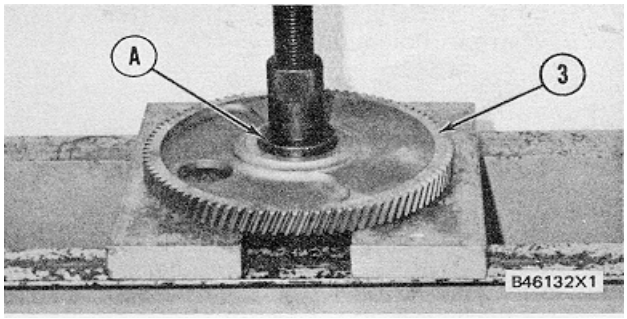
3. Use tool group (A) and a press to install the bearing in balancer gear (3). Make sure the bearing joint is in the center of the heavy section in gear (3). The bore in the bearing must be 75.00 ± 0.053 mm (2.9528 ± .0021 in.) after assembly.

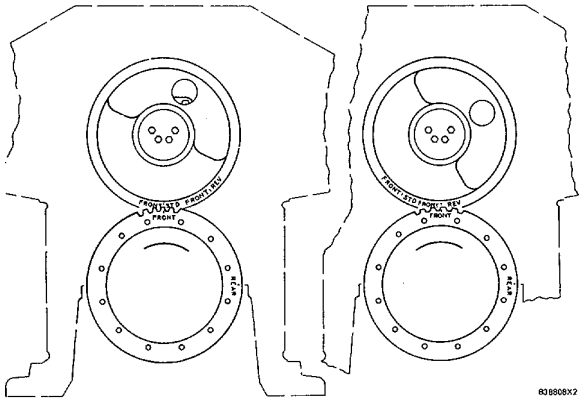
4. Put balancer gear (3) in position on the shaft. Make sure the marks on the balancer gear and the crank gear are in alignment according to the rotation of the engine as shown.

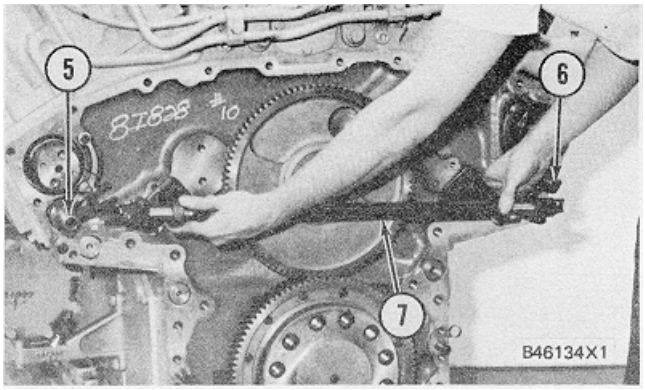
5. Install plate (4) and the bolts to hold it on the balancer gear.

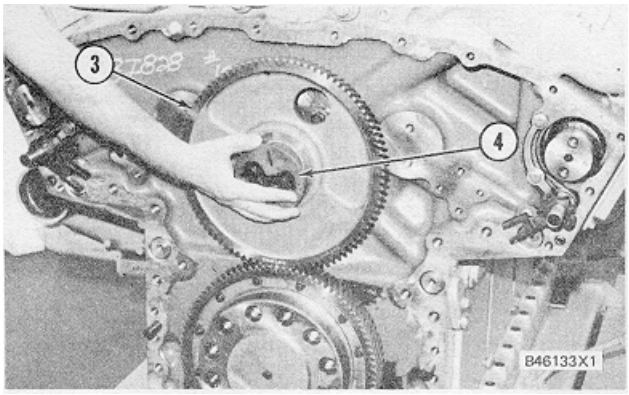
6. Put shaft (7) in position on the cylinder block. Make sure the levers on shaft (7) are correctly engaged with the levers on shafts (5) and (6) and install the bolts to hold the brackets and shaft (7) to the cylinder block.
   end by:
   a) install front drive housing











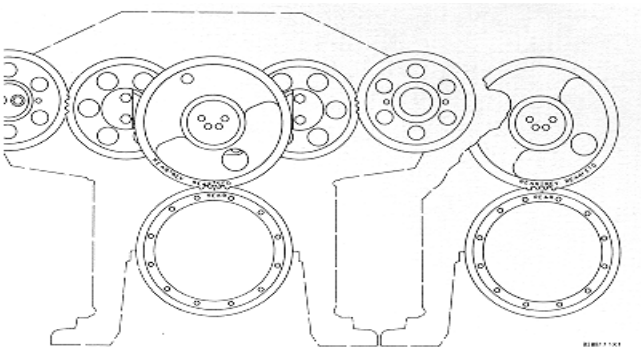
REAR GEAR GROUP

REMOVE REAR GEAR GROUP 1212-11

Tools Needed	A
1P520 Driver Group	1

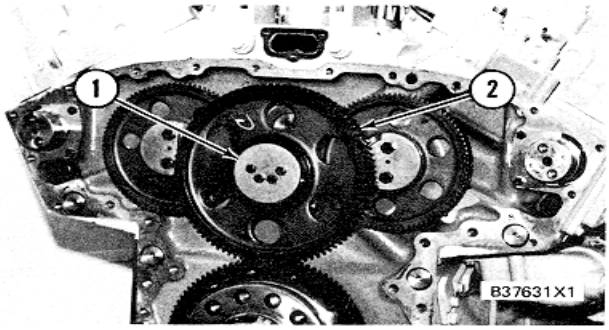
start by:
a) remove flywheel housing

NOTE: Before the flywheel housing is removed, the 3508 engine must be put in time to make sure the rear gear group is in alignment according to the rotation of the engine as shown.



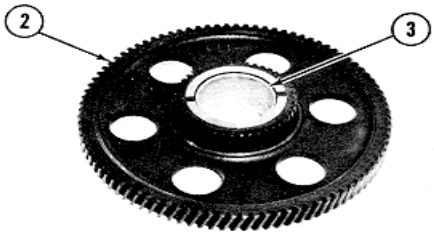
3508 ONLY

1. Remove plate (1) to remove gear assembly (2) from the shaft.

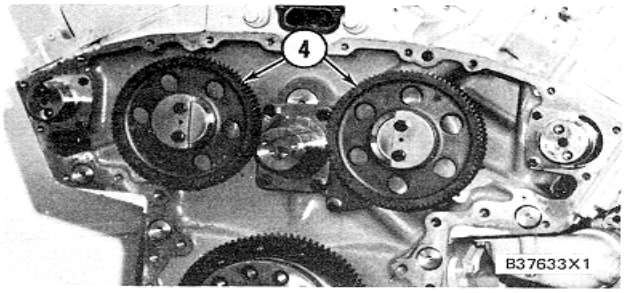


2. Use tool group (A) and a press to remove bearing (3) from gear assembly (2).

3. Use tool group (A) and a press to make a separation of the gears for gear assembly (2).

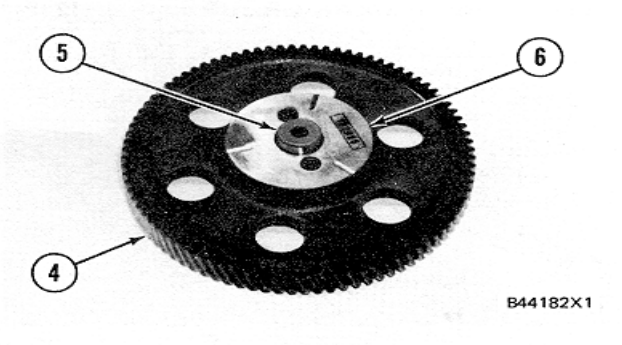


4. Remove the bolts to remove the shafts, gears (4) and the washers from the cylinder block.

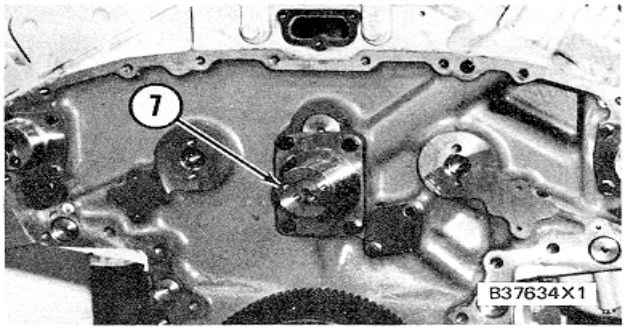


REAR GEAR GROUP

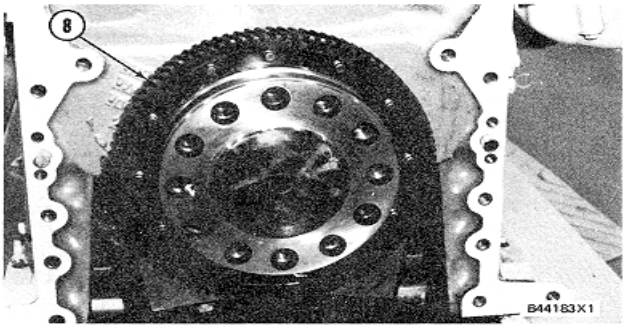
5. Remove washers (6) and shafts (5) from gears (4).



6. Use tool group (A) and a press to remove the bearings from gears (4). Remove shaft (7) from engine.



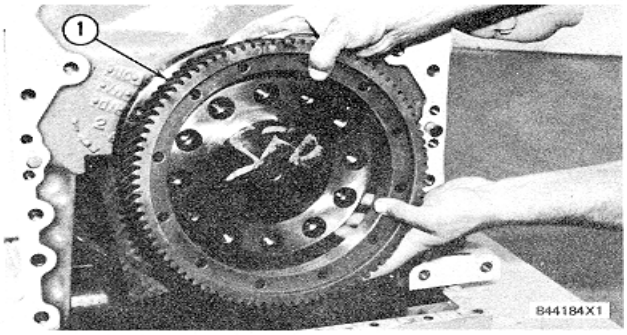
7. Remove the bolts and remove gear (8) from the end of the crankshaft.



INSTALL REAR GEAR GROUP 1212-12

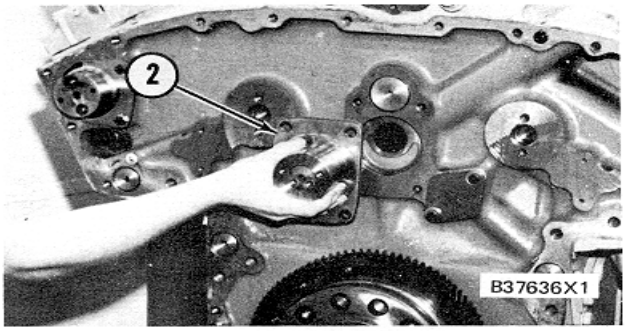
	Tools Needed	A
1P520	Driver Group	1

1. Put gear (1) in position on the end of the crankshaft and install the bolts.

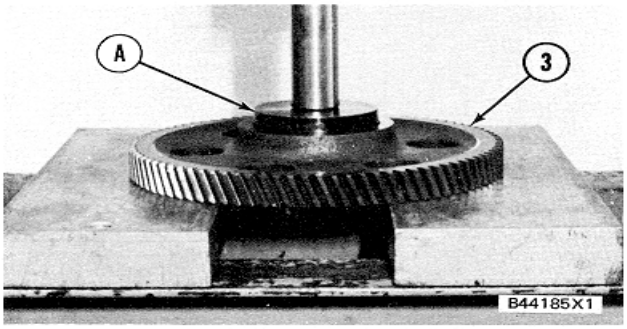


REAR GEAR GROUP

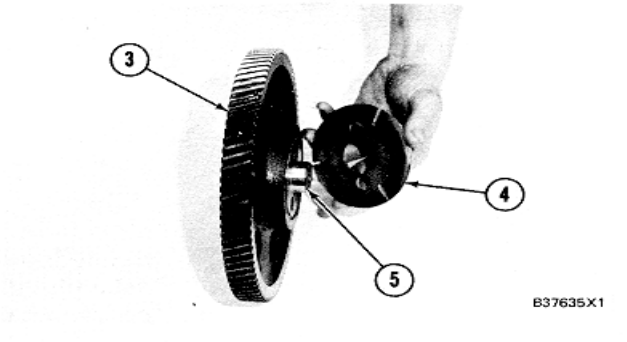
2. Install shaft (2) on the cylinder block.



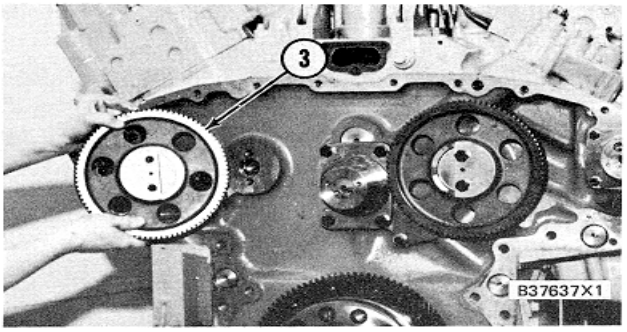
3. Use tool group (A) and a press to install the bearings in both gears (3) until the bearings are in the center of their bores. The bore in the bearing must be 75.00 ± 0.053 mm (2.9528 ± .0021 in.) after assembly.



4. Put clean engine oil on the bearings and install shafts (5) in gears (3). Install washers (4) on the shafts.

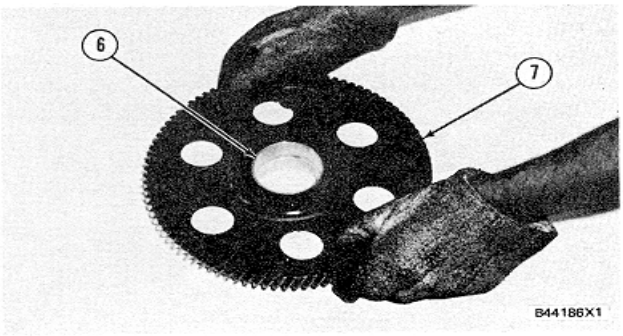


5. Put gears (3) in position on the cylinder block and install the bolts to hold the gears in position.



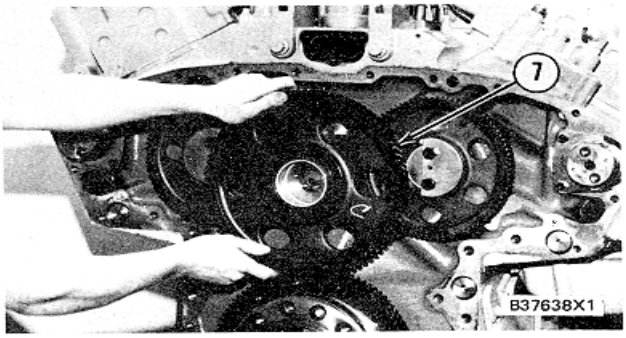
REAR GEAR GROUP

6. Use tool group (A) and a press to install bearing (6) in gear assembly (7). The bore in bearing (6) must be 75.00 ± 0.053 mm (2.9528 ± .0021 in.) after assembly.

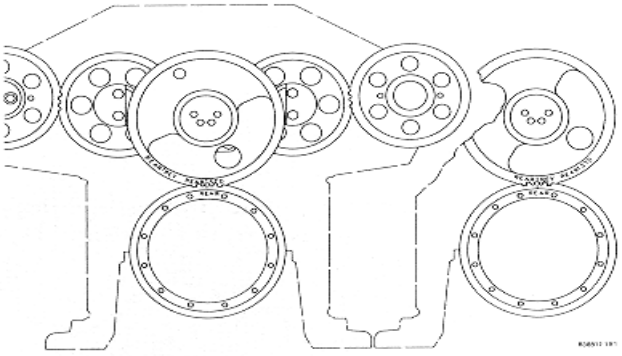


7. Heat the larger gear of gear assembly (7) to a maximum temperature of 400° C (752° F) and install it on the smaller gear as shown.

8. Put clean engine oil on the bearing and install gear assembly (7) on the shaft.



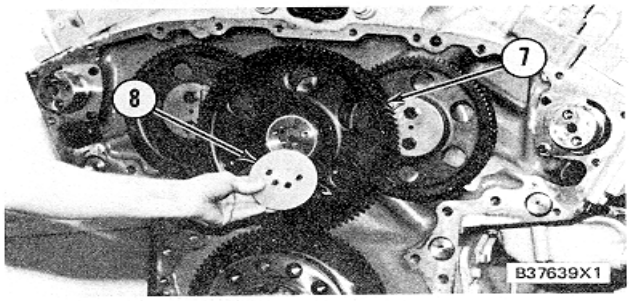
NOTE: Step 9 is for the 3508 Engine.



3508 ONLY

9. Put clean engine oil on the bearing and install the gear assembly on the shaft. Make sure the marks on the gear assembly and the crankshaft gear are in alignment according to the rotation of the engine as shown.

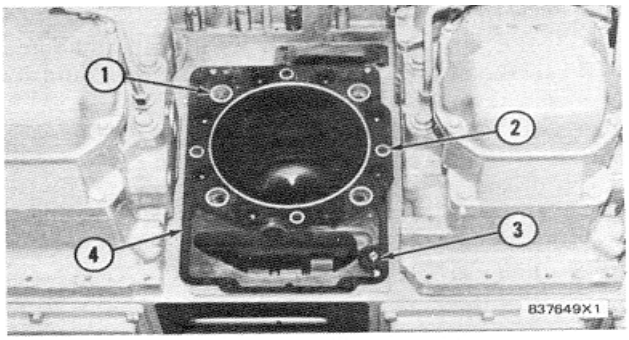
10. Put plate (8) in position on gear assembly (7) and install the bolts.
end by:
a) install flywheel housing



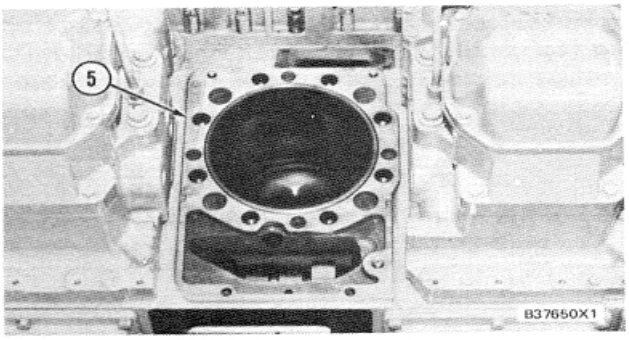
SPACER PLATES

REMOVE SPACER PLATES 1221-11

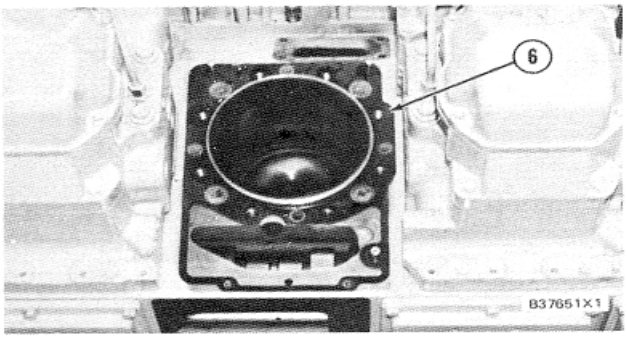
start by:
a) remove cylinder heads



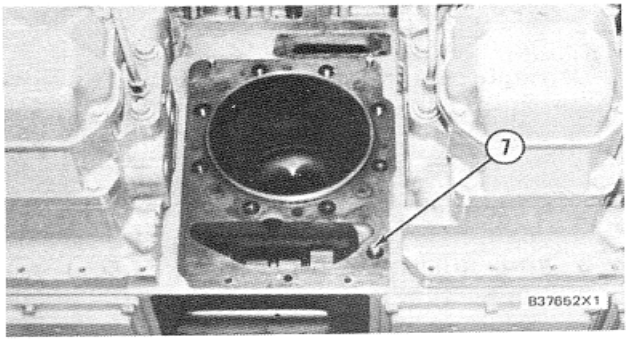
1. Remove gasket (4), seals (1), seals (2) and O-ring seal (3) from the spacer plate.



2. Remove spacer plate (5) from the dowels in the cylinder block.



3. Remove gasket (6) from the dowels.

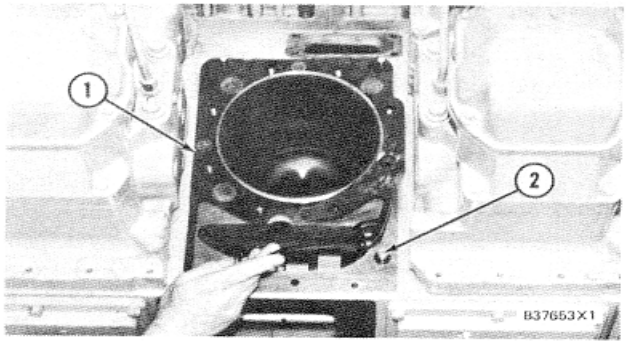


4. Remove the O-ring seal from around dowel (7).

SPACER PLATES

INSTALL SPACER PLATES 1221-12

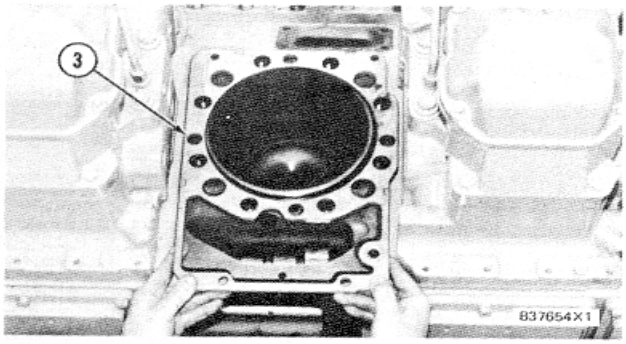
1. Make sure the spacer plate and the machined surface of the cylinder block are clean and free of dirt and foreign material.



2. Install the O-ring seal around dowel (2).

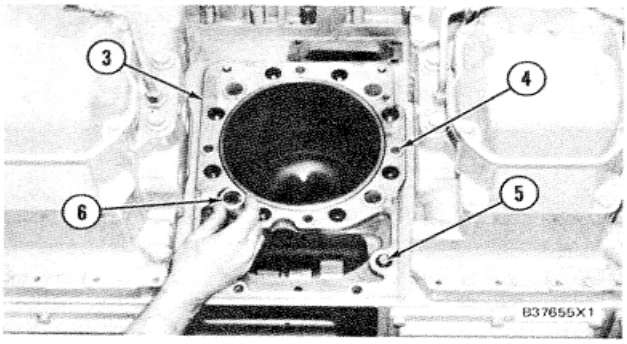
NOTICE

Both surfaces of the spacer plate gasket and the top of the cylinder block must be clean. Do not use a gasket adhesive on these surfaces.



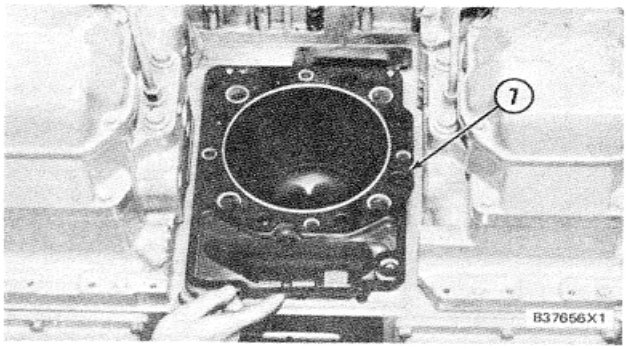
3. Install new spacer plate gasket (1) over the dowels in the cylinder block.

4. Install spacer plate (3) on the dowels.



5. Install the O-ring seal around dowel (5).

6. Install new water seals (4) and (6) in spacer plate (3).



7. Install new cylinder head gasket (7) on the spacer plate.

8. Check the cylinder liner projection. See INSTALL CYLINDER LINERS.
end by:
a) install cylinder heads

CRANKSHAFT MAIN BEARINGS

REMOVE CRANKSHAFT MAIN BEARINGS 1203-11

	Tools Needed	A	B	C
9S9082	Engine Turning Tool	1		
6V3147	Main Bearing Wrench		1	
2P5517	Bearing Removal and Installation Tool			1

start by:
a) remove piston cooling jets

1. Drain the oil from the oil pan.

2. Use tool (A) to turn the engine flywheel to move counterweights (1) in position for removal. Remove counterweights (1) from the crankshaft through the side of the cylinder block.

3. Use tool (A) and turn the engine flywheel to move the connecting rod bearing surface (journal) to the top center position.

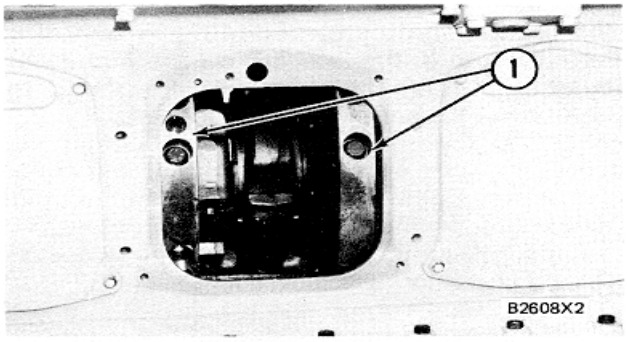
4. Use tool (B) and loosen the four bolts that hold the main bearing cap in position.

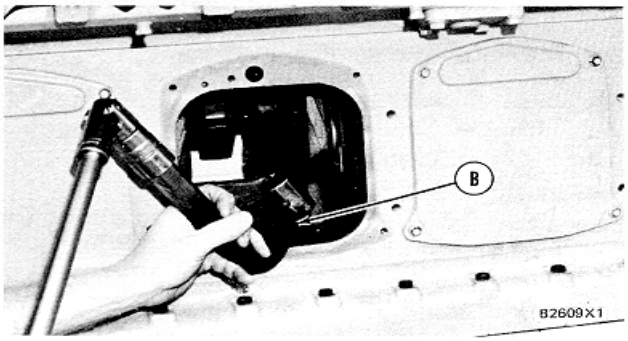
5. Hold the main bearing cap in position with a pry bar and remove the bolts and lower the bearing cap from the cylinder block.

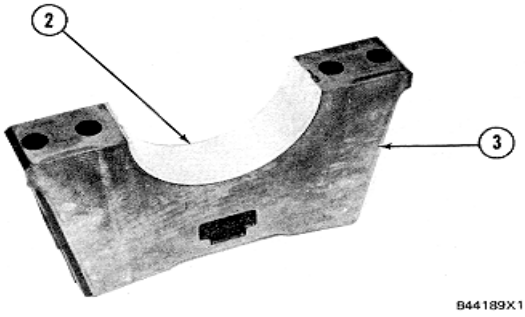
6. Remove the bearing caps from the side of the engine. The weight of the bearing cap is 16 kg (35 lb.).

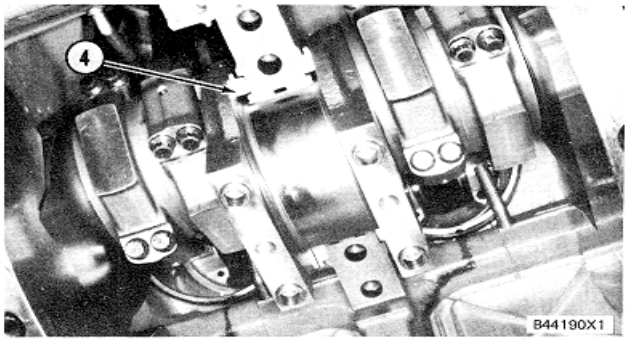
7. Remove the lower bearing half (2) from bearing cap (3).

8. Remove thrust plates (4) from each side of the center main bearing.









CRANKSHAFT MAIN BEARINGS

NOTICE

If the crankshaft is turned in the wrong direction, the tab of the bearing will be pushed between the crankshaft and cylinder block. This can cause damage to either or both.

NOTE: On the center main journal that has no oil hole, put a thin piece of soft material that will not damage the crankshaft journal against the end of the bearing, opposite the tab. Hit the bearing with the soft material until the tab of the bearing is free from the cylinder block. Remove the upper half of the main bearing.

9. Install tool (C) in the oil hole in the crankshaft journal and remove upper main bearing halves (5) as the crankshaft is turned and the bearing is moved out of the cylinder block.

INSTALL CRANKSHAFT MAIN BEARINGS 1203-12

	Tools Needed	A	B	C	D
9S9082	Engine Turning Pinion	1			
2P5517	Bearing Removal and Installation Tool		1		
	8S2328Dial Test Indicator Group			1	
6V3147	Main Bearing Wrench				1

NOTICE

Make sure the upper and lower halves of bearings are installed so the bearing tabs fit into the notch in cylinder block and bearing caps.

NOTE: Install the main bearings dry when the clearance checks are made. Put clean engine oil on the main bearings for final assembly.

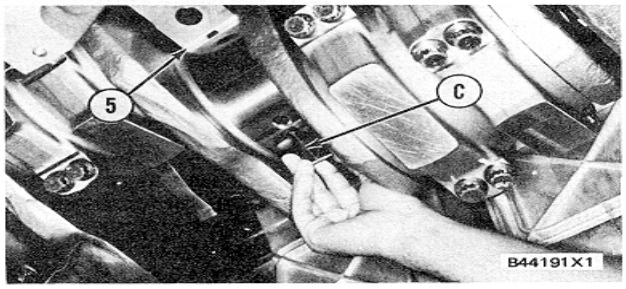
1. Install tool (B) in the oil hole of the crankshaft. Put the upper bearing half (half with oil hole) in position on the crankshaft. Use tool (A) to turn the engine flywheel and push the bearing half in position with tool (B).
2. Make sure the bearing caps are clean and install the lower bearing halves in the caps.

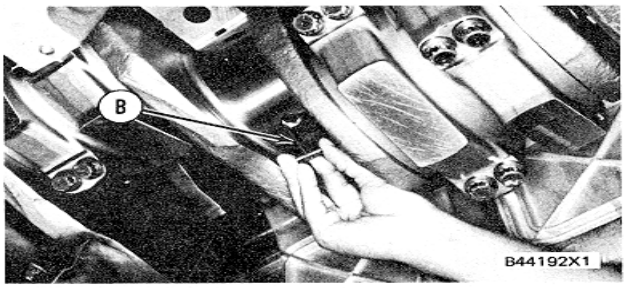
NOTICE

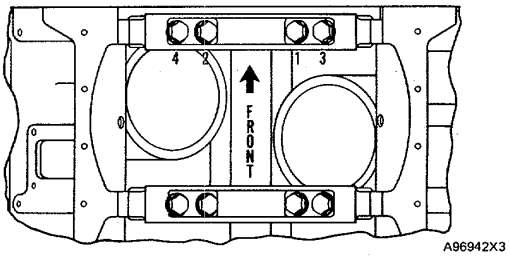
Do not use an impact wrench to tighten the bolts the additional 180 ± 5° of a turn more.

NOTE: When the bearing clearance is checked and the engine is in a vertical position, such as in the vehicle, the crankshaft will have to be lifted up and held against the upper halves of the main bearings to get a correct measurement with the Plastigage. The Plastigage will not hold the weight of the crankshaft and give a correct indication. If the engine is in a horizontal position, it is not necessary to hold the crankshaft up. Do not turn the crankshaft when the Plastigage is in position to check clearances.

3. Check the bearing clearances with Plastigage as follows:



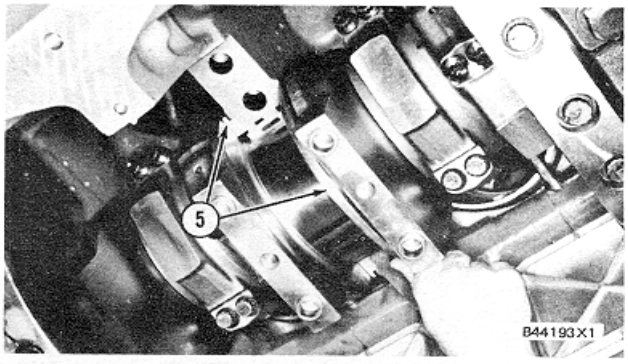




a) Put a piece of the Plastigage on the surface of the lower bearing half.
b) Install the main bearing caps with the word "FRONT" and the cast part number toward the front of the cylinder block. Each cap has a number on the bottom surface and must be installed in the same position as the correct number on the right side of the block pan rail.
c) Put clean engine oil on the main bearing cap bolts and tighten them in the number sequence shown with tool (D) to a torque of 136 ± 14 N.m (100 ± 10 lb.ft.). Then tighten the bolts in the number sequence shown 180 ± 5° of a turn more.
d) Remove the caps and measure the Plastigage. The main bearing clearance must be 0.122 to 0.241 mm (.0048 to .0095 in.).

CRANKSHAFT MAIN BEARINGS

4. Put clean engine oil on thrust plates (5) and install them on each side of the center main bearing with the grooves in the plates against the crankshaft.



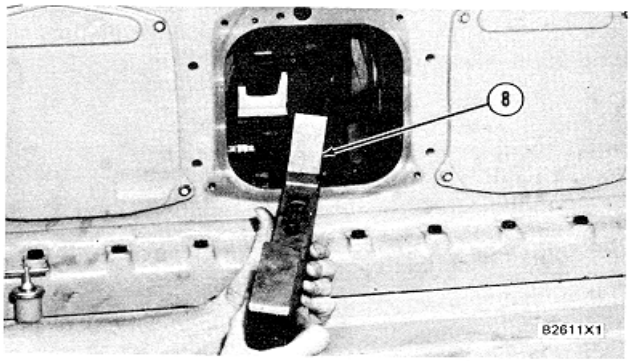
5. Put clean engine oil on bearings (7) and put bearing caps (6) in position and tighten the bolts as in Step 3.



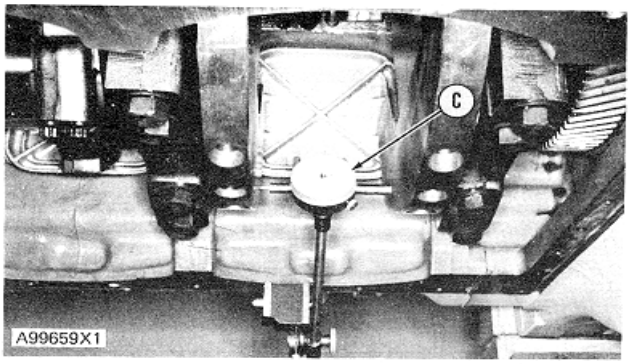
NOTICE

Each counterweight has a number and must be installed in the same position as the correct number on the crankshaft mounting pad to prevent damage to the crankshaft when the engine is run. Also do not use an impact wrench to tighten the bolts the additional 120 ± 5° of a turn more.

6. Make sure the dowels are in position and install counterweights (8) on the crankshaft. Put 2P2506 Thread Lubricant on the bolts and tighten them evenly to a torque of 50 ± 5 N•m (37 + 4 lb.ft.). Then tighten the bolts 120 ± 5° of a turn more.



7. Check the crankshaft end play with tooling (C). The end play is controlled by the thrust plates on the center main bearing. End play with new bearings must be 0.15 to 0.50 mm (.006 to .020 in.).



8. Fill the engine with oil to the correct level.
end by:
a) install piston cooling jets

PISTONS

REMOVE PISTONS 1214-11

Tools Needed		A	B	C
9S9082	Engine Turning Pinion	1		
	Pliers		1	
6V4020	Piston Ring Expander			1

start by:
a) remove spacer plates
b) remove piston cooling jets

1. If necessary, remove the cover from the front right side of the flywheel housing and use tool (A) to turn the engine flywheel until all four of bolts (1) can be removed.

2. Remove bolts (1) and bearing cap (2) from the connecting rod.

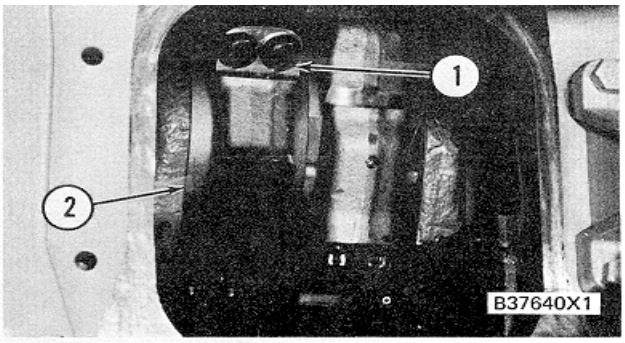
3. Push the piston up until the piston rings are clear of the cylinder liner. Remove pistons (3) and the connecting rods.

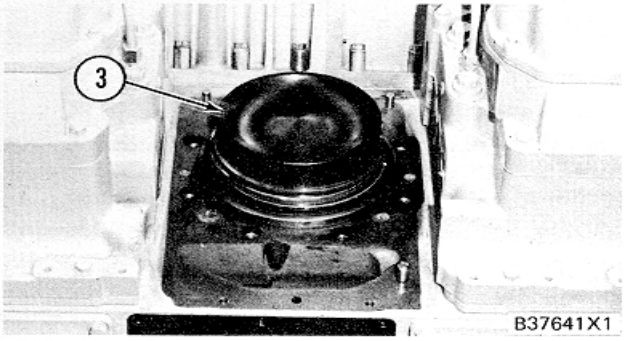
NOTE: Put identification on each piston as to its location for correct installation and alignment. Keep each bearing cap with its connecting rod.

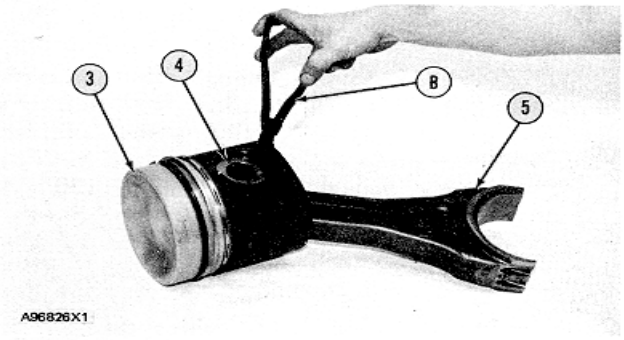
4. Use tool (B) and remove the rings that hold piston pin (4) in position. Remove pin (4) and remove piston (3) from connecting rod (5).

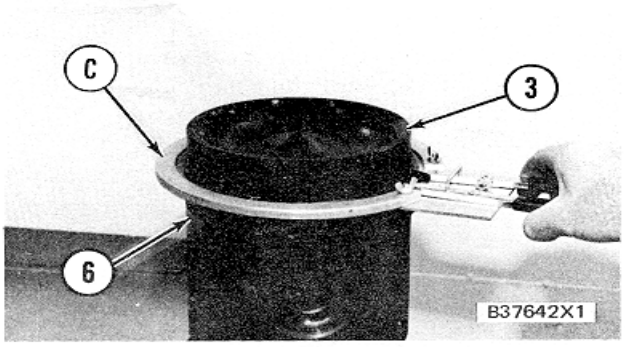
5. Remove the bearings from the bearing cap and connecting rod (5).

6. Use tool (C) to remove piston rings (6) from piston (3).









PISTONS

INSTALL PISTONS **1214-12**

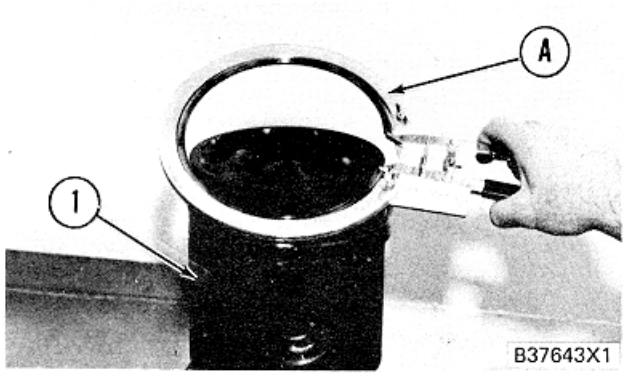
	Tools Needed	A	B	C	D
6V4020	Piston Ring Expander	1			
	Pliers		1		
9S9082	Engine Turning Pinion			1	
6V4021	Piston Ring Compressor				1

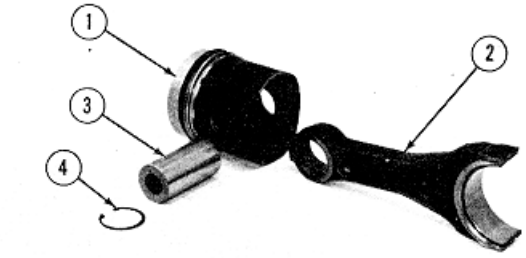
1. Clean the ring grooves in the piston.
2. Use tool (A) to install the oil ring on piston (1). Make sure the oil ring spring ends are 1800 apart from the ring end gap.
3. Use tool (A) to install the two compression rings on piston (I). Make sure the sides with the "UP" marks are toward the top of the piston and all three ring end gaps are 120° apart after installation.
4. Put clean engine oil on pin (3), the pin bearing in rod (2) and the pin bore in piston (1). Put rod (2) in position in piston (1) and install pin (3). Use tool (B) to install rings (4) on each side of pin (3).
5. Install the upper half of the connecting rod bearing in the connecting rod and put clean engine oil on it. Make sure the tab on the back of the bearing fits in the groove of the rod.
6. Put clean engine oil on the piston rings and cylinder liner bore. Use tool (D) to put the piston rings under compression and install the pistons and connecting rods in the cylinder liners.

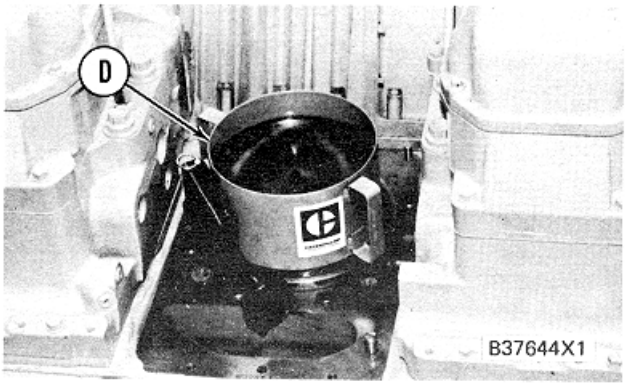
NOTICE

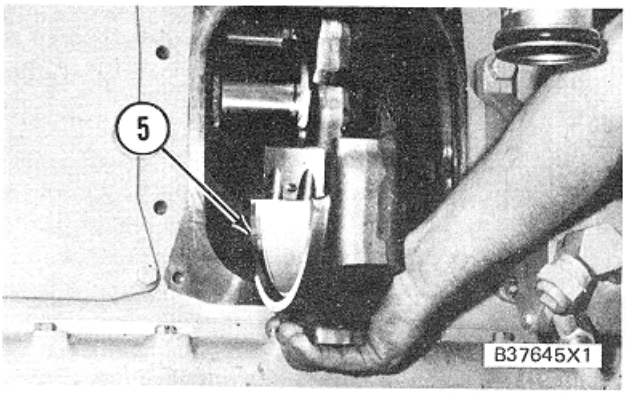
Make sure the piston is installed with the side of the connecting rod that has the chamfer in the rod bearing bore next to the crankshaft thrust surface. The side with the square shoulder for the connecting rod bearing bore must be next to the other connecting rod on the same crankshaft journal.

7. Install the lower half of the connecting rod bearing in cap (5) and put clean engine oil on it. Make sure the tab on the back of the bearing fits in the groove of the cap.
8. See INSTALL CONNECTING ROD BEARINGS for the procedure to install the connecting rod caps and to check the bearing clearance.
9. Check the side clearance between two connecting rods on the same crankshaft journal. The clearance must be 0.85 ± 0.23 mm (.0335 +end by: .0091 in.) for the 12 cylinder and 0.900 + .282 a) install cooling jets mm (.0354 + .0111 in) for the 8 cylinder. b) install spacer plates









CYLINDER LINERS

REMOVE CYLINDER LINERS 1216-11

	Tools Needed	A
5P8665	Cylinder Liner Puller	1
6V4133	Wedge Bracket	1

start by:

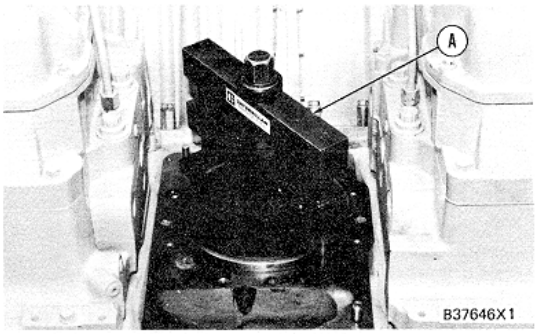
a) remove pistons

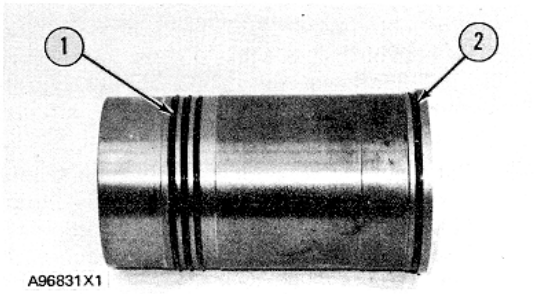
1. Drain the coolant from the cooling system and cylinder block.

2. Put covers on the crankshaft journals for protection from dirt and coolant.

3. Remove the cylinder liner with tool (A).

4. Remove seals (I) and filler band (2) from the cylinder liner.





INSTALL CYLINDER LINERS 1216-12

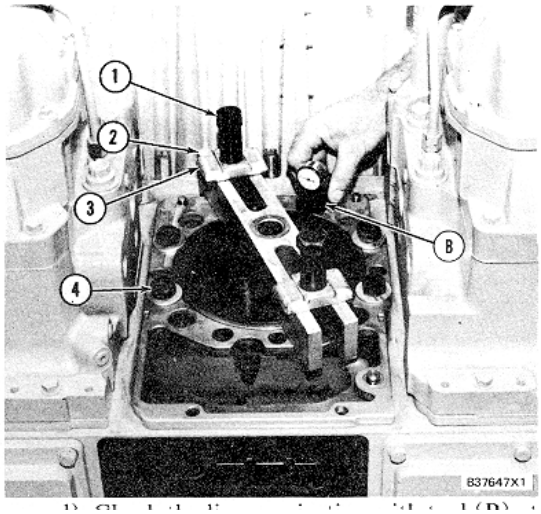
	Tools Needed	A	B	C
8B7548	Puller Assembly (Crossbar)	1		
3H465	Plate	2		
8F6123	Bolt (Y4"-16 NF x 5 /2 in. long)	2		
3B1925	Washer (3/4"-Copper)	4		
S1575	Bolt (3/4"-16 NF x 3 in. long)	4		
1P5510	Liner Projection Tool Group		1	
2P8260	Liner Installation Group			1
7N1961	Bolt (from Cylinder head)			1
FT1543	Plate			1

1. Install the gasket and spacer plate.

2. Clean the cylinder liners and liner bores in the cylinder block.

3. Install the cylinder liners in the cylinder block without seals or bands.

4. Check the cylinder liner projection as follows:
   a) Install four bolts (4) and washers from tooling (A) around each cylinder liner as shown. Tighten the bolts evenly to a torque of 95 N-m (70 lb. ft.).
   b) Install crossbar (2), plates (3) and bolts (I) from tooling (A). Be sure the crossbar is in position at the center of the liner and the liner surface is clean. Tighten bolts (1) evenly to a torque of 70 N-m (50 lb. ft.).
   c) Check the distance from the bottom edge of crossbar (2) to the top edge of the spacer plate. The distance on each end of the crossbar must be the same.

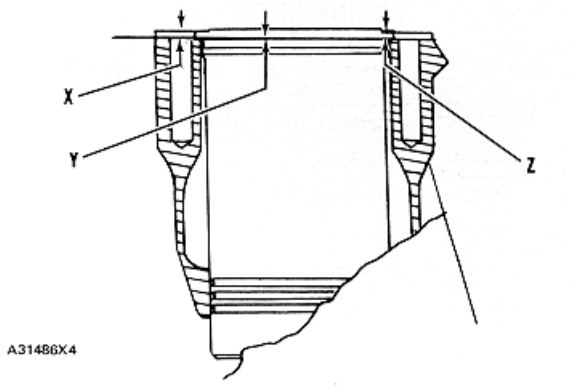


   d) Check the liner projection with tool (B) at four locations around the liner. Liner projection must be 0.059 to 0.199 mm (.0023 to .0078 in.). The difference between the four measurements on the same liner must not be more than 0.05 mm (.002 in.).

NOTE: If the liner is turned in the cylinder block, it can make a difference in liner projection.

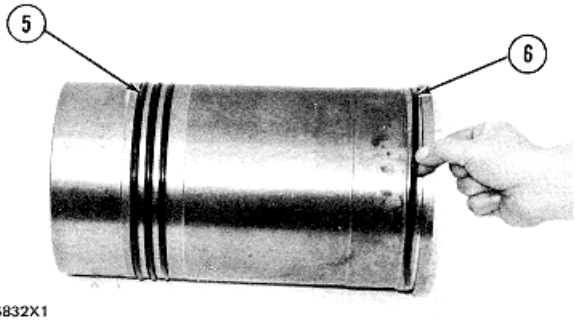
CYLINDER LINERS

5. If the liner projection is not 0.059 to 0.199 mm (.0023 to .0078 in.), check the thickness of the following parts:
   a) Spacer plate (X): 10.313 ± 0.025 mm (.4060 ± .0010 in.).
   b) Spacer plate gasket (Y): 0.208 ± 0.025 mm (.0082 ± .0010 in.). [All surfaces must be clean and dry when gaskets are installed].
   c) Cylinder liner flange (Z): 10.65 ± 0.02 mm (.419 ± .001 in.).



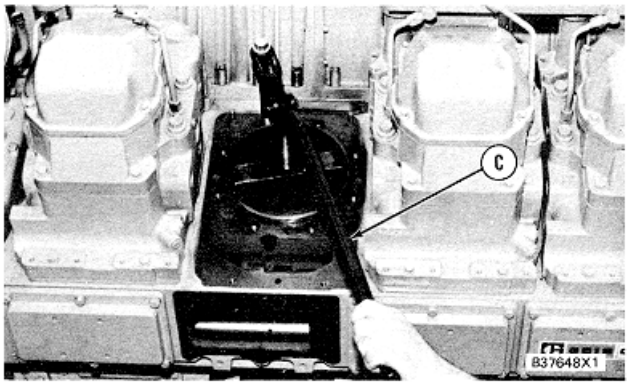
6. Put a mark on the cylinder liners and block so the liners can be installed in same position.

7. Remove tooling (A) and tool (B). Remove the liner.

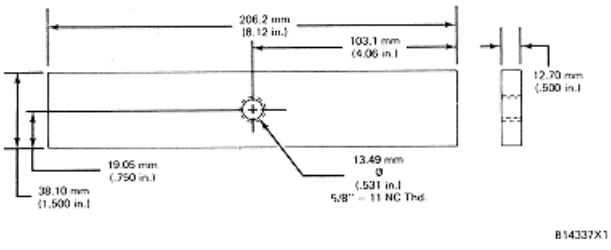


8. Put liquid soap on seals (5), grooves of the liner and the bore of the block. Install the seals on the cylinder liner.

9. Put the filler band completely in clean engine oil for a moment. Install filler band (6) in the groove under the liner flange without delay.



10. Install the liner immediately after the filler band is installed before expansion of the band. Make sure the mark on liner is in alignment with the mark on the block. Use tooling (C) to push the liner into position.



11. Use Steps 7 through 10 for the remainder of the liners.

end by:

a) install pistons

CAMSHAFTS

REMOVE CAMSHAFTS 1210-11

	Tools Needed	A	B	C
9S9082	Engine Turning Tool	1		
8B7548	Push-Puller Assembly		1	
8B7559	Threaded Adapter		2	
8B7561	Step Plate		1	
8H684	Ratchet Wrench		1	
6V4019	Camshaft Pilot Group			1

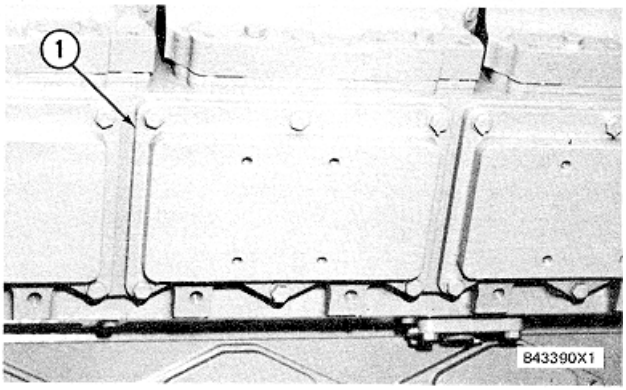
start by:

a) remove rocker shafts and push rods

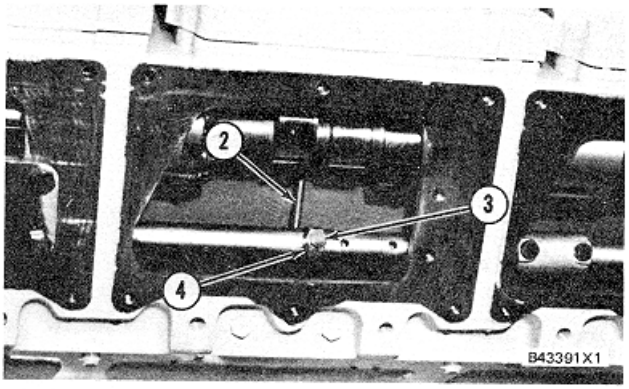
b) remove crankcase breathers (left side only)

c) remove hydramechanical shutoff drive (right side only)

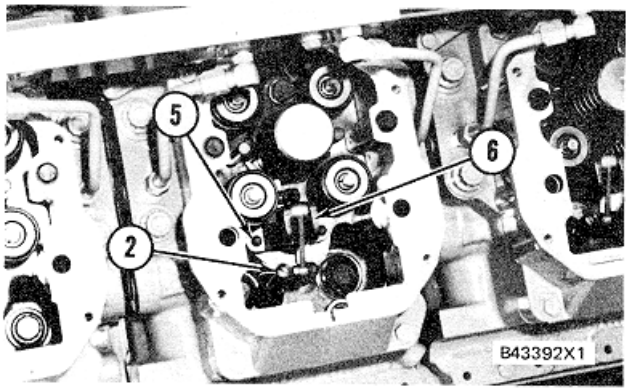
d) remove governor (right side only)



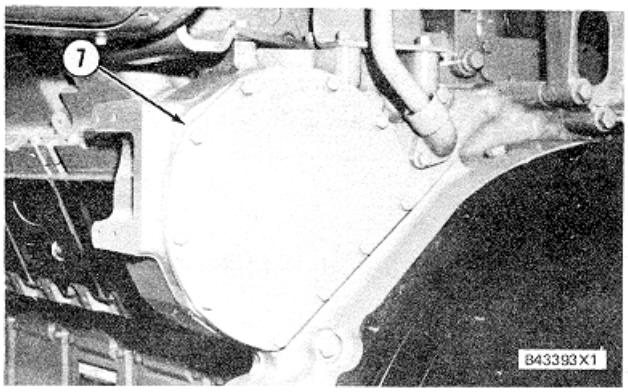
1. Remove access covers (1) from the sides of the engine.



2. Remove bolt (3) and cap (4) that hold fuel rod assembly (2) to the fuel control shaft.



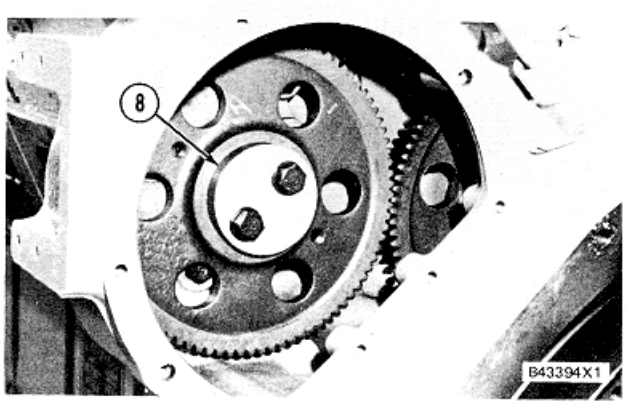
3. Remove bolts (5) to remove lever assembly (6) and fuel rod assembly (2) as a unit from the cylinder heads. If necessary, use tool (A) to turn the flywheel until the camshaft is moved in a position so that the fuel rod assembly can be removed between the engine block and camshaft.



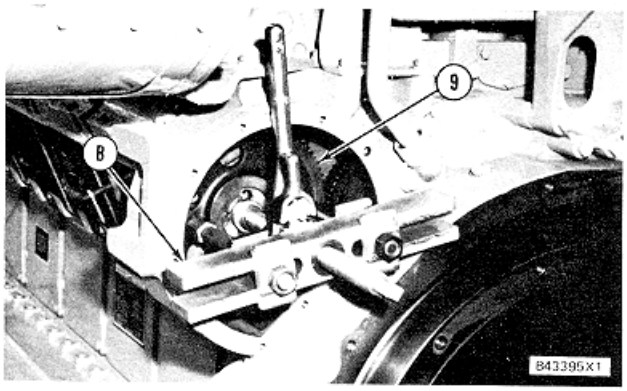
4. Remove cover (7) from the left side of the flywheel housing.

CAMSHAFTS

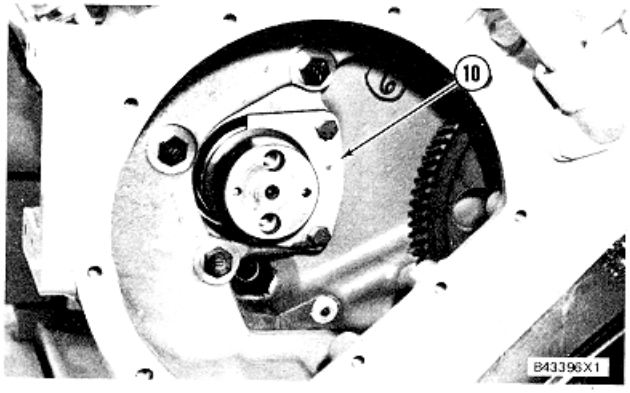
5. Remove the bolts and remove plate (8) from the end of the camshaft on the left side of the engine.



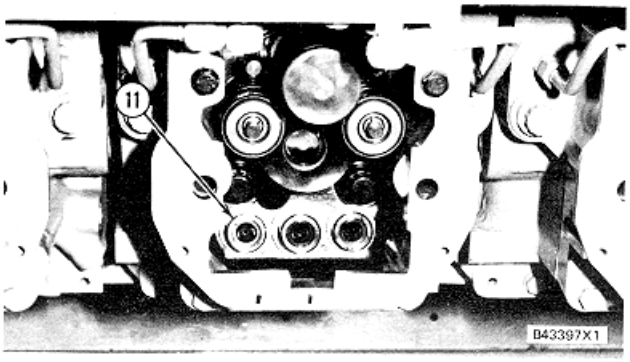
6. Use tooling (B) to remove drive gear (9) from the end of the camshaft on each side of the engine. Remove the drive gears from the flywheel housing.



7. Remove the bolts and remove washer (10) from the end of the camshaft on each side of the engine.

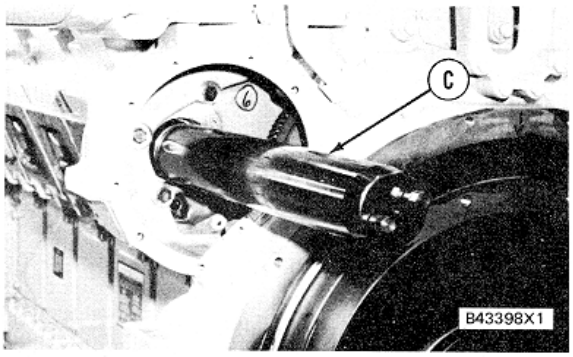


8. Push valve lifters (11) up away from the camshaft into the cylinder heads and hold the lifters in this position. An O-ring seal can be used to hold the valve lifters up.

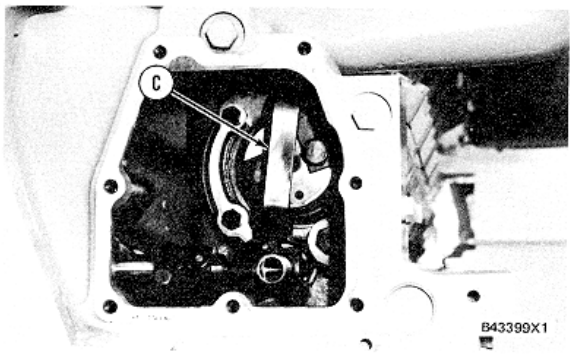


CAMSHAFTS

9. Install the pilot assembly part of tool group (C) on one end of the camshaft.

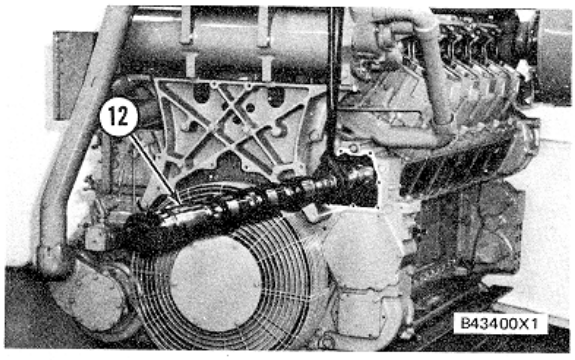


10. Install the handle part of tool group (C) on the other end of the camshaft.

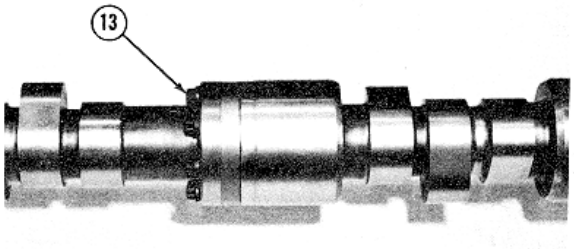


11. Pull camshaft (12) out of the engine block until a hoist can be fastened to it.

12. Put identification on the camshafts as to their location in the engine so they can be installed correctly.



13. Remove camshaft (12) and tool group (C) from the engine. The weight of the 3512 camshaft is 63 kg (140 lb.). The 3508 Camshaft weight is 43 kg (95 lb.).

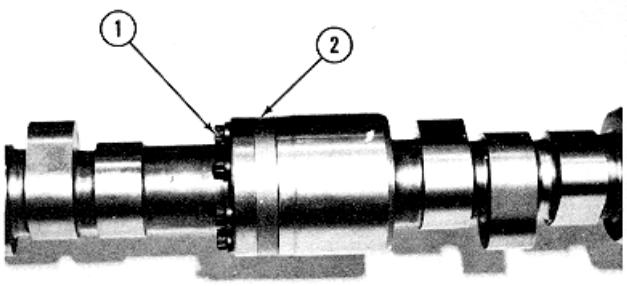


14. If necessary, remove bolts (13) to make a separation of the 3512 Camshaft only.

CAMSHAFTS

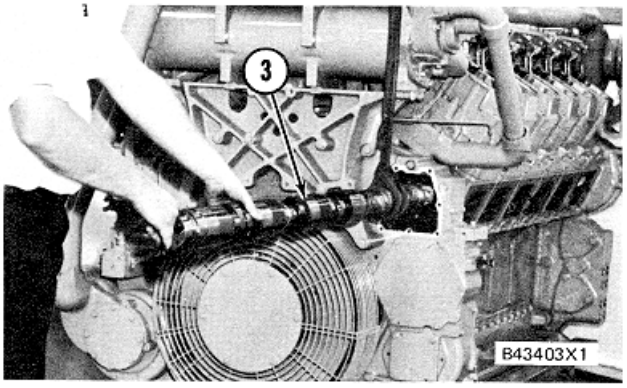
INSTALL CAMSHAFTS 1210-11

	Tools Needed	A	B
6V4019	Camshaft Pilot Group	1	
9S9082	Engine Turning Tool		1



B43402X1

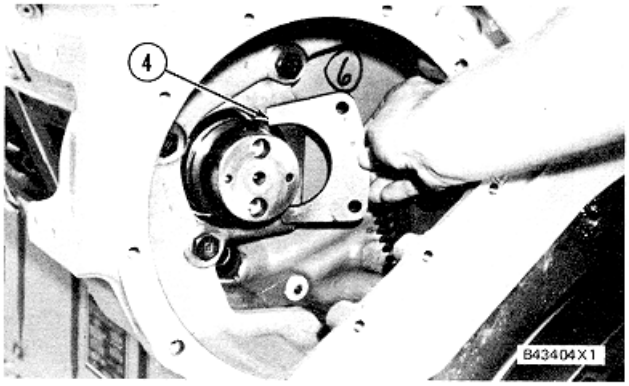
1. If the 3512 Camshafts were taken apart, make sure spacer (2) is in position between the camshaft and camshaft assembly. Put 9S3263 Thread Lock on the threads of bolts (1) and tighten the bolts by hand only to a torque of 45 ± 7 N•m (33 ± 5 lb. ft.).



B43403X1

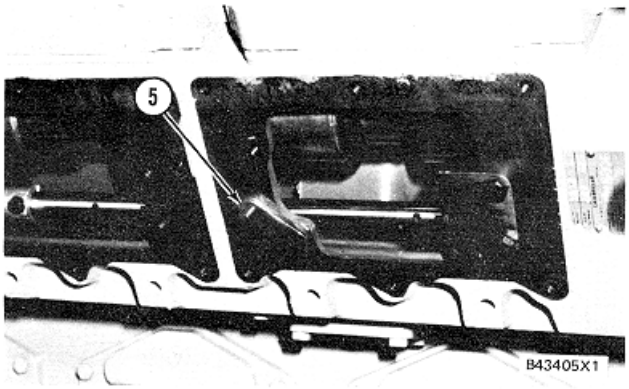
NOTE: Make sure the camshafts are installed respective to the marks (Rear L.H., Rear R.H.) on the ends of the camshafts.

2. Install the pilot assembly part of tool group (A) to one end of the camshaft and the handle part of tool group (A) to the other end.



B43404X1

3. Fasten a hoist to camshaft (3) and put the camshaft in position and push it into the engine block. Remove the hoist and tool group (A).



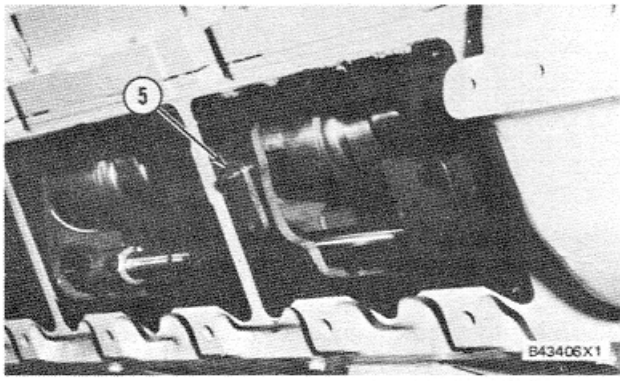
B43405X1

4. Install washers (4) on each side of the engine to hold the camshafts in position.

5. Remove timing pins(5) from their storage positions on each side of the engine.

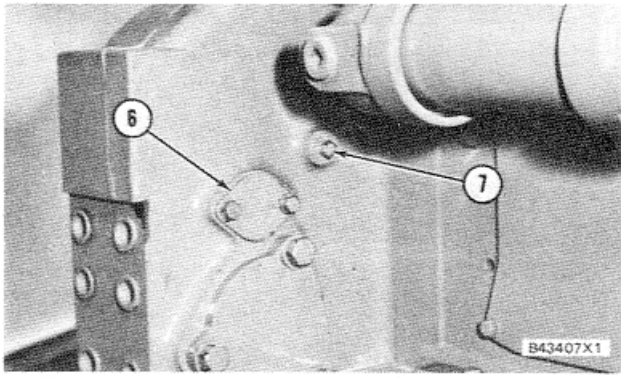
CAMSHAFTS

6. Turn the camshafts until timing pins (5) can be installed through the engine block and into the grooves (slots) in the camshafts.



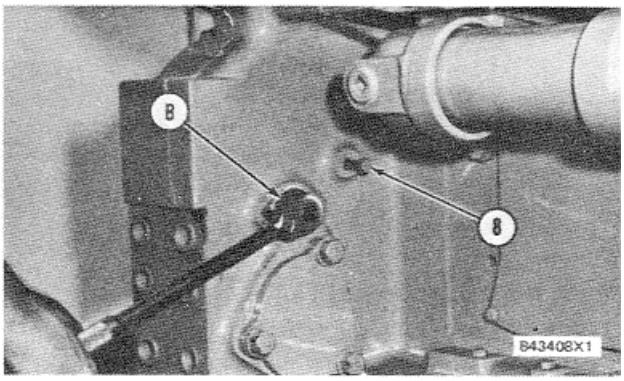
7. Remove cover (6) and plug (7) from the right front side of the flywheel housing.

8. Put timing bolt (8) in position in the flywheel housing. Use tool (B) and a ratchet wrench to turn the flywheel until the timing pin engages with the hole in the flywheel. The No. 1 cylinder is now at top center.

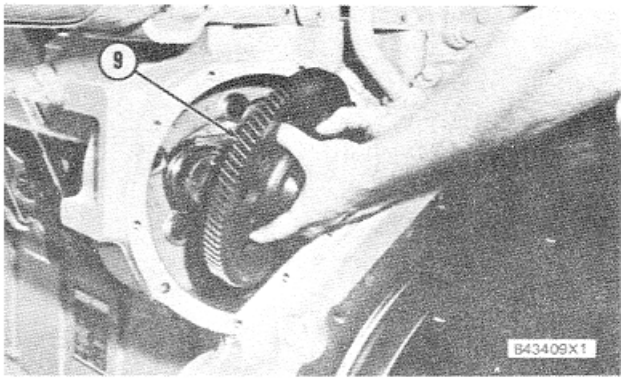


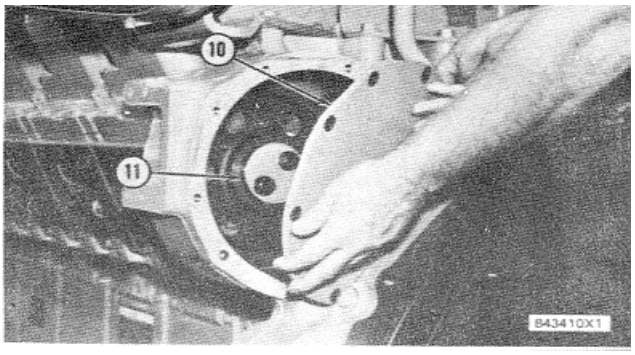
9. Put drive gears (9) in position on the end of the camshaft on each side.

10. Install plate (11) and the bolts to hold the drive gear to the camshaft. Tighten the bolts evenly to a torque of 100 + 15 N•m (75 + 10 lb. ft.). Hit the plate with a hammer and tighten the bolts again to the same torque. Do this until the torque does not change.



11. Install the gasket and cover (10) over the camshaft.





CAMSHAFTS

12. Install the tachometer drive adapter on the other camshaft to hold the drive gear in position. See INSTALL TACHOMETER DRIVE.

13. Remove the timing pins for the camshaft and install the pins in their storage positions.

14. Remove the timing bolt from the flywheel and install the plug in the timing hole in the housing. Remove tool (B) and install the cover on the housing.

15. Remove the O-ring seals from valve lifters (12) and push the lifters down against the camshaft.

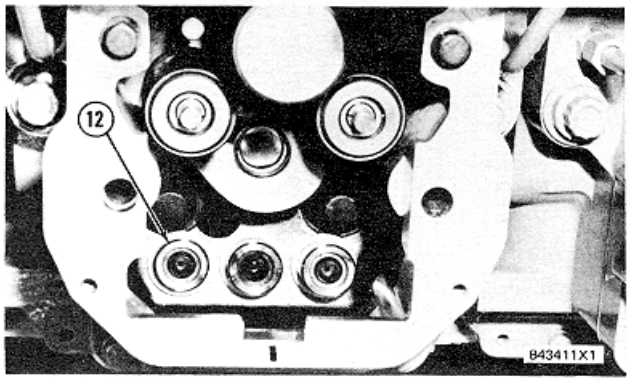
16. Install fuel rod assembly (14) and lever assembly (13) as a unit in the cylinder heads. If necessary use tool (B) to turn the flywheel until camshafts move enough to permit the fuel rod assembly to move into position.

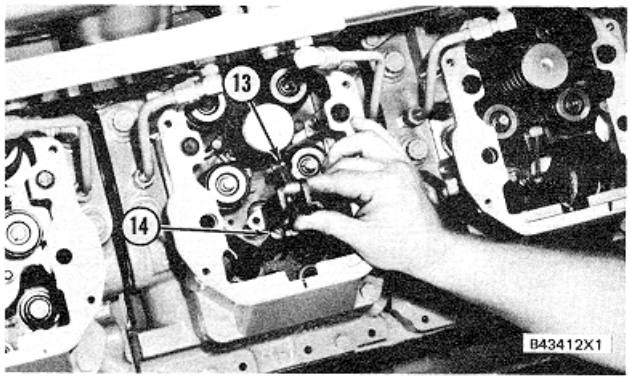
17. Make sure lever assembly (13) is engaged correctly with the fuel injection pump rack and install the bolts.

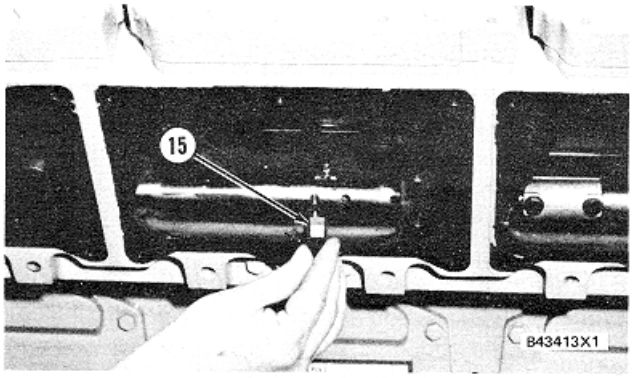
18. Install the bolt and cap (15) to hold the fuel rod assembly to the fuel control shaft.

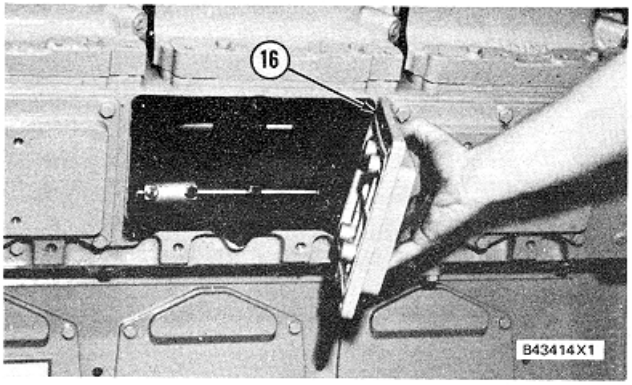
19. Install access covers (16) on each side of the engine.

20. See TESTING AND ADJUSTING section for the correct adjustment of the fuel injection control group.
end by:
a) install rocker shafts and push rods
b) install crankcase breather
c) install hydramechanical shutoff drive
d) install governor









CAMSHAFT BEARINGS

REMOVE AND INSTALL CAMSHAFT BEARINGS 1211-10

	Tools Needed	A	B	C	D	E	F
S1621	Bolt (1/2"-13 NC x 1 in. long)	1					
6V4012	Backup Plate	1					
6V4014	Cam Bearing Pilot	1					
6V4015	Pulling Bar		1				
6V4005	Spacer			2			
6V4011	Spacer				1		
6V4010	Pulling Plate				1		
8S8292	Short Extension (part of 8S2241)					4	
8S8293	Long Extension (part of 8S2241)					2	1
6V4013	Screw						1
5P3100	Pump Group (or electric)						1
5P5247	Hydraulic Puller						1
5H1504	Washer (3/4"-Hardened)						1
2J3506	Nut (3/4"-Hardened)						1

start by:

a) remove camshafts

1. Install tooling (A) as follows:
   a) Install the cam bearing pilot in the camshaft bearing.
   b) Put the backup plate in position so the bearing is between the parts.
   c) Install the bolt to hold the tooling together.

NOTE: Tooling (D) is used in place of tooling (B) and (C) to remove and install the camshaft bearings when the flywheel and front drive housings have been removed from the cylinder block.

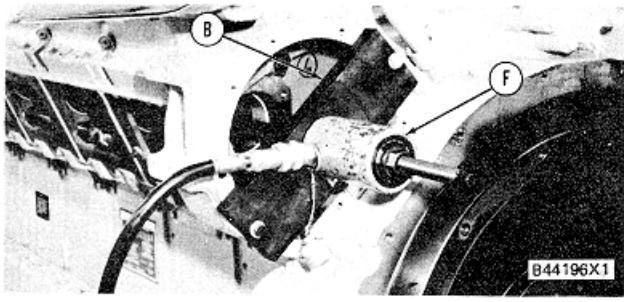
2. Install tool (B) on the flywheel housing as shown or install tooling (B) and (C) on the front drive housing. Tooling (C) must be used behind the bolt holes for clearance to install tool (B) on the front drive housing.

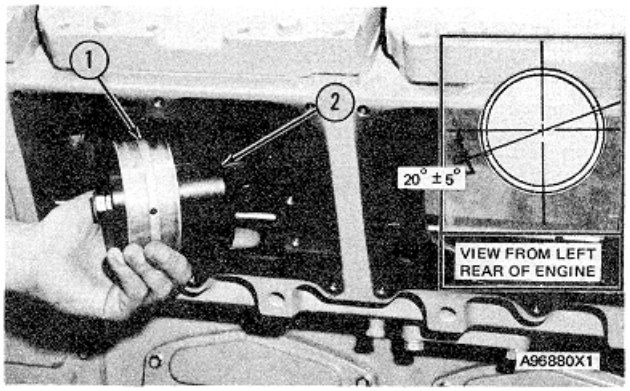
3. Use tooling (E) as needed to get the correct length. Connect the extensions to the stud on tooling (A).

NOTE: The threaded shaft, thrust bearing assembly and nut (all part of 8S2241 Tool Group) can be used with an 8H684 Ratchet Box Wrench in place of tooling (F) if a hydraulic puller is not available.

4. Connect tooling (F) to extensions of tool group (E) and pull the bearing from its bore in the cylinder block.







NOTE: When the bearings are installed in the bore of the block, the bearing joint must be on the horizontal centerline of the bore and the upper oil hole of the bearing toward the vee of the block. The upper bearing oil hole must be put 20 + 50 above the horizontal centerline of the bore in the block and the location of the lower (outside or outboard) bearing oil hole will be (and must be) 20 ± 5° below the horizontal centerline of the bearing bore as shown. Also, the bearing joint of the right side bearings must be toward the vee of the block and the left side bearings must be toward the outside of the block.

5. Install the camshaft bearings as follows:
   a) Install camshaft bearing (1) on tooling (A) as shown and put unit (2) in position in the bearing bore.

CAMSHAFT BEARINGS, CRANKSHAFT

b) Follow Steps 2, 3 and 4 to install the tooling and pull the bearing into the center of its bore.
c) Check the bore in bearing (1) after it is installed. The bore must be 86.00 ± 0.06 mm (3.386 ± .002 in.).
end by:
a) install camshafts

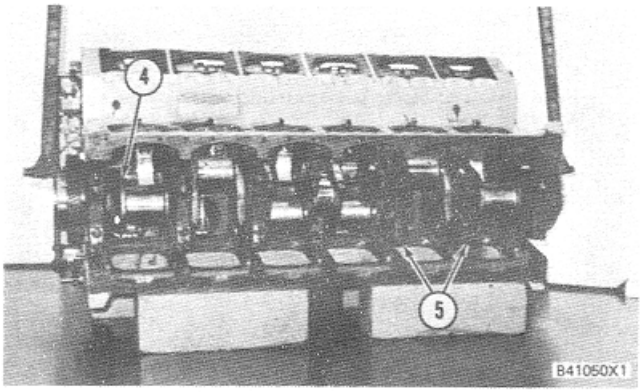
REMOVE CRANKSHAFT 1202-11

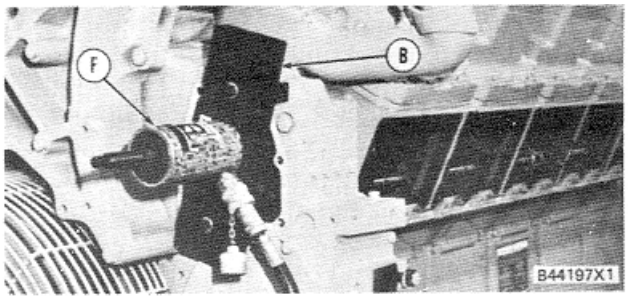
start by:
a) remove rocker shafts and push rods
b) remove front drive housing
c) remove front balancer group (3508)
d) remove rear gear group (Step 1 only)
e) remove piston cooling jets

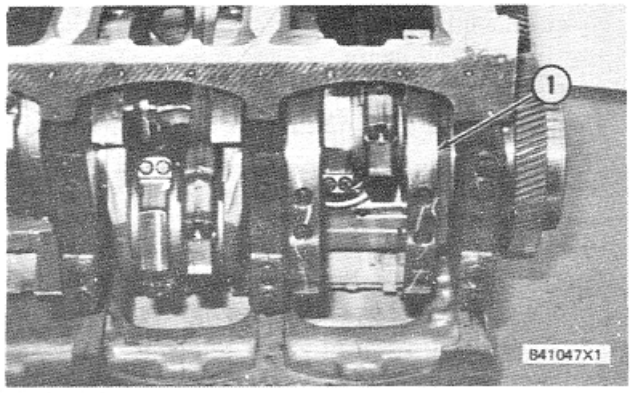
NOTICE

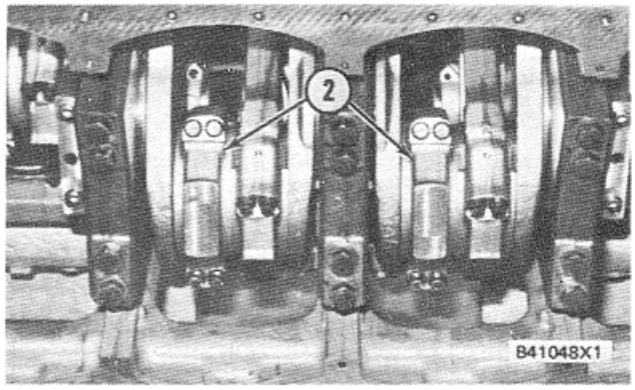
The rocker shafts and push rods do not have to be removed to remove the crankshaft but bent push rods can be the result if they are not removed.

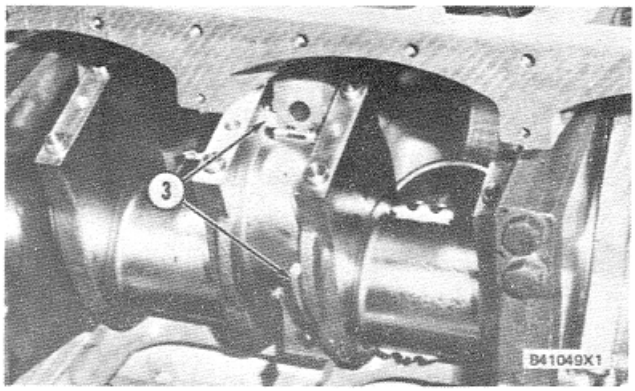
1. Put the engine in the position as shown. The weight of the 3512 Engine is approximately 5443 kg (12, 000 lb.). The weight of the 3508 Engine is approximately 4445 kg (9800 lb.).
2. Remove counterweights (1) from the crankshaft.
3. Remove bearing caps (2) from the connecting rod and push the connecting rods away from the crankshaft. Use wire to hold the upper half of the connecting rods away from the crankshaft.
4. Remove the center main bearing cap and remove two thrust plates (3) from each side of the main bearing.
5. Use two of the bolts that hold the flywheel to the crankshaft and install a bolt in each end of the crankshaft. Fasten a hoist to the crankshaft as shown.





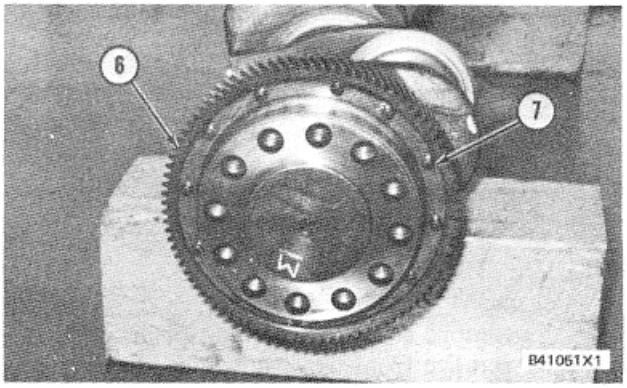






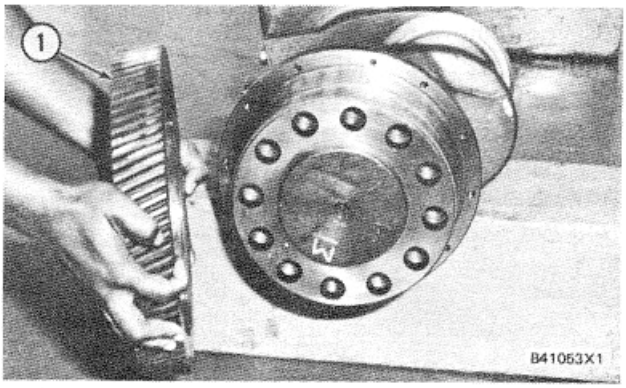
CRANKSHAFT

6. Remove the remainder of main bearing caps (5) and remove crankshaft (4) from the engine block. The weight of the 3512 Crankshaft is 454 kg (1000 lb.). The weight of the 3508 Crankshaft is 299 kg (660 lb.).
7. If necessary, remove bolts (7) to remove gears (6) from each end of the crankshaft.



INSTALL CRANKSHAFT1202-12

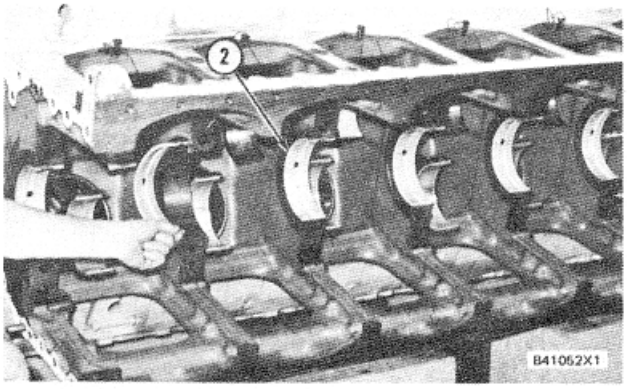
1. If gears (I) were removed, install gears (1) on each end of the crankshaft and install the bolts to hold the gears.
2. Make sure the upper halves of main bearings (2) (bearings with oil holes) are in position in the cylinder block. Put clean engine oil on the bearings.
3. Fasten a hoist to crankshaft (3) with two fly-wheel bolts and put it in position. Make sure the word "FRONT" on the end of the crankshaft is toward the front of the cylinder block.
4. Make sure the lower halves of the main bearings are in position in the main bearing caps. Put clean engine oil on the bearings and install all but the center main bearing cap on the cylinder block. The caps must be installed with the word "FRONT" and the cast part number toward the front of the cylinder block. Each cap has a number on the bottom surface and must be installed in the same position as the correct number on the right side of the block pan rail.

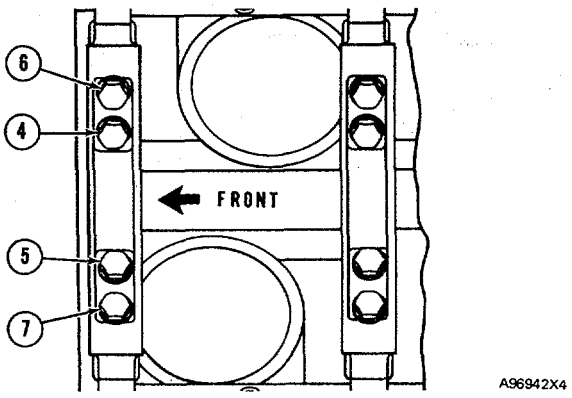


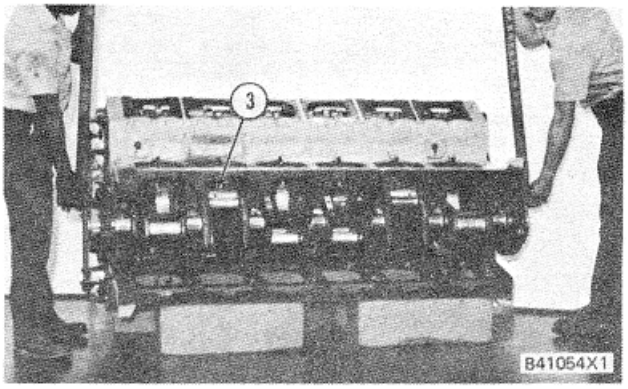
NOTICE

Do not use an impact wrench to tighten the bolts 1800 + 50 of a turn more.

5. Put clean engine oil on the main bearing cap bolts and tighten the bolts in the number sequence as shown to a torque of 136 + 14 Nm (100 + 10 lb.ft.). Then tighten each bolt in the number sequence as shown 1800 + 50 of a turn more.







CRANKSHAFT

6. Put clean engine oil on the thrust plates and install thrust plates (8) on each side of the center main bearing. Install the center main bearing cap and the bolts to hold it. Use the same procedure in Step 5 to tighten the bolts.

NOTE: See INSTALL CRANKSHAFT MAIN BEARINGS for the correct bearing clearance check and crankshaft end play.

7. Remove the wire that holds the upper half of the connecting rods in position. Make sure the upper and lower halves of the bearings are in position on the connecting rods and the rod caps. Put clean engine oil on the bearings.

NOTICE

Do not use an impact wrench to tighten the bolts 900 + 50 of a turn more.

8. Put the connecting rods in position on the crankshaft. Install caps (9) in the same location as they were removed from with the number on the side of the cap next to the number on' the side of the connecting rod. Put 5P960 Multi- purpose Type Grease on the bolt threads and contact surfaces of the bolts and caps and tighten the bolts in number sequence as follows:

NOTE: Bolts (12) and (13) are on the end of the rod cap opposite the end that has the location pin for correct installation.

a) Tighten bolts No. 10 and 11 to a torque of 90 + 5 N-m (65 + 4 lb.ft.).
b) Tighten bolts No. 12 and 13 to a torque of 90 + 5 N-m (65 + 4 lb.ft.).
c) Tighten bolts No. 12 and 13 again to 90 ± 5 N-m (65 ± 4 lb.ft.).
d) Tighten each bolt 90 + 50 of a turn more.

NOTE: See INSTALL CONNECTING ROD BEARINGS for the correct bearing clearance check.

NOTICE

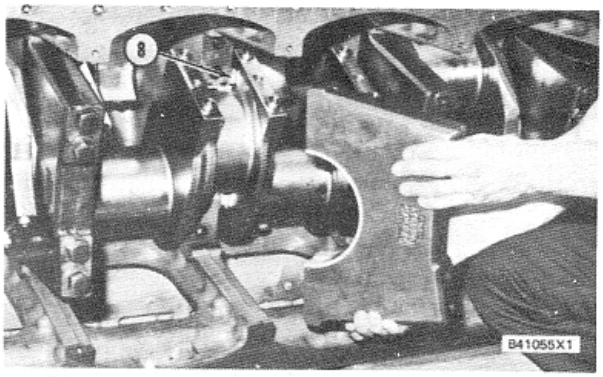
Each counterweight has a number and must be installed in the same position as the correct number on the crankshaft mounting pad to prevent damage to the crankshaft when the engine is run.

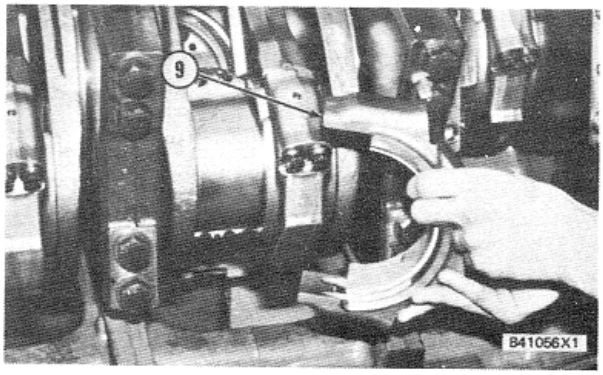
9. Make sure the dowels are in position and install counterweight (14) on the crankshaft.

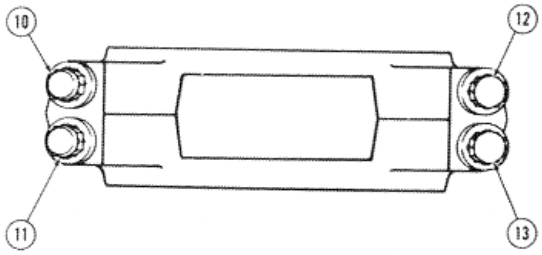
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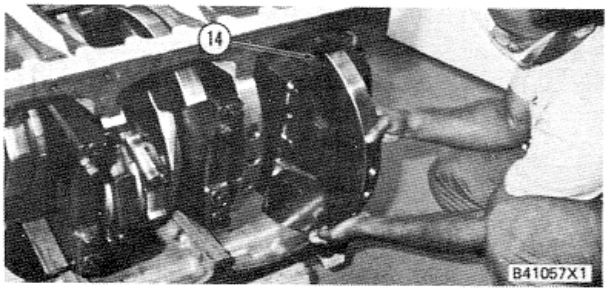
Do not use an impact wrench to tighten the bolts 1200 + 5 of a turn more.

10. Put 2P2506 Thread Lubricant on the counter-weight bolts and tighten the bolts to a torque of 50 + 5 N-m (37.5 + 4.0 lb.ft.). Then tighten the bolts 120° + 5° of a turn more.
11. Put engine in a vertical position.





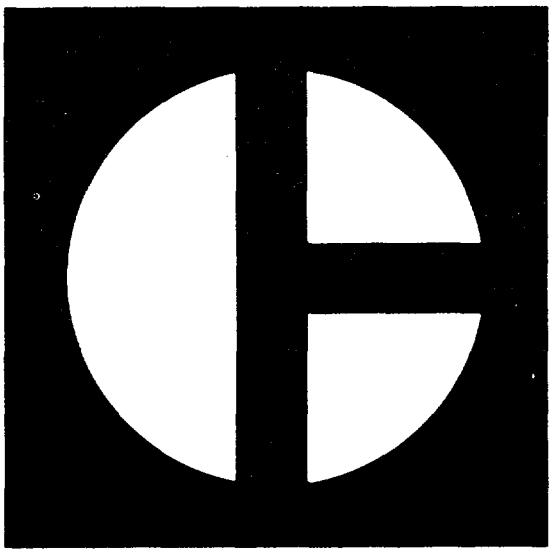




end by:

a) install rocker shafts and push rods
b) install front drive housing
c) install front balancer (3508)
d) install rear gear group
e) install piston cooling jets

FORM NO. SENR2353-01
FOR USE IN SERVICE MANUALS
3500 INDUSTRIAL ENGINES,
SENR2573
VOLUME I SPECIFICATIONS
REG01312



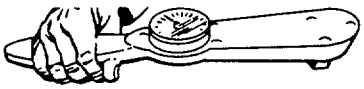
SPECIFICATIONS

FOR

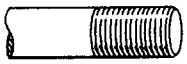
3500 INDUSTRIAL
ENGINE ATTACHMENTS

49Y1-UP	**65Z1-UP**
95Y1-UP	**68Z1-UP**
27Z1-UP	71Z1-UP

GENERAL TIGHTENING TORQUE FOR BOLTS, NUTS AND TAPERLOCK STUDS



The following charts give the standard torque values for bolts, nuts and taperlock studs of SAE Grade 5 or better quality. Exceptions are given in other sections of the Service Manual where needed.

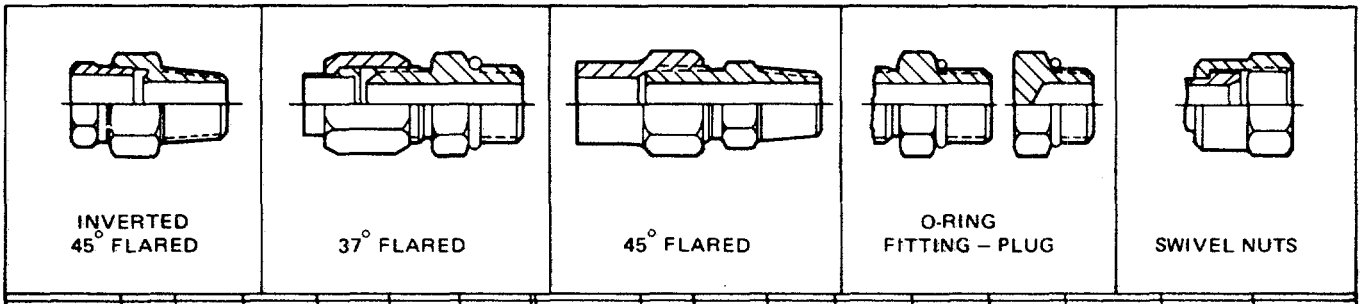
THREAD DIAMETER		STANDARD TORQUE	
inches	millimeters	lb. ft.	N·m*
Standard thread 		Use these torques for bolts and nuts with standard threads (conversions are approximate).	
1/4	6.35	9 ± 3	12 ± 4
5/16	7.94	18 ± 5	25 ± 7
3/8	9.53	32 ± 5	45 ± 7
7/16	11.11	50 ± 10	70 ± 15
1/2	12.70	75 ± 10	100 ± 15
9/16	14.29	110 ± 15	150 ± 20
5/8	15.88	150 ± 20	200 ± 25
3/4	19.05	265 ± 35	360 ± 50
7/8	22.23	420 ± 60	570 ± 80
1	25.40	640 ± 80	875 ± 100
1 1/8	28.58	800 ± 100	1100 ± 150
1 1/4	31.75	1000 ± 120	1350 ± 175
1 3/8	34.93	1200 ± 150	1600 ± 200
1 1/2	38.10	1500 ± 200	2000 ± 275
		Use these torques for bolts and nuts on hydraulic valve bodies.	
5/16	7.94	13 ± 2	20 ± 3
3/8	9.53	24 ± 2	35 ± 3
7/16	11.11	39 ± 2	50 ± 3
1/2	12.70	60 ± 3	80 ± 4
5/8	15.88	118 ± 4	160 ± 6
Taperlock stud 		Use these torques for studs with Taperlock threads.	
1/4	6.35	5 ± 2	7 ± 3
5/16	7.94	10 ± 3	15 ± 5
3/8	9.53	20 ± 3	30 ± 5
7/16	11.11	30 ± 5	40 ± 10
1/2	12.70	40 ± 5	55 ± 10
9/16	14.29	60 ± 10	80 ± 15
5/8	15.88	75 ± 10	100 ± 15
3/4	19.05	110 ± 15	150 ± 20
7/8	22.23	170 ± 20	230 ± 30
1	25.40	260 ± 30	350 ± 40
1 1/8	28.58	320 ± 30	400 ± 40
1 1/4	31.75	400 ± 40	550 ± 50
1 3/8	34.93	480 ± 40	650 ± 50
1 1/2	38.10	550 ± 50	750 ± 70

*1 newton meter (N·m) is approximately the same as 0.1 mkg.

T95416-7

TORQUE FOR FLARED AND O-RING FITTINGS

The torques shown in the chart that follows are to be used on the part of 37° Flared 45° Flared and Inverted Flared fittings (when used with steel tubing), O-ring plugs and O-ring fittings.



TUBE SIZE (O.D.)	mm	3.18	4.78	6.35	7.92	9.52	TUBE SIZE (O.D.)	mm	12.70	15.88	19.05	22.22	25.40	31.75	38.10	50.80
	in.	.125	.188	.250	.312	.375		in.	.500	.625	.750	.875	1.000	1.250	1.500	2.000
THREAD SIZE (in.)		5/16	3/8	7/16	1/2	9/16 5/8	THREAD SIZE (in.)		3/4	7/8	1 1/16	1 3/16 1 1/4	1 5/16	1 5/8	1 7/8	2 1/2
TORQUE N·m		5 ±1	11 ±1	16 ±2	20 ±2	25 ±3	TORQUE N·m		50 ±5	75 ±5	100 ±5	120 ±5	135 ±10	180 ±10	225 ±10	320 ±15
TORQUE lb.in.		45 ±10	100 ±10	145 ±20	175 ±20	225 ±25	TORQUE lb.ft.		35 ± 4	55 ± 4	75 ± 4	90 ± 4	100 ± 7	135 ± 7	165 ± 7	235 ± 10

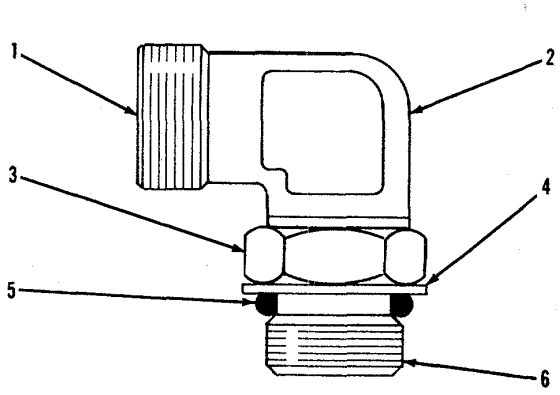
ASSEMBLY OF FITTINGS WITH STRAIGHT THREADS AND O-RING SEALS

1. Put locknut (3), backup washer (4) and O-ring seal (5) as far back on fitting body (2) as possible. Hold these components in this position. Turn the fitting into the part it is used on, until backup washer (4) just makes contact with the face of the part it is used on.

NOTE: If the fitting is a connector (straight fitting) or plug, the hex on the body takes the place of the locknut. To install this type fitting tighten the hex against the face of the part it goes into.

2. To put the fitting assembly in its correct position turn the fitting body (2) out (counterclockwise) a maximum of 359°. Tighten locknut (3) to the torque shown in the chart.

A71009X3



ELBOW BODY ASSEMBLY

1. End of fitting body (connects to tube). 2. Fitting body. 3. Locknut. 4. Backup washer. 5. O-ring seal. 6. End of fitting that goes into other part.

INTRODUCTION

The specifications given in this book are on the basis of information available at the time it was written. The specifications torques, pressures of operation, measurements, adjustments and other items can change at any time. These changes can effect the service given to the product. Get the complete and most current information before you start any job. Caterpillar Dealers have the most current information which is available. For a list of the most current modules and form numbers available for each Service Manual, see the SERVICE MANUAL CONTENTS MICROFICHE REGI 139F.

When the words "use again" are in the description, the specification given can be used to determine if a part can be used again. If the part is equal to or within the specification given, use the part again.

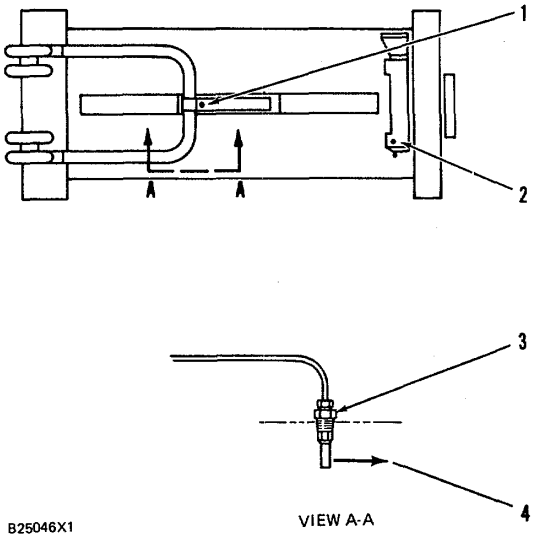
When the word "permissible" is in the description, the specification given is the "maximum or minimum" tolerance permitted before adjustment, repair and/or new parts are needed.

A comparison can be made between the measurements of a worn part, and the specifications of a new part to find the amount of wear. A part that is worn can be safe to use if an estimate of the remainder of its service life is good. If a short service life is expected, replace the part.

77200X2

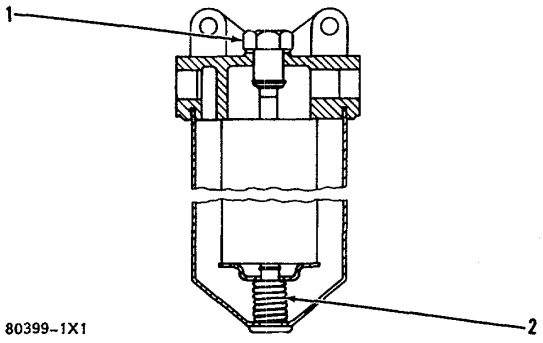
ETHER STARTING AID

(1) Location of atomizer on air inlet manifold.
(2) Location of temperature switch on regulator housing.
NOTE: Ether will not inject when water temperature is above 38°C (100° F).
(3) Atomizer identification mark.
(4) Direction of spray (toward front of engine).



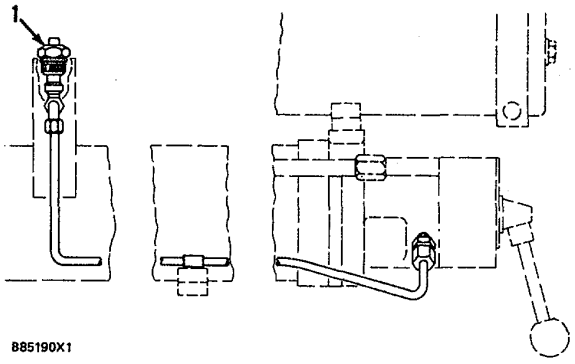
PRIMARY FUEL FILTER

(1) Torque for nut ..... 25 ± 5 N-m (18 ± 4 lb. ft.)
(2) 7S9323 Spring:
Length under test force ..... 27.9 mm (1.10 in.)
Test force ..... 125 to 145 N (28 to 33 lb.)
Free length after test ..... 42.7 mm (1.68 in.)
Outside diameter ..... 17.3 mm (.68 in.)

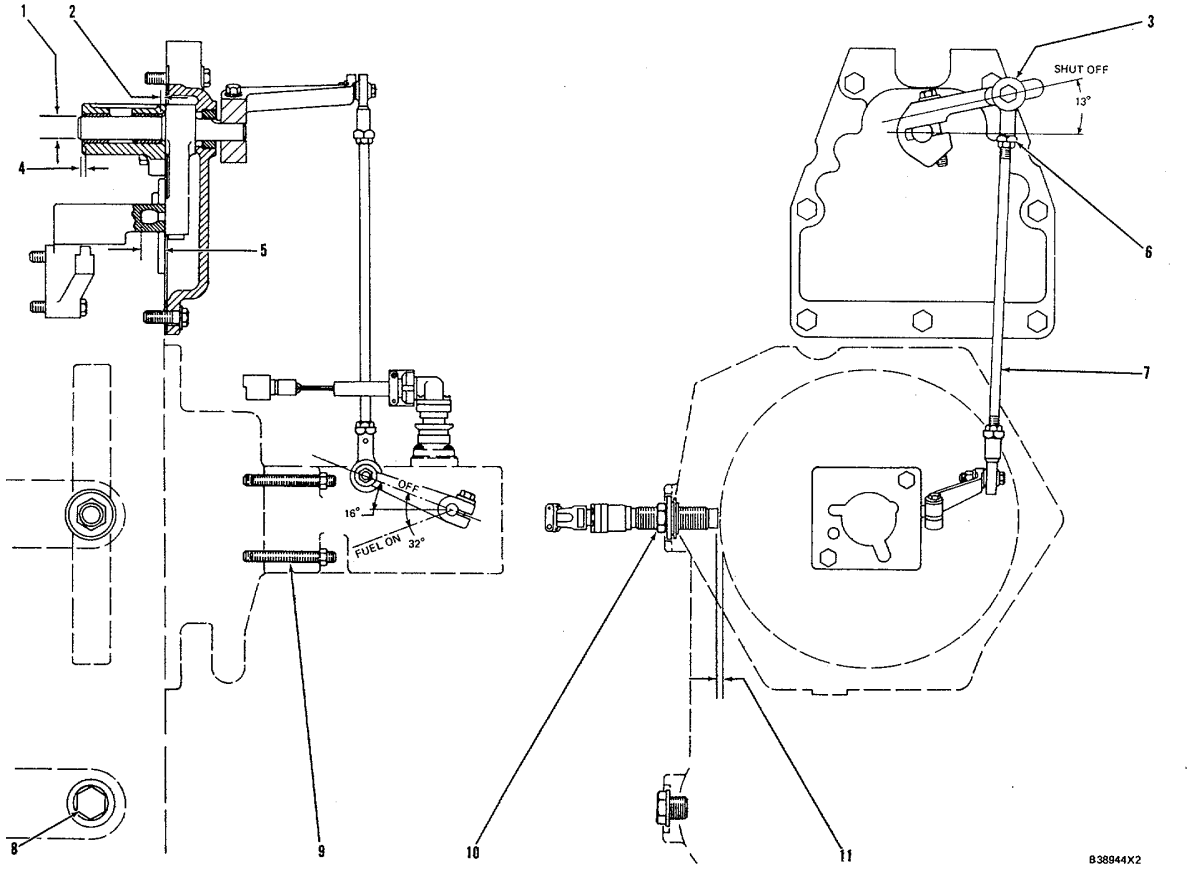


FUEL FILTER CHANGE INDICATOR GROUP

(1) Indicator assembly.
Tighten to a torque of ..... 55 + 10 N-m (40 ± 7 lb. ft.)
When indicator can be seen at a position 1/2 of the distance from the top, the fuel pressure
differential is ..... 85 to 105 kPa (12 to 15 psi)



GOVERNOR FASTENER GROUP
(2301 Governor with EG3P Actuators)



8N116 Fastener Group

(1) Diameter of shaft on lever assembly ..... 19.050 ± 0.013 mm (.7500 ± .0005 in.)
Bore in bearings after assembly in bracket ..... 19.126 ± 0.038 mm (.7530 ± .0015 in.)

(2) Distance bearing is installed from end of bracket ..... 4.0 + 0.5 mm (.16 + .02 in.)

(3) Rod end. Adjust rod end (3) on rod assembly (7) to put the levers in the shut off position as shown.

(4) Distance bearing is installed from end of bracket ..... 0.5 + 0.5 mm (.02 ± .02 in.)

(5) Distance pin is installed from lever ..... 18 ± 1 mm (.71 + .04 in.)

(6) Tighten nut to a torque of ..... 3.4 + 0.5 N-m (2.3 + .4 lb. ft.)

(7) Rod assembly.

(8) Tighten the plug to a torque of ..... 70 ± 15 N-m (50 + 11 lb. ft.)

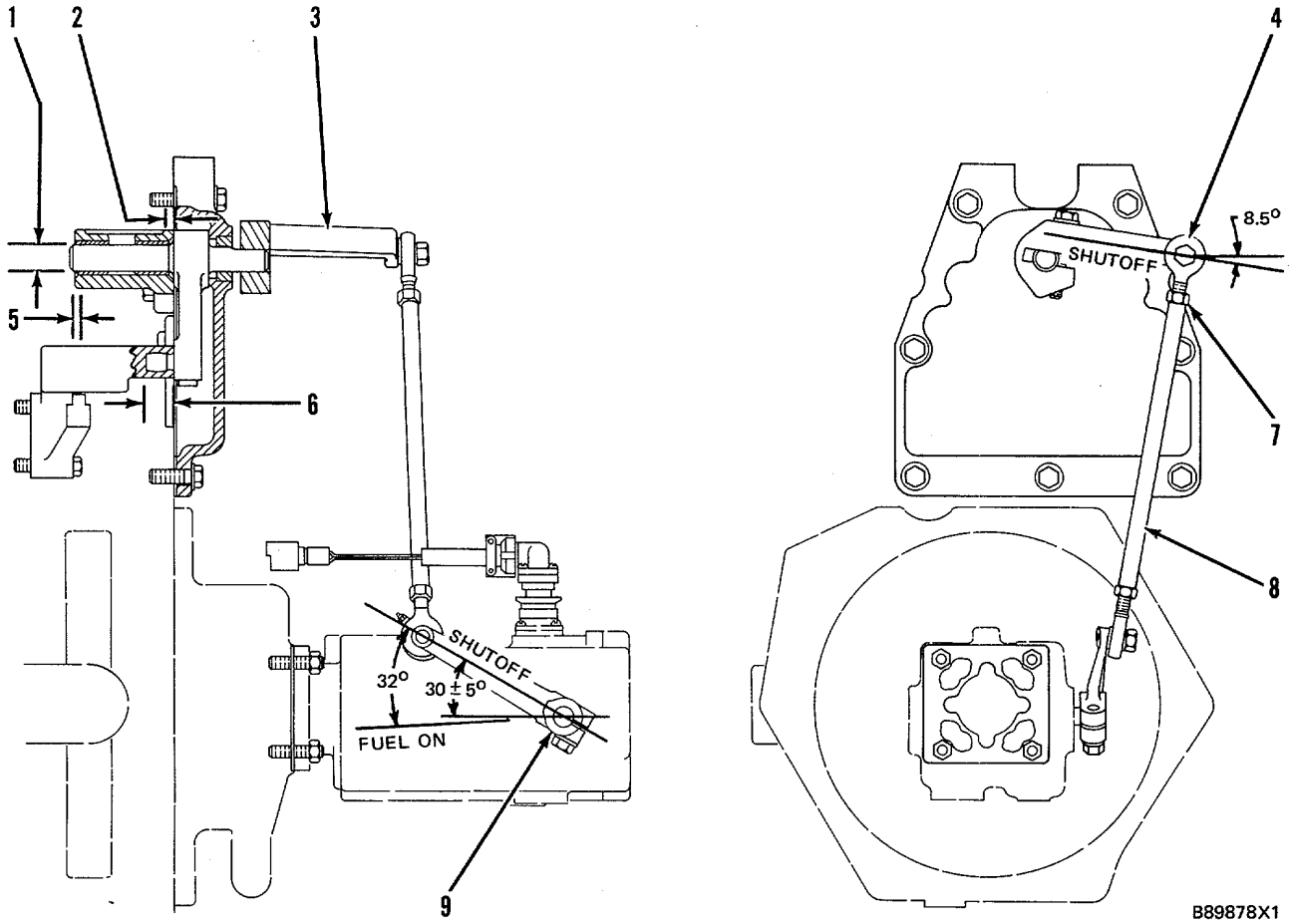
(9) Tighten the studs in the bearing adapter to a torque of ..... 15 + 5 N-m (11 + 4 lb. ft.)

(10) Tighten nut to a torque of ..... 68 + 13 N-m (50 ± 10 lb. ft.)

(11) Distance between end of magnetic pick-up and gear ..... 0.50 to .075 mm (.020 to .030 in.)

NOTE: FOR TORQUE VALUES NOT GIVEN, SEE THE FIRST PAGE OF SPECIFICATIONS FOR GENERAL TIGHTENING TORQUES

GOVERNOR FASTENER GROUP
(2301 Governors With EG10P Actuators)



4W5030 Fastener Group

(1) Diameter of shaft on lever assembly ..... 19.050 + 0.013 mm (.7500 + .0005 in.)
Bore in bearings after assembly in bracket ..... 19.126 _ 0.038 mm (.7530 + .0015 in.)

(2) Distance bearing is installed from end of bracket 4.0 _+ 0.5 mm (.16 + .02 in.)

(3) Lever.

(4) Rod end.

(5) Distance bearing is installed from end of bracket 0.5 ± 0.5 mm (.02 + .02 in.)

(6) Distance pin is installed from lever ..... 181 mm (.71 + .04 in.)

(7) Nut: Tighten on each end of rod assembly to a torque of ..... 12 + 4 N-m (9 + 3 lb. ft.)

(8) Rod assembly.

(9) Lever.

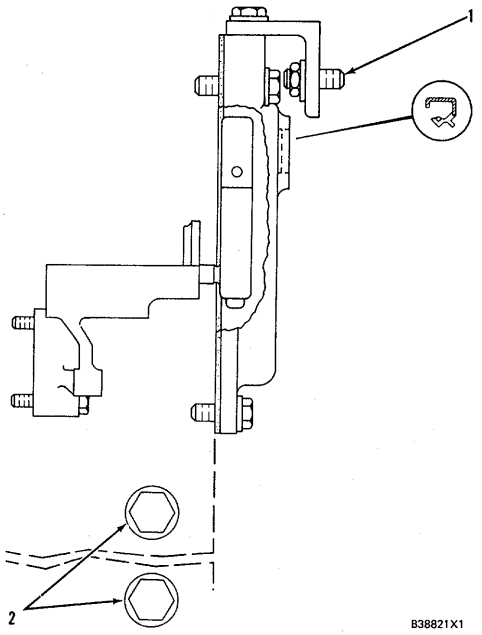
Linkage Adjustment:

1. With control linkage in the SHUTOFF position against its stop, install lever (3) as shown.
2. With actuator shaft in the SHUTOFF position against its stop, lever (9) must be installed at the angle shown.
3. With levers (3) and (9) in the SHUTOFF position, adjust rod end(4) and rod assembly (8) to the needed length. Tighten nuts (7) to hold rod ends in position.

NOTE: Threads of rod ends (4) must be visible through holes in rod to make sure there is minimum thread engagement. Fill holes in rod with 9S3263 Thread Lock after adjustment is correct.

4. Connect levers (3) and (9) together with rod assembly (8).

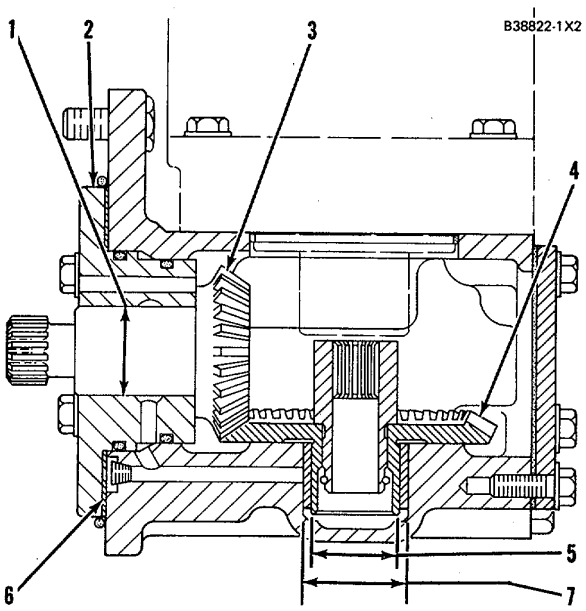
GOVERNOR FASTENER GROUP
(UG8L & 3161 Governors)



(1) Torque for:
Bolts (3161) ..... 45± 7N•m (32±5 lb. ft.)
Studs (UG8) ..... 30±5N•m(22±4 lb. ft.)
(2) Torque for plugs ..... 70±15N•m (50±11 lb. ft.)

GOVERNOR DRIVE

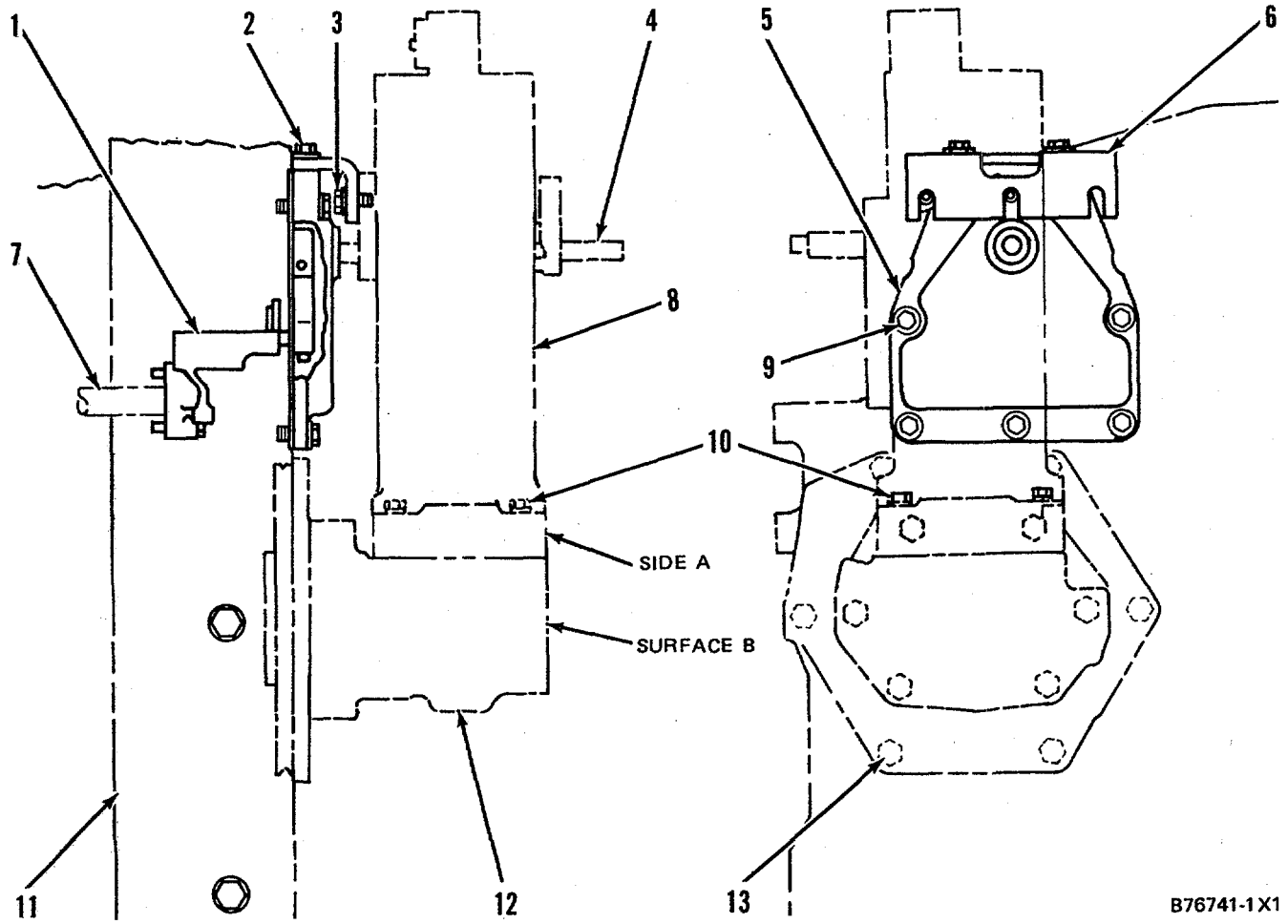
7N1889 & 8N9662 Drive Groups Used With UG8-L Woodward Governors
1W2135 Drive Group Used With Caterpillar 3161 Governors



(1) Diameter of bore in adapter (2)..... 34.072±0.025mm (1.3414±0.010 in.)
Diameter of shaft on governor drive pinion (3) ..... 34.000±0.013mm(1.3386±.0005 in.)
(2) Adapter.
(3) Governor drive pinion.
(4) Bevel gear.
(5) Diameter of shaft on bevel gear (4) ..... 34.000±0.013mm (1.3386±.0005)
(6) Shims. Use as required to get a gear clearance (backlash) between pinion (3) and gear (4) of ..... 0.100+0.050 or-0.025mm(.0039+.0020or -.0010 in.)
(7) Diameter of bore in drive housing 40.032±0.025mm(1.5918±0.010 in.)
Diameter of bearing..... 40.545±0.013mm (1.5963±.0005 in.)

NOTE: FOR TORQUE VALUES NOT GIVEN, SEE THE FIRST PAGE OF SPECIFICATIONS FOR GENERAL TIGHTENING TORQUES

GOVERNOR ALIGNMENT PROCEDRE
(UG8L & 3161 Governors)

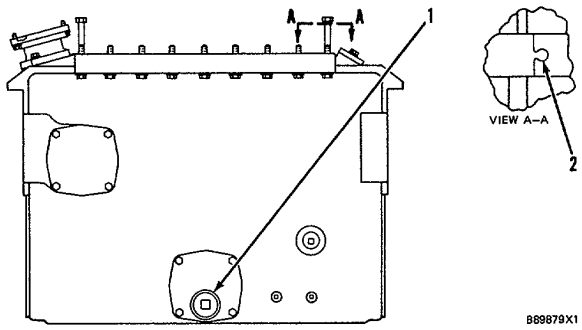


NOTE: Make sure governor output lever is connected correctly to rack fork lever (1).

1. Position base of governor (8) so side (A) of base is parallel with surface (B) of governor drive housing (12). Tighten governor mounting bolts (10).
2. Now loosen adapter bolts (13).
3. Move the governor and drive housing as needed until holes in cover (5) are in alignment with holes in accessory drive housing (11). Install, but do not tighten, the seven cover bolts (9).
4. Tighten the six adapter bolts (13).
5. Now tighten the seven cover bolts (9).
6. After all bolts are tightened, check to be sure governor terminal shaft (4.) has free rotation.

NOTE: Spring pressure in the Caterpillar 3161 Governor should cause the output terminal shaft to go back to the fuel-off position when released from the full-fuel position. Spring pressure in the Woodward UG8 Governor should cause the output terminal shaft to move when released from the full-fuel position, but it will not go all the way to the fuel-off position.

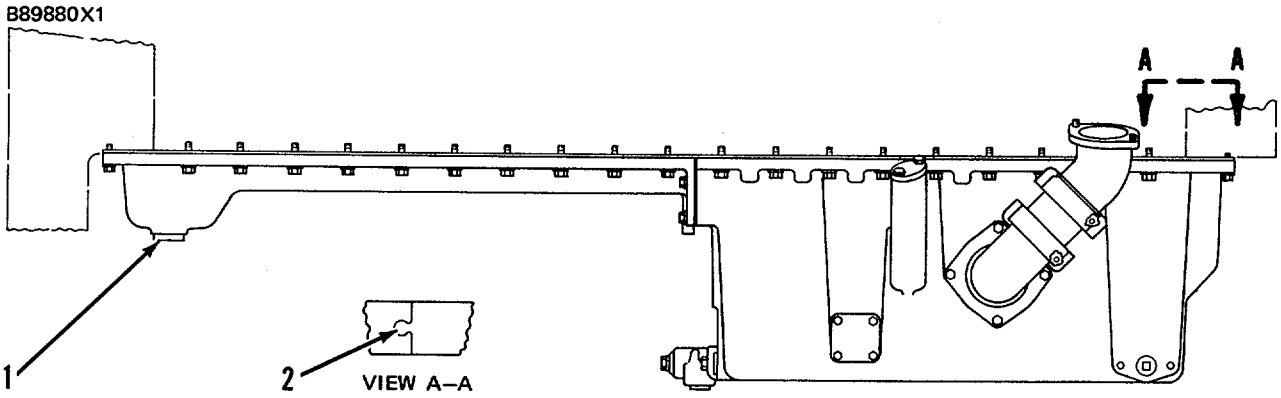
7 If output terminal shaft does not turn freely, do Steps 2 thru 6 again.
8. Put bracket (6) in position with open slots over bolts (3). Install washers and bolts (2) that hold bracket (6) to cover (5), but do not tighten these bolts.
9. Tighten bolts (3) that hold bracket to governor first, then tighten bolts (2) that hold bracket to cover.



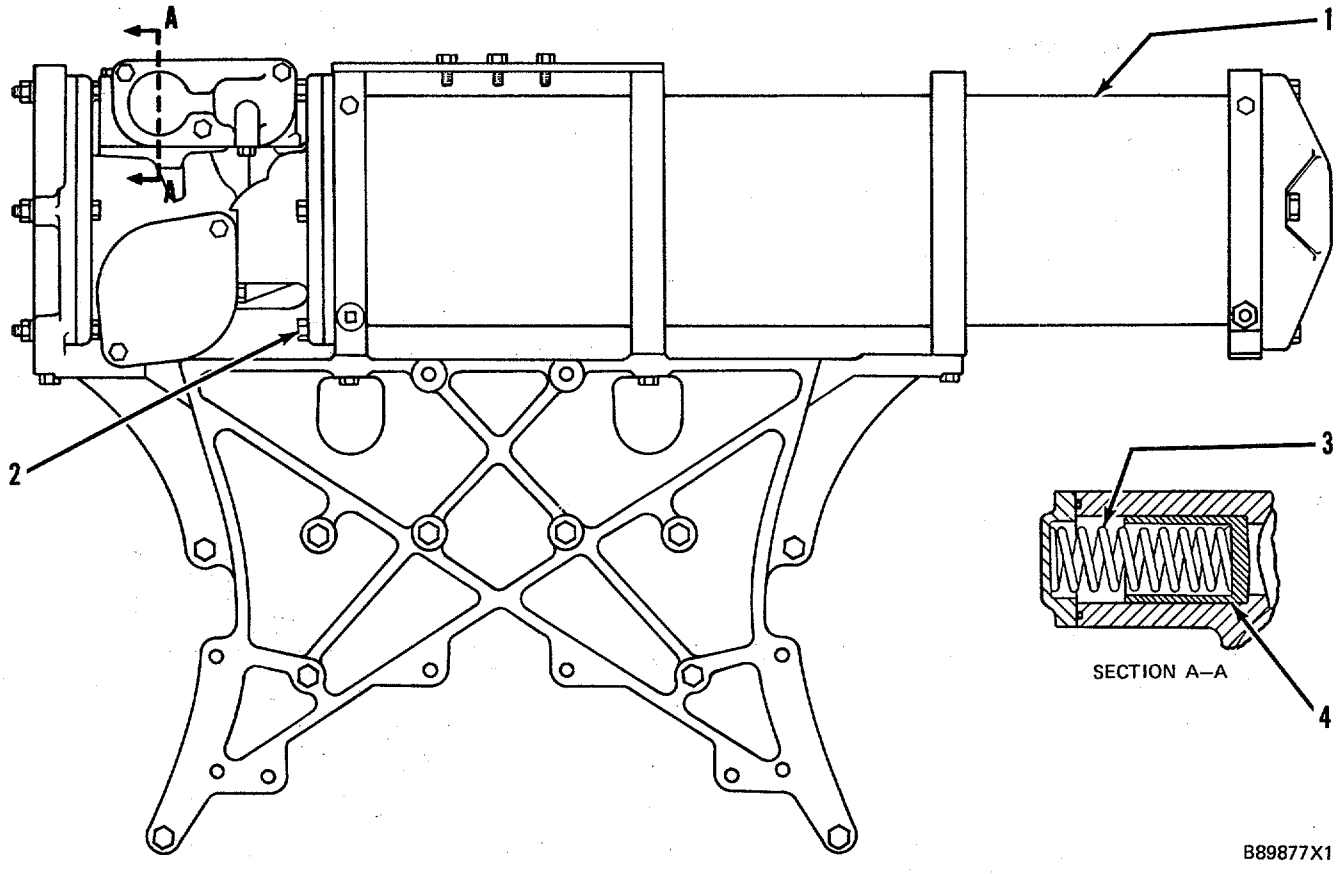
OIL PANS

(1) Tighten all 4B2363 Plugs in the oil pans to a torque of ..... 145 + 15 N-m (105 +11 lb. ft.)

(2) At assembly, put 7M7260 Liquid Gasket or PERMATEX NO. 2 on all gasket joints and where gaskets contact each other.



NOTE: FOR TORQUE VALUES NOT GIVEN, SEE THE FIRST PAGE OF SPECIFICATIONS FOR GENERAL TIGHTENING TORQUES421



OIL FILTER BYPASS VALVE
(L.H.)

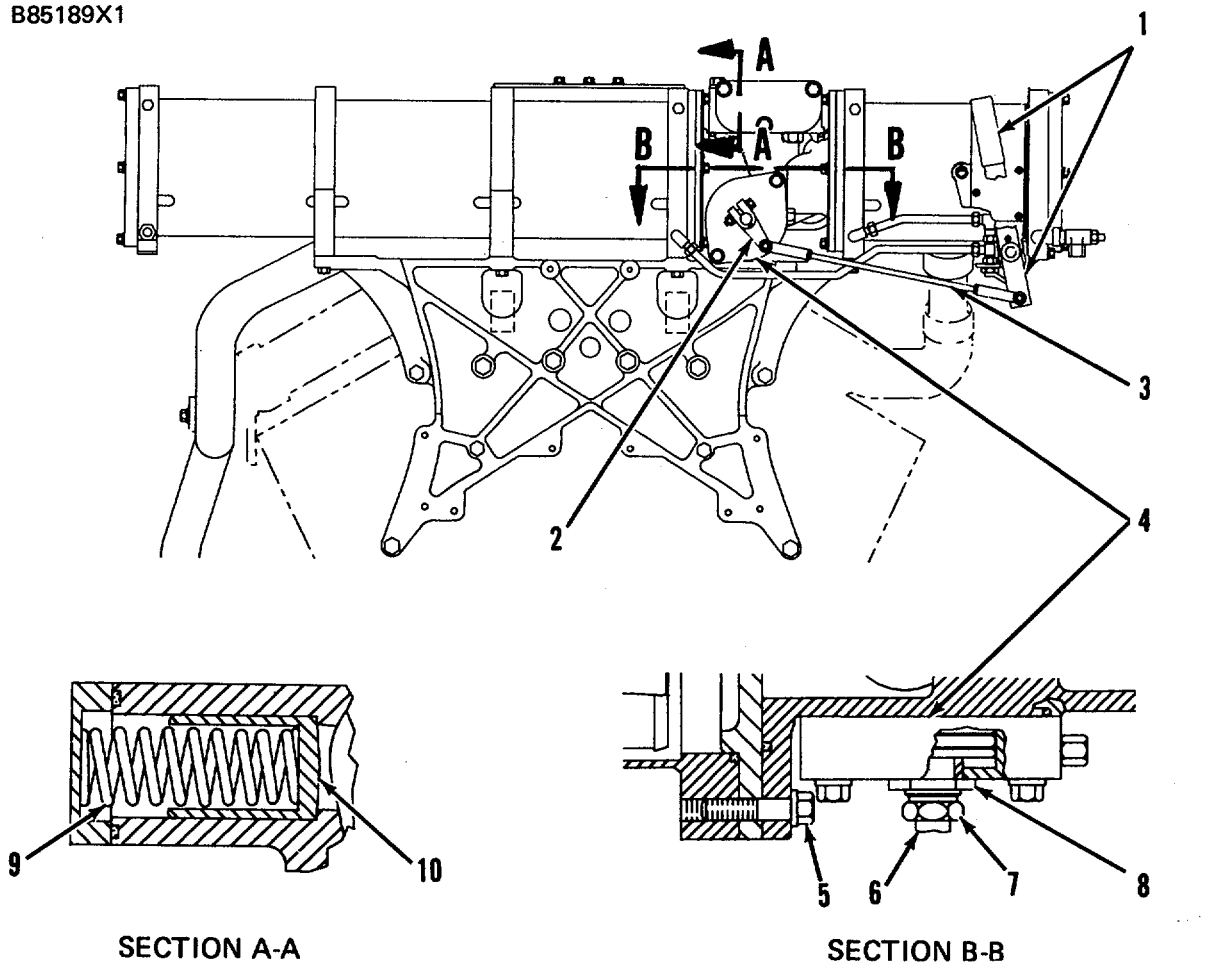
(1) Oil filter housing.

(2) Torque for three bolts that hold bypass housing to filter housing .....55±7 N-m (41 + 5 lb. ft.)

(3) 2W1635 Spring for the filter bypass valve:
Length under test force .....102 mm (4.02 in.)
Test force5 ..... 518 N (115 lb.)
Free length after test .....143.4 mm (5.65 in.)
Outside diameter .....37.25 mm (1.470 in.)

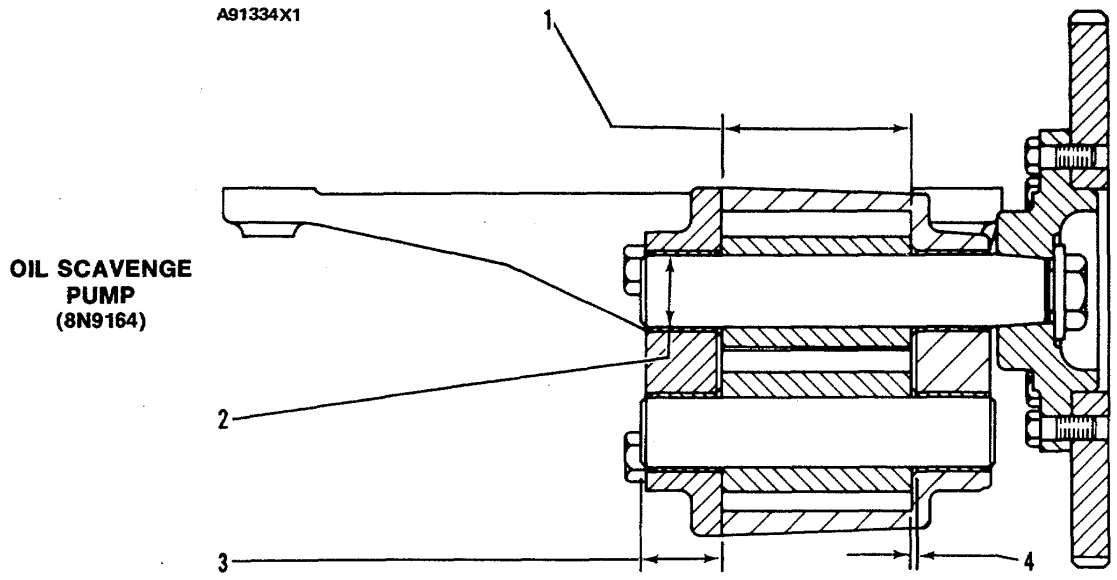
(4) Oil filter bypass valve must start to open at .....287 + 7 kPa (42 1 psi)
and fully open at ..... 480 + 7 kPa (70 + 1 psi)

DUPLEX OIL FILTER



(1) Handle.
(2) Lever.
(3) Linkage.(9) 2W1635 Spring for oil filter bypass valve:
(4) Valve assembly cover.
(5) Bolt (three at each end of valve body housing.)
Tighten to a torque of 55 ± 7 N'm (40 ± 5 lb. ft.)
(6) Valve assembly shaft.
(7) Adjustment nut be fully opened at 480 + 7 kPa (70 + 1 psi).
See Testing and Adjusting for adjustment procedure..
(8) Jam nut.
(9) 2W1635 Spring for oil filter bypass valve: Length under test force ..... 102 mm (4.02 in)
Test force .....518 N (116.55 lb.)
Free length after test ..... 143.4 mm (5.65 in.)
Outside diameter ..... 37.25 mm (1.470 in.)
Bypass valve must start to open at 287 ± 7 kPa (42 + 1 psi) and
(10) Bypass Valve

NOTE: FOR TORQUE VALUES NOT GIVEN, SEE THE FIRST PAGE OF SPECIFICATIONS FOR GENERAL TIGHTENING TORQUES



Rotation of drive gear (as seen from drive end) ..... Counterclockwise

(1) Length of gears (new)..... 84.000± 0.015 mm (3.3071±0006 in.)
Depth of bores for gears (new) ..... 84.15 ± 0.02 mm (3.313 ± .001 In.)

(2) Diameter of gear shafts (new) ... 31.742 ± 0.008 mm (1.2497 ± .0003 In.)
Bore In bearings for gear shafts after assembly (new) ... 31.837 ± 0.070 mm (1.2534 + .0028 in.)

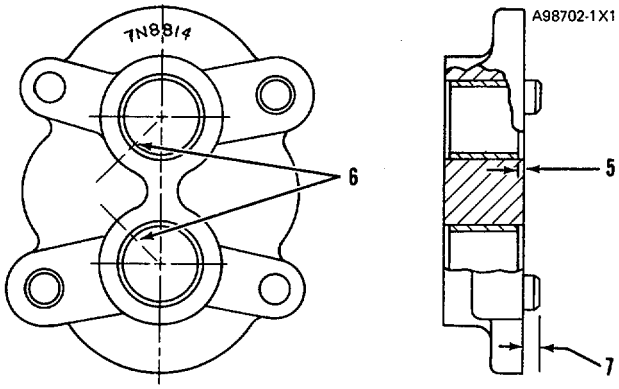
(3) Distance from the end of the shafts to the gear faces..... 34.0 ± 0.5 mm (1.34 ± .02 in.)

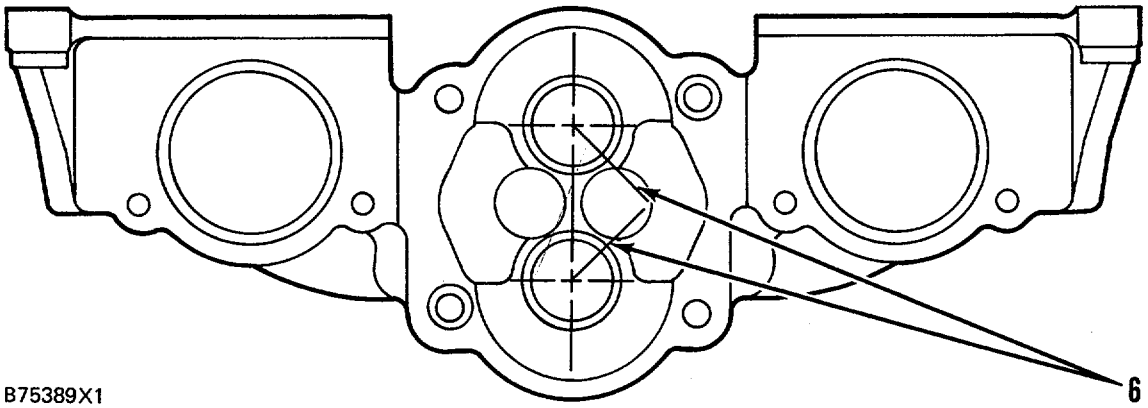
(4) Depth that bearings are installed in pump body ..... 1 5 ± 0.5 mm (.06 + .02 in.)

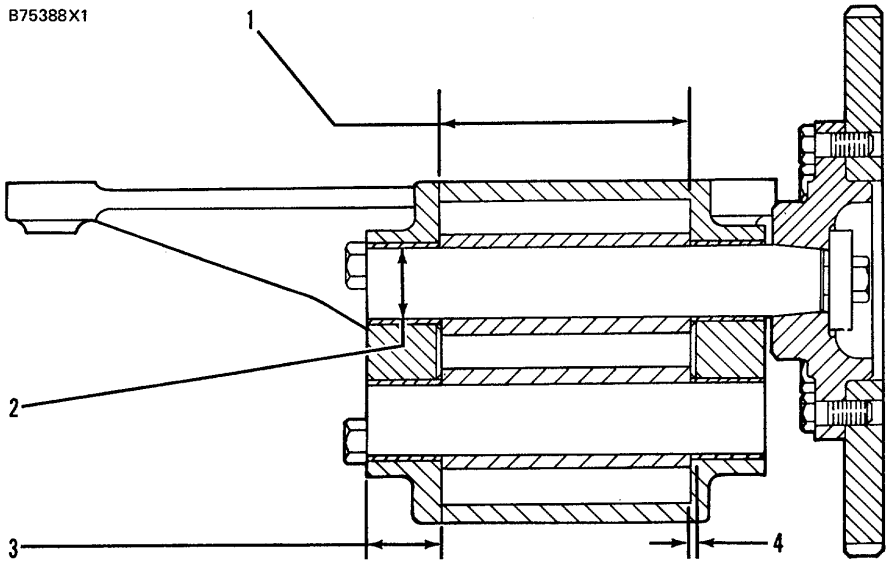
(5) Depth that bearings are installed In cover ..... 1.5 ± 0.5 mm (.06 + .02 in.)

(6) Position of bearing joints from the centerline through the bearing bores ..... 45 ± 15°

(7) Distance dowels extend from cover ..... 6.4 ± 0.5 mm (.25 ± .02 In.)







OIL SCAVENGE PUMP (1W8505)

Rotation of drive gear (as seen from drive end) ..... Counterclockwise

(1) Length of gears (new)..... 110.000± 0.015 mm (4.3307±0006 in.)
Depth of bores for gears (new) ..... 110.15 ± 0.02 mm (4.337 ± .001 In.)

(2) Diameter of gear shafts (new) ... 31.742 ± 0.008 mm (1.2497 ± .0003 In.)
Bore In bearings for gear shafts after assembly (new) ... 31.837 ± 0.070 mm (1.2534 + .0028 in.)

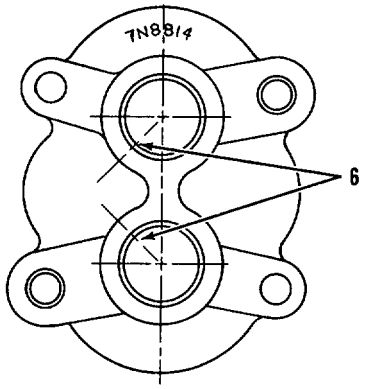
(3) Distance from the end of the shafts to the gear faces..... 34.0 ± 0.5 mm (1.34 ± .02 in.)

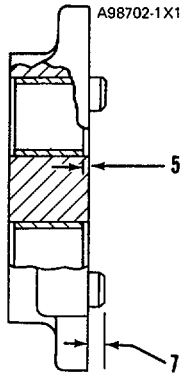
(4) Depth that bearings are installed in pump body ..... 1 5 ± 0.5 mm (.06 + .02 in.)

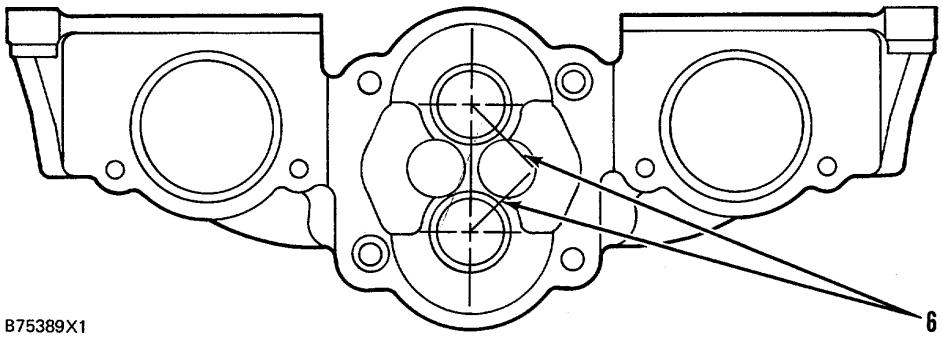
(5) Depth that bearings are installed In cover ..... 1.5 ± 0.5 mm (.06 + .02 in.)

(6) Position of bearing joints from the centerline through the bearing bores ..... 45 ± 15°

(7) Distance dowels extend from cover ..... 6.4 ± 0.5 mm (.25 ± .02 In.)

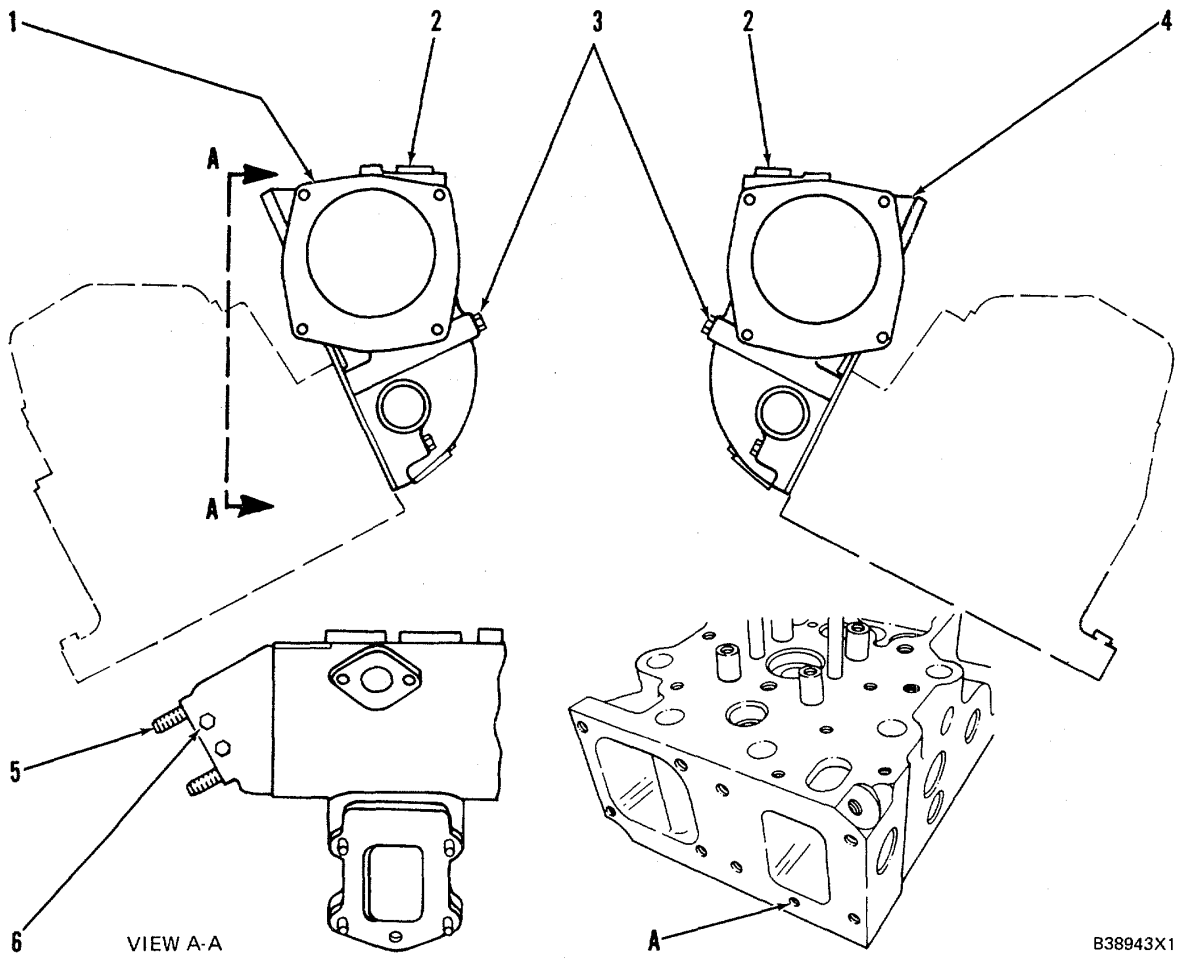






NOTE: FOR TORQUE VALUES NOT GIVEN, SEE THE FIRST PAGE OF SPECIFICATIONS FOR GENERAL TIGHTENING TORQUES

EXHAUST MANIFOLDS
(WATER COOLED)



(3508 & 3512 ILLUSTRATED)

(1) Right exhaust manifold.
(2) Plugs. Tighten plugs to a torque of ..... 90 Nm (65 lb.ft.)

NOTE: Put 5P3931 Anti-Seize Compound on the threads of bolts (3), studs (5) and plugs (6) at assembly.

(3) Bolts. Tighten the bolts that hold exhaust manifolds (1) and (4) to a torque of ..... 45 + 7 N-m (32 + 5 lb.ft.)
(4) Left exhaust manifold.
(5) Studs. Tighten the studs in the exhaust manifolds to a torque of ..... 30 + 5 N-m (22 + 4 lb.ft.)
(6) Plugs. Tighten the plugs to a torque of ..... 25 N-m (20 lb.ft.)

NOTICE

Before installation of this cylinder head on an engine that has water cooled manifolds, the plug at location (A) MUST be removed. If the engine has dry manifolds, the plug at location (A) MUST NOT be removed.

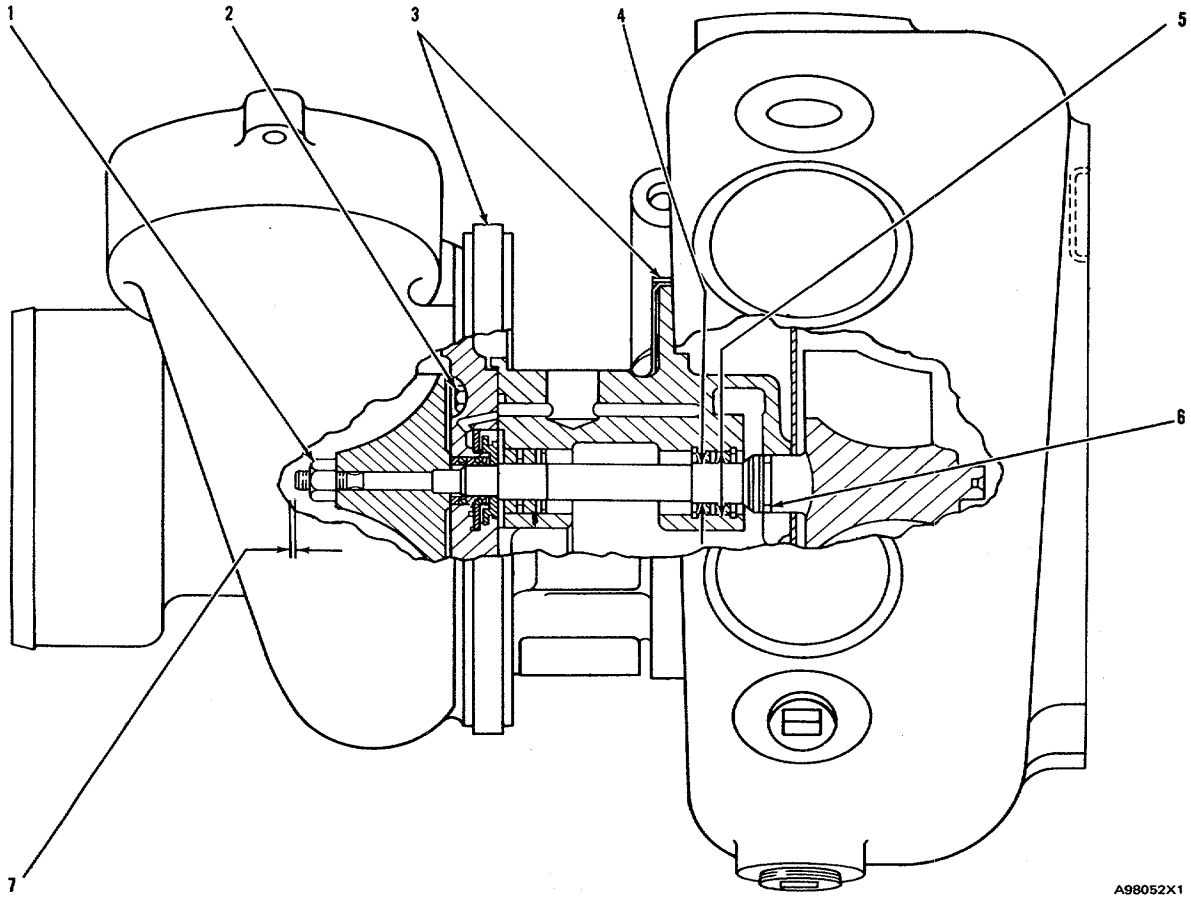
NOTE: FOR TORQUE VALUES NOT GIVEN, SEE THE FIRST PAGE OF SPECIFICATIONS FOR GENERAL TIGHTENING TORQUES

TURBOCHARGER IMPELLER INSTALLATION

INSTALLATION PROCEDURE CHART					
	TURBOCHARGER MODELS				
Step by Step Procedure	T04, T04B, T04C, TW4B, TW4C TL4B, TL4C	TM51 TM54	T12, TV61, TW61, TL61	T18, TV81, TW81, TL81, TV72, TW72, TL72, TV78, TW78, TL78	TV91, TW91, TL91, TV92, TW92, TL92
A. Put impeller on the shaft.					
B. Put a small amount of clean oil on the threads and impeller face area that contacts the nut.					
C. Install and tighten the nut to:	2.25 N•m (20 lb. in.)	5 N•m (50 lb. in.)	17 N•m (13 lb. ft.)	17 N•m (13 lb. ft.)	31 N•m (23 lb. ft.)
NOTICE **Do not bend or add stress to the shaft when the nut is loosened or tightened.**					
D. Loosen the nut on the shaft.	*	*			
E. Now tighten the nut to:	*	*	3.5 N•m (30 lb. in.)	3.5 N•m (30 lb. in.)	5 N•m (50 lb. in.)
F. Tighten the nut more:	110°	120°	120°	120°	135°
G. Remove the nut from the shaft.					
H. Use 6V1541 Quick Cure Primer on the threads of the shaft and nut.					
J. Put 9S3265 Retaining Compound on the threads of the shaft and nut.					
K. Install and tighten the nut to:	2.25 N•m (20 lb. in.)	5 N•m (50 lb. in.)	3.5 N•m (30 lb. in.)	3.5 N•m (30 lb. in.)	5 N•m (50 lb. in.)
L. Tighten the nut more:	110°	120°	120°	120°	135°

*Does not apply to these turbochargers.

TURBOCHARGER TW61



(1) Nut for impeller (See TURBOCHARGER IMPELLER INSTALLATION).

NOTICE

Do not bend or add stress to the shaft when the nut is loosened or tightened.

(2) Torque for the bolts that hold the backplate ..... 10 ± 1 N•m (90 ±10 lb. in.)

(3) Torque for the clamp bolts ..... 14.0 ± 1.5 N•m (120 ± 13 lb. in.)

Lightly hit all around clamp with a soft faced hammer and again tighten to..... 14.0 ± 1.5 N•m (120 ± 13 lb. in.)

(4) Bore in the bearings.... 15.921 to 15.931 mm (.6268 to .6272 in.)

Diameter for the surfaces (journals) on the shaft for the bearings.... 15.875 to 15.885 mm (.6250 to .6254 in.)

(5) Bore in the housing ..... 24.961 to 24.973 mm (.9827 to .9832 in.)

Outside diameter of the bearings..... 24.846 to 24.859 mm (.9782 to .9787 in.)

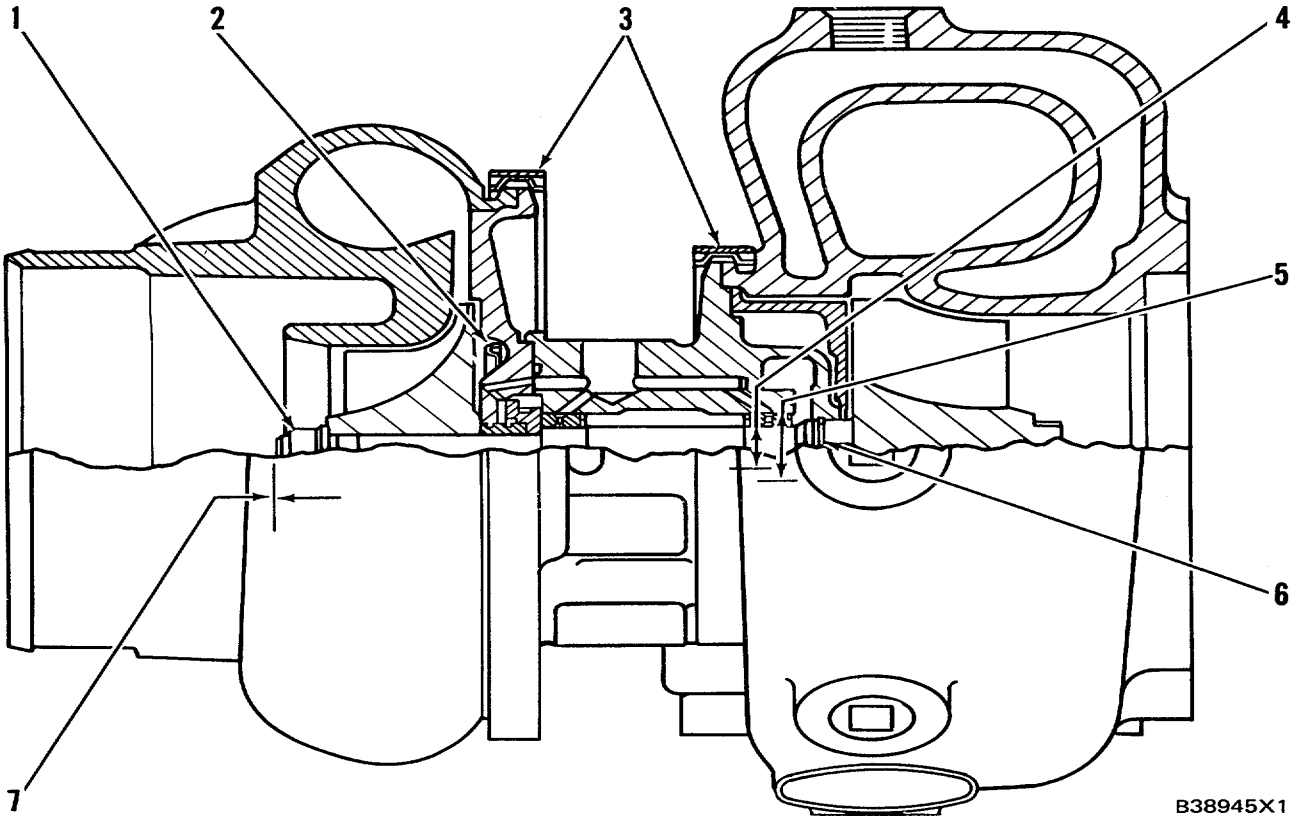
(6) Clearance between the ends of the oil seal ring (when installed in its bore) ..... 0.20 to 0.38 mm (.008 to .015 in.)

(7) End play for the shaft. ..... 0.08 to 0.25 mm (.003 to .010 in.)

Torque for bolts and nuts that hold the turbocharger to the exhaust manifold (put 5P3931 Anti-Seize Compound on the threads) ..... 54 ± 5 N•m (40 + 4 lb. ft.)

NOTE: FOR TORQUE VALUES NOT GIVEN, SEE THE FIRST PAGE OF SPECIFICATIONS FOR GENERAL TIGHTENING TORQUES

TURBOCHARGER TW81



(1) Nut for impeller (See TURBOCHARGER IMPELLER INSTALLATION).

NOTICE

Do not bend or add stress to the shaft when the nut is loosened or tightened.

(2) Torque for the bolts that hold the backplate ..... 101 N•m (90 ± 10 lb. in.)

(3) Torque for the clamp bolts..... 14.0 ± 1.5 N•m (120 ± 13 lb. in.)

Lightly hit all around clamp with a soft faced hammer and again tighten to..... 14.0 ± 1.5 N•m (120 ± 13 lb. in.)

(4) Bore in the bearings.... 15.921 to 15.931 mm (.6268 to .6272 in.)

Diameter for the surfaces (journals) on the shaft for the bearings.... 15.875 to 15.885 mm (.6250 to .6254 in.)

(5) Bore in the housing ..... 24.961 to 24.973 mm (.9827 to .9832 in.)

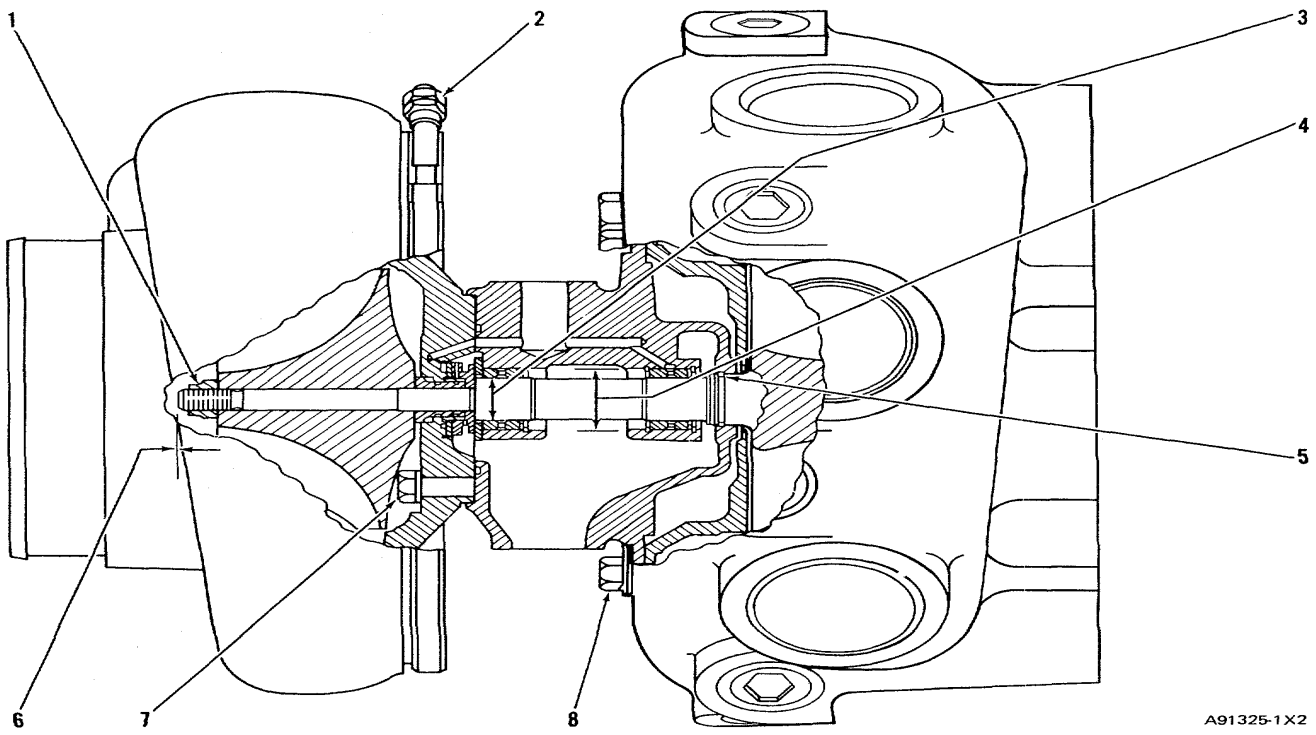
Outside diameter of the bearings.... 24.846 to 24.859 mm (.9782 to .9787 in.)

(6) Clearance between the ends of the oil seal ring (when installed in its bore)..... 0.20 to 0.38 mm (.008 to .015 in.)

(7) End play for the shaft ..... 0.08 to 0.25 mm (.003 to .010 in.)

Torque for bolts and nuts that hold the turbocharger to the exhaust manifold (put 5P3931 Anti-Seize Compound on threads)..... 54 ± 5 N•m (40 ± 4 lb. ft.)

TURBOCHARGER TW91



(1) Nut for impeller. (See TURBOCHARGER IMPELLER INSTALLATION.)

NOTICE

Do not bend or add stress to the shaft when the nut is loosened or tightened.

(2) Torque for the clamp bolt..... 14.0 ±1.5 N•m (120 + 13 lb. in.)

Hit lightly all around clamp with a soft faced hammer and again tighten to..... 14.0 + 1.5 N-m (120 + 13 lb. in.)

(3) Bore in the bearings.... 21.585 to 21.595 mm (.8498 to .8502 in.)

Diameter of the surfaces (journals) on the shaft... 21.539 to 21.549 mm (.8480 to .8484 in.)

(4) Bore in the housing... 30.594 to 30.607 mm (1.2045 to 1.2050 in.)

Outside diameter of bearings..30.467 to 30.480 mm (1.1995 to 1.2000 in.)

(5) Clearance between the ends of oil seal ring (when installed in its bore)..... 0.20 to 0.38 mm (.008 to .015 in.)

(6) End play for the shaft ..... 0.165 ± 0.063 mm (.0065 ± .0025 in.)

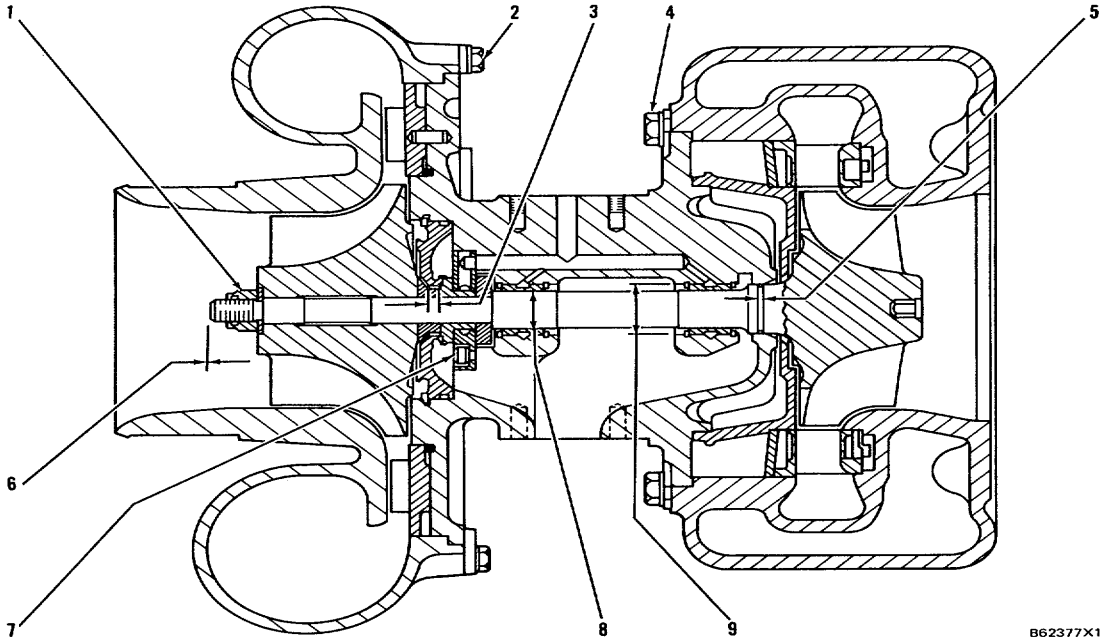
(7) Torque for the bolts that hold the backplate..... 40 ± 2 N•m (30 ± 1 lb. ft.)

(8) Torque for the bolts that hold the turbine housing to the cartridge housing (put 5P3931 Anti-Seize Compound on the threads)..... 40 ± 2 N•m (30 ± 1 lb. ft.)

Torque for bolts and nuts that hold the turbocharger to the exhaust manifold (put 5P3931 Anti-Seize Compound on threads)..... 54 ± 5 N•m (40 ± 4 lb. ft.)

NOTE: FOR TORQUE VALUES NOT GIVEN, SEE THE FIRST PAGE OF SPECIFICATIONS FOR GENERAL TIGHTENING TORQUES

TURBOCHARGER W153



NOTICE

Do not bend or add stress to the shaft when the nut is loosened or tightened.

(1) Turbocharger impeller installation:
   a. Put impeller on the shaft.
   b. Put a small amount of 2P2506 Thread Lubricant on the threads and impeller face that will be under the nut.
   c. Tighten the nut to..... 95 ± 5 N•m (70 ± 4 lb. ft.)

(2) Torque for the bolts that hold the compressor housing to the cartridge housing..... 25 ± 5 N•m (18 ± 4 lb. ft.)

(3) Width of oil seal ring at compressor end..... 2.500 ± 0.010 mm (.0984 + .0004 in.)

Width of oil seal ring bore at compressor end..... 2.635 ± 0.035 mm (.1037 ± .0014 in.)

(4) Torque for the bolts that hold the turbine housing to the cartridge housing (put 5P3931 Anti-Seize Compound on the threads) ..... 48 ± 3 N•m (35 ± 2 lb. ft.)

(5) Width of oil seal ring at turbine end..... 2.500 ± 0.010 mm (.0984 ± .0004 in.)

Width of oil seal ring groove at turbine end ..... 2.550 + 0.030 - 0.010 mm (.1004 + .0012 - .0004 in.)

(6) End play for the shaft ..... 0.090 to 0.130 mm (.0035 to .0051 in.)

(7) Torque for the three bolts that hold the thrust bearing ..... 12 ± 4 N-m (9 ± 3 lb. ft.)

(8) Bore in the bearings ..... 24.020 + 0.010 - 0.0 mm (.9457 + .0004 - .00 in.)

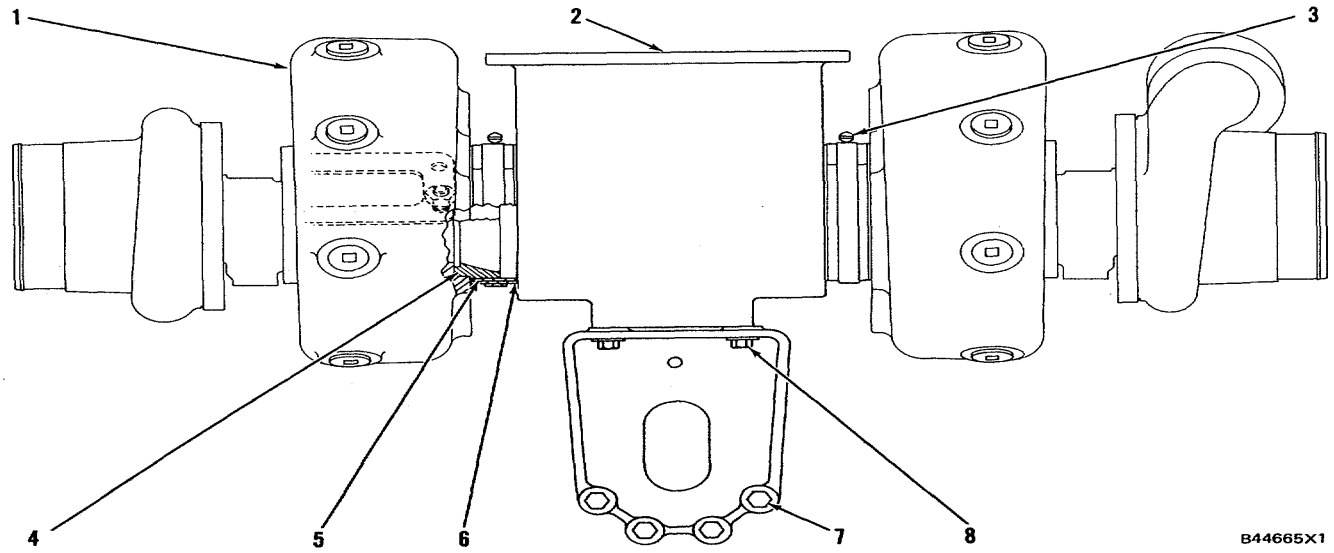
Diameter of the surfaces (journals) on the shaft ..... 24.000 + 0.0 - 0.009 mm (.9449 + .00 - .0004 in.)

(9) Bore in the housing..... 32.000 + 0.016 - 0.0 mm (1.2598 + .0006 - .00 in.)

Outside diameter of the bearings ..... 31.890 + 0.0 - 0.010 mm (1.2555 + .00 - .0004 in.)

Torque for bolts that hold the turbocharger to the exhaust manifold (put 5P3931 Anti-Seize Compound on threads) ..... 135 ± 15 N•m (100 ± 11 lb. ft.)

TURBOCHARGER INSTALLATION
(Watercooled Exhaust Elbow)
(3508 - 95Y & 68Z)



(1) Turbine housing.

(2) Exhaust elbow.

(3) Clamp.

(4) Adapter.

(5) Seal.

(6) Collar.

(7) Bracket mounting bolts.

(8) Exhaust elbow mounting bolts.

Seal installation procedure:

A. Loosen exhaust elbow and bracket mounting bolts (8) and (7).

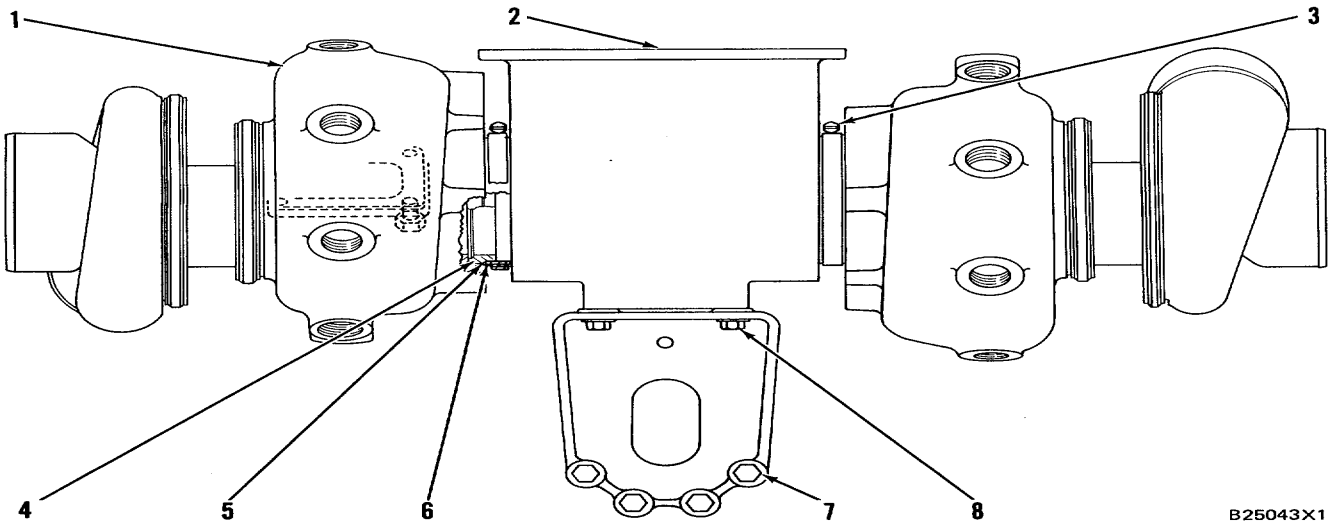
B. Slide adapter (4) out of bore of turbine housing (1) until it contacts pilot of exhaust elbow (2).

C. Install seal (5) and collar (6). Make sure collar joint and clamp tightening mechanism are offset. Tighten clamps to a torque of..... 6.0 ± 0.5 N•m (55 ± 4 lb. in.)

D. After both clamps are tightened, tighten exhaust elbow mounting bolts (8) and bracket mounting bolts (7).

NOTE: FOR TORQUE VALUES NOT GIVEN, SEE THE FIRST PAGE OF SPECIFICATIONS FOR GENERAL TIGHTENING TORQUES

TURBOCHARGER INSTALLATION
(Watercooled Exhaust Elbow)
(3512 - 49Y & 65Z, 3516 - 71Z)



(1) Turbine housing.

(2) Exhaust elbow.

(3) Clamp.

(4) Adapter.

(5) Seal.

(6) Collar.

(7) Bracket mounting bolts.

(8) Exhaust elbow mounting bolts.

Seal installation procedure:

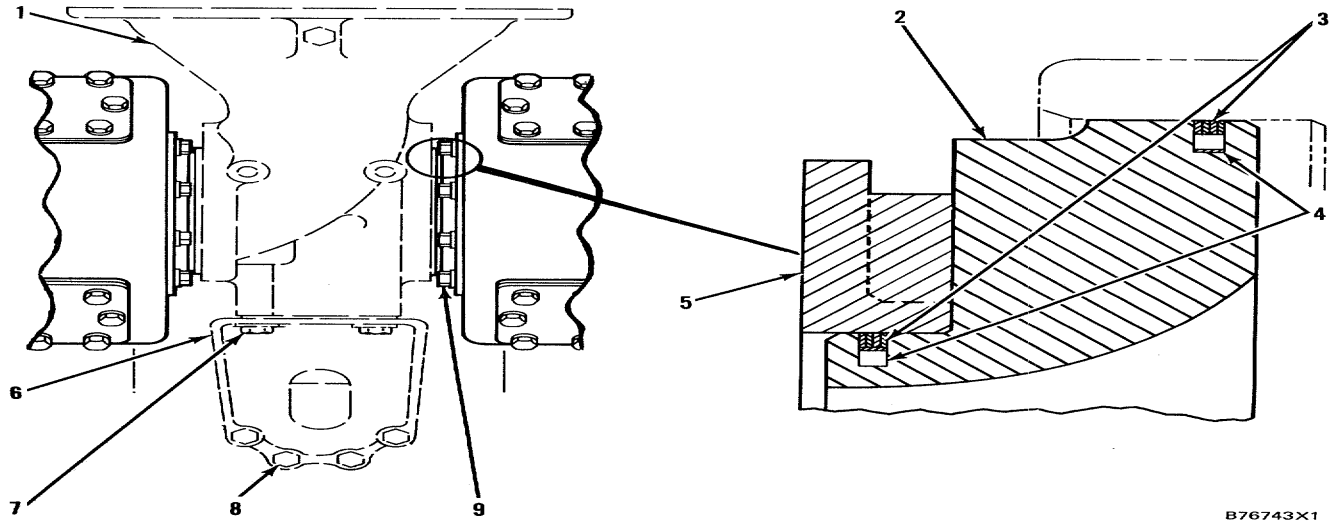
A. Loosen exhaust elbow and bracket mounting bolts (8) and (7).

B. Slide adapter (4) out of bore of turbine housing (1) until it contacts pilot of exhaust elbow (2).

C. Install seal (5) and collar (6). Make sure collar joint and clamp tightening mechanism are offset. Tighten clamps to a torque of.....6 0 ± 0 5 N•m (55 ± 4 lb. in.)

D. After both clamps are tightened, tighten exhaust elbow mounting bolts (8) and bracket mounting bolts (7)

TURBOCHARGER INSTALLATION
(Watercooled Turbochargers)
(3516 - 27Z)



(1) Exhaust elbow (not water cooled).
(2) Coupling.
(3) Metal seal rings.
(4) Ring expander.
(5) Adapter.
(6) Exhaust elbow support bracket.
(7) Exhaust elbow mounting bolts.
(8) Support bracket mounting bolts.
(9) Adapter bolts.

Installation Procedure:

A. Install correct ring expander (4) in each groove of coupling (2). Now install the correct four metal seal rings (3) in each groove over ring expander (4).

NOTE: Seal rings (3) must be installed with the gaps of each ring spaced approximately 90° apart from each other.

B. Install coupling (2) in elbow (1), and then install adapter (5) over coupling (2).

NOTE: Position coupling (2) in elbow so that largest lug is at top as marked on coupling.

C. Install turbocharger to exhaust manifold, and make sure face of turbocharger is in vertical alignment with adapter (5).

D. Install gasket between adapter (5) and turbocharger. Now install bolts (9) that hold the adapter to the turbocharger, but do not tighten the bolts.

E. Use the same procedure for the other coupling, adapter and turbocharger.

F. Loosen bolts (7) and (8). Loosen or remove bolts that hold exhaust pipe to exhaust elbow (1).

G. Shake the exhaust elbow to be sure that the couplings and metal seals are not binding. Now position exhaust elbow in alignment with the turbochargers.

H. Tighten the bolts snugly (not tight) in the sequence that follows:
   a. Support bracket to exhaust elbow bolts (7).
   b. Support bracket to flywheel housing bolts (8).
   c. Adapter to turbocharger bolts (9).

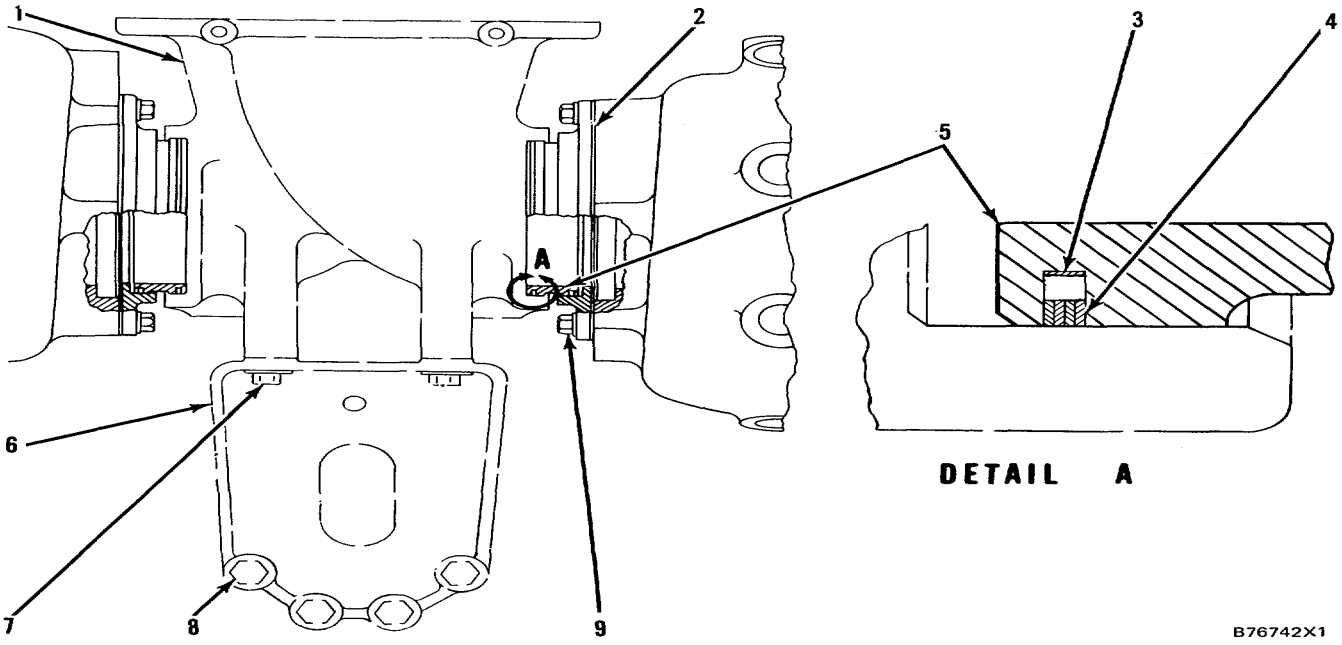
J. Hit adapters (5) lightly with a soft hammer, and check alignment of parts again.

K. Now tighten all bolts again in same sequence.

L. Install and tighten bolts that hold exhaust elbow to exhaust pipe.

NOTE: FOR TORQUE VALUES NOT GIVEN, SEE THE FIRST PAGE OF SPECIFICATIONS FOR GENERAL TIGHTENING TORQUES

TURBOCHARGER INSTALLATION
(Watercooled Turbochargers)
(3508 - 95Y & 68Z, 3512 - 49Y & 65Z, 3516 - 71Z)



(1) Exhaust elbow (not water cooled).
(2) Adapter.
(3) Ring expander.
(4) Metal seal rings.
(5) Coupling.
(6) Exhaust elbow support bracket.
(7) Exhaust elbow mounting bolts.
(8) Support bracket mounting bolts.
(9) Adapter bolts.

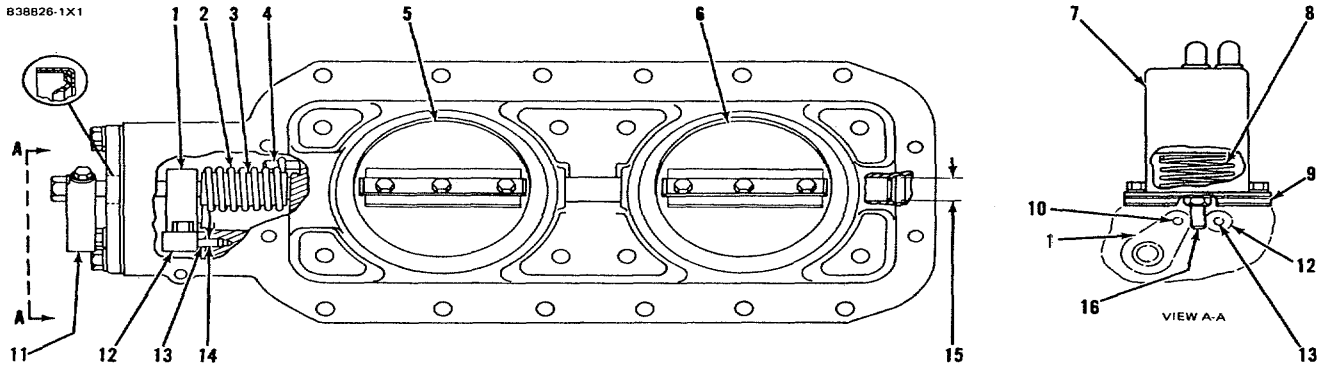
Installation Procedure:

A. Install ring expander (3) in each groove of coupling (5). Now install the four metal seal rings (4) in each groove over ring expander (3).

NOTE: Seal rings (4) must be installed with the gaps of each ring spaced approximately 90° apart from each other.

B. Install coupling (5) in elbow (1), and then install adapter (2) over coupling (5).
C. Install turbocharger to exhaust manifold, and make sure face of turbocharger is in vertical alignment with adapter (2).
D. Install gasket between adapter (2) and turbocharger. Now install bolts (9) that hold the adapter to the turbocharger, but do not tighten the bolts.
E. Use the same procedure for the other coupling, adapter and turbocharger.
F. Loosen bolts (7) and (8). Loosen or remove bolts that hold exhaust pipe to exhaust elbow (1).
G. Shake the exhaust elbow to be sure that the couplings and metal seals are not binding. Now position exhaust elbow in alignment with the turbochargers.
H. Tighten the bolts snugly (not tight) in the sequence that follows:
   a. Support bracket to exhaust elbow bolts (7).
   b. Support bracket to flywheel housing bolts (8).
   c. Adapter to turbocharger bolts (9).
J. Hit adapters (2) lightly with a soft hammer, and check alignment of parts again.
K. Now tighten all bolts again in same sequence.
L. Install and tighten bolts that hold exhaust elbow to exhaust pipe.

AIR INTAKE SHUTOFF
(5N9060)



(1) Shaft assembly. Install in housing as follows:
- a. Install spacer (3) and spring (2) on shaft assembly (1).
- b. Install the assembly in the housing. Turn spring (2) until it engages correctly with pin (4).
- c. Temporarily install handle (11) on the shaft assembly (1). Turn shaft assembly (1) upward and install pin (13) a small distance in bore (14) so handle (11) can rest on pin (13).
- d. With the shaft assembly and handle (11) in contact with pin (13), install plate assemblies (5) and (6) on the shaft assembly.
- e. Remove pin (13) to release the handle and let plate assemblies (5) and (6) move to the "shutoff" position. A 0.08 mm (.003 in.) feeler gauge should not pass between each plate assembly and the housing.
- f. Remove handle (11) and install pin (13), spacer assembly (12), the gasket, cover assembly and handle (11).

(2) Spring.

(3) Spacer for spring (2):
Bore in spacer for shaft..... 20.80 ± 0.25 mm (.819 + .010 in.)
Diameter of shaft..... 18.94 ± 0.02 mm (.746 ± .001 in.)

(4) Pin.

(5) Plate assembly.

(6) Plate assembly.

(7) Electric solenoid assembly. Install solenoid assembly to housing as follows:
- (a) Remove the plunger from solenoid assembly (7) and install stop (16) to the plunger.
- (b) Turn air shutoff handle (11) to the "open" position and put plunger in position so the stop is between spacer assemble (12) and shaft assembly (1). Now release handle (11) to allow shaft assembly to rest against stop (16).
- (c) Install the lower gasket, spacer plate (9) and the upper gasket.
- (d) Install spring (8) over plunger and install the solenoid assembly.

(8) Spring.

(9) Spacer plate.

(10) Diameter of
pin ..... 6.299 ± 0.008 mm (.2480 ± .0003 in.)
Bore in spacer bushing for pin (after assembly)..... 6.314 ± 0.011 mm (.2486 ± .0004 in.)
Bore in spacer for bushing ..... 7.938 ± 0.013 mm (.3125 ± .0005 in.)

(11) Handle.

(12) Spacer assembly.

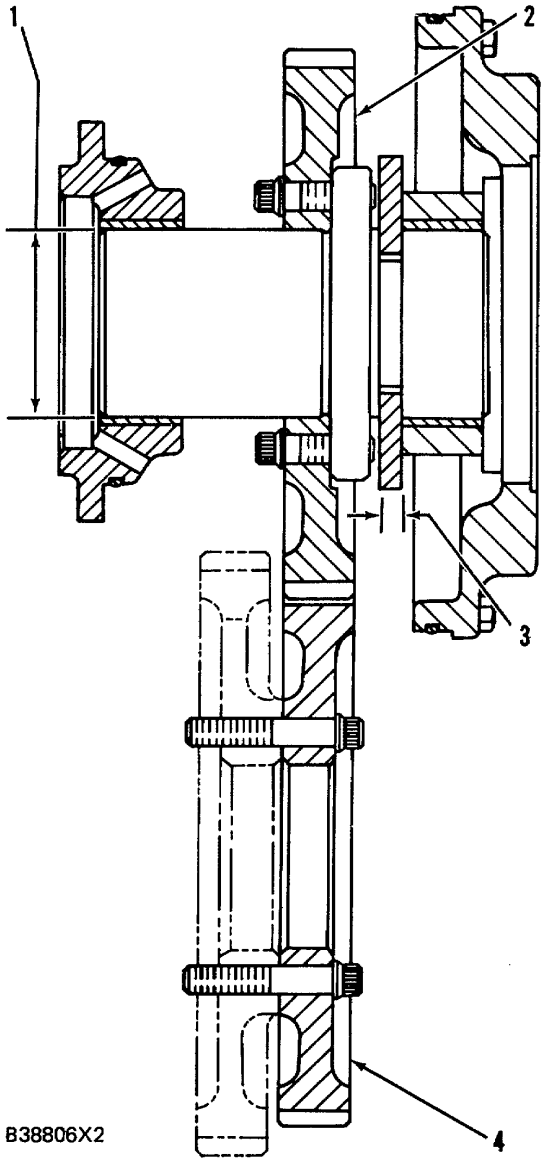
(13) Pin.

(14) Diameter of
pin (13)..... 6.299 ± 0.008 mm (.2480 ± .0003 in.)
Bore in housing for pin ..... 6.408 ± 0.051 mm (.2523 ± .0020 in.)
Bore in spacer assembly bushing for pin (after assembly)... 6.314 ± 0.011 mm (.2486 ± .0004 in.)
Bore in spacer for bushing..... 7.938 ± 0.013 mm (.3125 ± .0005 in.)

(15) Diameter of
shaft ..... 18.94 ± 0.02 mm (.746 ± .001 in.)
Inside diameter of bushings for shaft ..... 19.050 ± 0.044 mm (.7500 ± .0017 in.)

(16) Stop.

NOTE: FOR TORQUE VALUES NOT GIVEN, SEE THE FIRST PAGE OF SPECIFICATIONS FOR GENERAL TIGHTENING TORQUES



(UPPER) FRONT GEAR GROUPS

7N4871 (Right Hand) (Standard Rotation) 8N9166 (Left Hand) (Standard Rotation)

8N5768 (Right Hand) (Reverse Rotation) 8N5745 (Left Hand) (Reverse Rotation)

8N5769 (Right Hand) (Reverse Rotation) 8N5743 (Left Hand) (Reverse Rotation)

(1) Bore in the bearings (after assembly)..... 75.000 ± 0.055 mm (2.9528 ± .0022 in.)

Diameter of shaft.... 74.900 ± 0.015 mm (2.9488 ± .0006 in.)

(2) Drive gear on shaft for governor drive.

(3) Thickness of washer (new)..... 8.50 ± 0.05 mm (.335 ± .002 in.)

Width of groove in shaft (new)..... 8.750 ± 0.025 mm (.3445 ± .0010 in.)

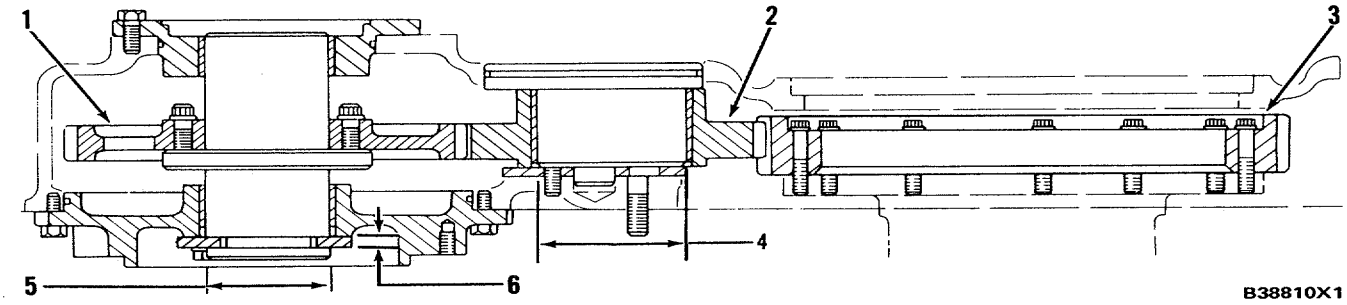
End play for the shaft..... 0.175 to 0.325 mm (.0069 to .0128 in.)

(4) Gear fastened to water and oil pump drive.

LOWER FRONT GEAR GROUPS

8N7174 (Right Hand) (Standard Rotation) 8N9167 (Left Hand) (Standard Rotation)

8N5768 (Right Hand) (Reverse Rotation) 8N5767 (Left Hand) (Reverse Rotation)



8N7174 FRONT GEAR GROUP SHOWN

(1) Drive gear for water and oil pumps.

(2) Idler gear.

(3) Crankshaft gear.

(4) Bore in bearing (after assembly..... 90.000 ± 0.065 mm (3.5430 ± .0026 in.)

Diameter of shaft (new)..... 89.880 ± 0 020 mm (3.5386 ± .0008 in.)

(5) Bore in bearings (after assembly) ..... 75.000 ± 0.055 mm (2.9528 ± .0022 in.)

Diameter of shaft (new)..... 74.900 ± 0.015 mm (2.9488 ± .0006 in.)

(6) Thickness of thrust washer (new)..... 8.50 ± 0.05 mm (.335 ± .002 in.)

Width of groove in shaft (new)..... 8.750 ± 0.025 mm (.3445 ± .0010 in.)

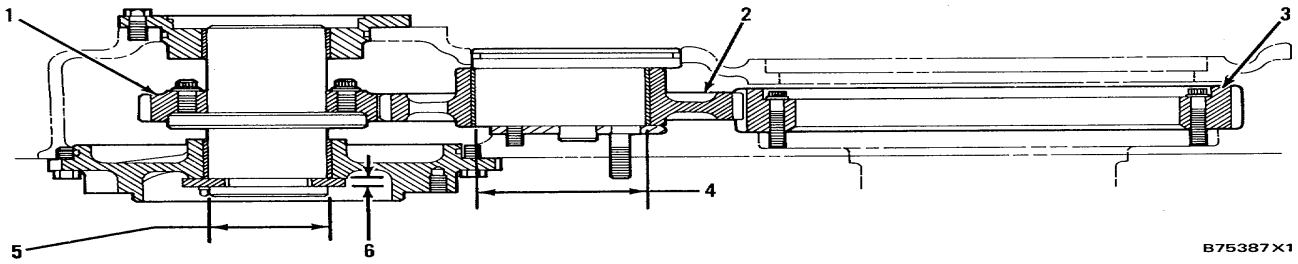
End play for shaft ..... 0.175 to 0.325 mm (.0069 to .0128 in.)

NOTE: FOR TORQUE VALUES NOT GIVEN, SEE THE FIRST PAGE OF SPECIFICATIONS FOR GENERAL TIGHTENING TORQUES

LOWER FRONT GEAR GROUPS

8N5620 (Right Hand) (Standard Rotation) 8N5678 (Left Hand) (Standard Rotation)

8N5769 (Right Hand) (Reverse Rotation) 8N5767 (Left Hand) (Reverse Rotation)



8N5620 FRONT GEAR GROUP SHOWN

(1) Drive gear for water and oil pumps.

(2) Idler gear.

(3) Crankshaft gear.

(4) Bore in bearing (after assembly) ..... 106.000 ± 0.065 mm (4.1732 ± .0026 in.)

Diameter of shaft (new)..... 105.880 ±0.020 mm (4.1685 ± .0008 in.)

(5) Bore in bearings (after assembly) ..... 75.000 ± 0.055 mm (2.9528 ± .0022 in.)

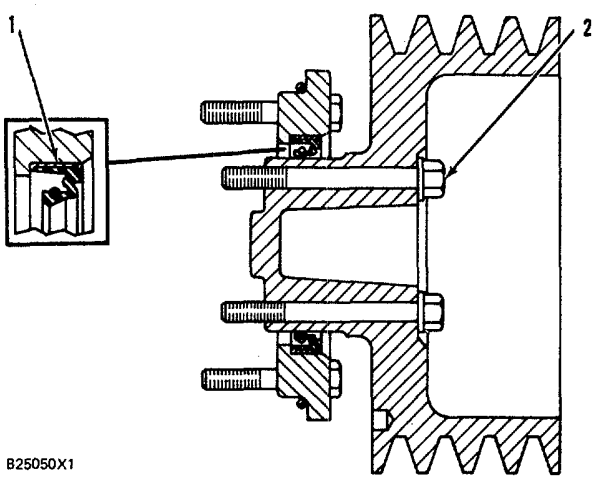
Diameter of shaft (new)..... 74.900 ± 0.015 mm (2.9488 ± .0006 in.)

(6) Thickness of thrust washer (new)..... 8.50 ± 0.05 mm (.335 ± .002 in.)

Width of groove in shaft (new)..... 8.750 ± 0.025 mm (.3445 ± .0010 in.)

End play for shaft..... 0.175 to 0.325 mm (.0069 to .0128 in.)

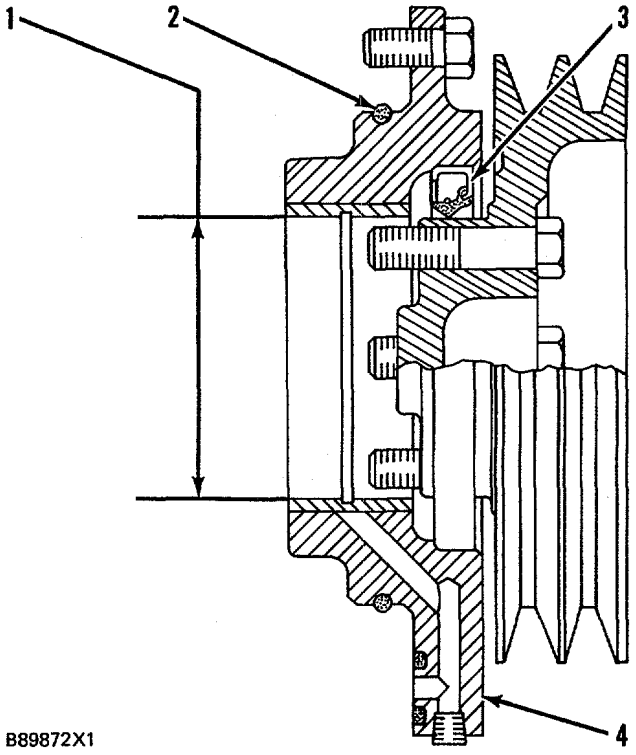
AUXILIARY DRIVE PULLEY GROUPS



7N8041 Pulley Group:

(1) Seal. Install seal as shown and put clean engine oil on the lip of the seal at assembly.

(2) Tighten bolts to..... 55 ± 7 N•m (41 ± 5 lb. ft.)



8N8467 Pulley Group:

(1) Bore in bearing (after assembly)..... 75.000 ± 0.055 mm (2.9528 ±.0022 in.)

Diameter of drive shaft (new).... 74.900 ± 0.015 mm (2.9488 ± .0006 in.)

(2) O-ring seal.

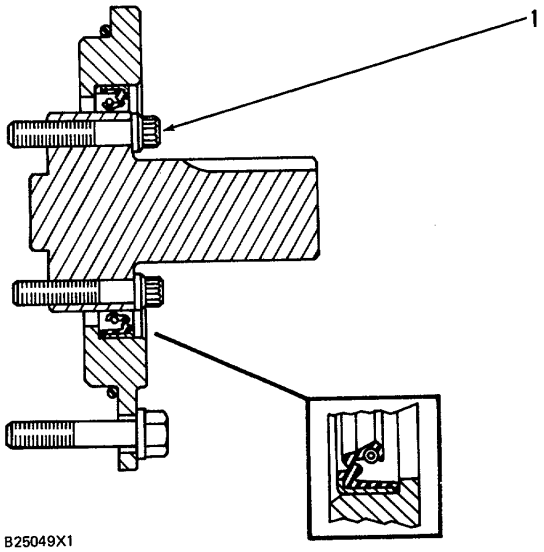
(3) Seal. Install seal with the lip toward the bearing as shown.

NOTE: Put clean engine oil on O-ring seal (2) and the lip of seal (3) at assembly.

(4) Adapter assembly.

NOTE: FOR TORQUE VALUES NOT GIVEN, SEE THE FIRST PAGE OF SPECIFICATIONS FOR GENERAL TIGHTENING TORQUES

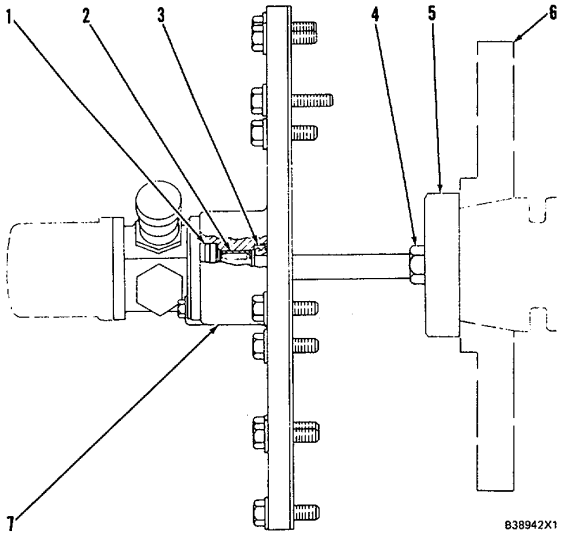
AUXILIARY DRIVE SHAFT GROUP



(1) Tighten bolts to a torque
of ..... 45 ± 7 N-m (32 ± 5 lb. ft.)

Install seal as shown and put clean engine oil on the lip of the seal at assembly.

TACHOMETER DRIVE



(1) Put clean engine oil or glycerin on the O-ring seal at assembly.

(2) Bearing.

(3) Install seal in cover (7) with the lip of the seal toward bearing (2).

Put clean engine oil on the lip of the seal after it is installed.

(4) Tighten bolts in steps to a torque
of ..... 100 ± 15 N•m (75 ± 11 lb. ft.)

Hit face of adapter (5) and tighten bolts in steps to a torque
of ..... 100 ± 15 N•m (75 ± 11 lb. ft.)

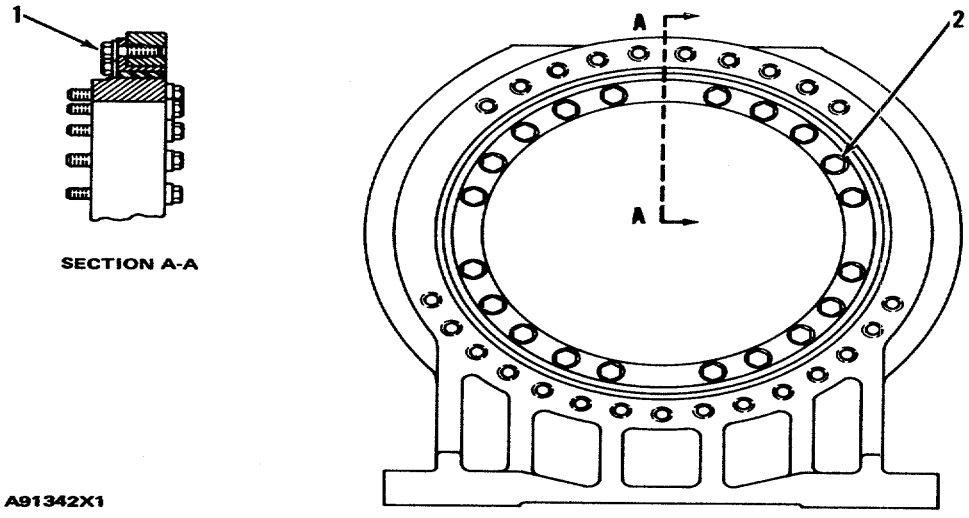
Again hit face of adapter (5) and again tighten bolts in steps to a torque
of ..... 100 ± 15 N•m (75 ± 11 lb. ft.)

(5) Tachometer drive adapter.

(6) Camshaft drive gear.

(7) Cover (RH rear of engine).

TRUNNION

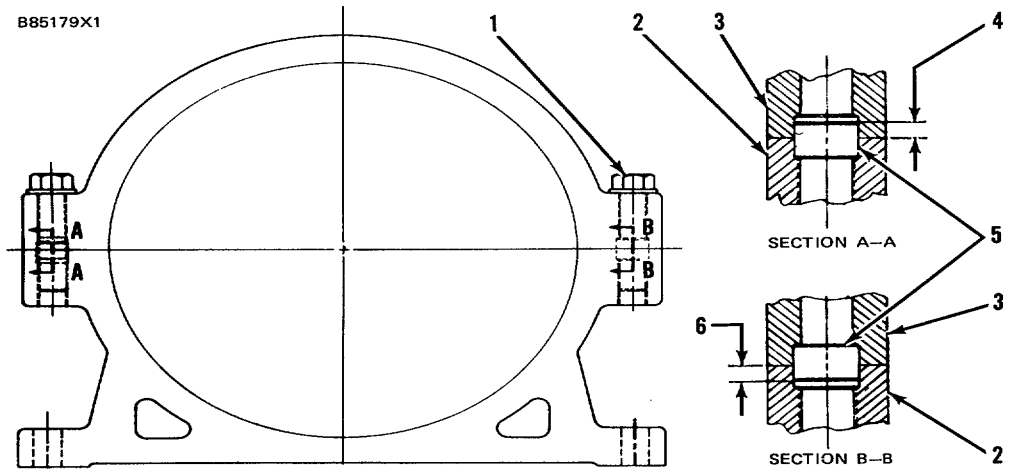


(1) Tighten the bolts that hold the mount assembly to the support to a torque of..... 200 ± 20 N•m (150 ± 15 lb. ft.)

(2) Tighten the bolts that hold trunnion to front drive housing to a torque of..... 135 ± 15 N-m (100 ± 11 lb. ft.)

NOTE: FOR TORQUE VALUES NOT GIVEN, SEE THE FIRST PAGE OF SPECIFICATIONS FOR GENERAL TIGHTENING TORQUES

FRONT TRUNNION SUPPORT



(1) Bolt.

Put 2P2506 Thread Lubricant on the threads and face of bolt head. Tighten bolt to a torque of ..... 100 ± 15 N•m (75 ± 10 lb. ft.)

Now turn bolt an additional..... 120 ± 5°

(2) Bottom half of support.

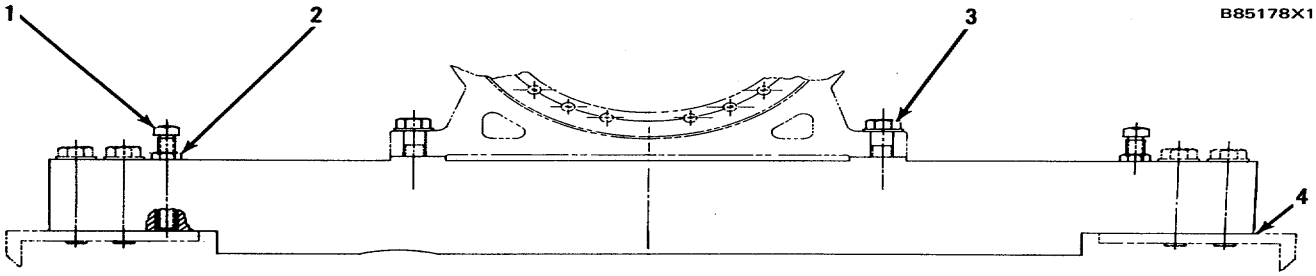
(3) Top half of support.

(4) Distance ferrule extends from surface of bottom support ..... 8 mm (.31 in.)

(5) Ferrule.

(6) Distance ferrule extends from surface of top support ..... 8 mm (.31 in.)

ENGINE FRONT SUPPORT GROUP (WIDE)



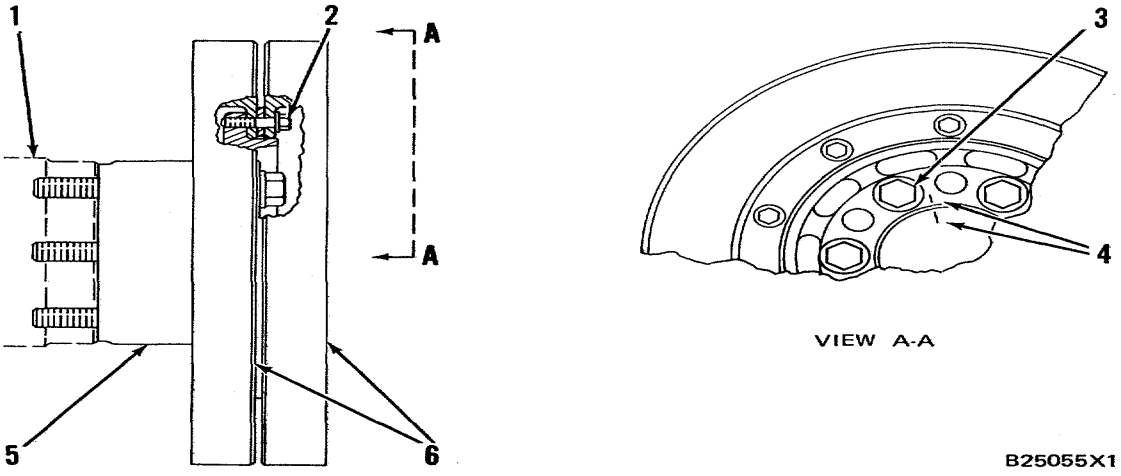
(1) Leveling screw.

(2) Tighten locknut to a torque of ..... 150 ± 20 N•m (110 ± 15 lb. ft.)

(3) Trunnion support bolts. Tighten to a torque of..... 750 ± 80 N•m (550 ± 60 lb. ft.)

(4) Use shims as required between rails and support.

VIBRATION DAMPER GROUP
(FOR HIGH INERTIA DRIVEN EQUIPMENT)



(1) Crankshaft (front end).

(2) Damper mounting bolts. Tighten to a torque of..... 100 ± 15 N•m (75 ± 10 lb. ft.)

(3) Adapter mounting bolts. Put 2P2506 Thread Lubricant on threads and tighten to a torque of..... 875 ± 100 N•m (640 ± 80 lb. ft.)

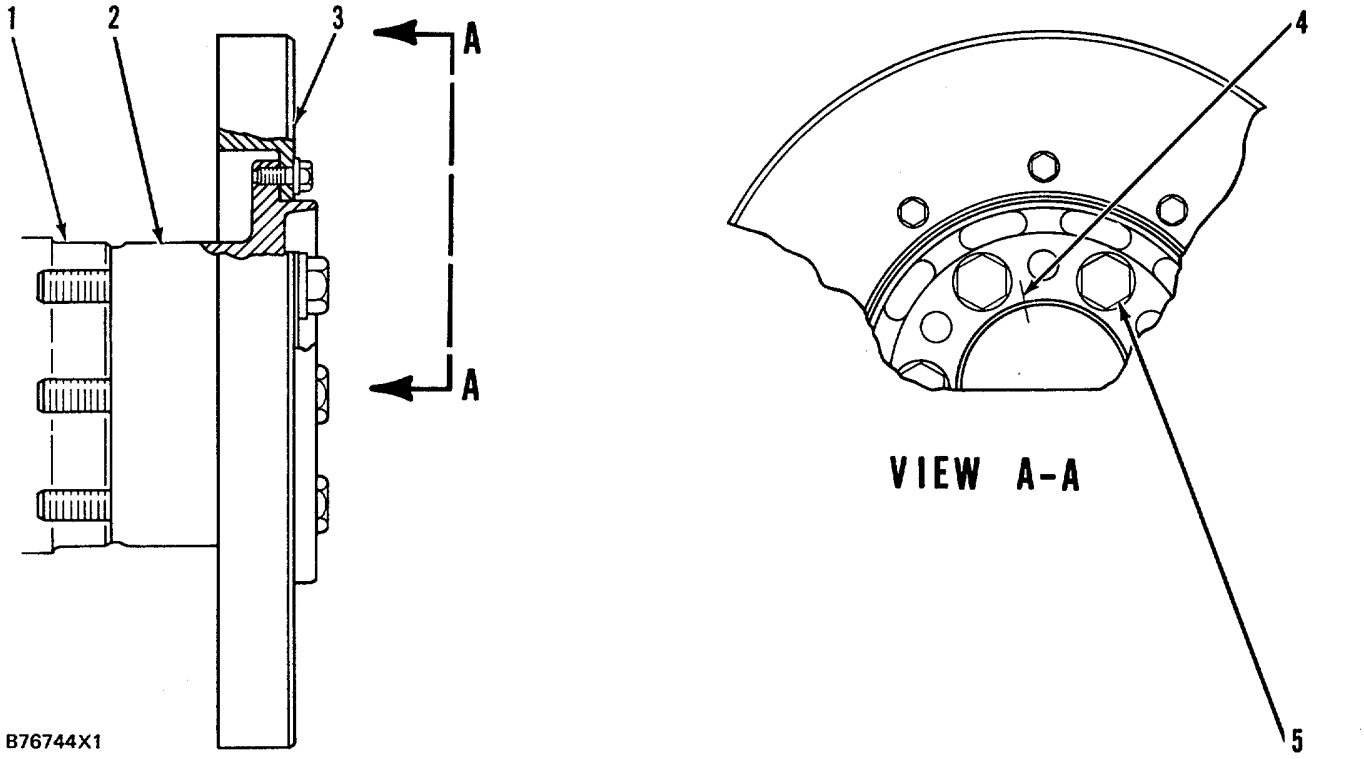
(4) Alignment marks. Put mark on adapter in alignment with mark on crankshaft.

(5) Adapter.

(6) Damper (two).

NOTE: FOR TORQUE VALUES NOT GIVEN, SEE THE FIRST PAGE OF SPECIFICATIONS FOR GENERAL TIGHTENING TORQUES

VIBRATION DAMPER GROUP
(3508 & 3512)



8N7182 Damper Group:

(1) Crankshaft.

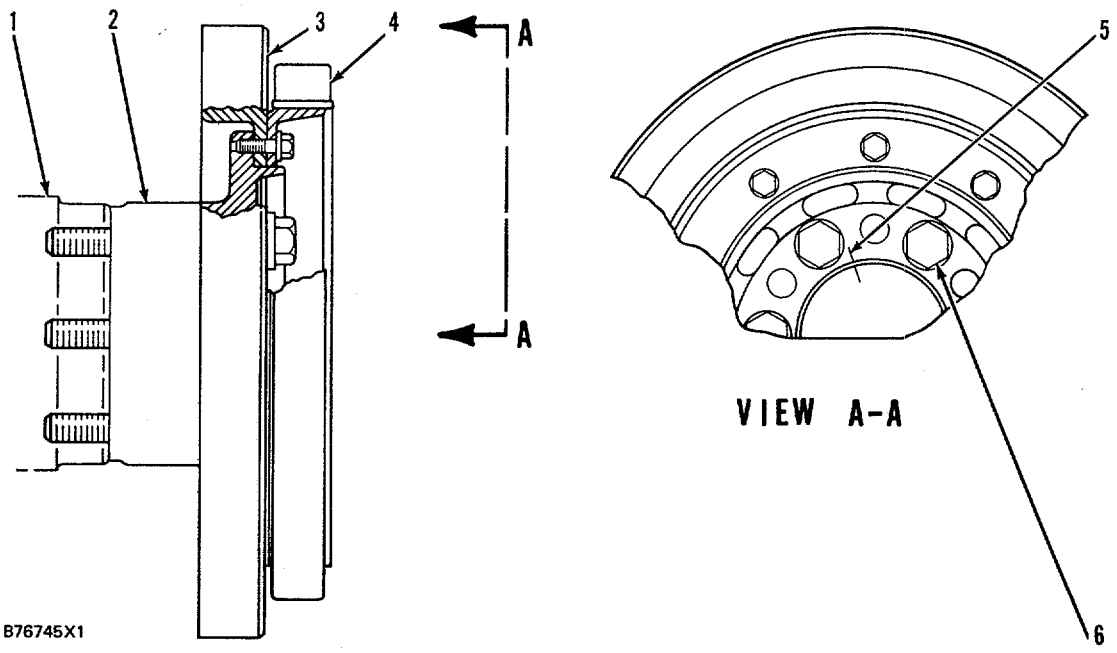
(2) Adapter.

(3) Damper.

(4) Put mark on adapter (2) in alignment with mark on end of crankshaft (1) before installation of bolts (5).

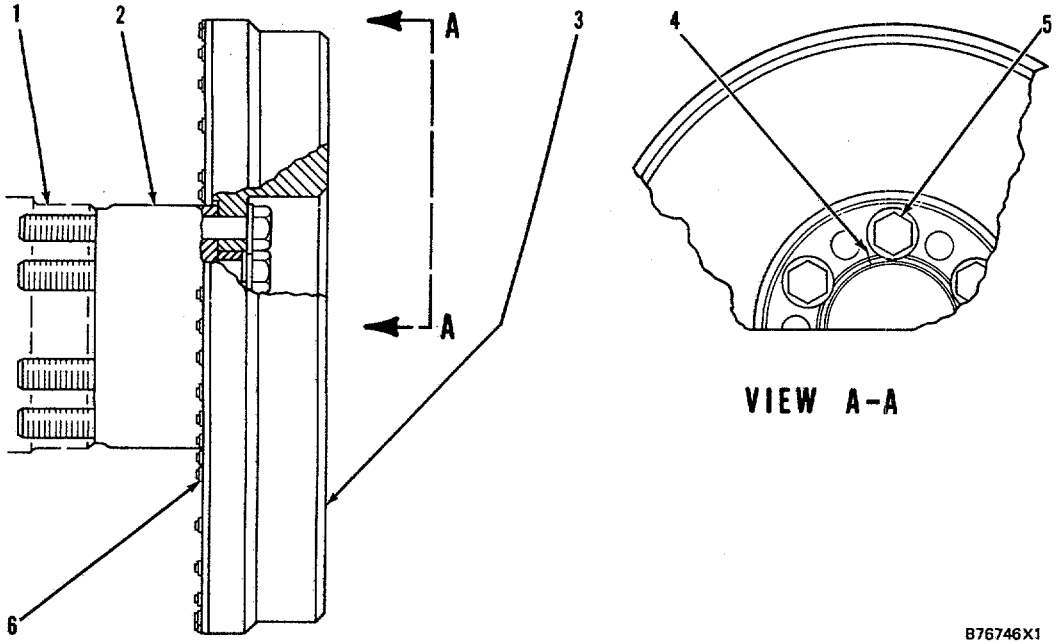
(5) Bolts.

VIBRATION DAMPER GROUPS
(3516)



4W278 Damper Group:

(1) Crankshaft.
(2) Adapter.
(3) Damper (fluid).
(4) Damper (rubber).
(5) Put mark of adapter (2) in alignment with mark on end of crank-shaft (1) before installation of bolts (6).
(6) Bolts.

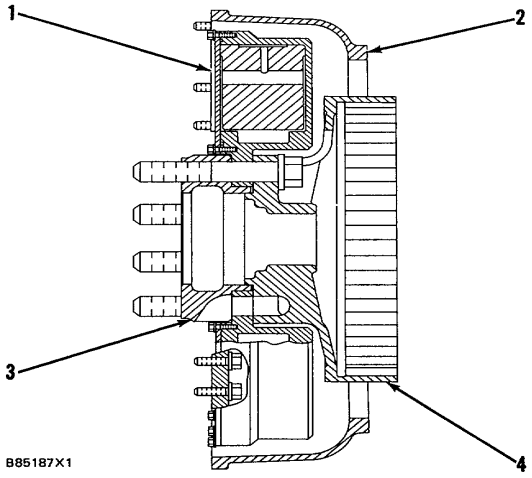


8N339 Damper Group:

(1) Crankshaft.
(2) Adapter.
(3) Damper.
(4) Put all marks of crankshaft (1), adapter (2) and damper (3) in alignment before installation of bolts (5).
(5) Bolts.
(6) Bolts. Tighten to a torque of ..... 55 ± 7 N•m (41 ± 5 lb. ft.)

NOTE: FOR TORQUE VALUES NOT GIVEN, SEE THE FIRST PAGE OF SPECIFICATIONS FOR GENERAL TIGHTENING TORQUES

FRONT MOUNTING GROUP
(For Hydraulic Pump or PTO Clutch)

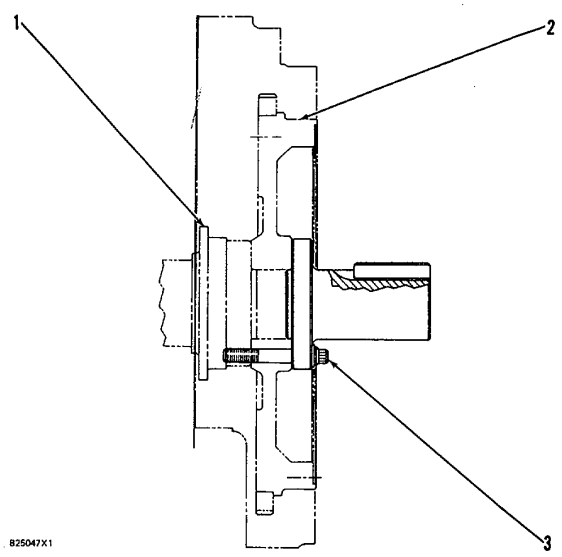


(1) Damper.
(2) Adapter.
(3) Damper adapter.
At assembly, put 2P2506 Thread Lubricant on the threads of the bolts that hold damper adapter (3) to the crankshaft. Tighten the bolts to a torque of 875 ± 100 N•m (640 ± 80 lb. ft.)

(4) Coupling.

Put dash mark on coupling in alignment with marks on damper adapter and crankshaft.

REAR STUB SHAFT

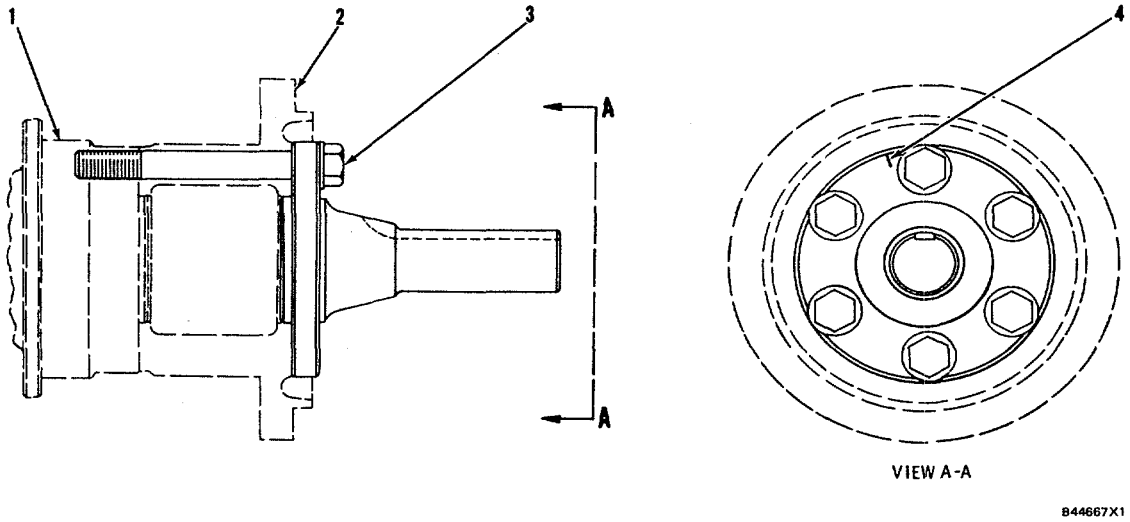


(1) Crankshaft.

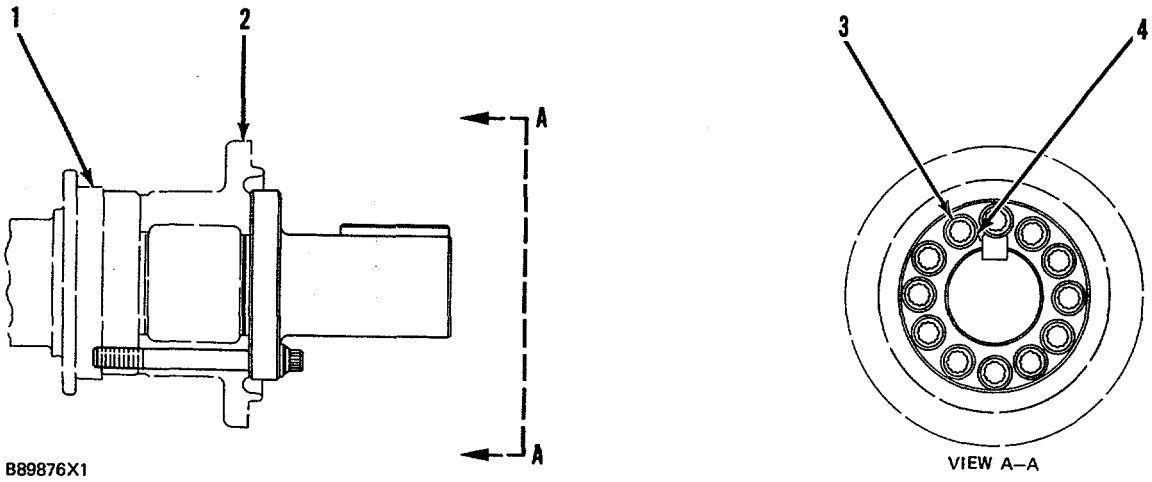
(2) Flywheel.

(3) Put 2P2506 Thread Lubricant on threads and tighten bolts that hold stub shaft and flywheel to crankshaft to a torque of
.....1150 + 30 N-m (840 _ 22 lb. ft.)

FRONT STUB SHAFT



FOR LOW KW (HP) APPLICATIONS



FOR FULL ENGINE KW (HP) APPLICATIONS

(1) Crankshaft.

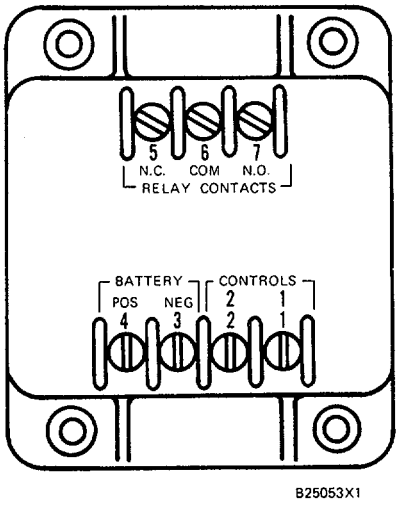
(2) Adapter.

(3) Put 2P2506 Thread Lubricant on the threads and tighten bolts to a torque of..... 875 ± 100 N-m (640 + 80 lb. ft.)

(4) Put dash mark on shaft in alignment with dash mark on adapter.

NOTE: FOR TORQUE VALUES NOT GIVEN, SEE THE FIRST PAGE OF SPECIFICATIONS FOR GENERAL TIGHTENING TORQUES

TIME DELAY RELAY



5N2124 (Dynalco Corp. Number DSC-9)
Operating voltage range.....8 to 40 VDC

On Delay.

Control 1.....No delay on setting (O seconds)

Control 2..... 8 to 10 second delay on setting

Off Delay.

60 to 80 second delay on resetting

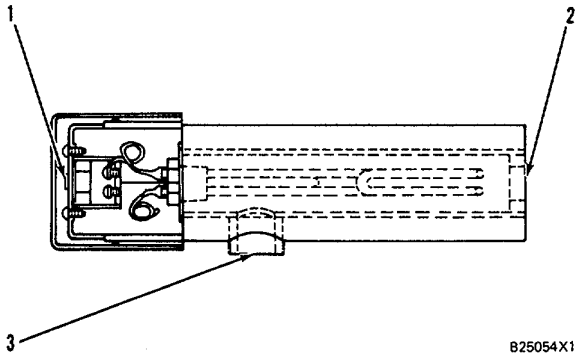
JACKET WATER HEATERS

5N5739 120 VAC, 3000 Watts
5N5740 240 VAC, 3000 Watts

(1) Thermostat adjustment range ..... 16 to 82° C (60 to 180° F)

(2) Coolant inlet

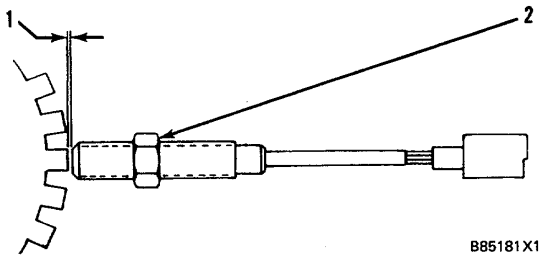
(3) Coolant outlet



MAGNETIC PICKUP

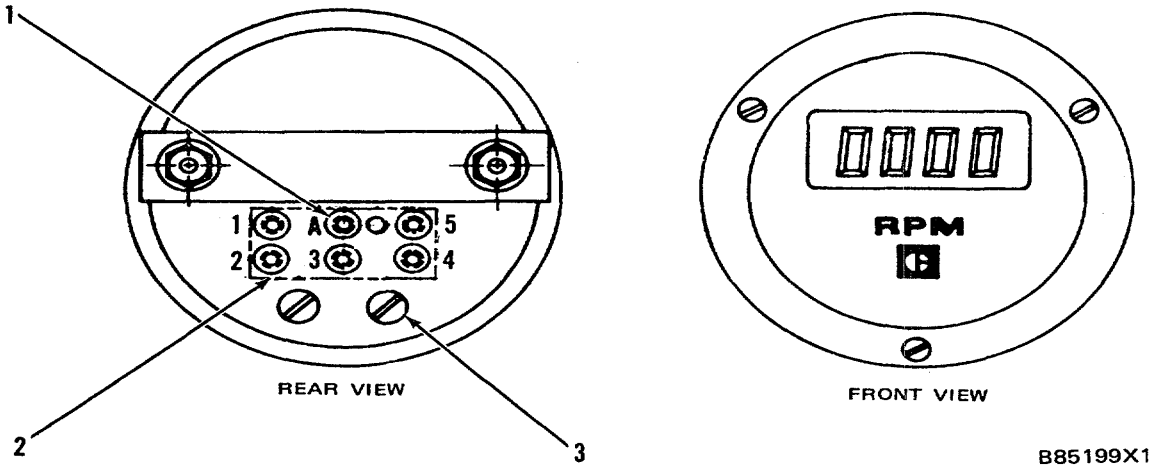
(1) Distance between end of magnetic pickup and gear .....0.56 to .085 mm (.022 to .033 in.)

(2) Nut. Tighten nut to a torque of .....45 ± 7 N-m (33 ± 5 lb. ft.)



NOTE: FOR TORQUE VALUES NOT GIVEN, SEE THE FIRST PAGE OF SPECIFICATIONS FOR GENERAL TIGHTENING TORQUES

DIGITAL TACHOMETER



3T2159 Digital Tachometer

(1) Program terminals (Ratio 1:1).
(2) Program boards (5 available).

3T2159 TACHOMETER PROGRAM RANGE	
Number of Flywheel Teeth	**Correct Jumper Locations For Program Boards**
183	Terminal A to Terminal 1
156	Terminal A to Terminal 2
151	Terminal A to Terminal 3
136	Terminal A to Terminal 4
113	Terminal A to Terminal 5

(3) Magnetic Pickup terminals.

General Specifications:

(a) Operating temperature range .....-20 to ± 85° C (-4 to ± 185° F)

(b) Tachometer must be accurate within ± .5%

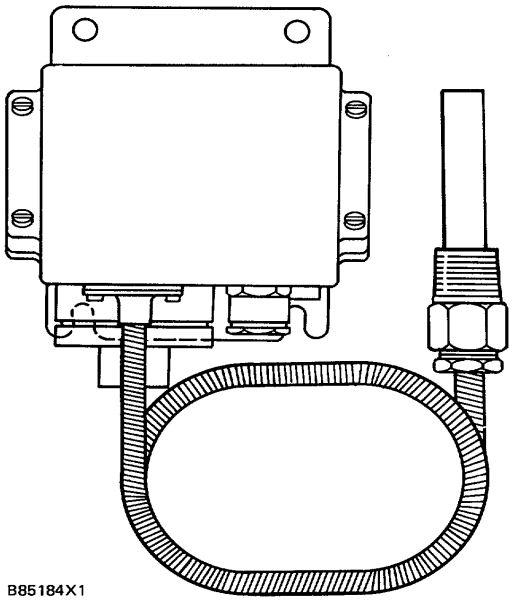
(c) Input frequency range ..... 750 to 9000 Hz

(d) Time required for display update

Maximum .....1.0 second

Minimum .....25 second

TEMPERATURE CONTACTOR


B85184X1

4W2637 Contactor

With an increase in temperature, contacts close at .....92 ± 2° C (198 ± 36° F)

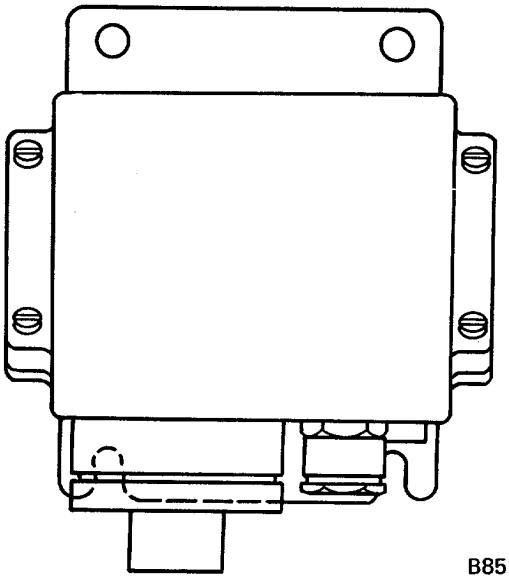
With a decrease in temperature, contacts open at ..... 82 ± 2° C (180 ± 37° F)

4W2640 Contactor

With an increase in temperature, contacts close at .....98 ± 2° C (208 ± 36° F)

With a decrease in temperature, contacts open at .....88 ± 3° C (190 ± 37° F)

PRESSURE CONTACTOR


B85185X1

4W2641 Contactor
NOTE: Test contactor at 25° C (77° F).

With an increase in pressure, contacts close at .....160 ± 20 kPa (23 ± 3 psi)

With a decrease in pressure, contacts open at .....120 ± 10 kPa (17 ± 1.5 psi)

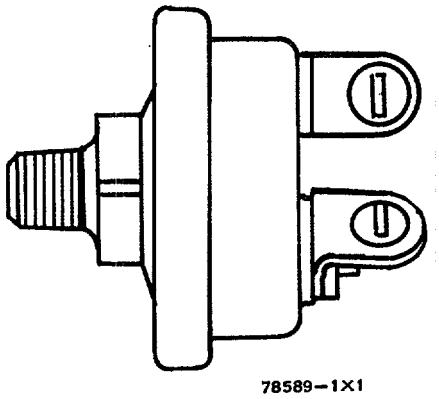
4W2642 Contactor
NOTE: Test contactor at 25° C (77° F).

With an increase in pressure, contacts close at .....310 ± 20 kPa (45 ± 3 psi)

With a decrease in pressure, contacts open at .....260 ± 20 kPa (38 ± 3 psi)

NOTE: FOR TORQUE VALUES NOT GIVEN, SEE THE FIRST PAGE OF SPECIFICATIONS FOR-GENERAL TIGHTENING TORQUES

PRESSURE SWITCHES



67750 Switch

With an increase in pressure, switch
opens at .....275 ± 28 kPa (40 ± 4 psi)

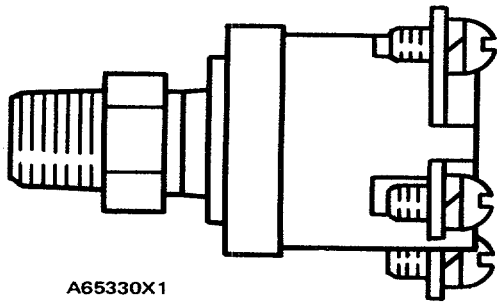
2L3402 Switch

With an increase in pressure, switch
closes at .....20.7 to 27.6 kPa (3 to 4 psi)

3N1400 Switch

With an increase in pressure, switch
closes at .....6.9 to 10.35 kPa (1 to 1.5 psi)

7N5946 Switch



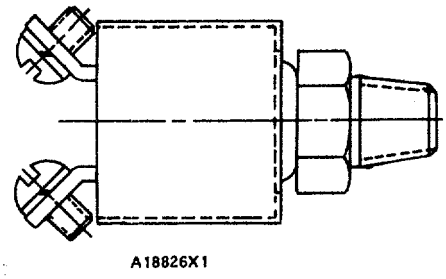
Circuit 1 normally closed

Circuit 2 normally open

With an increase in pressure, circuit 1 opens
and circuit 2 closes at.....145 kPa (21 psi) max.

With a decrease in pressure, circuit 2 opens
and circuit 1 closes at.....75 ± 20 kPa (11 ± 3 psi)

907032 Switch



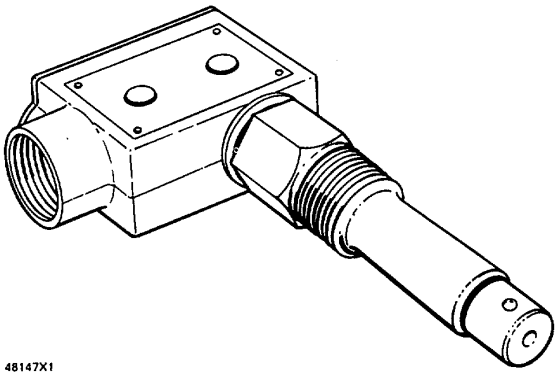
With an increase in pressure, switch
closes at .....517 ± 35 kPa (75 ± 5 psi)
With a decrease in pressure, switch
opens at .....415 ± 35 kPa (60 ± 5 psi)

9G8010 Switch
NOTE: Test switch at 25° C (77° F)

With an increase in pressure, switch closes
at .....110 ± 20 kPa (16 ± 3 psi)
With a decrease in pressure, switch opens
at .....62 ± 20 kPa (9 ± 3 psi)

8N407 Switch
NOTE: Test switch at 25° C (77° F).
With an increase in pressure,
switch opens at.....152 ± 20 kPa (22 ± 3 psi)
With a decrease in pressure,
switch closes at .....110 ± 20 kPa (16 ± 3 psi)

TEMPERATURE SWITCHES



7W705 Contactor (Coolant)

Switch operates when temperature
increases to .....104.5 ± 0.6° C (220 ± 1° F)

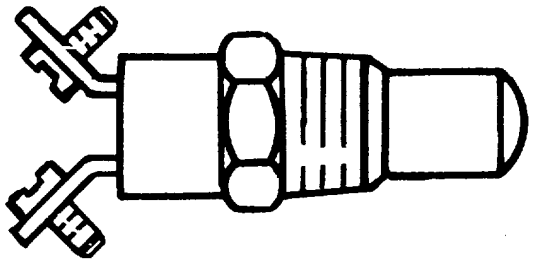
5N8596 Contactor (Coolant)
Switch operates when the temperature
increases to .....91.7 ± 1° C (197 ± 1° F)

5N8597 Contactor (Coolant)
Switch operates when temperature
increases to ..... 98.3 ± 0.6° C (208 ± 1° F)

5L6435 Contactor (Coolant)
Switch operates when the temperature
increases to ..... 98° ± 1° C (209° ± 1°F)

6L4207 Contactor (Inlet Air)
Switch operates when the temperature
increases to .....110 ± 1° C (230 ± 1° F)

8N1693 Switch (Ether Aid)



Switch must open
between .....35 and 40.5° C (95 and 105° F)

Switch must close
at a minimum of..... 26.7° C (80° F)

3N7442 Switch (Low Coolant Temperature)

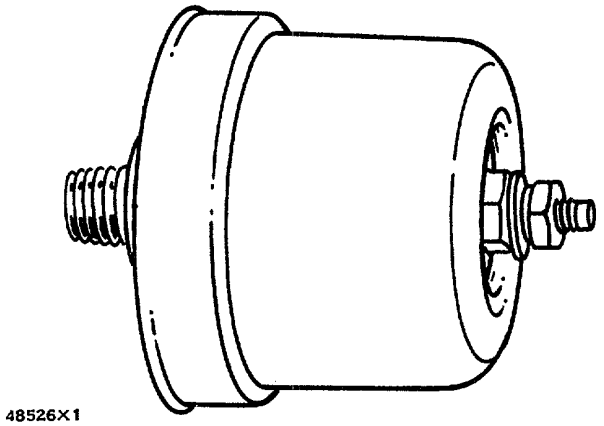
Switch must open
between .....24 and 29.5° C (75 and 85° F)
Switch must close
at a minimum of..... 18.3° C (65° F)

NOTE: FOR TORQUE VALUES NOT GIVEN, SEE THE FIRST PAGE OF SPECIFICATIONS FOR GENERAL TIGHTENING TORQUES

SENDING UNITS

5L7450 Sending Unit (Oil Pressure) for 24V or 32V systems

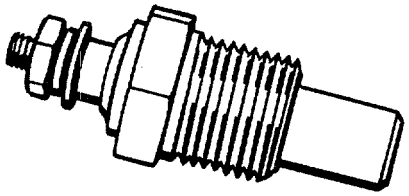
Resistance at'
- 0 kPa (0 psi) ..... 0 ohms
- 140 kPa (20 psi) ..... 13.5 ohms
- 550 kPa (80 psi) ..... 30 ohms



48526X1

5L7442 Sending Unit (Coolant Temperature) for 24V or 32V systems

Resistance at:
- 93°C (200° F) ..... 800 to 900 ohms

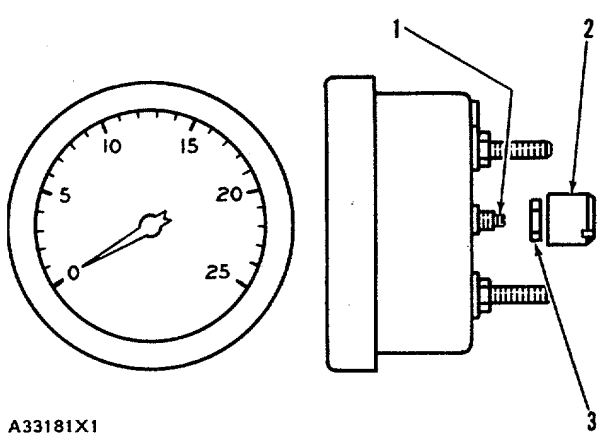


48736X1

ELECTRIC TACHOMETER

3N7288 (Faria No. B-1594-2); Use with 5N8176 Sender Assembly.

Output to input ratio ..... 2 to 1
Range ..... 0 to 2500 rpm
Check at normal engine operating speed
Amount of adjustment available (dial reading ..... ± 5%
Maximum external circuit resistance ..... 20 ohms
Maximum temperature rating ..... 82°C (180° F)
(1) Adjustment screw
(2) Sealed cap.
(3) Rubber washer.
NOTE A maximum of two tachometers can be operated with one sender assembly.

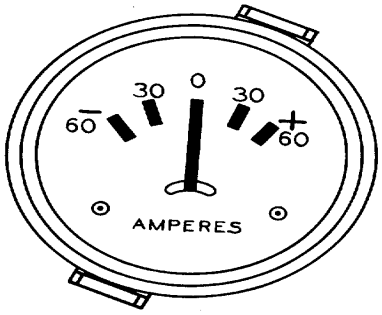


A33181X1

AMMETER

3N5992 Gauge (Stewart-Warner Number 690-C)

CALIBRATION CHART		
POINTER POSITION	A	± 60 A
TOLERANCE	± 0.8 mm (.03 in.)	± 12 A



A65340X1

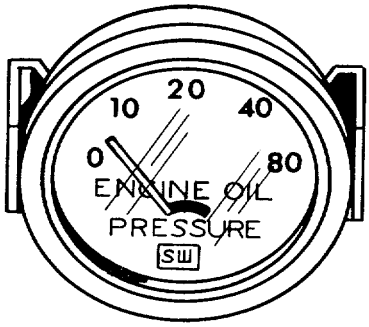
OIL PRESSURE GAUGE (ELECTRIC)

5L7456 Gauge 24V; Use with 5L7450 Sending Unit**
Range .....0 to 550 kPa (0 to 80 psi)
Test voltage 285 V

TEST RESISTANCE (ohms)	0	13 5	30
POINTER POSITION	0	20	80
TOLERANCE*	± 0.8 mm (.03 in.)		

*Measure tolerance from the end of the pointer to the center-line of the mark on the face of the gauge.

*For 32V systems the 5L7441 Resistor (65 ohms) Is used with this gauge.



95584X1

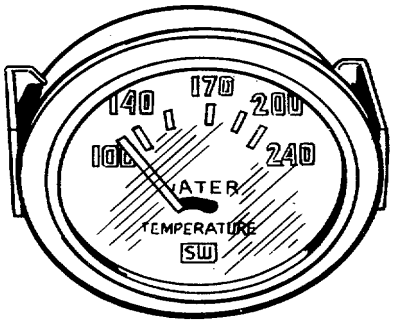
WATER TEMPERATURE GAUGE (ELECTRIC)

5L7444 Gauge 24V; Use with 5L7442 Sending Unit**

Range .....38 to 116° C (100 to 240° F)
Test voltage .....28 5 V

TEST RESISTANCE ohms)	3388	1050	460
POINTER POSITION	100	170	240
TOLERANCE*	+ 0.8 mm (.03 In.)		

'Measure tolerance from the end of the pointer to the center-line of the mark on the face of the gauge
**For 32V systems the 5L7441 Resistor (65 ohms) is used with this gauge



48735X1

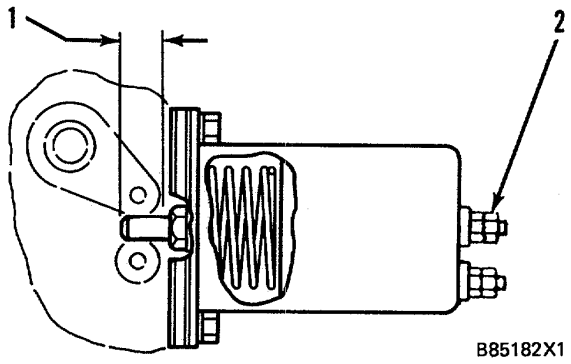
NOTE: FOR TORQUE VALUES NOT GIVEN, SEE THE FIRST PAGE OF SPECIFICATIONS FOR GENERAL TIGHTENING TORQUES

AIR SHUTOFF SOLENOIDS

6T4751 Solenoid (G. W. Lisk, W-1080-2)
Voltage rating .....24 to 32V
Coil resistance at 25° C (77° F)..... 3.3 to 4.1 ohms
Activate to ..... shutoff

NOTICE
This solenoid must not be used in constant operation for more than 2.5 minutes or damage may result.

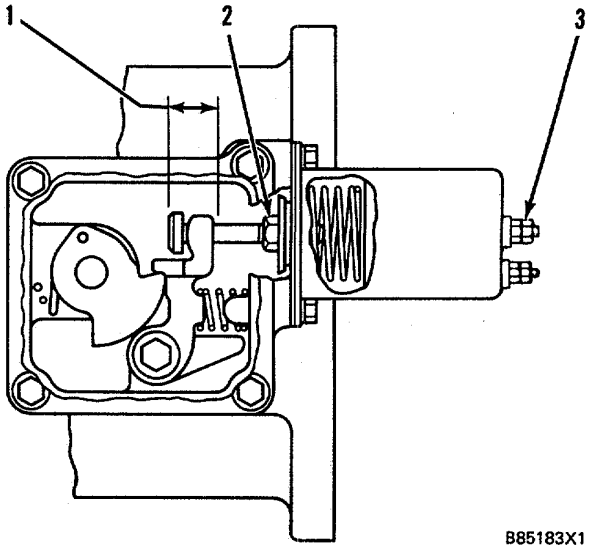
Distance of plunger travel
.....15.75 mm (.620 in.)
(2) Torque for terminal nuts
..... 1.23 to 1.92 N-m (11 to 17 lb. in.)



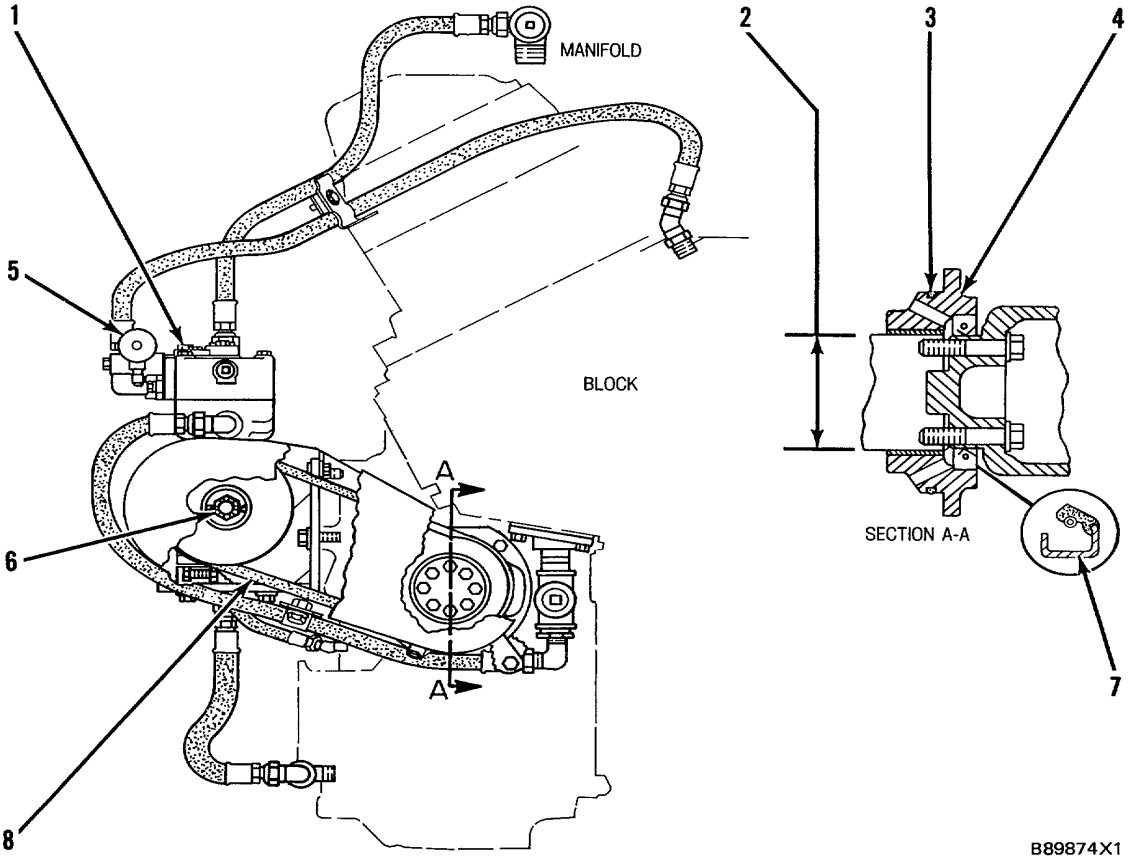
9G8180 Solenoid (G. W. Lisk, W-1121-2)
Voltage rating .....24 or 32V
Coil resistance at 25° C (77° F)..... 3.3 to 4.1 ohms
Activate to ..... shutoff

NOTICE
This solenoid must not be used in constant operation for more than 2.5 minutes or damage may result.

(1) Distance of plunger travel....15.75 mm (.620 in.)
(2) Tighten shaft nut to a torque of .....24 ± 7 N•m (18 ± 5 lb. ft.)
(3) Torque for terminal nuts ..... 1.23 to 1.92 N-m (11 to 17 lb. in.)



AIR COMPRESSOR GROUP
(8N8360)



(1) Air compressor.

(2) Bore in bearing (after assembly)
.....75.000 ± 0.055 mm (2.9528 ± .0022 in.)

(3) O-ring seal.
Diameter of drive shaft (new)
.....74.900 ± 0.015 mm (2.9488 ± .0006 in.)

(4) Adapter assembly.

(5) Governor. The governor air pressure range is
.....620 to 795 kPa (90 to 115 psi)

(6) Nut. Tightened the nut to a torque of..... 135 N•m (100 lb. Ft.) If the cotter pin can not be installed, tighten the nut more to make an alignment of the nearest slot in the nut with the hole in the shaft.

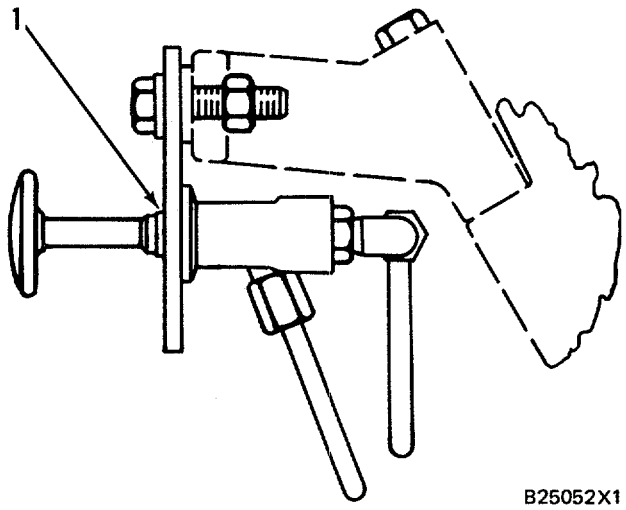
(7) Seal. Install the seal in adapter assembly (4) with the bearing as shown.

(8) V-Belt. Tighten the V-Belt to the specifications given in the V-BELT TENSION CHART.

NOTE: Put clean engine oil on O-ring seal (3) and the lip of seal (7) at assembly.

NOTE: FOR TORQUE VALUES NOT GIVEN, SEE THE FIRST PAGE OF SPECIFICATIONS FOR GENERAL TIGHTENING TORQUES

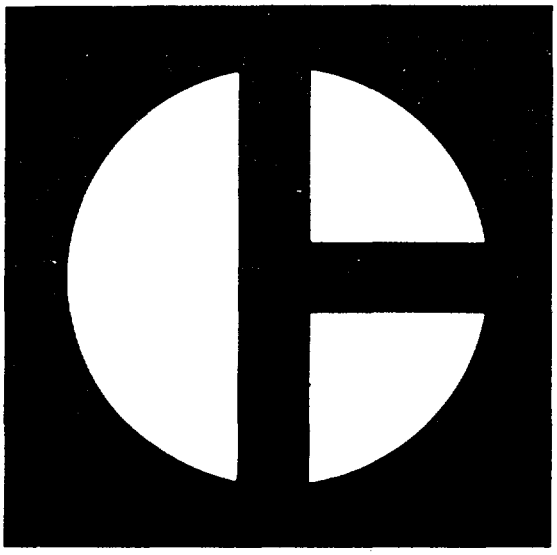
AIR CONTROL VALVE GROUPS



For Air Start And Oil Pressure Override

(1) Tighten locknut to a torque of .....32 ± 7 N•m (24 ± 5 lb. ft.)

FORM NO. SENR2984



SYSTEMS OPERATION
TROUBLESHOOTING
INDIVIDUAL CIRCUIT DESCRIPTION

ELECTRIC PROTECTIVE SYSTEM

FOR

ENGINES EQUIPPED WITH REVERSAL PROTECTION

459

INTRODUCTION

The electric protective system is designed to activate an alarm or shut the engine off if there is a problem or a failure in any of five different engine systems. The engine systems monitored are: engine overspeed, starter motor crank terminate, engine reversal, engine oil pressure and engine coolant temperature.

The electric protective system consists of the basic components that follow: tachometer speed sensor, electronic speed switch, water temperature contactor switch, two time delay relays and two slave relays. This system monitors the engine from starting through rated speed.

COMPONENT DESCRIPTION

Tachometer Speed Sensor (TSS) The sensor generates a signal that measures engine speed, but also has a special characteristic that sends the signal in a certain sequence. If the direction of rotation is changed, the signal sequence is changed.

Electronic Speed Switch (ESS) The speed switch has controls (in a single unit) to monitor four of the basic functions. These four functions are:

Engine Overspeed An adjustable engine speed setting (normally 118% of rated speed) that gives protection to the engine from damage if the engine runs too fast. This condition will cause a switch to close that shuts off both the inlet air and the fuel to the engine.

Crank Terminate (Starter Motors) An adjustable engine speed setting that gives protection to the starter motor from damage by overspeed. This condition will cause a switch to open that stops current flow to starter motor circuit, and the starter motor pinion gear will then disengage from engine flywheel ring gear.

Engine Reversal A condition where the engine starts to run backwards. This will cause a change in the signal from the TSS, which will close a switch to cause the fuel to be shut off to the engine.

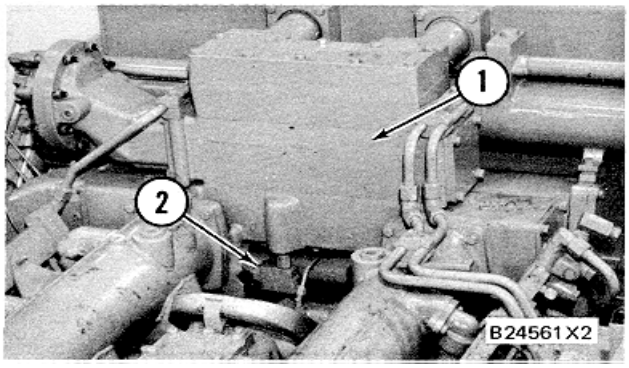
Engine Step Oil Pressure An adjustable engine speed setting that gives protection to the engine from a failure caused by not enough oil pressure. To maintain desired protection through the complete speed range of engine operation, two different oil pressure switches are used [280 kPa (40 psi), 140 kPa (20 psi)]. Once the step oil pressure speed setting is made, an engine that runs above this speed setting must maintain an oil pressure that is more than 280 kPa (40 psi). An engine that runs at a speed below this speed setting must maintain an oil pressure that is more than 140 kPa (20 psi). If either condition is not correct, a switch will close and cause the fuel to be shut off to the engine.

Water Temperature Contactor Switch This contactor switch is a separate unit (mounted in the regulator housing) that is wired into the shutdown circuit. It has an element that feels the temperature of the coolant (it must be in contact with the coolant). When the engine coolant temperature becomes too high, the switch closes to cause the fuel to be shut off to the engine.

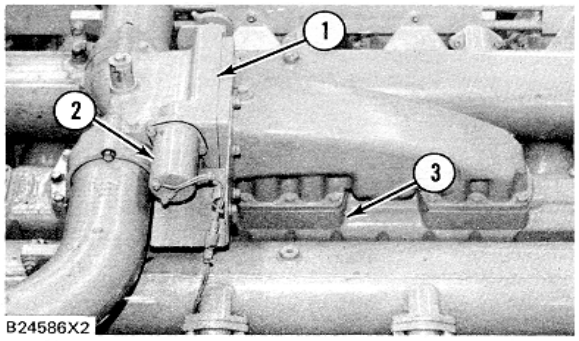
Time Delay Relays These relays are special ON/OFF switches with two controls that will either make the relay activate immediately, or after a 9 second delay. One of the time delay relays is used to arm the shutdown system, and the other time delay relay controls the oil pressure circuits for the two oil pressure switches. Both time delay relays have a 70 second OFF delay to be sure of complete engine shutdown.

Slave Relays These are standard type relays that, when energized, have contacts that open across one circuit and close across another circuit. When activated, one of the relays causes the fuel to be shut off, and the other relay causes the inlet air to be shut off.

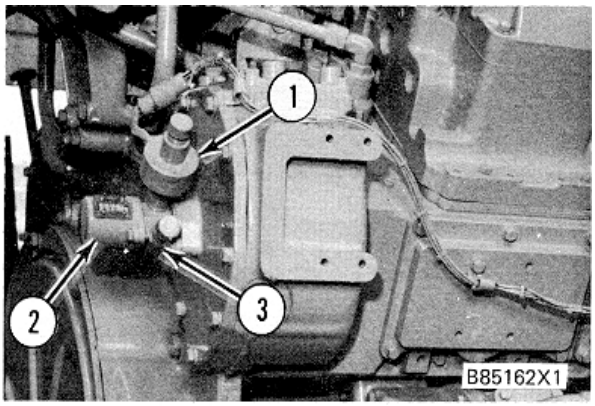
COMPONENT LOCATIONS ON ENGINE



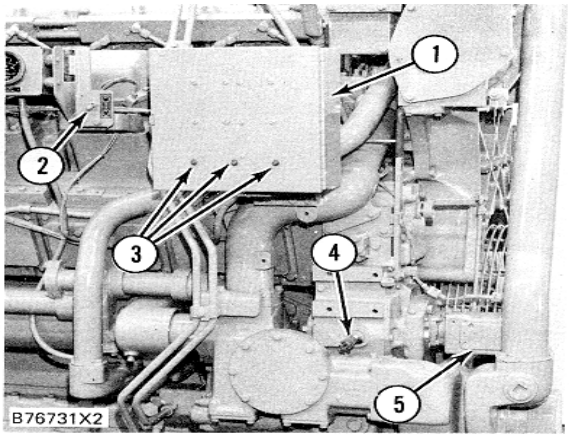
WATER TEMPERATURE CONTACTOR SWITCH
1. Regulator housing. 2. Contactor switch.



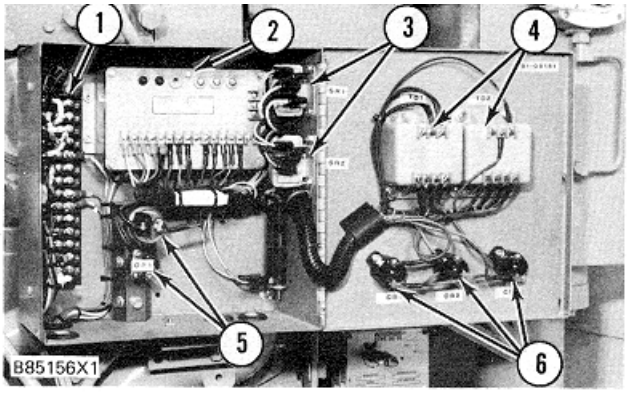
AIR SHUTOFF SOLENOID
1. Air shutoff housing. 2. Air shutoff solenoid. 3. After-cooler housing.



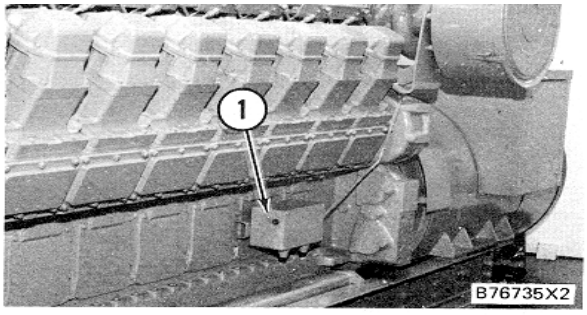
TACHOMETER SPEED SENSOR (TSS)
1. Tachometer speed sensor. 2. Service meter. 3. Tachometer drive housing.



JUNCTION BOX CLOSED
1. Junction box. 2. Fuel shutoff switch. 3. Circuit breakers. 4. Magnetic pickup. 5. Electric governor actuator (EGA).



JUNCTION BOX OPENED
1. Terminal strips. 2. Electronic speed switch (ESS). 3. Slave relays. 4. Time delay relays. 5. Oil pressure switches. 6. Circuit breakers.



LEFT SIDE OF ENGINE
1. Enclosure group.

INDIVIDUAL CIRCUIT DESCRIPTION

The information that follows show the current flow through the wiring schematic. As switches are opened or closed, either automatically or manually, the current flow of the individual circuit affected is shown schematically.

Also included (on each facing page) is a story that explains all the components involved for this particular condition, and why the current will take the path shown.

ENGINE STOPPED (Fig. 1)

With the engine stopped, power is always available across terminals 3 and 4 of time delay relays (TD1 and TD2) and across terminals 5 and 6 of electronic speed switch (ESS). At this time all switches are in their normally open or normally closed positions.

ENGINE STOPPED

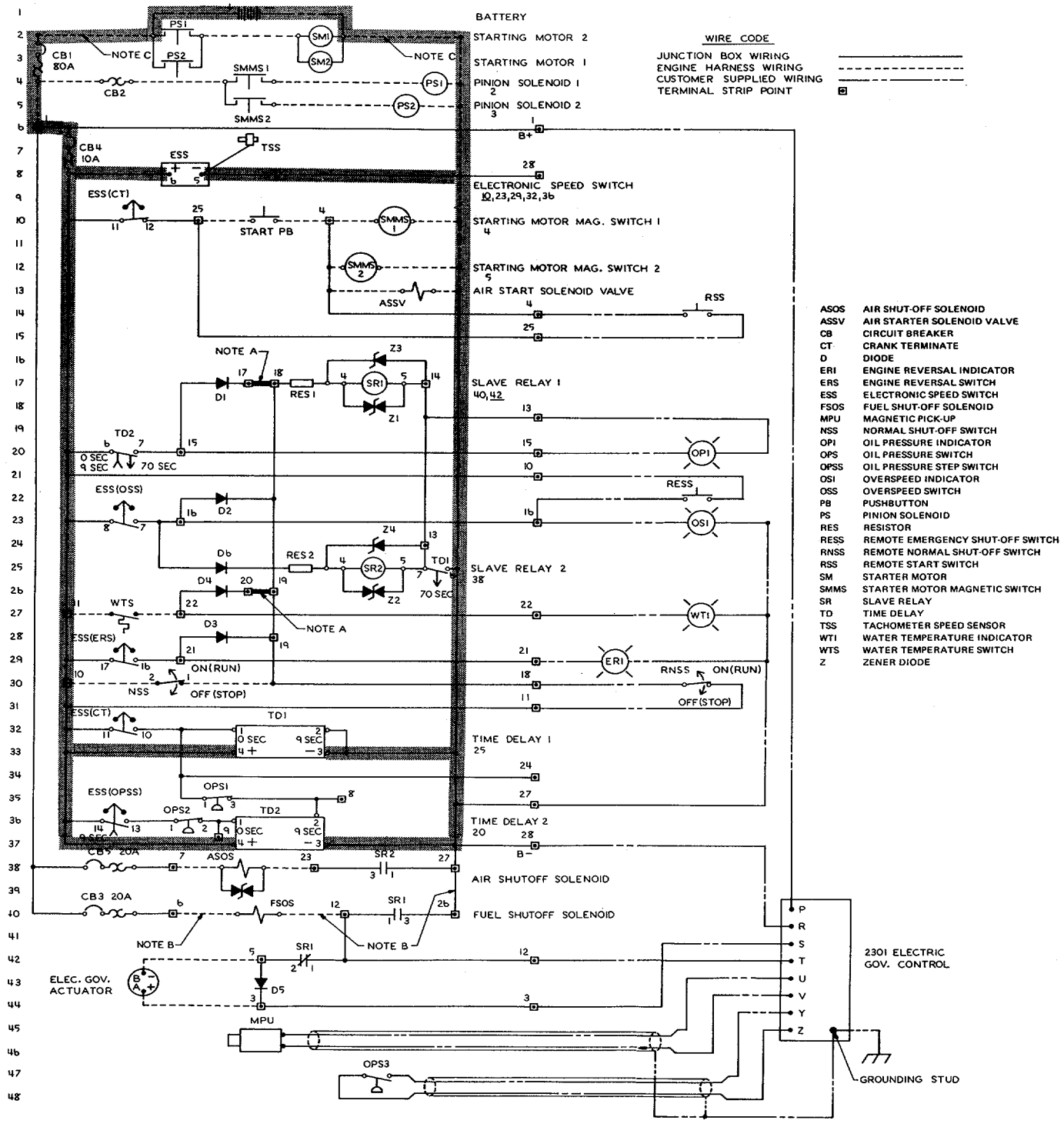


Fig. 1

MANUAL START Deleted.

Air Starter Motor
(Current Flow Not Shown in Fig. 2) Deleted.

STARTING ENGINE WITH ELECTRIC STARTER MOTORS Deleted

ENGINE STARTS TO RUN: NO FAULTS Deleted

ENGINE STARTS TO RUN: NO FAULTS Deleted

ENGINE RUNS AT RATED SPEED: NO FAULTS Deleted

ENGINE RUNS AT RATED SPEED: NO FAULTS Deleted

ENGINE SHUTDOWN DUE TO FAULT: LOSS OF ENGINE OIL PRESSURE (AT ENGINE SPEEDS ABOVE OIL STEP SPEED SETTING) Deleted

470

ENGINE SHUTDOWN DUE TO FAULT: LOSS OF ENGINE OIL PRESSURE (AT ENGINE SPEEDS ABOVE OIL STEP SPEED SETTING) Deleted

471

ENGINE RUNNING BELOW OIL STEP SPEED SETTING: NO FAULTS (OR JUST ACCELERATING THROUGH STEP SPEED) Deleted

472

ENGINE RUNNING BELOW OIL STEP SPEED SETTING: NO FAULTS (OR JUST ACCELERATING THROUGH STEP SPEED) Deleted

473

**ENGINE SHUTDOWN DUE TO FAULT:
LOW OIL PRESSURE
(AT ENGINE SPEEDS BELOW OIL STEP SPEED SETTING)**Deleted

474

ENGINE SHUTDOWN DUE TO FAULT: LOW OIL PRESSURE (AT ENGINE SPEEDS BELOW OIL STEP SPEED SETTING) Deleted

ENGINE SHUTDOWN DUE TO FAULT: COOLANT OVERHEATING Deleted

ENGINE SHUTDOWN DUE TO FAULT: COOLANT OVERHEATING Deleted

ENGINE SHUTDOWN DUE TO FAULT:
ENGINE OVERSPEED Deleted

478

ENGINE SHUTDOWN DUE TO FAULT: ENGINE OVERSPEED Deleted

ENGINE SHUTDOWN DUE TO FAULT:
ENGINE REVERSAL Deleted

ENGINE SHUTDOWN DUE TO FAULT: ENGINE REVERSAL Deleted

SHUTDOWN SYSTEM WITH 2301 ELECTRIC GOVERNOR CONTROL: NO FAULTS Deleted

482

SHUTDOWN SYSTEM WITH 2301 ELECTRIC GOVERNOR CONTROL: NO FAULTS Deleted

INTRODUCTION TO THE TROUBLESHOOTING GUIDE

The troubleshooting guide, when followed exactly as shown, can be an aid for the serviceman to find if a problem exists, and to find the cause of the existing problem.

ELECTRIC PROTECTIVE SYSTEM FUNCTIONAL TESTS

These tests are to be performed on an engine that is started for the first time and at recommended check intervals. They consist of quick and easy procedures for each system that can immediately identify if there is a problem in that system with a minimum amount of test time. If a problem is found, go to the correct chart of the more specific troubleshooting procedures.

ELECTRIC PROTECTIVE SYSTEM TROUBLESHOOTING PROCEDURES

The troubleshooting charts that follow show a definite sequence to be followed for a logical, one by one elimination of many variables. There are specific procedures written to check out different components of the system, and they can be found at the end of the troubleshooting charts. When the chart makes reference to a specific procedure, do this procedure before proceeding any farther in the chart.

When a problem is found and corrected, always check the system again by use of verify procedure as shown at bottom of charts.

Some areas of the charts say to go to an alphabetical letter. When told to go to this specific letter, find this letter with a circle around it in the chart. Follow the test procedures from this point to the bottom of the chart.

ELECTRIC PROTECTIVE SYSTEM FUNCTIONAL TEST

Check each system of the engine as shown to verify if all components of the protective system works properly. To find the correct engine speed, make reference to SPEED SPECIFICATION CHART in troubleshooting procedures for overspeed verify test (Procedure D).

TEST I. OVERSPEED (AIR AND FUEL SHUT-OFF)

STEP	RUN ENGINE AT:	ACTION	CORRECT RESULT
A.	25 ± 5 rpm Less Than Verify rpm (75% Overspeed)	Press 75% Verify Button	No Engine Shutdown
B.	25 ± 5 rpm More Than Verify rpm (75% Overspeed)	Press 75% Verify Button	Air and Fuel Shut-off
C.	Manually Reset Air Shut-off Lever At Top Of Air Inlet Housing and Press ESS Reset Button.		

TEST II. REVERSAL AND CRANK TERMINATION (FUEL SHUT-OFF ONLY)

STEP	RUN ENGIN AT:	ACTION	CORRECT RESULT
A.	Any Speed Above Crank Terminate rpm	Put Jumper Across Terminals ESS-16 & ESS-17	Fuel Shut-off
B.	Remove Jumper From Terminals ESS-16 and ESS-17		

TEST III. NORMAL SHUT-OFF SWITCH (FUEL SHUT-OFF ONLY)

STEP	RUN ENGINE AT:	ACTION	CORRECT RESULT
A.	Any Speed Above Crank Terminate rpm	Push Shut-off Switch to OFF Position	Fuel Shut-off

TEST IV. OIL PRESSURE (FUEL SHUT-OFF ONLY)

STEP	RUN ENGINE AT:	ACTION	CORRECT RESULT
A.	25 ± 5 rpm Less Than Oil Step Speed	Put Jumper Across Terminal 1 & Terminal 2 of Oil Pressure Switch OPS2	No Engine Shutdown
B.	-	Remove OPS2	-
C.	Same Speed as Step A	Put Jumper Across Terminal 1 & Terminal 3 of Oil Pressure Switch OPS1	Fuel Shut-off After 9 ± 1 Seconds
D.	-	Remove Jumper From OPS1	-
E.	25 ± 5 rpm More Than Oil Step Speed	After 9 Seconds, Put Jumper Across Terminals 1 and Terminal 2 (OPS2)	Fuel Shut-off
F.	Remove Jumper From OPS2 Terminals 1 and 2		

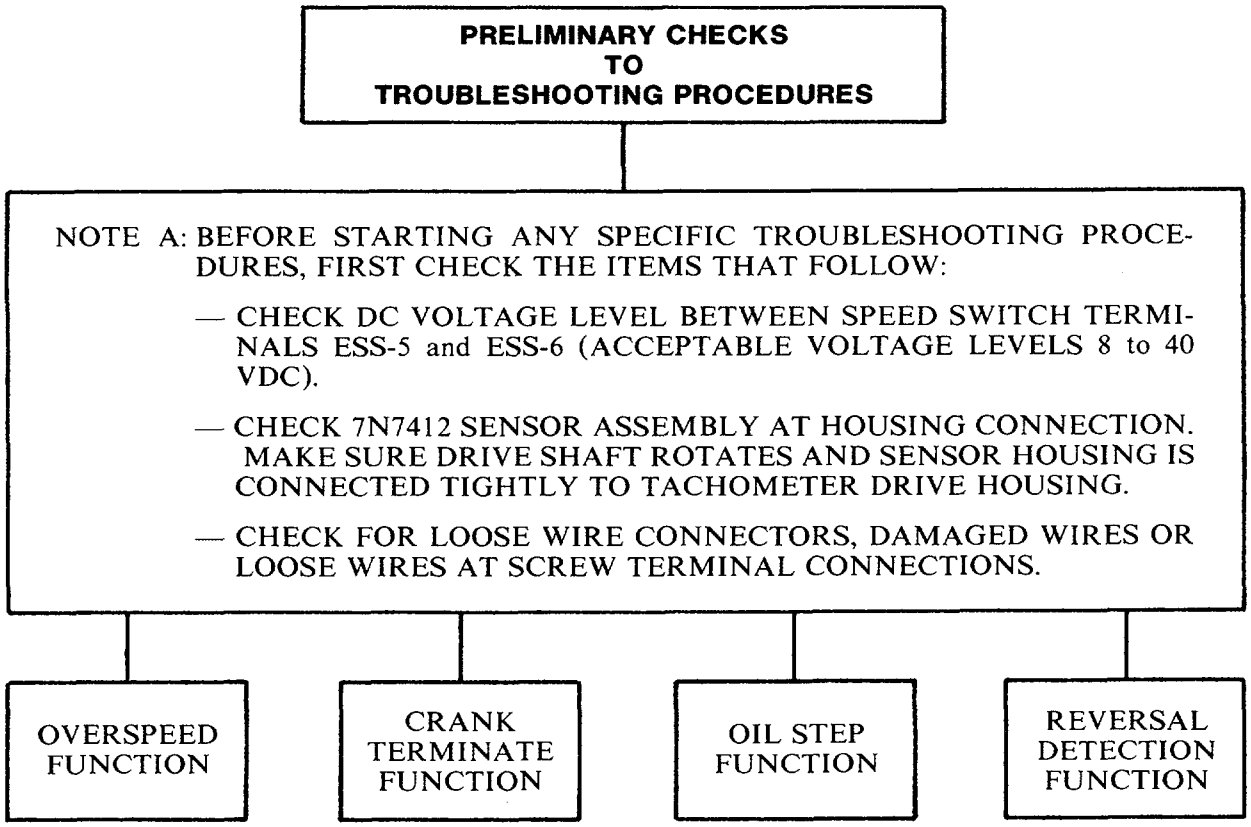
TEST V. WATER TEMPERATURE (FUEL SHUT-OFF ONLY)

STEP	RUN ENGINE AT:	ACTION	CORRECT RESULT
A.	Any Speed Above Crank Terminal rpm	Put Jumper Across Terminals TS11 & TS 22	Fuel Shut-off
B.	Remove Jumper From Terminals TS11 and TS 22		

SYSTEM PROBLEM INDEX

Engine Will Not Start	Chart	Page
Overspeed Switch Closed (Battery Voltage at Speed Switch Terminal ESS-7)	A	33
Overspeed Trips (Light ON) When Power is First Applied With Engine Stopped	A	33
Reversal Indication (System Voltage Across Strip Terminals TS-21 & TS-27)	D	38
Speed Switch Will Not Reset After Reversal Shutdown Indication	D	39
Starter Motor Cranks Intermittently	B	34
Starter Motor Cranking Stops Too Soon	B	34
Starter Motor Will Not Crank	B	35
Engine Runs, But There is Still a Problem:		
Overspeed Trips (Light ON) at Wrong Speed	A	32
Overspeed Trips Intermittently (Light ON and OFF) With Engine Running	A	32
Overspeed Will Not Trip (Light OFF) During 75% Overspeed Verify Test	A	32
Reversal Trips Intermittently (Light ON and OFF)	D	39
Starter Motor Cranking Stops at Wrong Speed	B	34
Starter Motor Will Not Disengage	B	35
Engine Will Not Shut Down:		
Engine RPM is Above Oil Step RPM and Engine Oil Pressure is Lower Than Preset Value (35 psi), But No Engine Shutdown	C	36
Engine RPM is Below Oil Step RPM and Engine Oil Pressure is Lower Than Preset Value (15 psi), But No Engine Shutdown	C	36
Overspeed Trips (Light ON), But No Engine Shutdown	A	33
Reversal Conditions Exist (Actual or Simulated), But No Engine Shutdown	D	38

SYSTEM TROUBLESHOOTING CHARTS



NOTE B: Do Not Leave Starter Motor Engaged With Engine Running. Engines that have electric starter motor(s), or a DC actuated air starter motor, automatically disengage when crank termination rpm is reached. Positive (+) battery voltage is removed from the engine mounted or remote mounted starter controls when the normally closed crank termination contacts open. To perform test measurements, one of the methods that follow may be necessary to disengage the starter motor:

1. Disconnect wire at speed switch terminal ESS-12.

2. Manually disengage by installing a toggle switch to control the electric starter motor magnetic switch (install the switch in series with the magnetic switch coil lead).

3. Manually disengage by installing a toggle switch to control the air starter solenoid valve (install the switch in series with either of the solenoid valve leads).

NOTE: For wiring diagrams and schematics, make reference to Wiring Diagrams Section.

TROUBLESHOOTING (OVERSPEED)

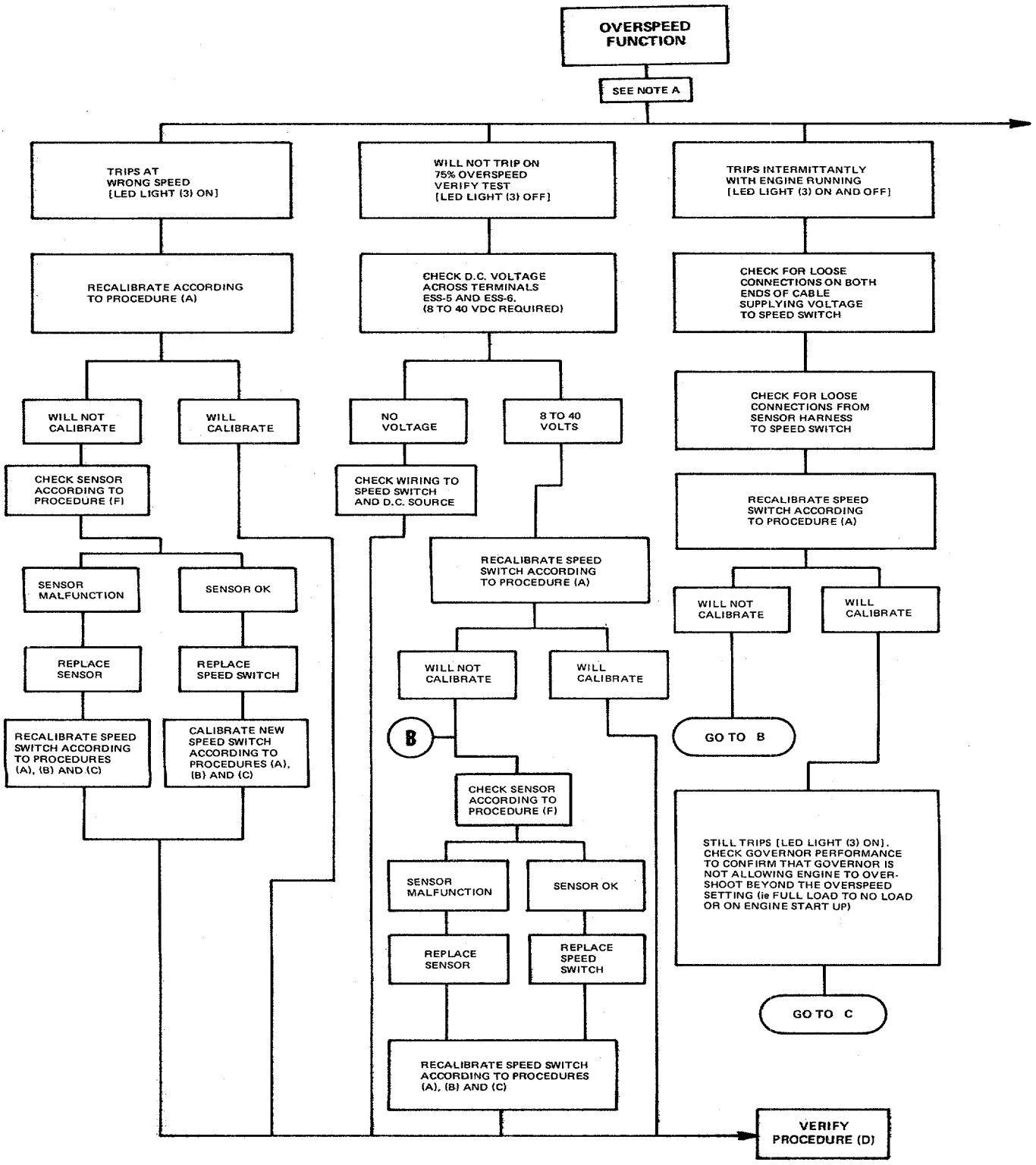


CHART A.

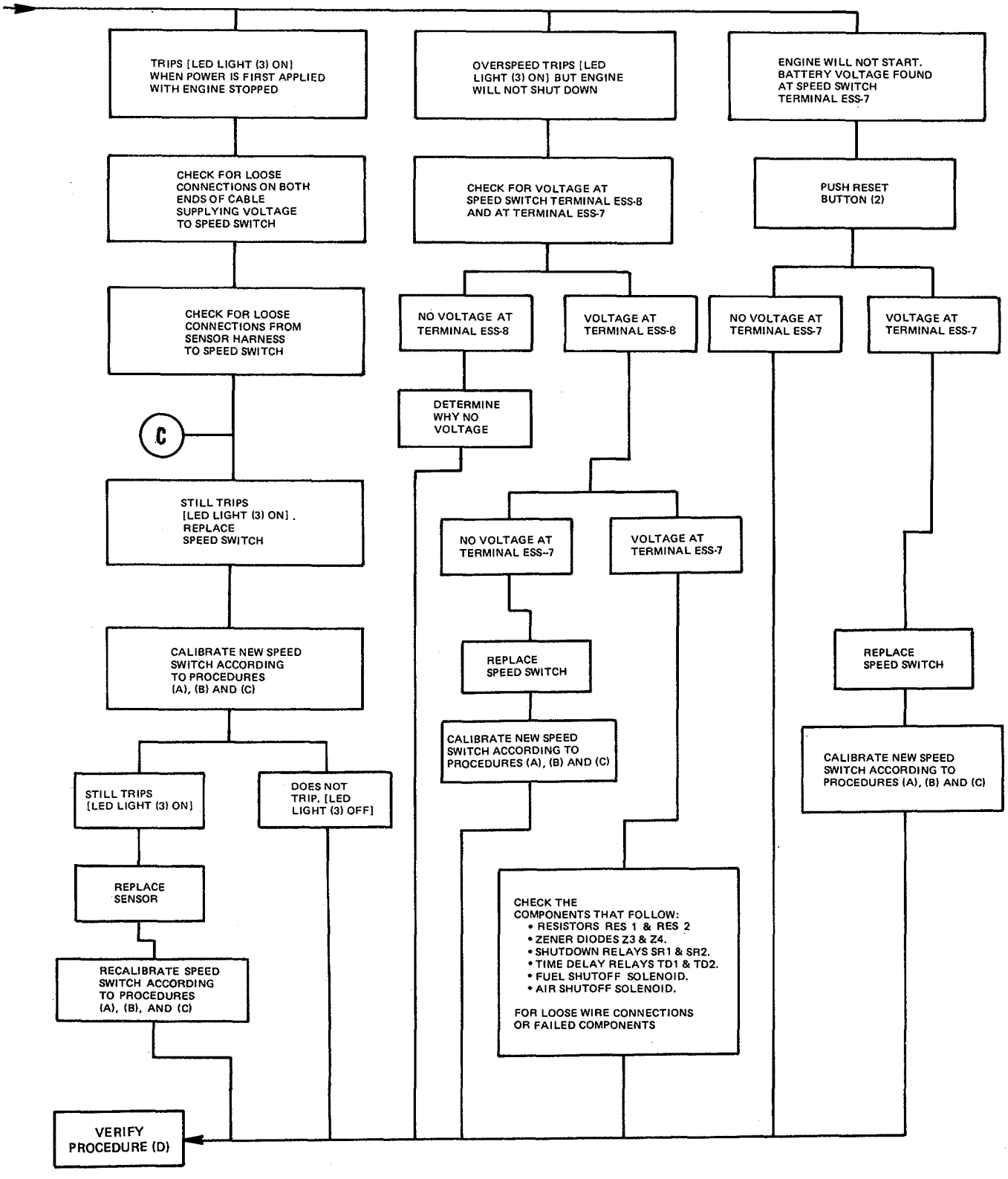


CHART A (Continued)

TROUBLESHOOTING (CRANK TERMINATE)

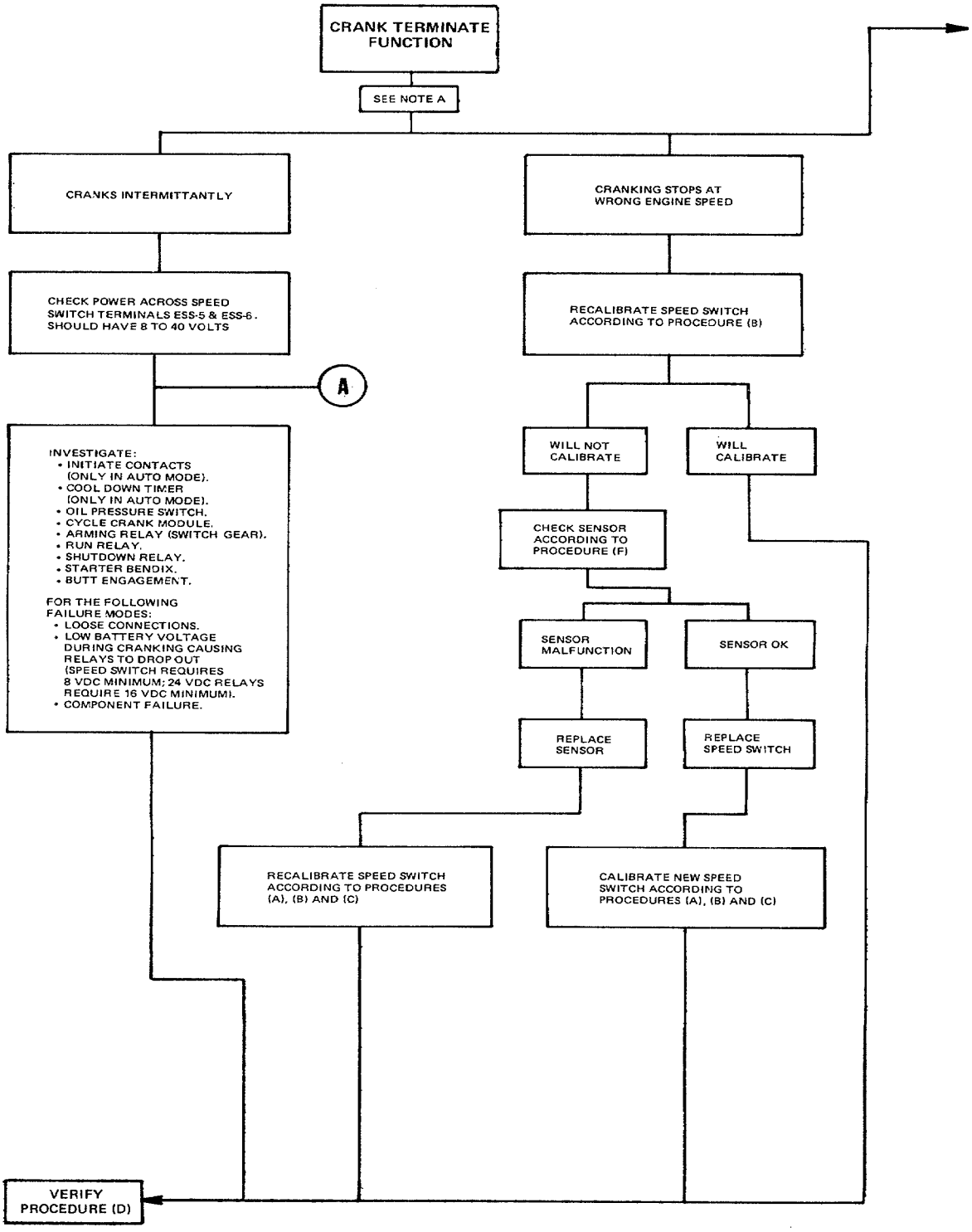


CHART B.

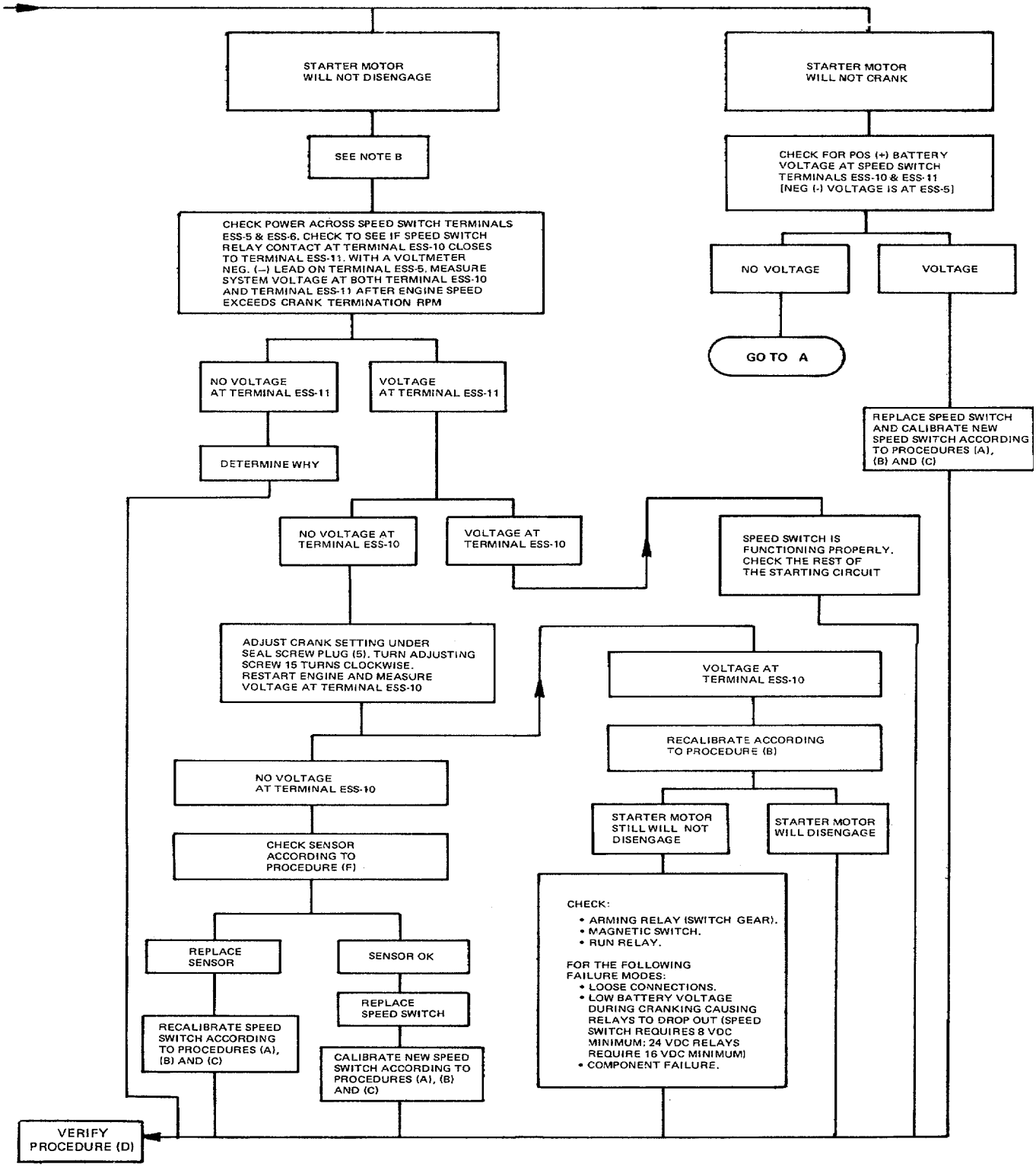


CHART B (Continued)

TROUBLESHOOTING (STEP OIL PRESSURE)

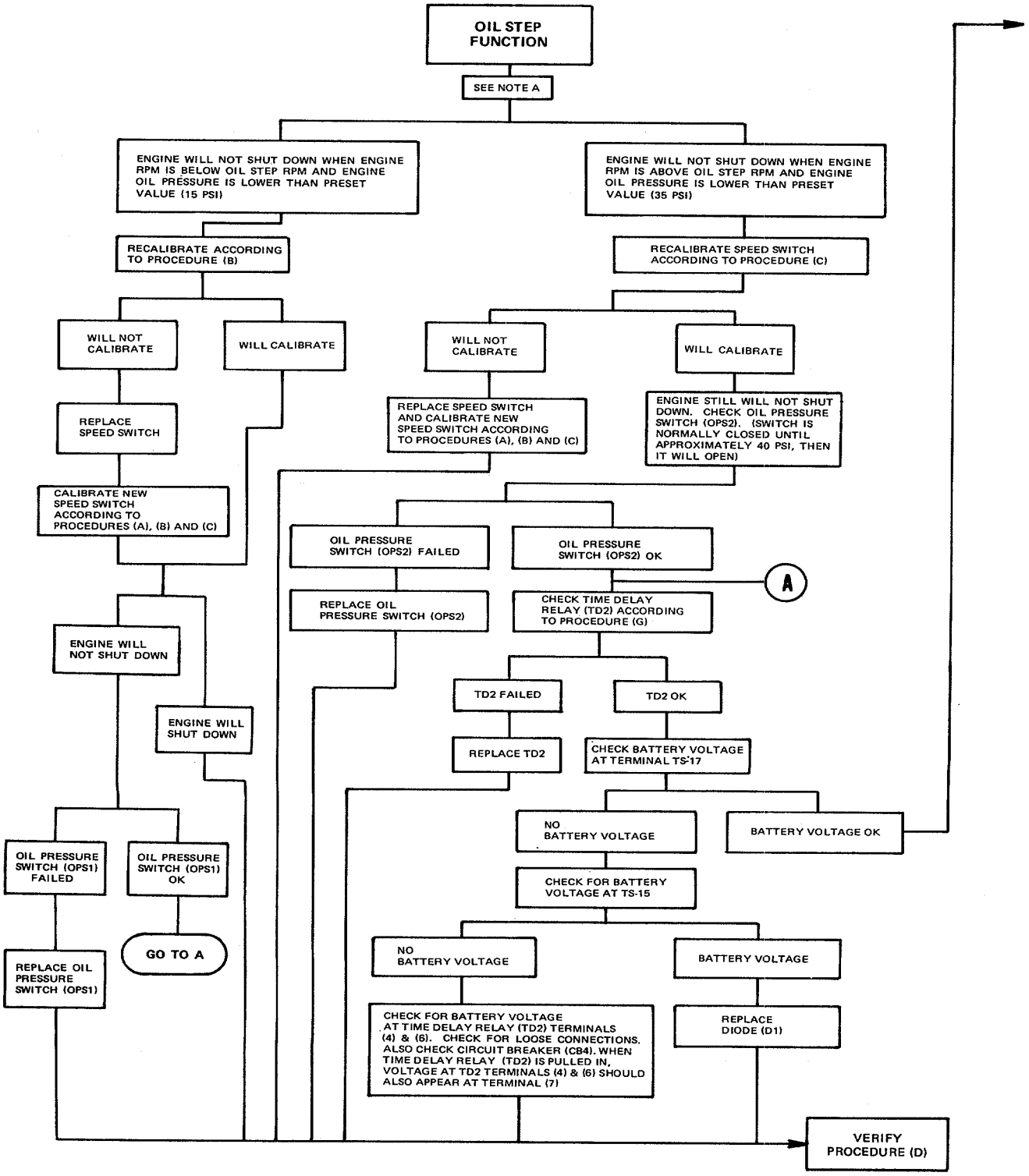


CHART C.

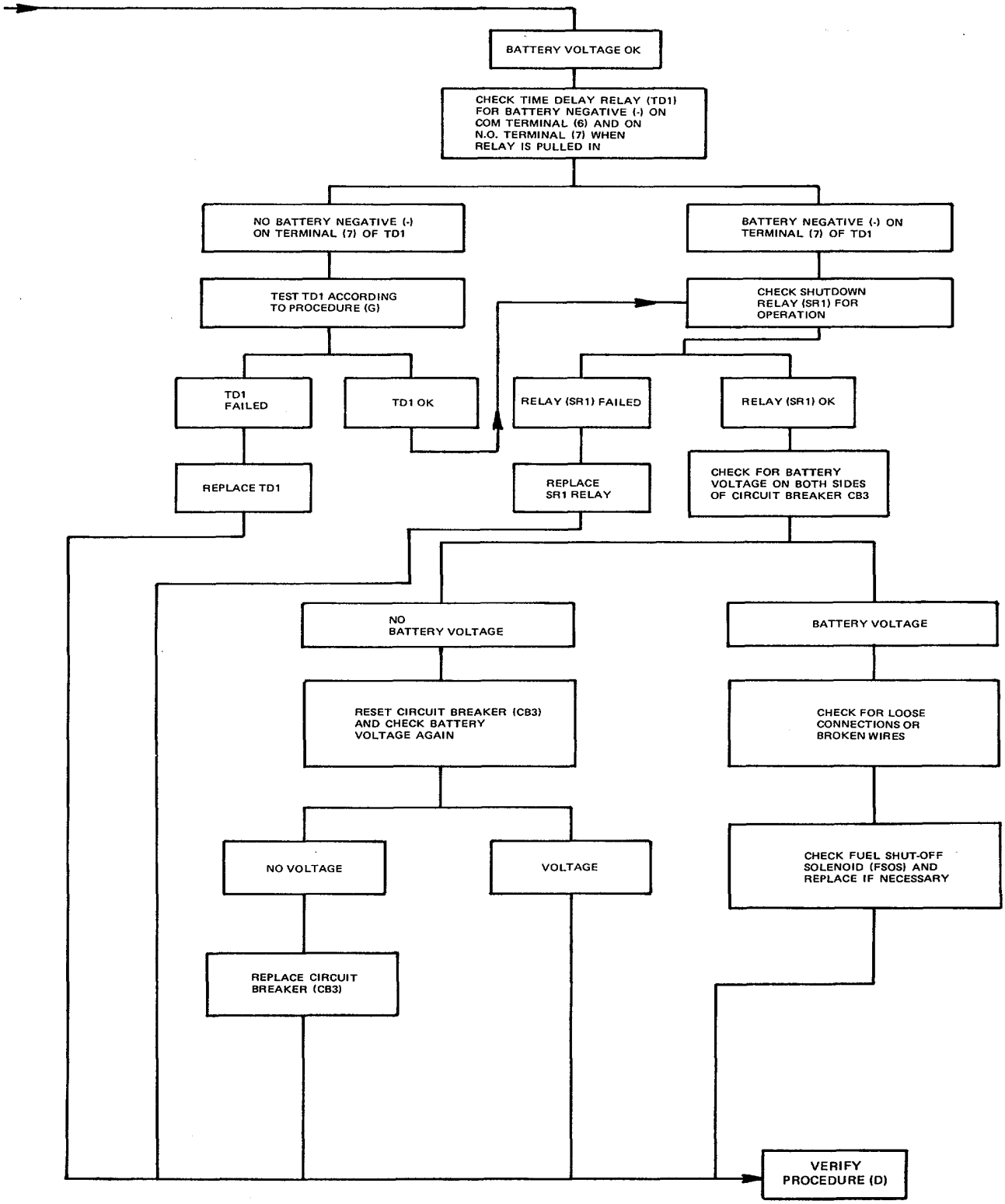


CHART C (Continued)

TROUBLESHOOTING (REVERSAL DETECTION)

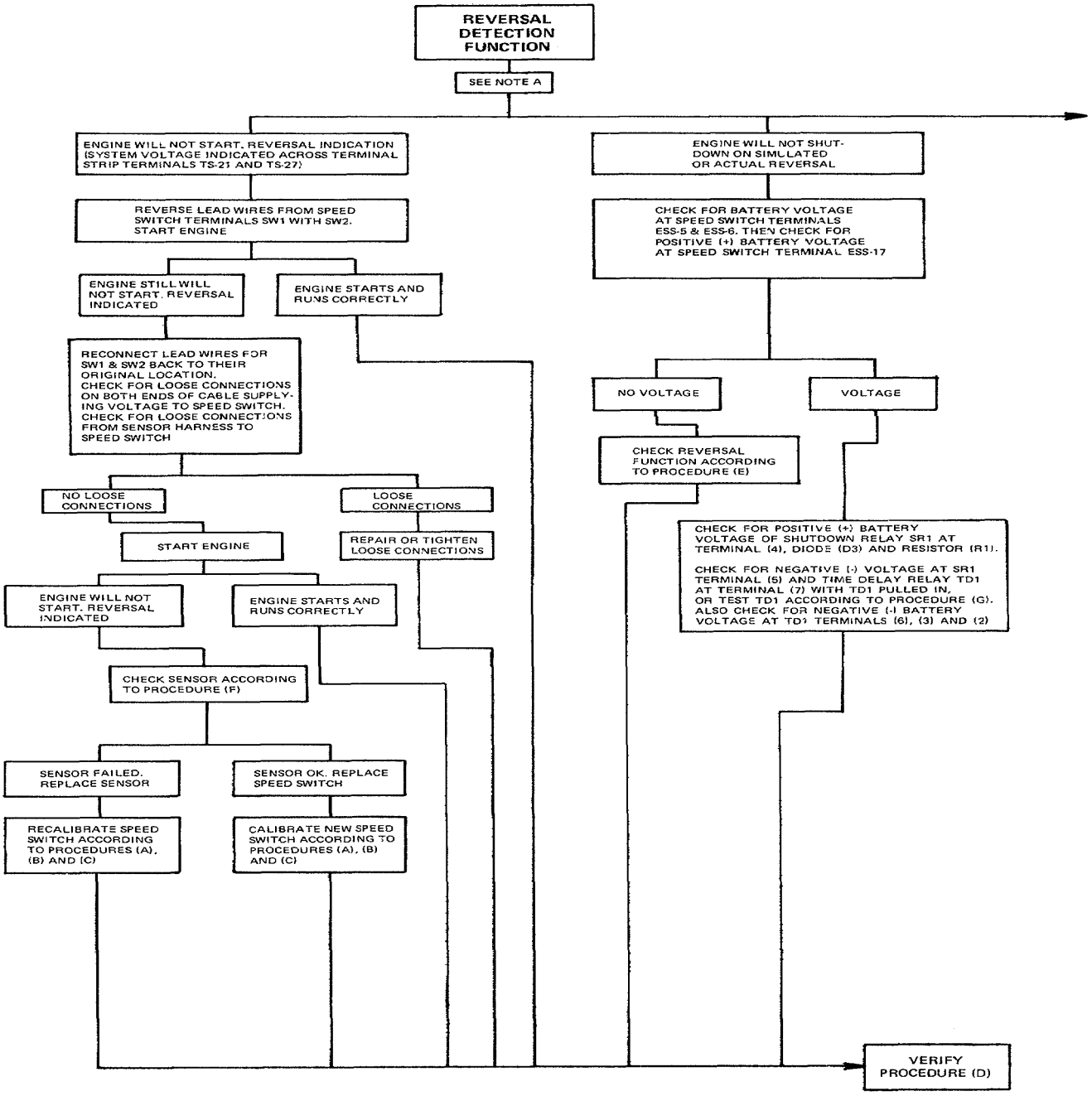


CHART D.

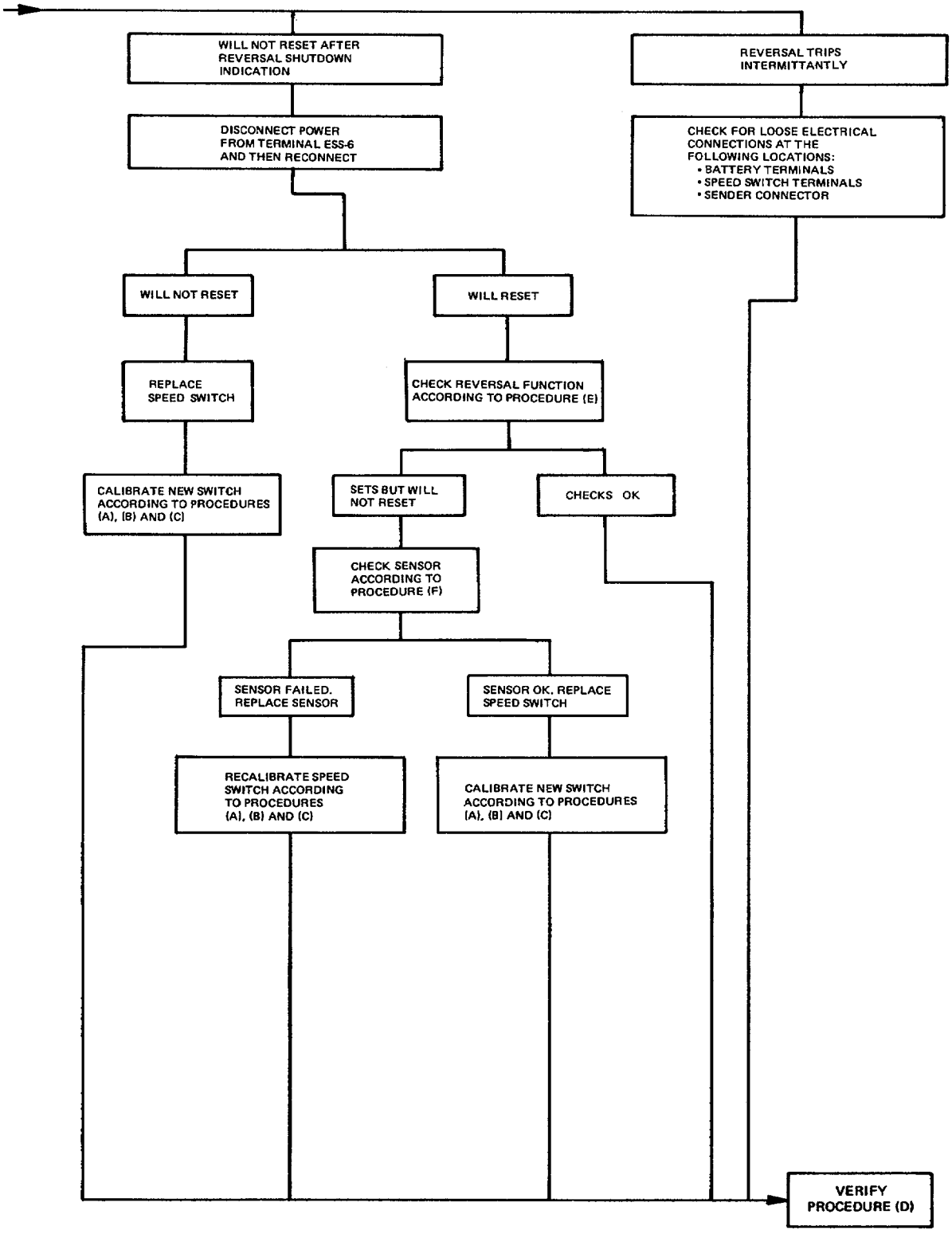
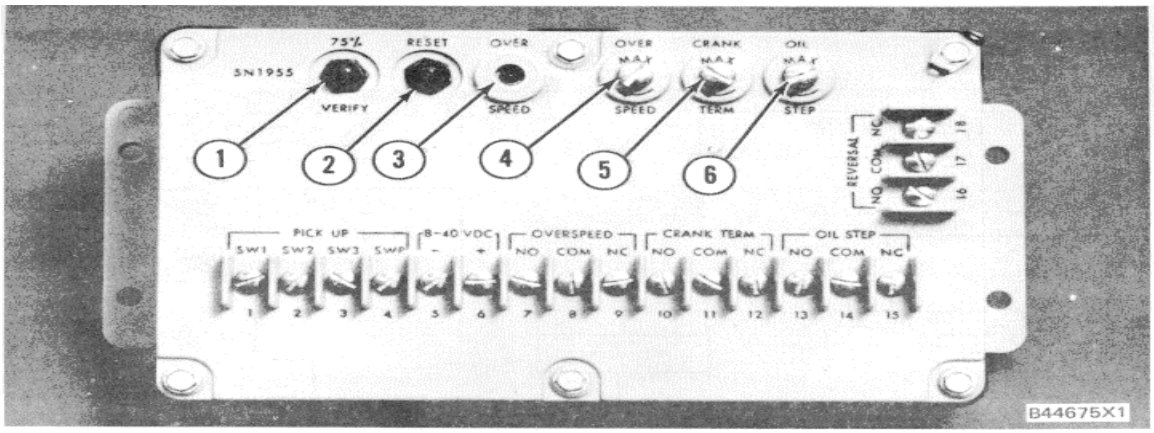


CHART D (Continued)

PROCEDURE A



5N1955 ELECTRONIC SPEED SWITCH

1. Verify button. 2. Reset button. 3. "LED" overspeed light. 4. Seal screw plug (overspeed). 5. Seal screw plug (crank terminate). 6. Seal screw plug (oil step).

OVERSPEED SETTING CALIBRATION

1. Remove lockwire and seal from seal screw plugs (4), (5) and (6). Remove seal screw plug (4) from access hole for overspeed adjustment screw.

2. Use a small screwdriver and lightly turn overspeed adjustment potentiometer twenty turns in the direction of "MAX ARROW" (clockwise).

NOTE: The overspeed adjustment screw is made so that it can not cause damage to the potentiometer, or be removed, if the adjustment screw is turned too many turns in either direction.

3. Run engine at 75% of desired overspeed setting rpm. Make reference to the SPEED SPECIFICATION CHART (Part of PROCEDURE D).

4. With engine at 75% of overspeed setting rpm, push VERIFY button (1) and hold in. Turn overspeed adjustment potentiometer in the direction opposite of "MAX ARROW" (counterclockwise) slowly until "LED" overspeed light (3) comes on. Engine will shutdown if speed switch is connected to the fuel shutoff solenoid and/or air inlet shutoff solenoid.

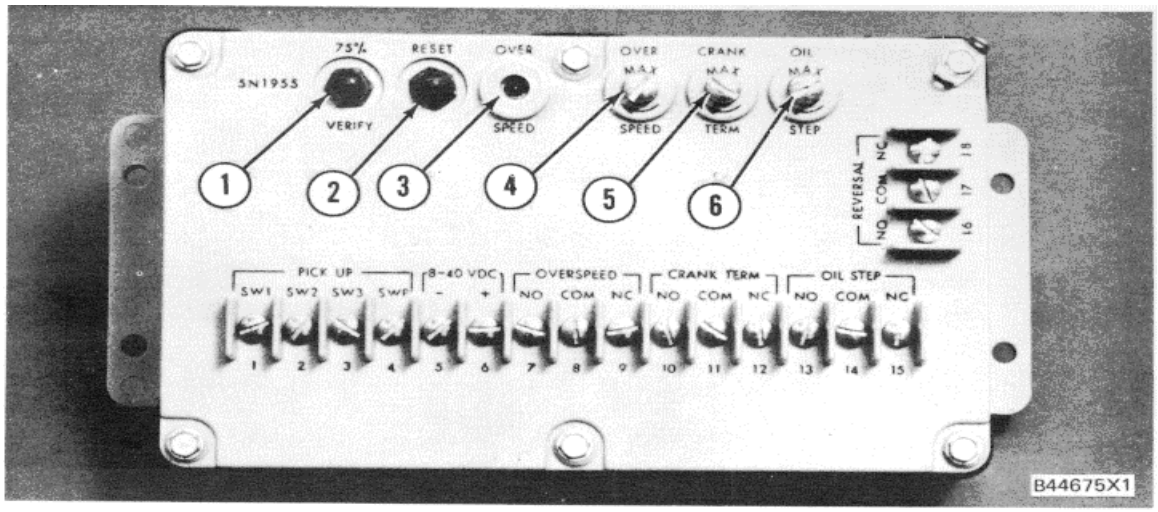
5. To reset speed switch, push in reset button (2). Air inlet shutoff must be manually reset.

6. Slowly turn overspeed adjustment potentiometer approximately one turn clockwise and do Steps 3, 4 and 5 again.

NOTE: More adjustment may be needed to get the correct setting. Turn adjustment potentiometer clockwise to increase speed setting, and counterclockwise to decrease speed setting. Turn adjustment potentiometer very slowly only a small amount at a time until adjustment is correct.

7. When the speed setting is correct, install seal screw plug (4) in overspeed adjustment access hole. Tighten screw to a torque of 0.20 ± 0.03 N•m (2 ± .3 lb. in.). Install the lockwire and seal (if crank termination and oil step adjustments are complete).

PROCEDURE B



5N1955 ELECTRONIC SPEED SWITCH

1. Verify button. 2. Reset button. 3. "LED" overspeed light. 4. Seal screw plug (overspeed). 5. Seal screw plug (crank terminate). 6. Seal screw plug (oil step).

CRANK TERMINATE SPEED ADJUSTMENT

1. Remove lockwire and seal from seal screw plug (4), (5) and (6). Remove seal screw plug (5) from the access hole for crank terminate adjustment screw.

2. Use a small screwdriver and lightly turn the crank terminate adjustment potentiometer twenty turns in the direction of "MAX ARROW" (clockwise).

NOTE: The crank terminate adjustment screw is made so that it can not cause damage to the potentiometer, or be removed, if the adjustment screw is turned too many turns in either direction.

3. Turn the crank terminate adjustment potentiometer twelve turns in a direction opposite of "MAX ARROW" (counterclockwise) for an approximate crank terminate setting.

4. Connect a voltmeter (6V3030 Multimeter or a voltmeter of same accuracy) with the positive lead at ESS-12 and the negative lead at ESS-5. Start the engine and make a note of the speed at which the system voltage is canceled (this is the speed at which the DC starter system disengages). See the SPEED SPECIFICATION CHART (Part of PROCEDURE D) for the correct crank terminate speed.

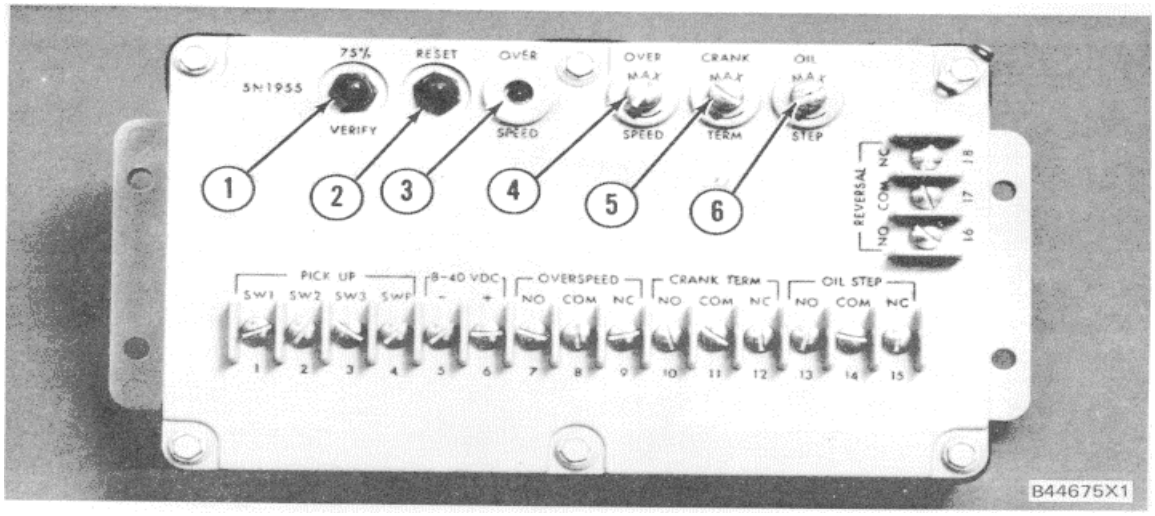
NOTE: If setting is not correct, do Steps 5, 6 and 7. If setting was correct, go to Step 7.

5. Stop the engine and turn the crank terminate adjustment potentiometer one full turn in the correct direction (clockwise to increase and counterclockwise to decrease).

6. With the voltmeter still connected as in Step 4, start the engine and make a note of the speed at which the system voltage is canceled (this is the speed at which the DC starter system disengages). If needed, make more small adjustments until the crank terminate speed is correct.

7. Install seal screw plug (5) in crank terminate adjustment access hole. Tighten to a torque of 0.20 ± 0.03 N.m (2 ± .3 lb. in.). Install the lockwire and seal (if overspeed and oil step adjustments are complete).

PROCEDURE C



5N1955 ELECTRONIC SPEED SWITCH

1. Verify button. 2. Reset button. 3. "LED" overspeed light. 4. Seal screw plug (overspeed). 5. Seal screw plug (crank terminate). 6. Seal screw plug (oil step).

OIL STEP CALIBRATION

1. Remove the lockwire and seal from seal screw plugs (4), (5) and (6). Remove seal screw plug (6) from access hole for the oil step adjustment screw.

2. Use a small screwdriver and lightly turn oil step adjustment potentiometer 20 turns in the direction opposite of "MAX ARROW" (counterclockwise). This will lower the oil step speed setting to its lowest value.

NOTE: The oil step adjustment screw is made so it can not cause damage to the potentiometer, or be removed, if the adjustment screw is turned too many turns in either direction.

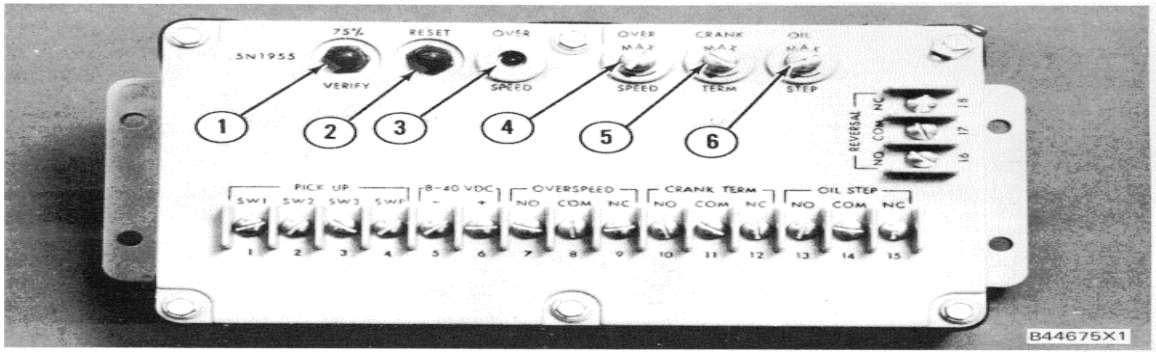
3. Use a 6V3030 Multimeter (or a voltmeter of same accuracy) to check for positive (+) voltage at terminal ESS-13 [negative (-) voltage is at terminal ESS-5].

4. Make reference to SPEED SPECIFICATION CHART (Part of PROCEDURE D). For a particular engine rating, find the specified rpm in column for Oil Step Speed Setting. Run the engine at this specified rpm.

5. With the engine running, look into the oil step adjustment access hole. A red "LED" (light emitting diode) light will be on. After an 8 to 10 second delay, positive (+) voltage will be seen at terminal ESS-13. Now turn the oil step adjustment potentiometer clockwise until the red light in the oil step access hole goes out. When the light goes out, this indicates that the oil step rpm setting is above the present running rpm of the engine. Slowly turn the adjustment potentiometer counterclockwise until the light comes back on. After an 8 to 10 second delay, positive (+) voltage will be seen at terminal ESS-13.

6. When the oil step setting is correct, install seal screw plug (6) into the adjustment access hole for the oil step function. Tighten plug to a torque of 0.20 $\pm$ 0.03 N•m (2 $\pm$ .3 lb. in.). If all other adjustments are complete (overspeed and crank terminate), install lockwire and seal.

PROCEDURE D



5N1955 ELECTRONIC SPEED SWITCH

1. Verify button. 2. Reset button. 3. "LED" overspeed light. 4. Seal screw plug (overspeed). 5. Seal screw plug (crank terminate). 6. Seal screw plug (oil step).

OVERSPEED VERIFY TEST

1. Run the engine at rated speed and push verify button (1) in for a moment. This will cause the speed switch to activate and shutdown the engine.

NOTE: Any time the engine speed is 75% or more of the overspeed setting, the engine will shutdown if the verify button is pushed.

EXAMPLE: For an engine with a rated speed of 1800 rpm, the overspeed setting is 2125 rpm (see SPEED SPECIFICATION CHART and Note E). The overspeed verify test will shutdown the engine at 75% (± 25 rpm) of the overspeed setting of 2125 rpm. In this example, 75% of 2125 rpm is approximately 1600 rpm. If the verify button is pushed at an engine speed of approximately 1600 rpm or above, the engine will shutdown.

The "LED" overspeed light (3) will come on and stay on until the reset button is pushed after an overspeed switch shutdown. To restart the engine, push in reset button (2) for a moment. This will reset the speed switch, and the "LED" overspeed light (3) will go off. The air inlet shutoff lever must now be manually reset before the engine can be started.

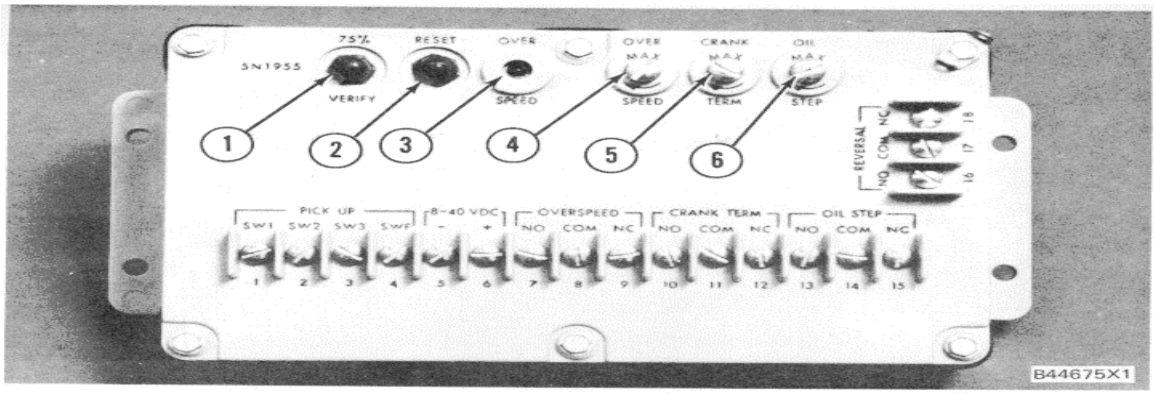
NOTE C: To verify overspeed shutdown system operation, push in the VERIFY button for a moment. The engine must shutdown at 75% or more of overspeed setting.

NOTE D: Input Voltage: Maximum 40 VDC; Minimum 8 VDC.

NOTE E: The engine overspeed setting rpm is 118% of rated engine rpm.

SPEED SPECIFICATION CHART (RPM)				
TYPICAL RATED ENGINE SPEED	**OVERSPEED SETTING (±25) NOTE E**	**75% OVERSPEED VERIFY (±25) NOTE C**	**OIL STEP SPEED SETTING**	**CRANK TERMINATE**
1800	2125	1600	1125	600
1600	1890	1415	1125	600
1500	1775	1325	1125	600
1300	1535	1150	750	400
1200	1415	1060	750	400
1000	1180	885	750	400
900	1065	800	750	400

PROCEDURE E



5N1955 ELECTRONIC SPEED SWITCH

1. Verily button. 2. Reset button. 3. "LED" overspeed light. 4. Seal screw plug (overspeed). 5. Seal screw plug (crank terminate). 6. Seal screw plug (oil step).

REVERSAL DETECTION

1. Stop the engine and reverse the wires from PICKUP terminals SW1 (ESS-1) and SW2 (ESS-2) [this will simulate an engine reversal when the engine is cranked at least two full revolutions]. Connect the 6V3030 Multimeter or a voltmeter between terminals ESS-16 and ESS-5. Crank the engine at least two full revolutions and check for positive (+) voltage at ESS16. If voltage is indicated, the reversal detection is functioning properly.

2. To reset the reversal function, connect again SW1 wire (white) back on terminal ESS-1 and SW2 wire (dark green) back on terminal ESS-2. Crank the engine at least two full revolutions and check for positive (+) voltage at ESS-16. No voltage should be indicated.

3. If no voltage is indicated, then reversal function has reset correctly.

4. If voltage is still indicated, crank the engine again and check PICKUP wires for proper connection. If voltage is still indicated, check 7N7412 Sensor Assembly according to Procedure F.

NOTE: Different wiring connections must be used for engines with different rotation. For a specific engine rotation, use the correct connections that follow:

*STANDARD ROTATION (Counterclockwise)
Connect -
White wire from sensor assembly to PICKUP terminal SW1 (ESS-1).

Dark green wire from sensor assembly to PICKUP terminal SW2 (ESS-2).

*REVERSE ROTATION (Clockwise)
Connect -
Dark green wire from sensor assembly to PICKUP terminal SW1 (ESS-1)

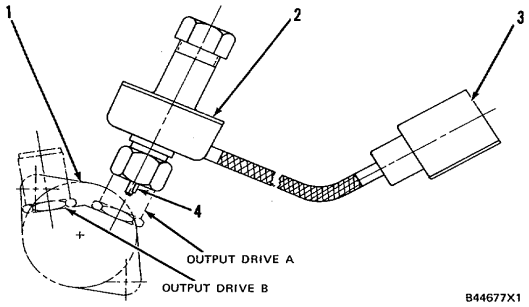
White wire from sensor assembly to PICKUP terminal SW2 (ESS-2).

*Rotation as viewed from flywheel end of engine.

PROCEDURE F

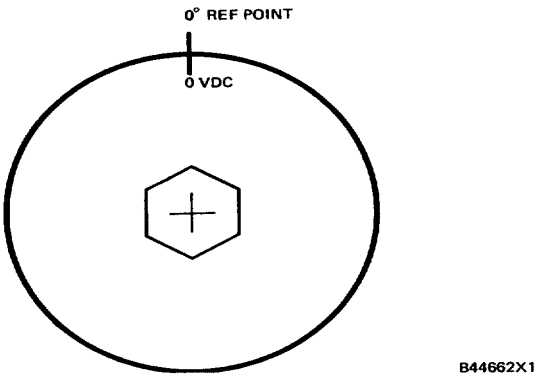
7N7412 SENSOR ASSEMBLY VERIFY

NOTE : For bench testing, connect a voltage source with a range from 8-40 VDC (24 VDC preferred) across the electronic speed switch (ESS) terminals ESS-5 and ESS-6. Terminal ESS-5 is the battery negative terminal, and ESS-6 is the battery positive terminal.



INSTALLED SENSOR ASSEMBLY
(Position shown is for RH rear of engine)
1. Tachometer drive housing. 2. 7N7412 Sensor Assembly. 3. Sensor harness connector. 4. Sensor drive end.

1. Disconnect 7N7412 Sensor Assembly (2) from engine tachometer drive housing (1). Set the voltmeter (6V3030 Multimeter or a voltmeter of same accuracy) voltage scale to a scale higher than 6 VDC. Connect the voltmeter to the 5N 1955 Electronic Speed Switch with the positive (+) voltmeter lead connected to SW1 (ESS-1) and the negative (-) voltmeter lead connected to terminal ESS-5 (-).



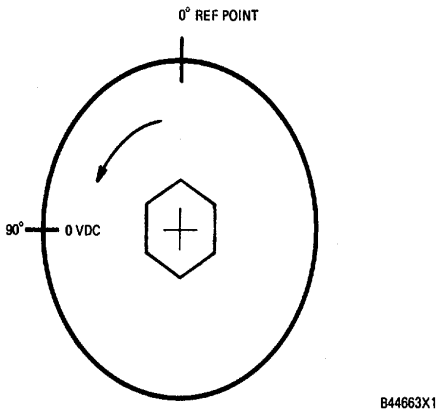
SW1 CHECK

A. **Slowly** turn the shaft of 7N7412 Sensor Assembly (2) one full turn in a **counterclockwise** direction [as viewed from drive end (4)]. and watch the voltage indication. A 4 to 6 VDC reading should be seen for all but one small area of the shaft rotation. Mark the position of the shaft where the voltage reading was zero volts. This point is called SW1 00 reference point.

NOTE : If no voltage is indicated between terminal SW1 (ESS-1) and terminal ESS-5 through one full turn of the sensor shaft rotation, check speed switch for proper voltages. A voltage of 4 to 6 VDC should be seen across terminals ESS-4 and ESS-5. If speed switch voltage is correct, then either the sensor is defective or the wiring from the sensor to the speed switch is defective.

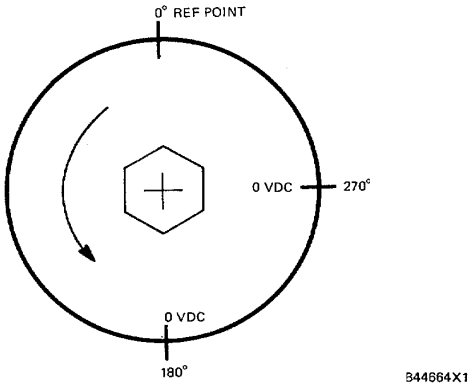
After finding SW1 0° reference point (the position where zero voltage was measured on the sensor), an additional zero volts indication will be measured once for every 900 of shaft rotation from the 0° reference point by using the sequence that follows:

B. Connect the positive (+) voltmeter lead to SW2 (ESS-2) and leave the negative (-) voltmeter lead connected to ESS-5. Now **slowly** turn the sensor shaft **counterclockwise.** A 4 to 6 VDC reading should be seen for all but one small area of shaft rotation at an interval 900 from the SW1 0° reference point. Zero volts will be indicated at this area.



SW2 CHECK

C With the negative (-) voltmeter lead still connected to ESS-5, connect the positive (+) voltmeter lead to SW3 (ESS-3). Again, slowly turn the sensor shaft counterclockwise. A 4 to 6 VDC reading should be seen for all but two small areas of shaft rotation; one at the 1800 interval and one at the 2700 interval (both measured from the SWI 0° reference point). Zero volts will be indicated at both of these areas.



SW3 CHECK

2. If all four zero volt levels are recorded in the proper sequence and at the proper degree of rotational position (900 apart from each other), then the 7N7412 Sensor Assembly operates properly.

3. Before installing 7N7412 Sensor Assembly (2) back on the engine, start the engine and check to be sure that the drive shaft in tachometer drive housing (1) is turning properly.

4. If tachometer drive shaft is in rotation, stop engine and install sensor assembly.

NOTE: The tachometer drive housing has two output drives (one marked A and the other marked B). Be sure that sensor assembly is always connected to output drive marked A.

PROCEDURE G

ON/OFF TIME DELAY (RELAY)



ON/OFF DELAY (RELAY)

Performance Check (either TD1 or TD2 relays can be checked with methods that follow)

A. Items Required For Check:

1. Battery or any D. C. source of 8 to 40 volts.
2. Voltmeter (6V3030 Multimeter or one of same accuracy).
3. Stop watch.

B. Bench Or Installed Test

Connect or verify source voltage to relay terminals 3 (-) and 4 (+) [if bench testing, also connect positive *(+*) voltage to relay terminal 6]. All connections must be maintained until tests are complete.

NOTE: There will be voltage when the relay is closed. When relay is open, there will be no voltage [voltage may be positive (+) or negative (-) when relay is tested on engine; when bench testing, voltage will always be positive (+)].

1. Use the voltmeter to verify chart that follows:

2.

Terminals	Relay Position
5	Closed
7	Open

2. (a) Apply positive (+) source voltage to terminal 1 (either relay) and immediately verify the chart that follows (do not leave voltage on terminal 1 for more than 60 seconds):

Terminals	Relay Position
5	Open
7	Closed

(b) Remove positive (+) source voltage from terminal 1. Use a stop watch and check the time from the moment of removal to verify chart that follows:

Terminals	Delay Time to Function	
	0 to 60 Secs.	After 80 Secs.
5	Open	Closed
7	Closed	Open

3. (a) Apply positive (+) source voltage to terminal 2.

NOTE: If bench testing, Step 3 can be used with either relay. When installed on engine, Step 3 can only be checked with TD2. **Do not apply positive (+) voltage to terminal 2 of TD1, or a direct short will result.**

Check the time from the moment voltage is applied to verify chart that follows (do not leave voltage on terminal 2 for more than 60 seconds):

Terminals	Delay Time to Function	
	0 to 8 Secs.	After 10 Secs.
5	Closed	Open
7	Open	Closed

(b) Remove positive (+) source voltage from terminal 2. Check the time from the moment of removal to verify chart that follows:

Terminals	Delay Time to Function	
	0 to 60 Secs.	After 80 Secs.
5	Open	Closed
7	Closed	Open

4. Remove wire from terminal 4 and verify chart that follows:

Terminals	Relay Position
5	Closed
7	Open

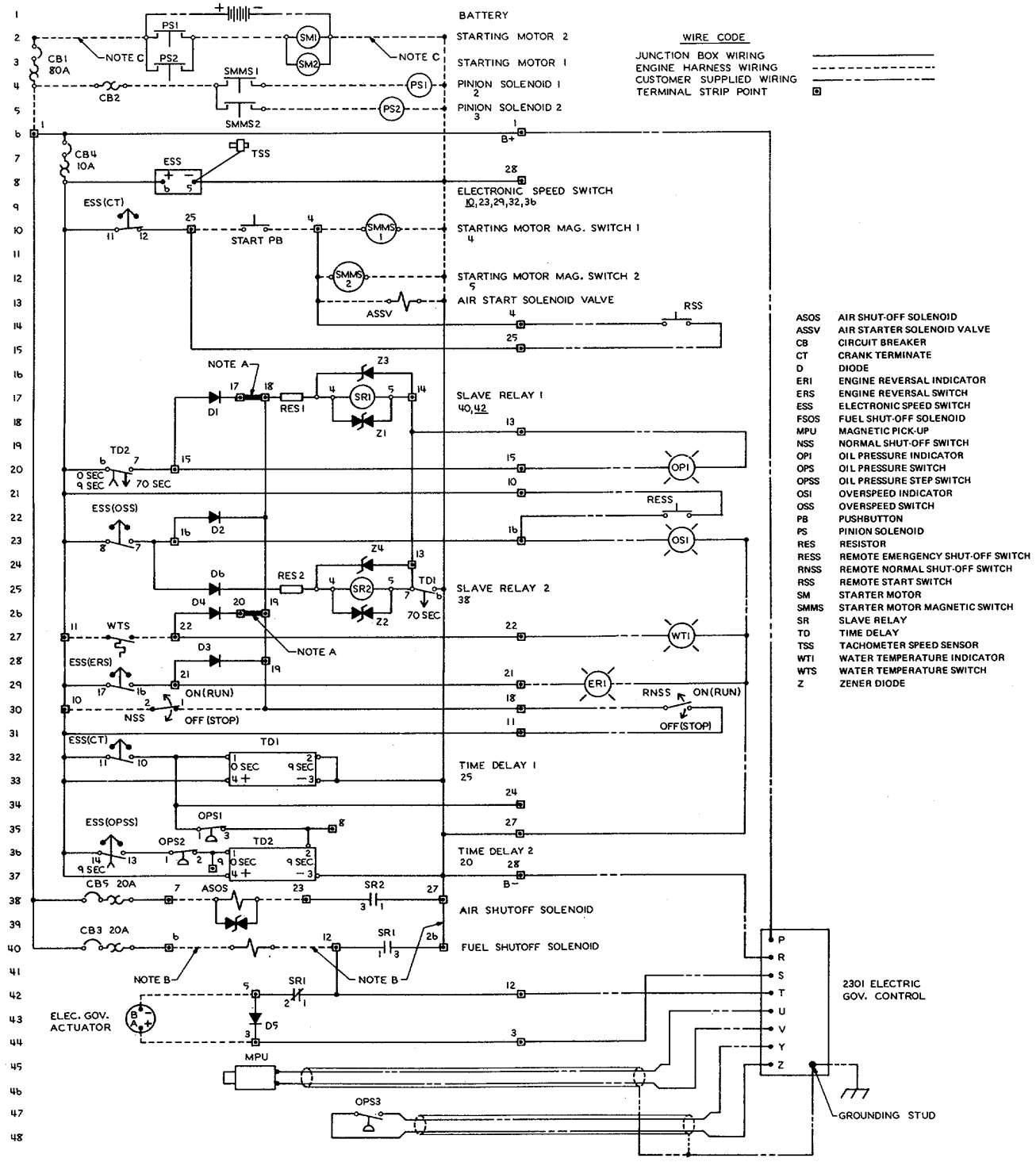
ELECTRIC PROTECTIVE SYSTEM WIRING DIAGRAMS

COMPONENT ABBREVIATIONS (REF 5N360)

ALT	ALTERNATOR
AMM	AMMETER
ASOS	AIR SHUT-OFF SOLENOID
ASSV	AIR START SOLENOID VALVE
B-	BATTERY NEGATIVE
B+	BATTERY POSITIVE
BATT	BATTERY
CB	CIRCUIT BREAKER
CT	CRANK TERMINATE
D	DIODE
EGA	ELECTRIC GOVERNOR ACTUATOR
EGC	ELECTRIC GOVERNOR CONTROL
ERI	ENGINE REVERSAL INDICATOR
ERS	ENGINE REVERSAL SWITCH
ESS	ELECTRIC SPEED SWITCH
FSOS	FUEL SHUT-OFF SOLENOID
HWTAS	HIGH WATER TEMPERATURE ALARM SWITCH
LOPAS	LOW OIL PRESSURE ALARM SWITCH
LWTAS	LOW WATER TEMPERATURE ALARM SWITCH
MGOPG	MARINE GEAR OIL PRESSURE GAGE
MGOPSU	MARINE GEAR OIL PRESSURE SENDING UNIT
MGOTAS	MARINE GEAR OIL TEMPERATURE ALARM SWITCH
MPU	MAGNETIC PICK-UP
NSS	NORMAL SHUT-OFF SWITCH
OPG	OIL PRESSURE GAGE
OPI	OIL PRESSURE INDICATOR
OPS	OIL PRESSURE SWITCH
OPSS	OIL PRESSURE STEP SWITCH
OPSU	OIL PRESSURE SENDING UNIT
OSI	OVERSPEED INDICATOR
OSS	OVERSPEED SWITCH
PB	PUSH BUTTON
PP	PRELUBE PUMP
PPMS	PRELUBE PUMP MAGNETIC SWITCH
PPPS	PRELUBE PUMP PRESSURE SWITCH
PS	PINION SOLENOID
RES	RESISTOR
RESS	REMOTE EMERGENCY SHUT-OFF SWITCH
RNS	REMOTE NORMAL SHUT-OFF SWITCH
RSS	REMOTE START SWITCH
SM	STARTER MOTOR
SMMS	STARTER MOTOR MAGNETIC SWITCH
SR	SLAVE (SHUTDOWN) RELAY
TD	TIME DELAY
TM	TACHOMETER
TS	TERMINAL STRIP
TSS	TACHOMETER SPEED SENSOR
WTG	WATER TEMPERATURE GAGE
WTI	WATER TEMPERATURE INDICATOR
WTS	WATER TEMPERATURE SWITCH
WTSU	WATER TEMPERATURE SENDING UNIT
Z	ZENER DIODE

WIRE COLOR CODE ABBREVIATIONS

B	BLACK
BR	BROWN
B/W	BLACK WITH WHITE STRIPE
CU	COPPER (BARE WIRE)
DK BL	DARK BLUE
DK GR	DARK GREEN
GR	GREEN
LT BL	LIGHT BLUE
O	ORANGE
0/B	ORANGE WITH BLACK STRIPE
P/B	PINK WITH BLACK STRIPE
PU/W	PURPLE WITH WHITE STRIPE
R	RED
W	WHITE
W/O	WHITE WITH ORANGE STRIPE
W/R	WHITE WITH RED STRIPE
Y	YELLOW
Y/BR	YELLOW WITH BROWN STRIPE

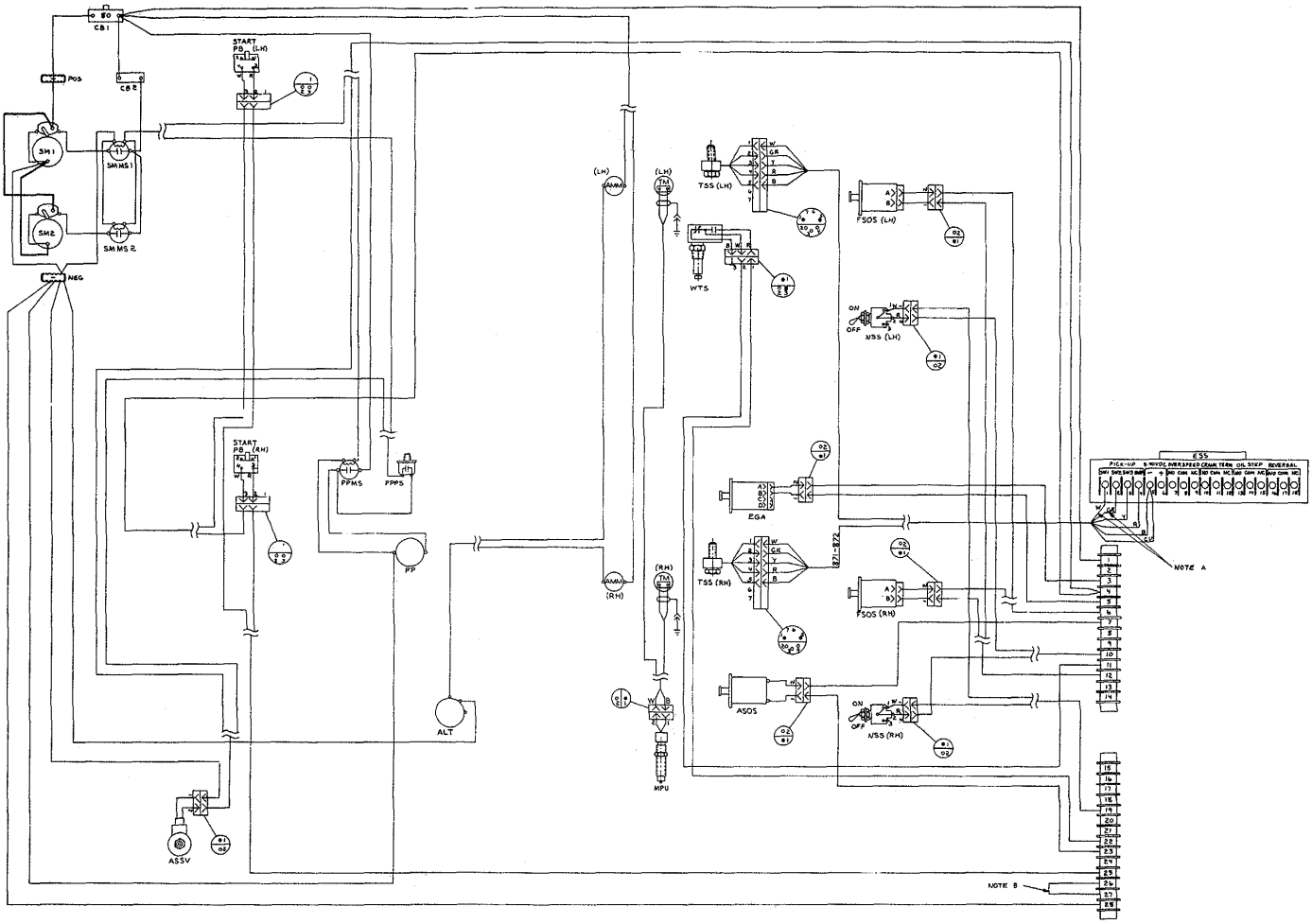


ELECTRIC PROTECTIVE SYSTEM SCHEMATIC

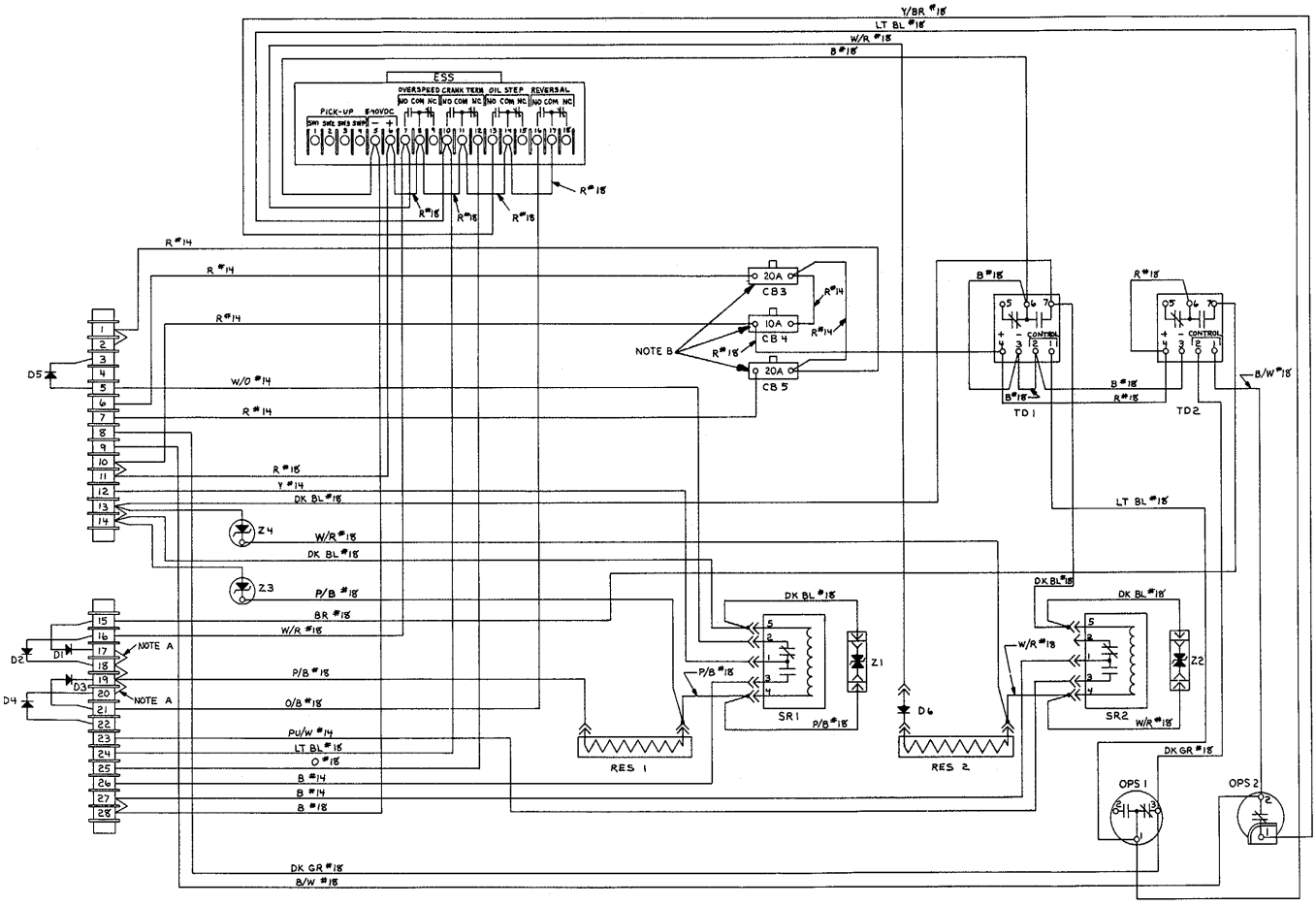
NOTE A: Terminal strip jumpers between terminals TS17 & TS18 and TS19 & TS20 are not required for low oil pressure and high water temperature alarms.

NOTE B: The wire at terminal strip between terminals TS26 & TS27 is in the wiring harness when a UG8D or UG8L is installed. No wire is required when an EGA is used.

NOTE C: This wire is provided by customer if electric starter motor(s) are not used.



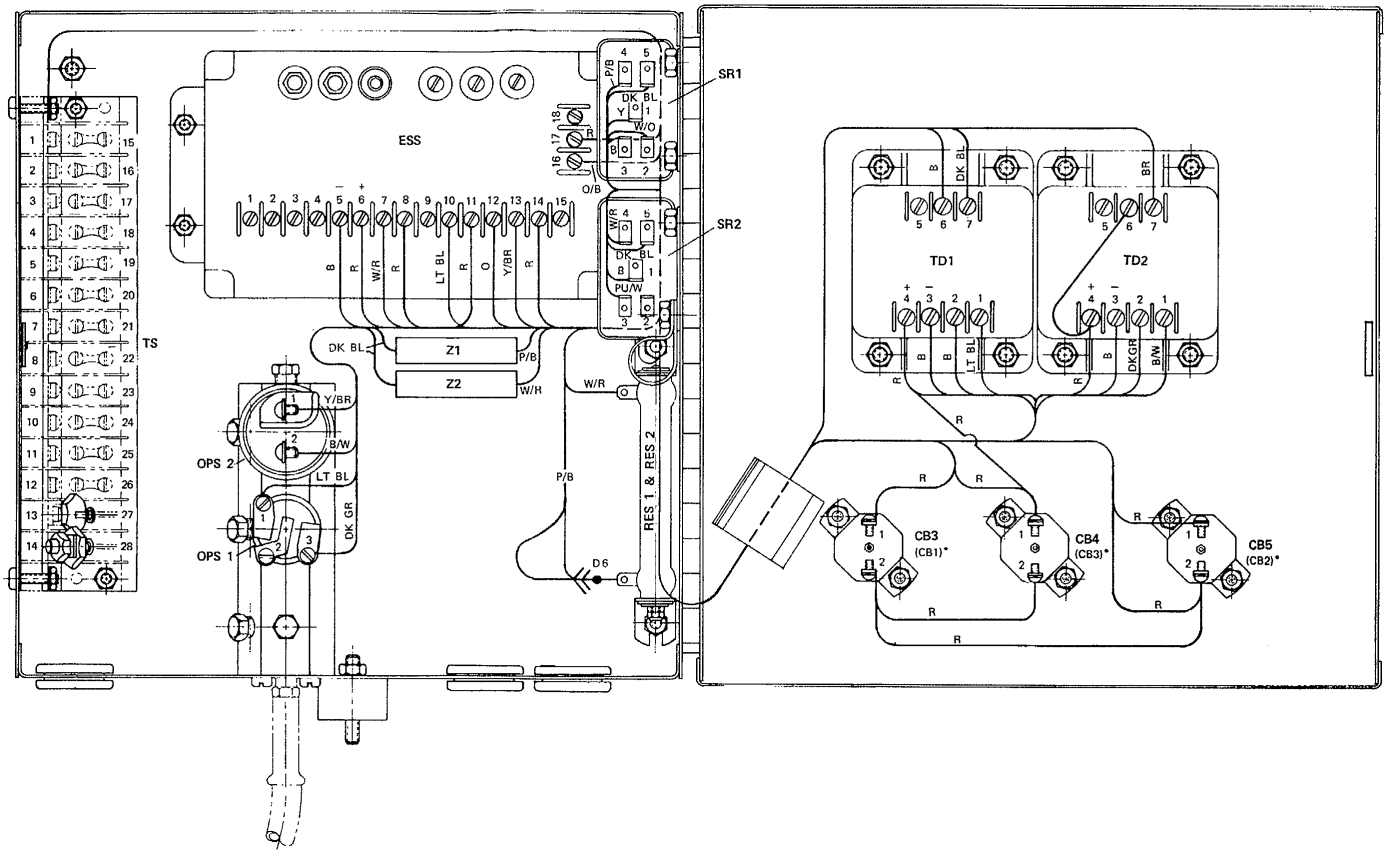
3500 ENGINE WIRING DIAGRAM (REF 5N8944)
(All Possible Combinations)
NOTE A: Reverse wires at SW1 and SW2 for reverse rotation engines.
NOTE B: Jumper required only with UG8D and UG8L governors.



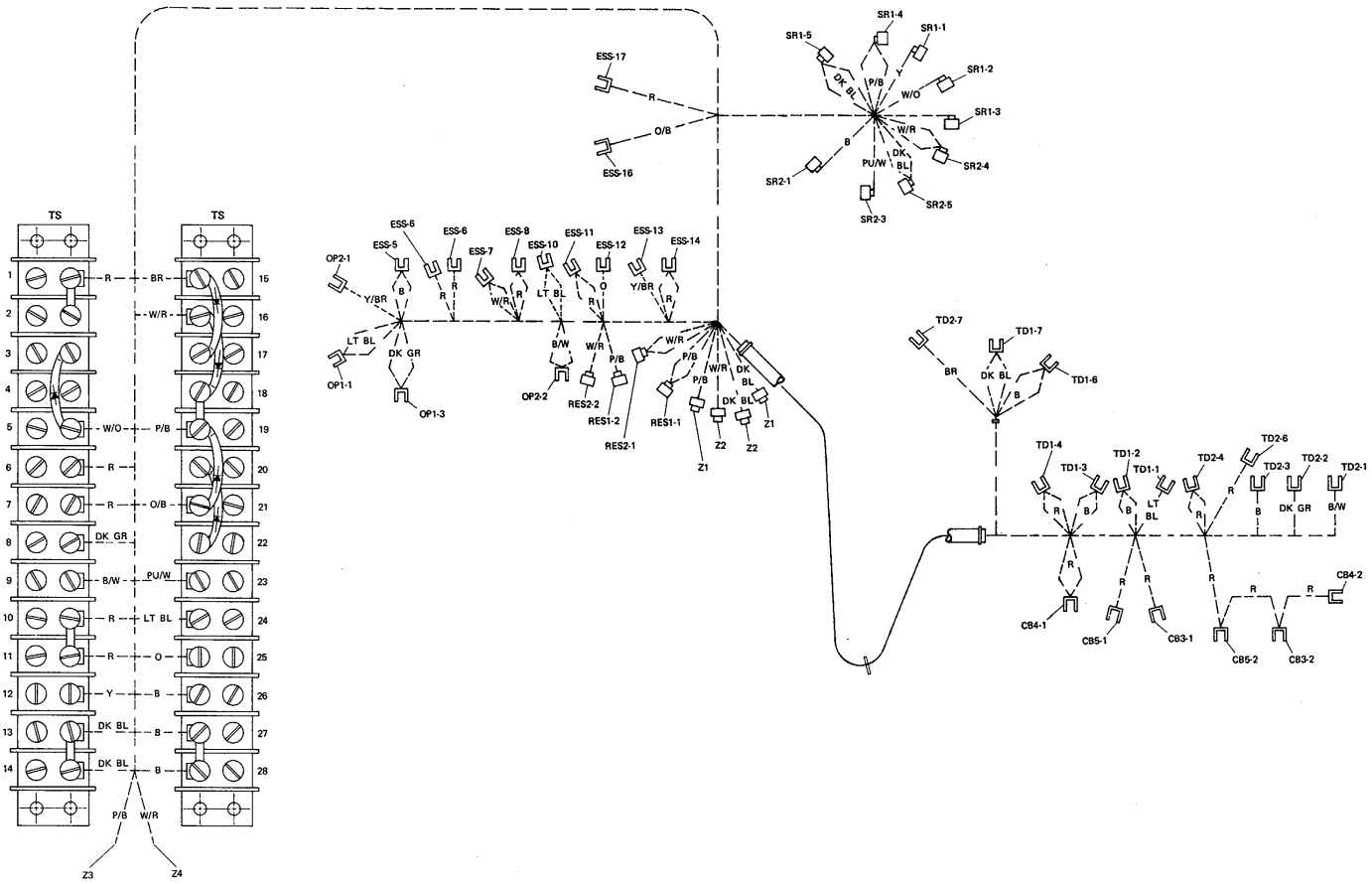
TYPICAL JUNCTION BOX WIRING DIAGRAM (REF 5N8944)

NOTE A: Terminal strip jumpers between terminals T817 & TS818 and TS819 T820 are not required on Marine Engines which have alarms only for low oil pressure and high water temperature.

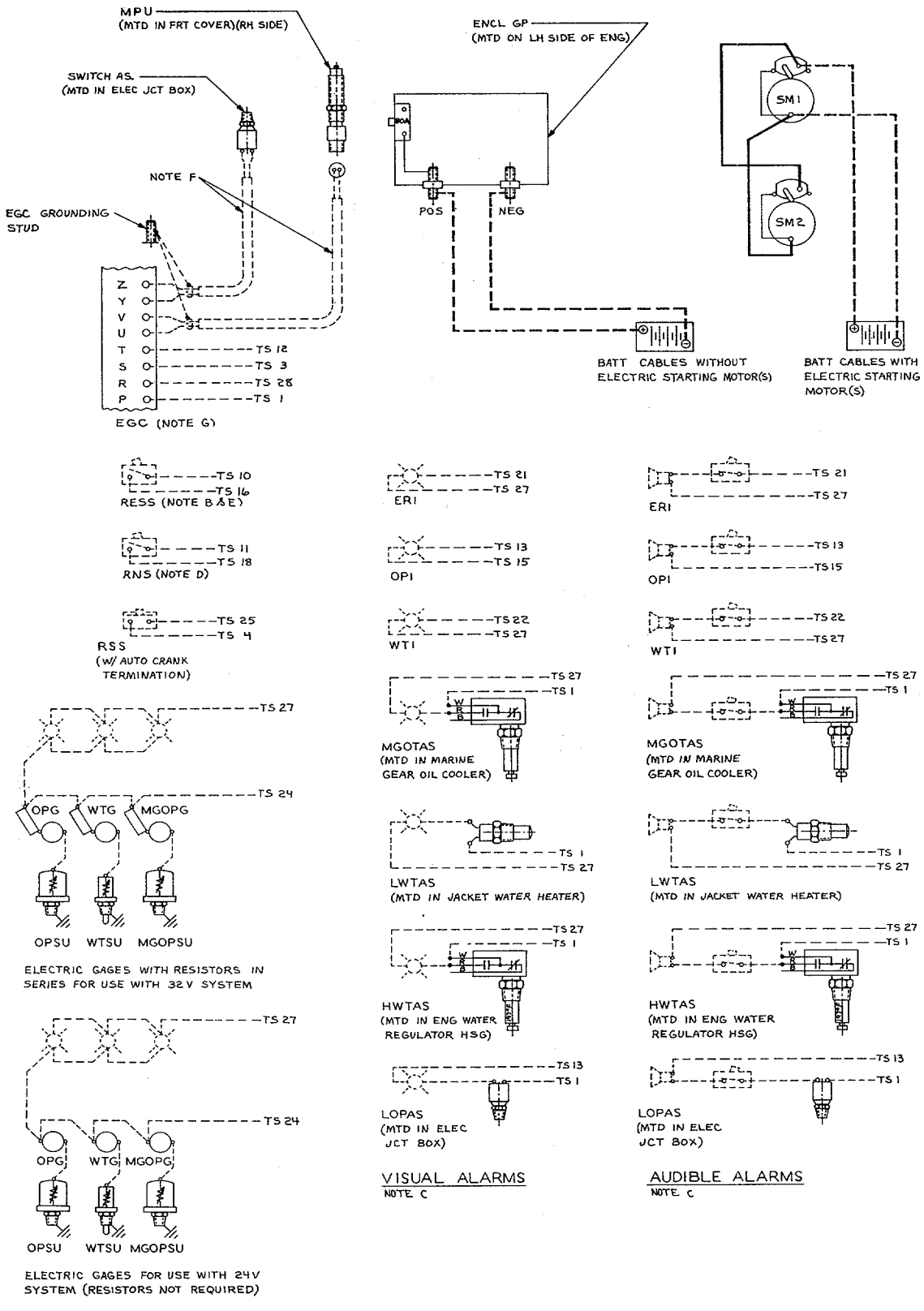
NOTE B: Earlier circuit breakers were as follows: CB3 and CB5, 15 amp; CB4, 4 amp.



JUNCTION BOX (REF 5N8513)
***Nomenclature in ( ) indicates former identification**



JUNCTION BOX WIRING HARNESS (REF 5N8511)



CUSTOMER WIRING WITH ELECTRIC PROTECTIVE SYSTEM (NOTE A)

SEE NOTES ON PAGE THAT FOLLOWS

NOTE A: Wire, cable and components shown with dotted lines are to be added by customer. See wire and cable gage charts for size selection.

NOTE B: Do not use remote emergency switch for normal engine shutdown. The use of emergency switch requires manual reset of air shut-off at top of air inlet housing.

NOTE C: Caterpillar alarm and prealarm contacts are rated for a maximum of 3 amps inductive at the charging system voltage.

NOTE D: Switch to be a single pole, normally open switch (may be latching if desired) with a minimum contact rating of .5 amp inductive at the charging system voltage.

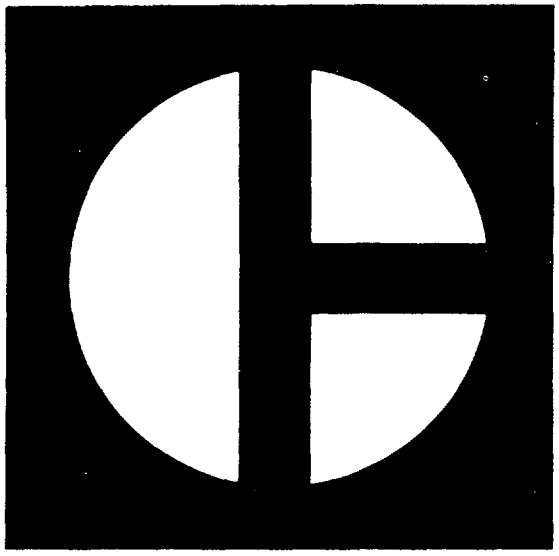
NOTE E: Switch to be a single pole, normally open switch (may be latching if desired) with a minimum contact rating of 1 amp inductive at the charging system voltage.

NOTE F: Magnetic pick-up and oil pressure switch to be wired to electric governor control (Woodward 2301) with a two conductor shielded cable (Belden Corp. type 8780 or equivalent). Shields are to be grounded at electric governor control grounding stud. Each shield should not have more than one ground connection.

NOTE G: Woodward 2301 Electric Governor Control terminal identification chart:

SYMBOL	FUNCTION	STAND-BY TS NO.	LOAD SHARING TS NO.
P	Batt +	2	12
R	Batt -	1	13
S	EGA +	6	17
T	EGA -	5	16
U	Mag Pick-up	7	18
V	Mag Pick-up	8	19
Y	Oil Pressure Speed Limiter	9	14
Z	Oil Pressure Speed Limiter	10	15

FORM NO. SENR2985



SYSTEMS OPERATION
TROUBLESHOOTING
INDIVIDUAL CIRCUIT DESCRIPTION

ELECTRIC PROTECTIVE SYSTEM

FOR

GENERATOR SET, INDUSTRIAL AND MARINE ENGINES

513

ELECTRIC PROTECTIVE SYSTEM

INTRODUCTION

The electric protective system is designed to activate an alarm or shut the engine off if there is a problem or a failure in any of four different engine systems. The engine systems monitored are: engine overspeed, starter motor crank terminate, engine oil pressure and engine coolant temperature.

The electric protective system consists of the basic components that follow: magnetic pickup, electronic speed switch, water temperature contactor switch, two time delay relays and two slave relays. This system monitors the engine from starting through rated speed.

COMPONENT DESCRIPTION

Magnetic Pickup (MPU) The magnetic pickup is a single pole, permanent magnet generator made of wire coils around a permanent magnet pole piece.

As the teeth of the flywheel ring gear go through the magnetic lines of force around the pickup, an AC voltage is made. A positive voltage is made when each tooth goes by the pole piece. Each time the space between the teeth goes by the pole piece, a negative voltage is made. Engine speed is then determined by the frequency of these signals.

Electronic Speed Switch (ESS) The 4W2218 Electronic Speed Switch can easily be identified by its black color (the earlier speed switch was yellow). This speed switch has controls (in a single unit) to monitor three of the basic functions. These three functions are:

Engine Overspeed An adjustable engine speed setting (normally 118% of rated speed) that gives protection to the engine from damage if the engine runs too fast. This condition will cause a switch to close that shuts off both the inlet air and the fuel to the engine.

Crank Terminate (Starter Motors) An adjustable engine speed setting that gives protection to the starter motor from damage by overspeed. This condition will cause a switch to open that stops current flow to starter motor circuit, and the starter motor pinion gear will then disengage from engine flywheel ring gear.

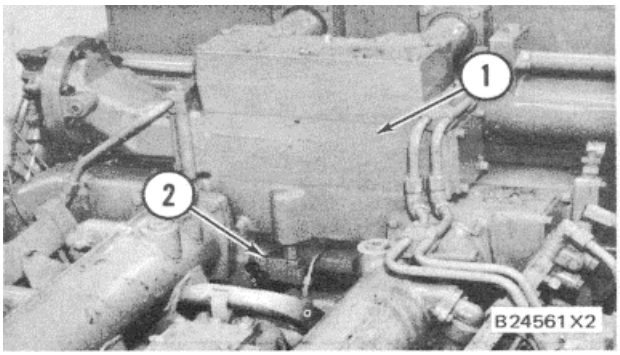
Engine Step Oil Pressure An adjustable engine speed setting that gives protection to the engine from a failure caused by not enough oil pressure. To maintain desired protection through the complete speed range of engine operation, two different oil pressure switches are used [280 kPa (40 psi), 140 kPa (20 psi)]. Once the step oil pressure speed setting is made, an engine that runs **above** this speed setting must maintain an oil pressure that is more than 280 kPa (40 psi). An engine that runs at a speed **below** this speed setting must maintain an oil pressure that is more than 140 kPa (20 psi). If either condition is not correct, a switch will close to activate an alarm or cause the fuel to be shut off to the engine.

Water Temperature Contactor Switch This contactor switch is a separate unit (mounted in the regulator housing) that is wired into the shutdown circuit. It has an element that feels the temperature of the coolant (it must be in contact with the coolant). When the engine coolant temperature becomes too high, the switch closes to activate an alarm or cause the fuel to be shut off to the engine.

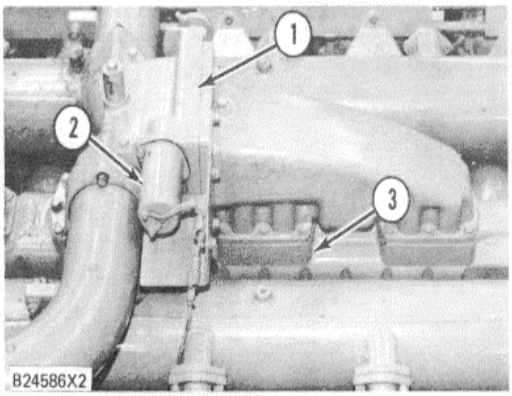
Time Delay Relays These relays are special ON/OFF switches with two controls that will either make the relay activate immediately, or after a 9 second delay. One of the time delay relays is used to arm the shutdown system, and the other time delay relay controls the oil pressure circuits for the two oil pressure switches. Both time delay relays have a 70 second OFF delay to be sure of complete engine shutdown.

Slave Relays These are standard type relays that, when energized, have contacts that open across one circuit and close across another circuit. When activated, one of the relays will activate an alarm or cause the fuel to be shut off, and the other relay will cause the inlet air to be shut off.

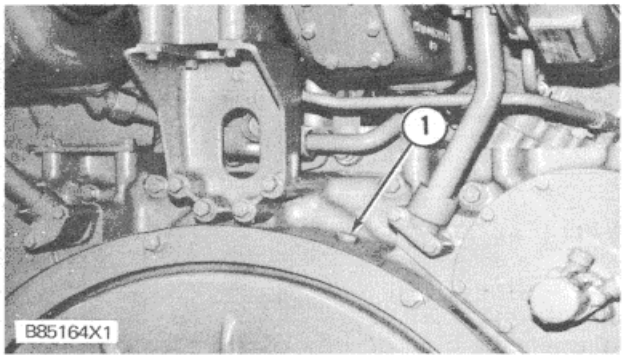
COMPONENT LOCATIONS ON ENGINE



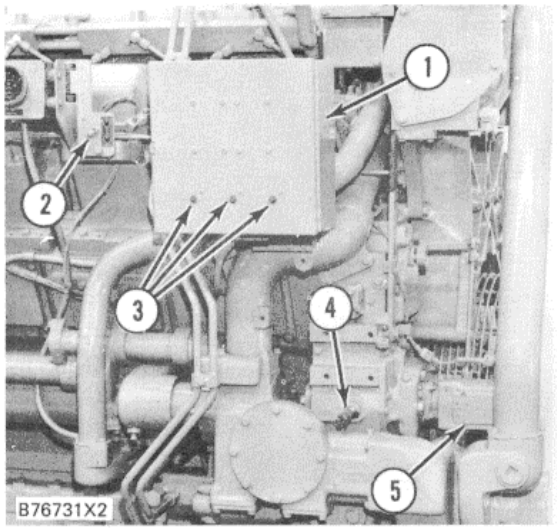
WATER TEMPERATURE CONTACTOR SWITCH
1. Regulator housing. 2. Contactor switch.



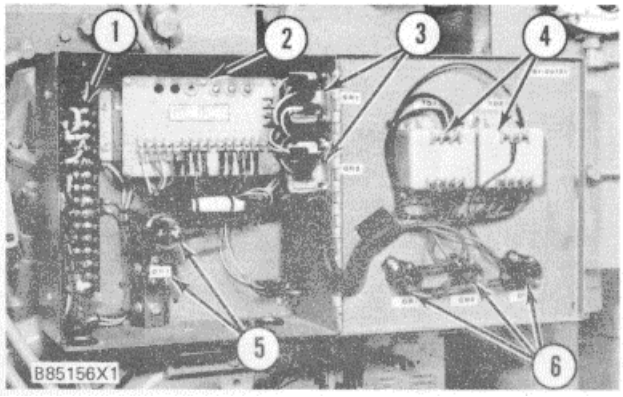
AIR SHUTOFF SOLENOID
1. Air shutoff housing. 2. Air shutoff solenoid. 3. After-cooler housing.



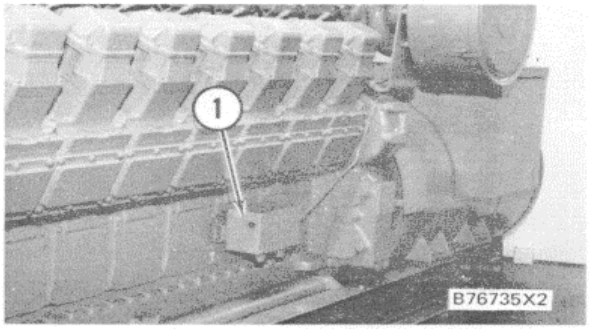
LOCATION FOR MAGNETIC PICKUP
(Later Engines)
1. Plug (one of three available locations on top of flywheel housing).



JUNCTION BOX CLOSED
1. Junction box. 2. Fuel shutoff switch. 3. Circuit breakers. 4. Magnetic pickup. 5. Electric governor actuator (EGA).



JUNCTION BOX OPENED
1. Terminal strips. 2. Electronic speed switch (ESS). 3. Slave relays. 4. Time delay relays. 5. Oil pressure switches. 6. Circuit breakers.



LEFT SIDE OF ENGINE
1. Enclosure group.

INDIVIDUAL CIRCUIT DESCRIPTION

The information that follows show the current flow through the wiring schematic. As switches are opened or closed, either automatically or manually, the current flow of the individual circuit affected is shown schematically.

Also included (on each facing page) is a story that explains all the components involved for this particular condition, and why the current will take the path shown.

ENGINE STOPPED (Fig. 1)

With the engine stopped, power is always available across terminals 3 and 4 of time delay relays (TD1 and TD2) and across terminals 5 and 6 of electronic speed switch (ESS). At this time all switches are in their normally open or normally closed positions.

ENGINE STOPPED

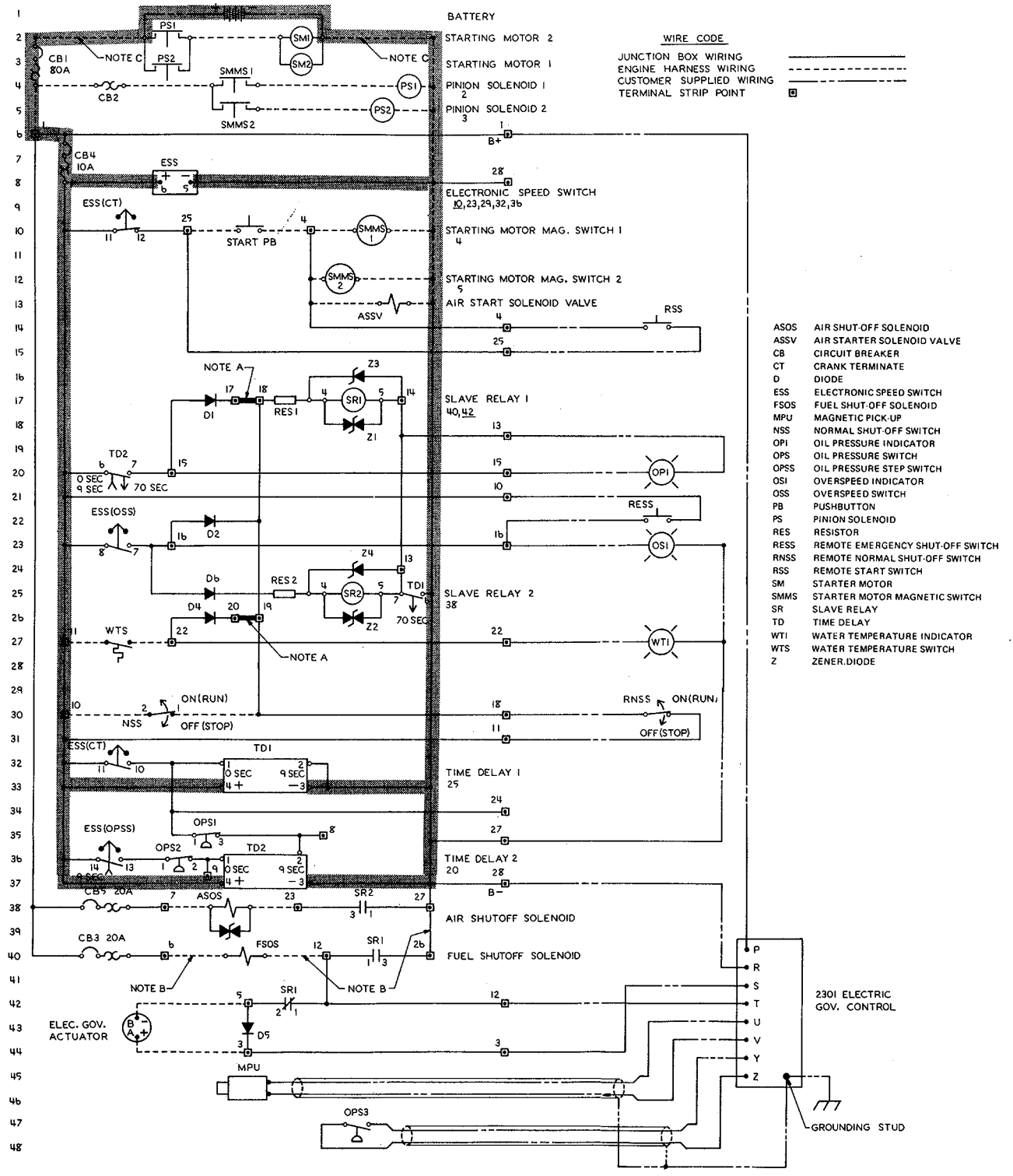


Fig. 1.

MANUAL START

Electric Starter Motors (Fig. 2)

When the start pushbutton (PB) or remote start switch (RSS) is pushed, current will flow through starter motor magnetic switches (SMMSI and SMMS2). With magnetic switches energized, contacts (SMMSI and SMMS2) close and pinion solenoids (PS I and PS2) are energized. This causes contacts (PS 1I and PS2) to close, and starter motors (SMI and SM2) will now crank the engine. When engine starts to run and the rpm increases to the speed of the crank terminate (CT) speed setting, the ESS(CT) switch will automatically open across terminals ESS-l I and ESS-12 to stop current flow to the start pushbutton.

Air Starter Motor
(Current Flow Not Shown in Fig. 2)

If engine has an air starter motor, current will flow through DC operated air start solenoid valve (ASSV) when start pushbutton (PB or RSS) is pushed. The ASSV will open the air supply to the air starter motor, which will now crank the engine. When the engine starts to run and the rpm increases to the speed of the crank terminate (CT) speed setting, ESS(CT) switch will automatically open across terminals ESS-11 and ESS-12 to stop current flow to ASSV pushbutton. This will move the valve to shut off the air supply to the air starter motor.

STARTING ENGINE WITH ELECTRIC STARTER MOTORS

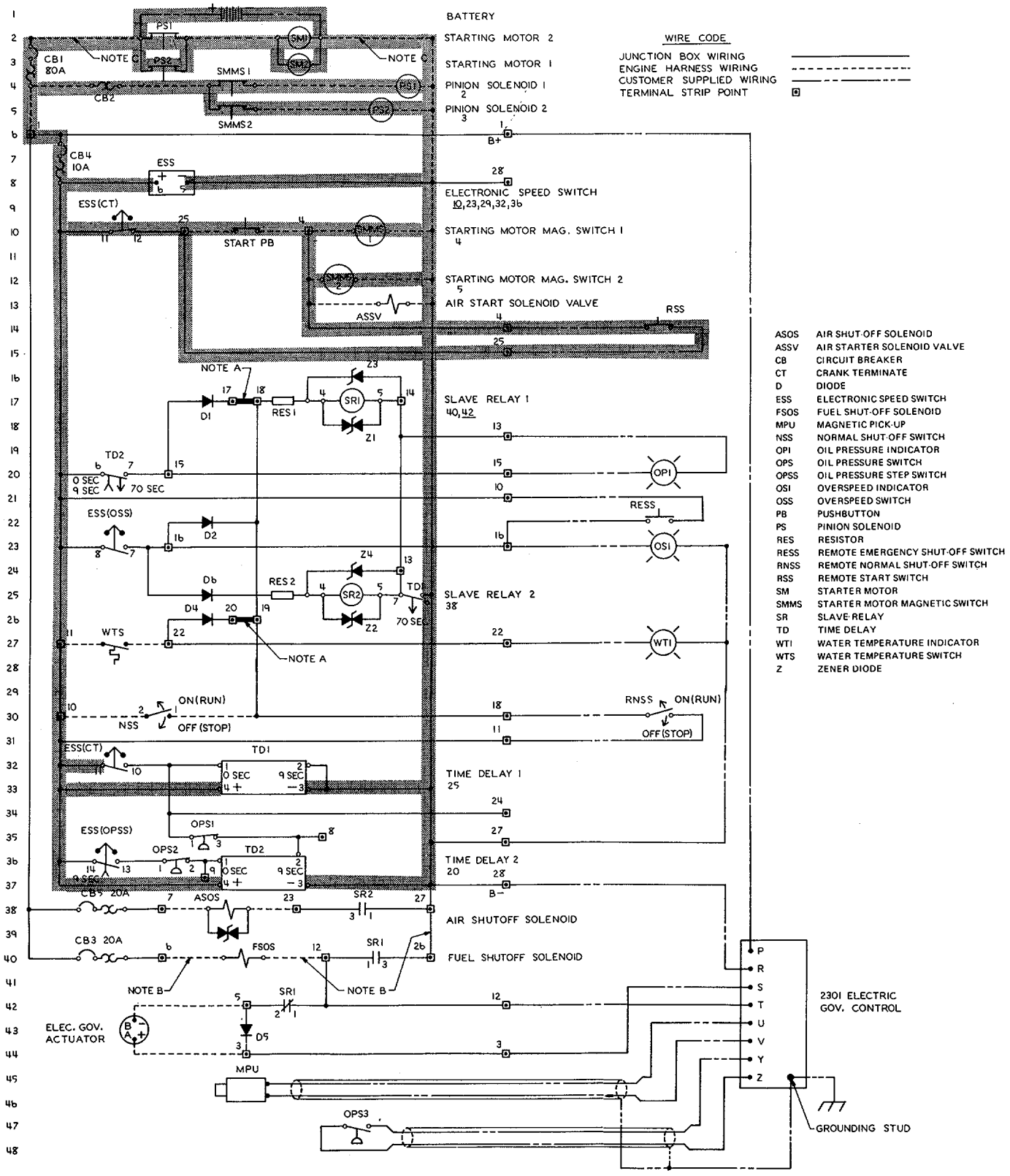


Fig. 2.

ENGINE STARTS TO RUN: NO FAULTS

When the engine starts to run, the speed will increase to the speed setting of the ESS crank terminate function, and the ESS(CT) switch across terminals ESS- I and ESS-12 will open. The current flow is now stopped to the start pushbutton for the starter motor(s) as shown in Fig. 3.

When the ESS(CT) switch (line 10) **opens** across terminals ESS-11 and ESS-12, ESS(CT) switch (line 32) will **close** across terminals ESS-11 and ESS-10. This closed switch will give current flow to Control 1 (terminal 1) of time delay relay (TDI), and will immediately **close** switch (TDI) across terminals TD1-6 and TDI-7 (line 25). The complete protection system is now armed to activate an alarm or cause engine shutdown if there is a fault in any of the three engine systems now being monitored.

ENGINE STARTS TO RUN: NO FAULTS

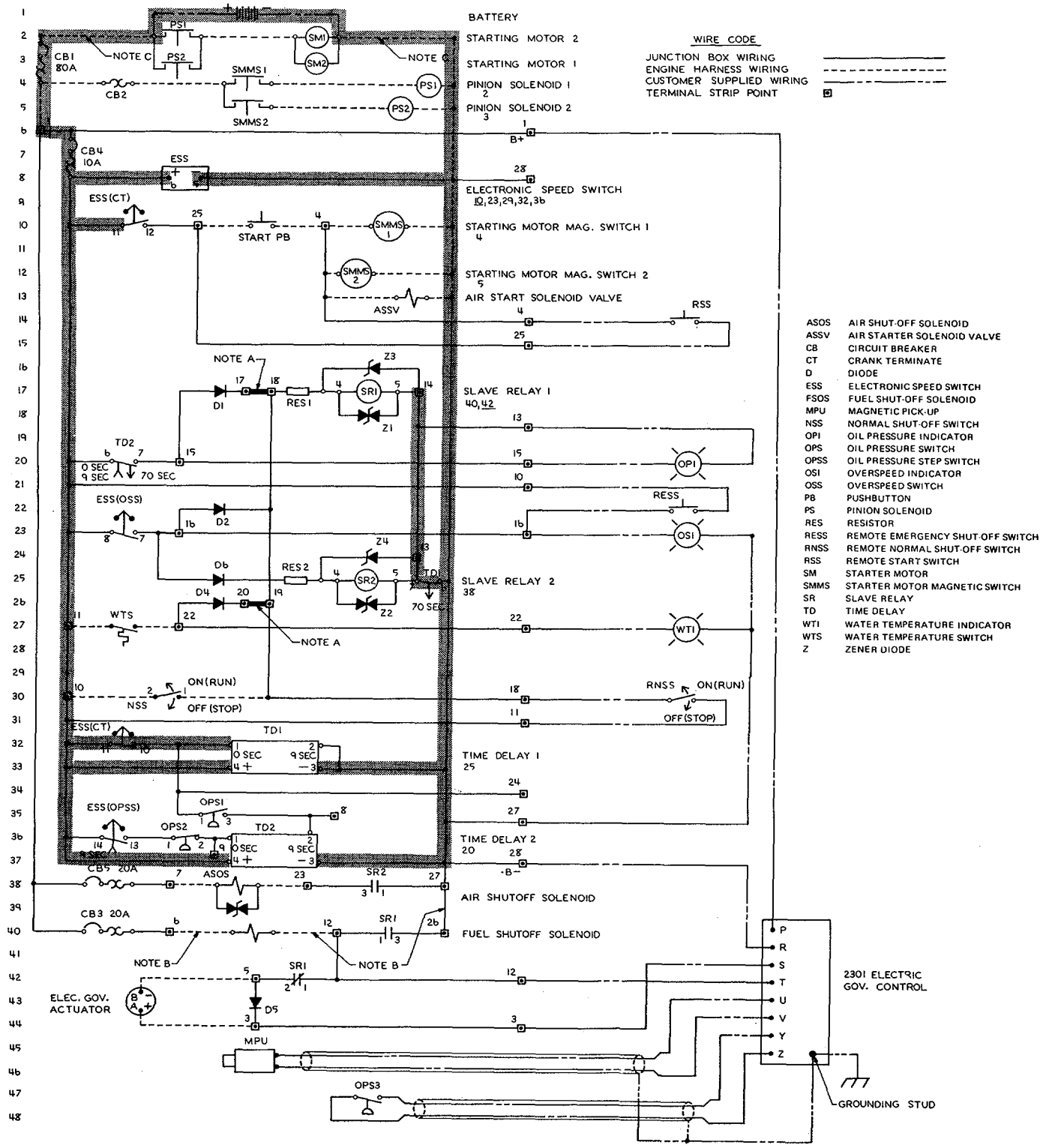


Fig. 3.

ENGINE RUNS AT RATED SPEED: NO FAULTS

With no existing problems and engine running at rated speed, or at some speed above the oil step speed setting, the circuit will look like Fig. 4. The oil pressure step switch (OPSS) at line 36 is now **closed,** but oil pressure switch (OPS2) is now **open,** so there is still no current flow to TD2. The engine will continue to run with these conditions.

OPS2 will not open until there is at least 280 kPa (40 psi) oil pressure available, and after opening, will not close again until the oil pressure has dropped below 240 kPa (35 psi). The ESS(OPSS) switch is not activated to open until engine speed is the same as, or above, the step oil pressure speed setting. After it is activated, the ESS(OPSS) switch has a 9 second delay before it closes. This makes sure that oil pressure has time to increase enough to open OPS2, or system would constantly activate engine shutdown.

ENGINE RUNS AT RATED SPEED: NO FAULTS

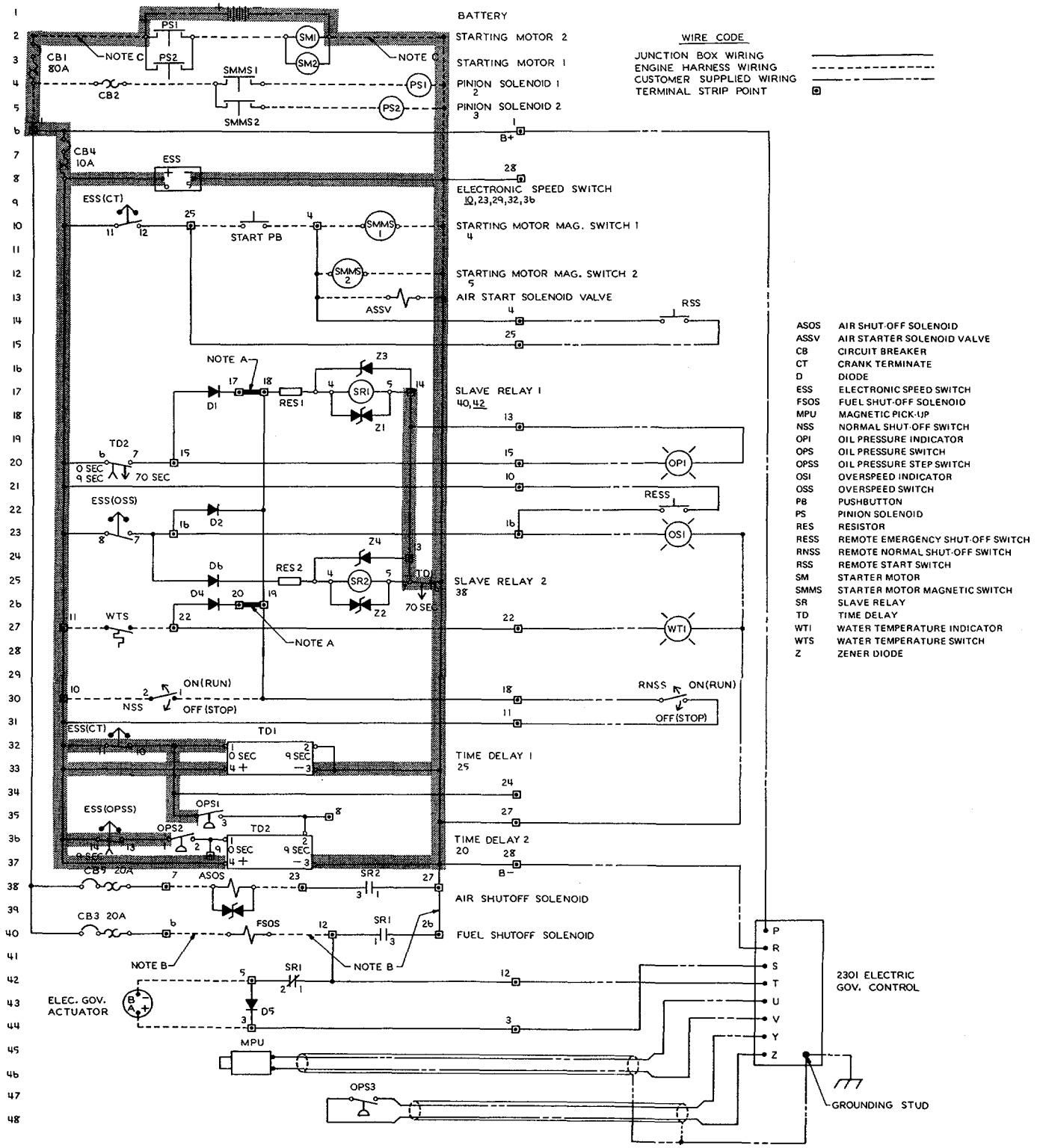


Fig. 4.

**ENGINE SHUTDOWN DUE TO FAULT:
LOSS OF ENGINE OIL PRESSURE
(AT ENGINE SPEEDS ABOVE OIL STEP
SPEED SETTING)**

The circuit of Fig. 5 shows the current flow if there is a fault in the high pressure side of the oil pressure circuit. When engine oil pressure drops below 240 kPa (35 psi), oil pressure switch (OPS2) will close. Since the engine is running at a speed above the step oil pressure setting, ESS(OPSS) switch is already closed and the circuit is now completed to Control 1 (terminal 1) of time delay relay (TD2). There is no time delay at Control 1, so TD2 relay contacts (line 20) will close immediately across terminals TD2-6 and TD2-7. This makes a complete circuit from the battery through TDI contacts (line 25) to activate oil pressure indicator (OPI) and to energize slave relay (SR1).

When SR1 is energized, contacts across terminals SR 1 - 1 and SR 1-2 **open** and contacts across terminals SR 1-1 and SR 1-3 close. The circuit is now completed to energize fuel shut-off solenoid (FSOS), and the fuel is shut off to the engine.

ENGINE SHUTDOWN DUE TO FAULT: LOSS OF ENGINE OIL PRESSURE (AT ENGINE SPEEDS ABOVE OIL STEP SPEED SETTING)

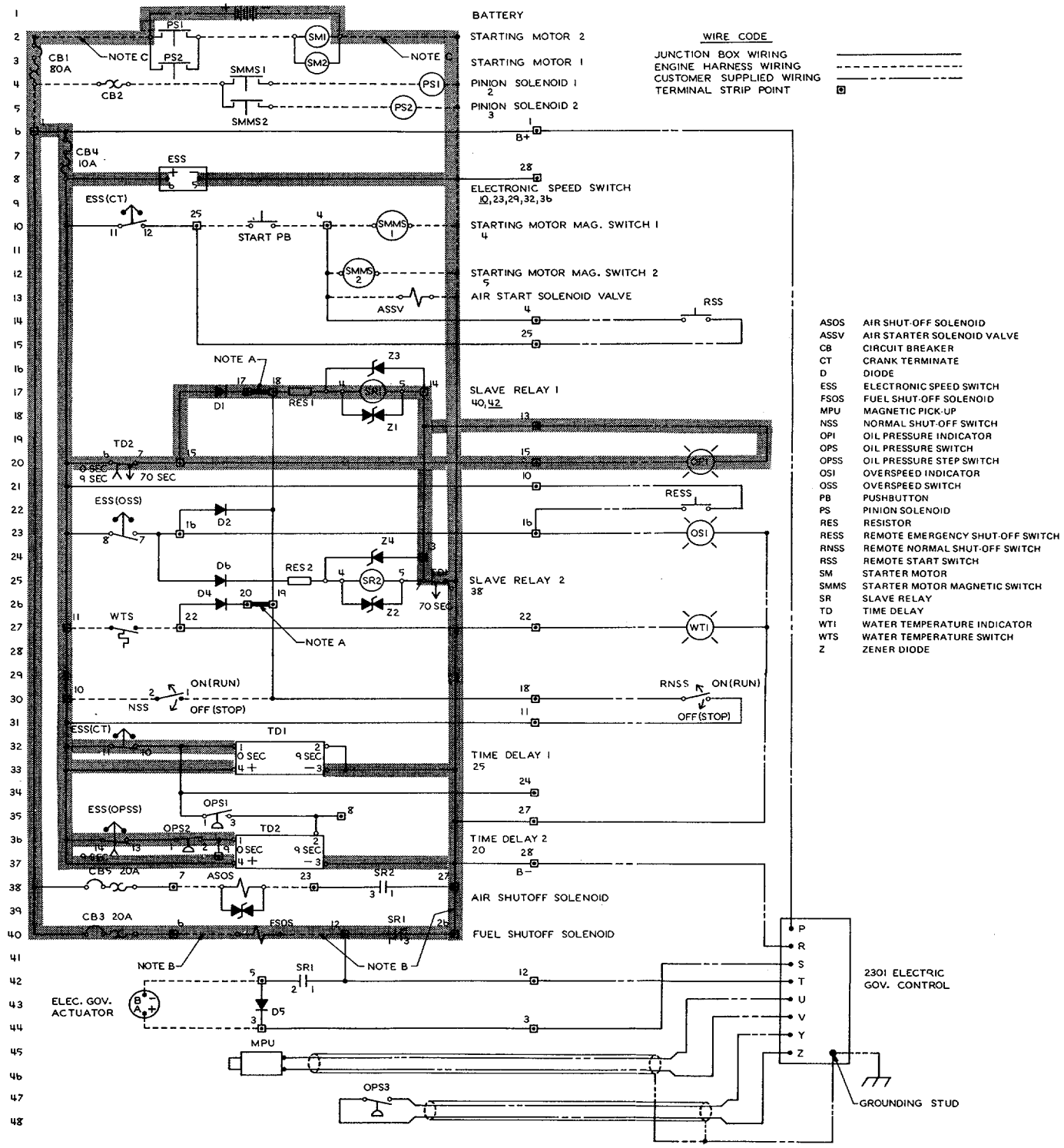


Fig. 5.

ENGINE RUNNING BELOW OIL STEP SPEED SETTING: NO FAULTS (OR JUST ACCELERATING THROUGH STEP SPEED)

If engine continues to run below the step oil pressure speed setting, oil pressure step switch (OPSS) will remain open and will not complete the circuit to shutdown as shown in Fig. 6. Since oil pressure has increased enough to run at this speed (OPS I switch is open), the engine can safely run at this speed and will not be shut down.

If the engine is accelerating through oil step speed setting, the circuit could still look as shown in Fig. 6. When engine speed is the same as (or goes above) the oil step speed setting engine oil pressure must increase to 280 kPa (40 psi) to open oil pressure switch (OPS2) within the 9 second time delay of the oil pressure step switch ESS(OPSS). The OPSS switch will close after 9 seconds and, if OPS2 is still closed, engine will shut down as shown in Fig. 5. If OPS2 has opened before OPSS has closed, engine will continue to run as shown in Fig. 4.

ENGINE RUNNING BELOW OIL STEP SPEED SETTING: NO FAULTS (OR JUST ACCELERATING THROUGH STEP SPEED)

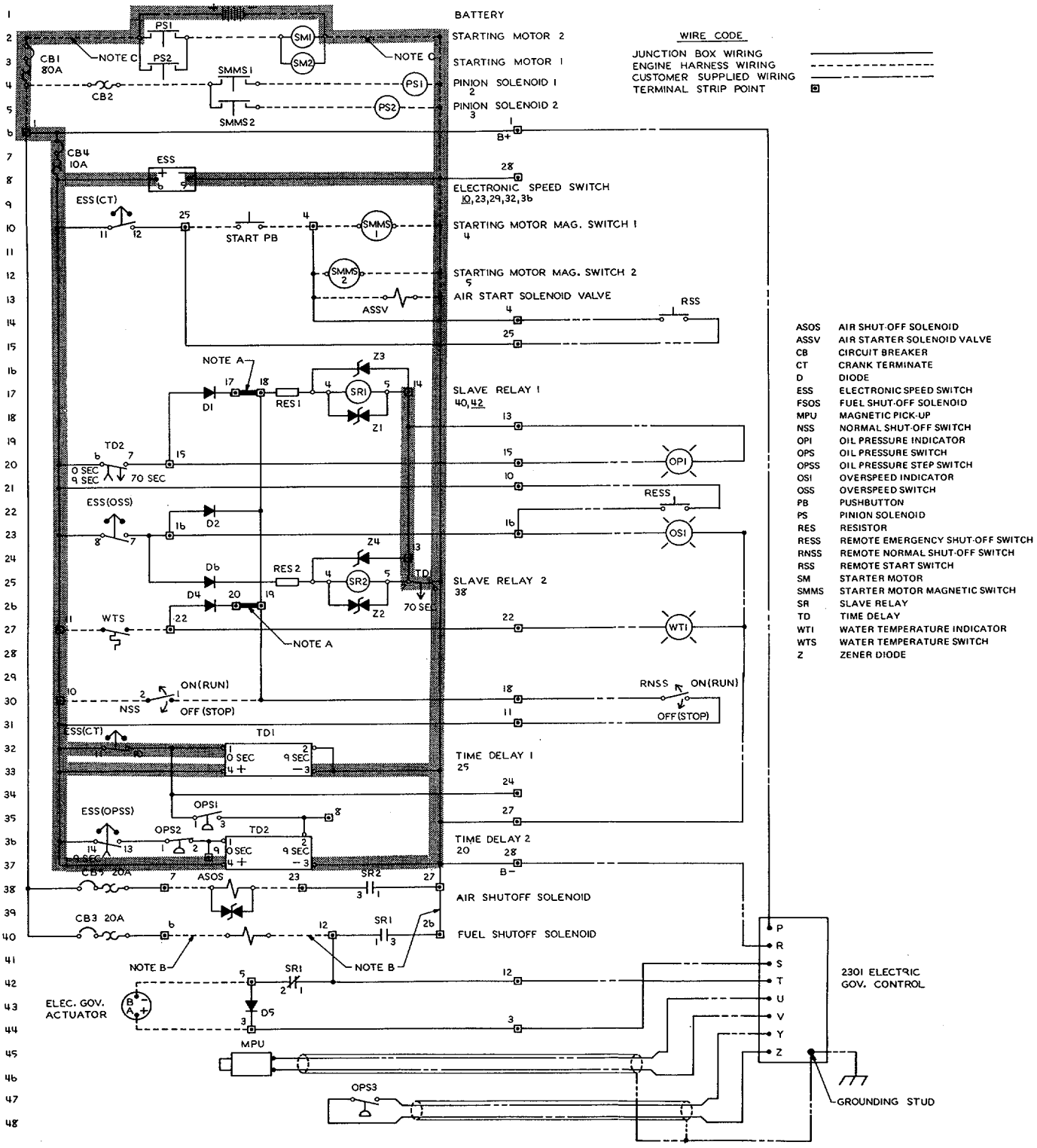


Fig. 6.

ENGINE SHUTDOWN DUE TO FAULT:
LOW OIL PRESSURE
(AT ENGINE SPEEDS BELOW OIL STEP SPEED SETTING)

As engine is started and begins to run, crank terminate switch ESS(CT) **opens** across terminals ESS-11 and ESS-12 and **closes** across terminals ESS-11 and ESS-10. This immediately arms the system when current is sent to Control I (terminal 1) of time delay relay (TD1), which **closes** TD1 relay contacts (line 25) across terminals TD1-6 and TDI-7.

At the same time that TD1 is armed, there is current flow to Control 2 (terminal 2) of time delay relay (TD2) if oil pressure switch (OPS I) has not yet opened. The engine oil pressure has 9 seconds (from the time that TD1 is armed) to increase to the 140 kPa (20 psi) necessary to open OPS1. If OPSI does **not open,** TD2 contacts will close across terminals TD2-6 and TD2-7 and slave relay (SRI) will be energized. SR1 relay contacts (line 42) will now open across terminals SRI-I and SRI-2, and SRI relay contacts (line 40) will close across terminals SR1-1 and SR 1-3. The fuel shut-off solenoid (FSOS) is now energized, and will shut the fuel off to the engine.

If the engine had been running (with no faults) at a speed less than the oil step setting, and then lost engine oil pressure, the protection system would cause engine shutdown in the same way as shown in Fig. 7. OPS1 would close when oil pressure decreased to 105 kPa (15 psi), and 9 seconds later the engine would shut down.

ENGINE SHUTDOWN DUE TO FAULT: LOW OIL PRESSURE (AT ENGINE SPEEDS BELOW OIL STEP SPEED SETTING)

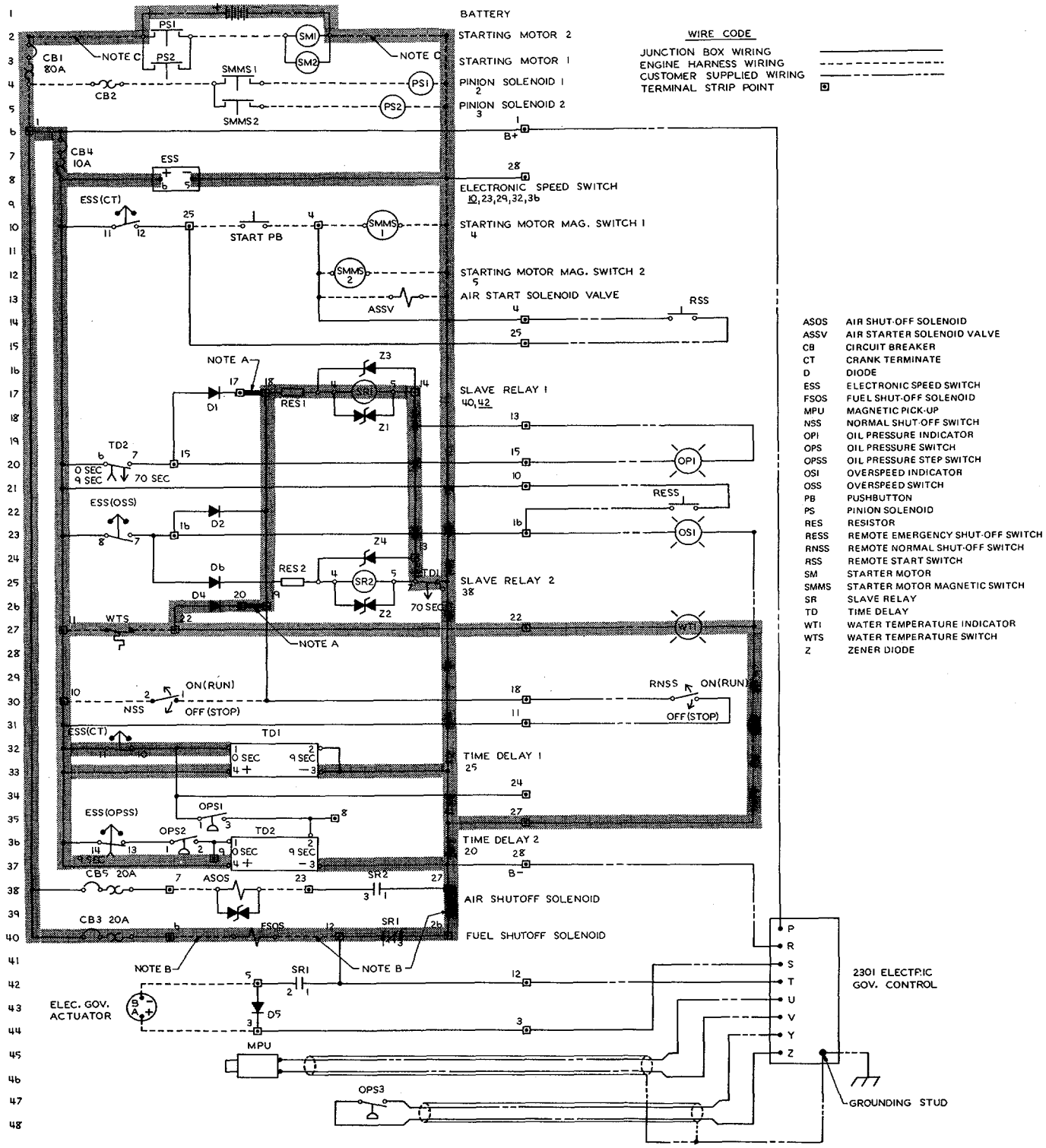


Fig. 7.

ENGINE SHUTDOWN DUE TO FAULT:
COOLANT OVERHEATING

The current flow of the circuit shown in Fig. 8 is for an engine running at a speed above the oil step setting with coolant temperature hot enough [980C (2080F)] to close water temperature contactor switch (WTS). When WTS closes, this completes the circuit through slave relay (SR1) and through water temperature indicator (WTI). When slave relay (SR 1) is energized, the contacts across terminals SR1-1 and SR1-3 will close. Now the fuel shut-off solenoid (FSOS) is energized to shut the fuel off to the engine.

After 70 seconds (when TDI contacts open), the engine can be started again, but it will immediately be shutdown. The engine will not continue to run until coolant temperature cools down enough to open switch WTS.

NOTE: Engine shutdown caused by coolant overheating will also be the same if the engine is running at a speed below the oil step setting.

ENGINE SHUTDOWN DUE TO FAULT: COOLANT OVERHEATING

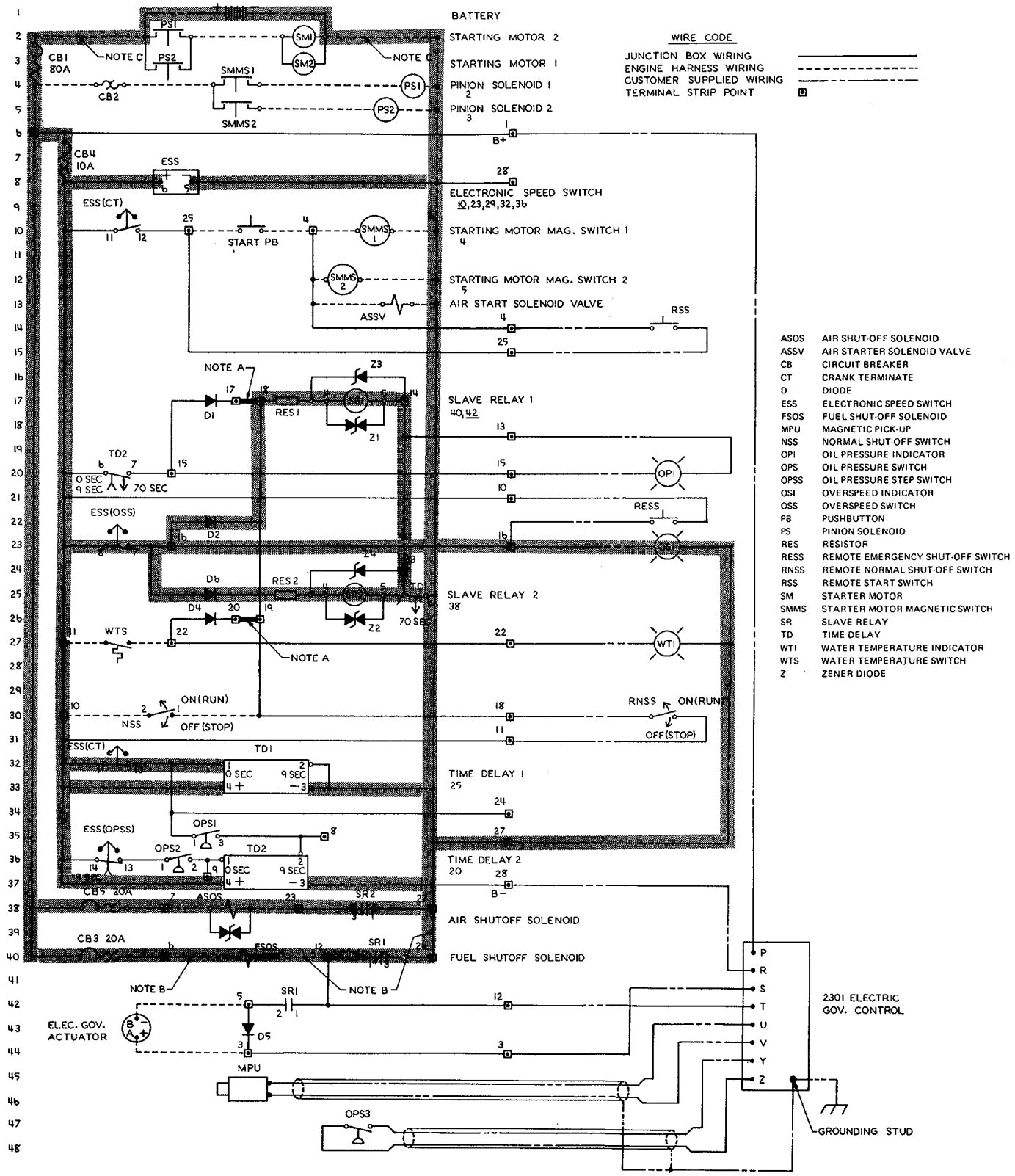


Fig. 8.

ENGINE SHUTDOWN DUE TO FAULT:
ENGINE OVERSPEED

When engine speed increases above the overspeed setting (118% of rated speed) of the electronic speed switch (ESS), the overspeed switch ESS(OSS) will close across terminals ESS-7 and ESS-8 (line 23). This completes the circuit from the battery through overspeed indicator (OSI) and also through both slave relays (SRI and SR2) as shown in Fig. 9.

Both slave relays (SR1 and SR2) are now energized at the same time. SR2 contacts will **close** across terminals SR2-1 and SR2-3 to activate air shut-off solenoid (ASOS). ASOS will now shut the inlet air off to the engine. At the same time, SRI contacts open across terminals SRI-I and SRI-2 (Line 42) and **close** across terminals SRI-I and SR1-3 (line 40). The fuel shut-off solenoid (FSOS) is now activated, and will shut the fuel off to the engine.

A reset button on the ESS must be pushed to open the overspeed switch ESS(OSS), and the air shut-off lever (at top of air inlet housing) must be manually reset before the engine will run.

ENGINE SHUTDOWN DUE TO FAULT: ENGINE OVERSPEED

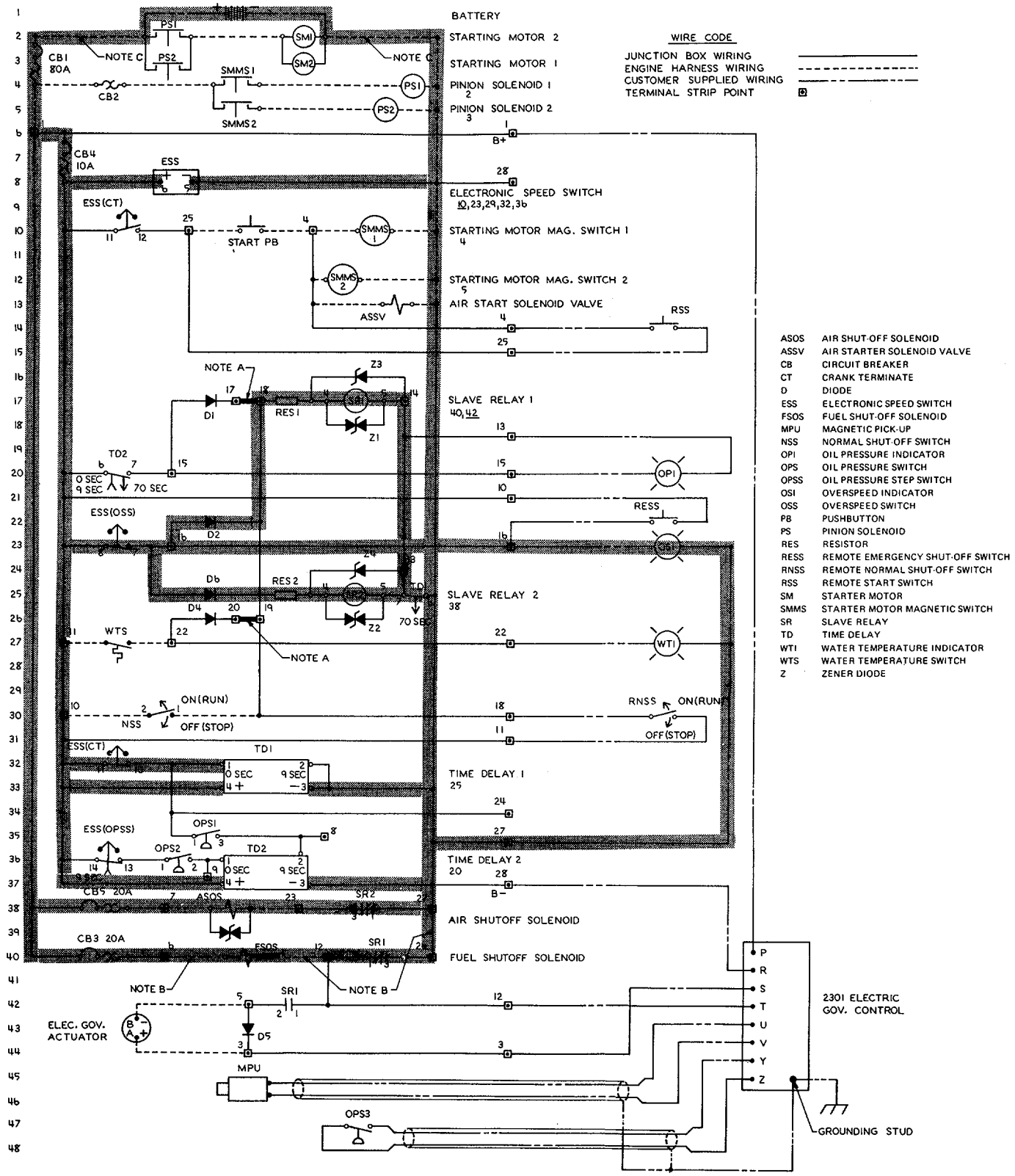


Fig. 9.

SHUTDOWN SYSTEM WITH 2301 ELECTRIC GOVERNOR CONTROL: NO FAULTS

When the 2301 Electric Governor Control (EGC) is used, all systems of the electronic speed switch (ESS) are activated the same way as shown with a 3161, UG8D or a UG8L governor. The only difference in the circuit is that the fuel shut-off solenoid (FSOS) at line 40 is not used, and a jumper between terminal 26 and 27 is not used.

With the circuit shown in Fig. 10, current normally flows through electric governor actuator (EGA). When a fault in the system causes current to energize slave relay (SRI), the contacts open across terminals SR1-1 and SR1-2 (line 42) and close across terminals SRI-I and SR1-3 (line 40).

When SR1 contacts open across terminals SR1-1 and SR1-2, the current can no longer flow through the EGA. The mechanical spring load in the EGA system will now move the fuel control rod to shut the fuel off to the engine.

NOTE: Except for the differences shown above, all fault circuits for the ESS system are the same for the EGC as those shown in Fig. 5 through Fig. 9 for the 3161 and UG8 governors.

SHUTDOWN SYSTEM WITH 2301 ELECTRIC GOVERNOR CONTROL: NO FAULTS (CIRCUIT SHOWN AT RATED SPEED)

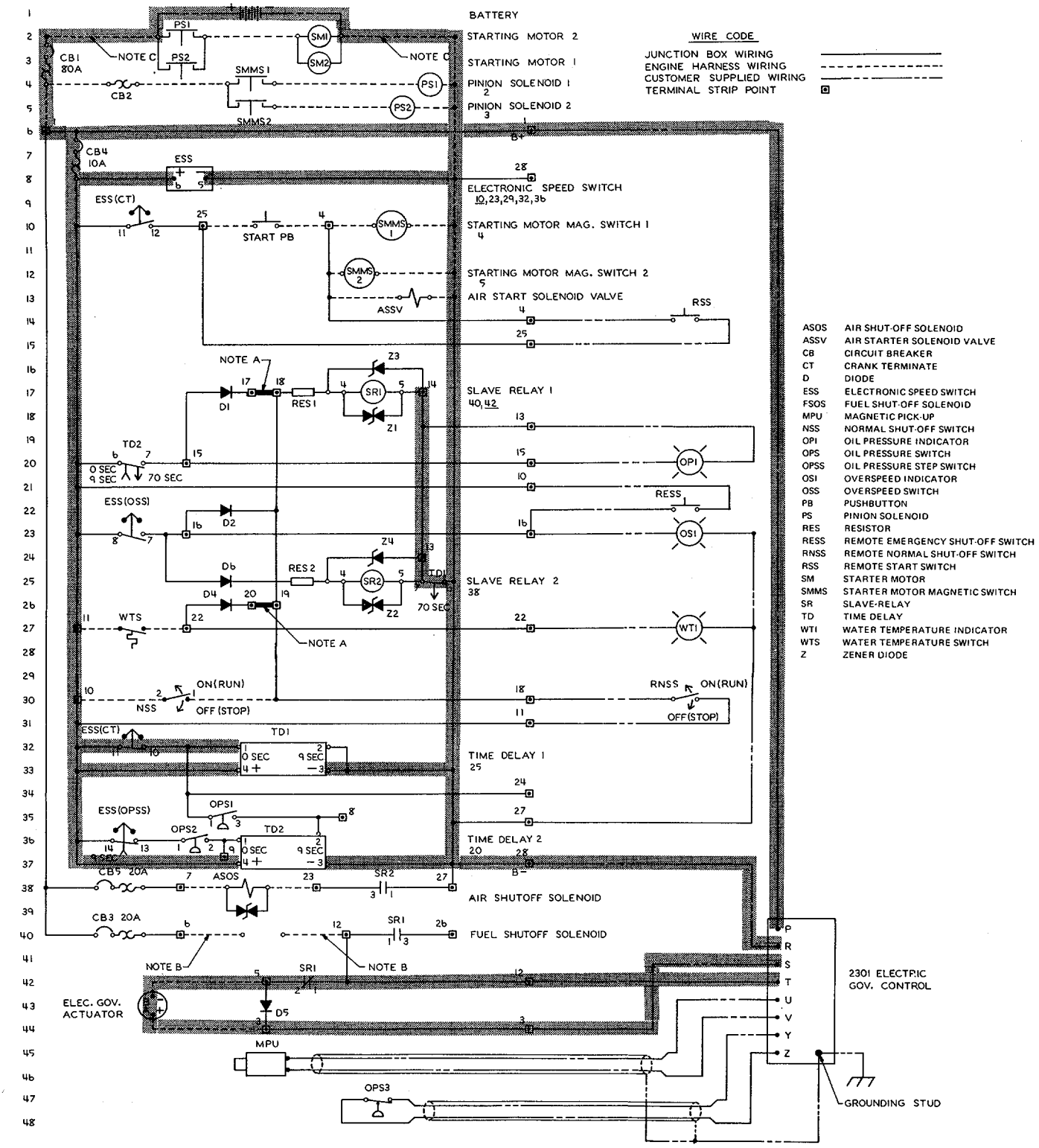


Fig. 10.

ELECTRIC PROTECTIVE SYSTEM FUNCTIONAL TEST

These tests are to be performed on an engine that is started for the first time and at recommended check intervals. They consist of quick and easy procedures for each system that can immediately identify if there is a problem in that system with a minimum amount of test time. If a problem is found, go to the correct chart of the more specific troubleshooting procedures.

Check each system of the engine as shown to verify if all components of the shut-off system works properly. To find the correct engine speed, make reference to SPEED SPECIFICATION CHART.

TEST I. OVERSPEED (AIR AND FUEL SHUTOFF)

STEP	RUN ENGINE AT:	ACTION	CORRECT RESULT
A.	25 + 5 rpm Less Than Verify rpm (75% Overspeed)	Press 75% Verify Button	No Engine Shutdown
B.	25 ± 5 rpm More Than Verify rpm (75% Overspeed)	Press 75% Verify Button	Air and Fuel Shut-off
C.	Manually Reset Air Shut-off Lever At Top Of Air Inlet Housing and Press ESS Reset Button.		

TEST II. NORMAL SHUTOFF SWITCH (FUEL SHUTOFF ONLY)

STEP	RUN ENGINE AT:	ACTION	CORRECT RESULT
A.	Any Speed Above Crank Terminate rpm	Push Shut-off Switch To OFF Position	Fuel Shut-off

TEST III. OIL PRESSURE (FUEL SHUTOFF ONLY)

STEP	RUN ENGINE AT:	ACTION	CORRECT RESULT
A.	25 ± 5 rpm Less Than Oil Step Speed	Put Jumper Across Terminal 1 & Terminal 2 of Oil Pressure Switch OPS2	No Engine Shutdown
B.	---	Remove OPS2 Jumper	-----
C.	Same Speed as Step A	Put Jumper Across	Fuel Shut-off After 9
D.	----	Terminal 1 & Terminal 3 of Oil Pressure sure Switch OPS1 Remove Jumper From OPSI	± 1 Seconds -----
E.	25 ± 5 rpm More Than Oil Step Speed	After 9 Seconds, Put Jumper Across Terminal 1 and Terminal 2 (OPS2)	Fuel Shut-off
F.	Remove Jumper From OPS2 Terminals 1 and 2		

TEST IV. WATER TEMPERATURE (FUEL SHUTOFF ONLY)

STEP	RUN ENGINE AT:	ACTION	CORRECT RESULT
A.	Any Speed Above Crank Terminate rpm	Put Jumper Across Terminals TS11 & TS 22	Fuel Shut-off
B.	Remove Jumper From Terminals TS11 and TS 22		

SPEED SPECIFICATION CHART

SPEED SPECIFICATION CHART (RPM)				
TYPICAL RATED ENGINE SPEED	OVERSPEED SETTING (±25) NOTE E	75% OVERSPEED VERIFY (±25) NOTE C	OIL STEP SPEED SETTING	CRANK TERMINATE
1800	2125	1600	1125	600
1600	1890	1415	1125	600
1500	1775	1325	1125	600
1300	1535	1150	750	400
1200	1415	1060	750	400
1000	1180	885	750	400
900	1065	800	750	400

INTRODUCTION TO THE TROUBLESHOOTING GUIDE

The troubleshooting guide, when followed exactly as shown, can be an aid for the serviceman to find if a problem exists, and to find the cause of the existing problem.

SYSTEM TROUBLESHOOTING CHARTS AND PROCEDURES

The troubleshooting charts that follow show a definite sequence to be followed for a logical, one by one elimination of many variables. There are specific procedures written to check out different components of the system, and they can be found at the end of the troubleshooting charts. When the chart makes reference to a specific procedure, do this procedure before proceeding any farther in the chart.

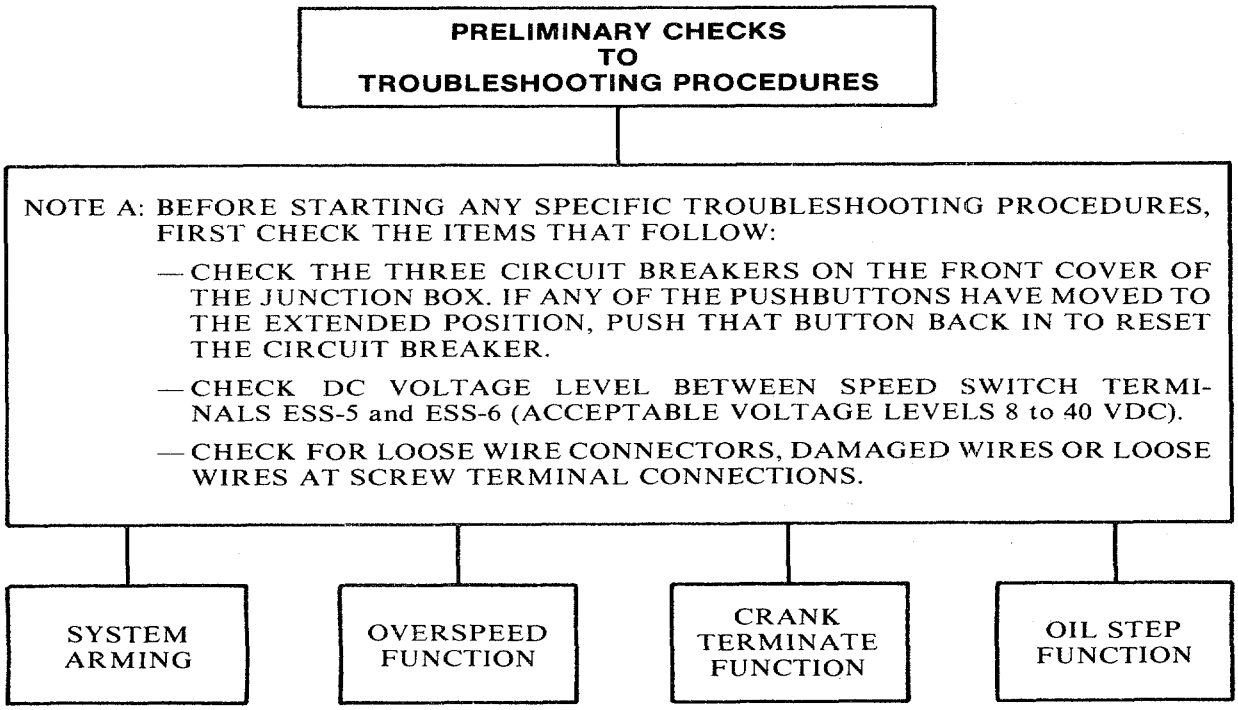
When a problem is found and corrected, always check the system again by use of verify procedure as shown at bottom of charts.

Some areas of the charts say to go to an alphabetical letter. When told to go to this specific letter, find this letter with a circle around it in the chart. Follow the test procedures from this point to the bottom of the chart.

PROBLEM IDENTIFICATION INDEX

Engine Will Not Start:	Chart	Page
Overspeed Switch Closed (Battery Voltage at Speed Switch Terminal ESS-7)	B	33
Overspeed Trips (Light ON) When Power is First Applied With Engine Stopped	B	33
Starter Motor Cranks Intermittently	C	34
Starter Motor Cranking Stops Too Soon	C	34
Starter Motor Will Not Crank	C	35
Engine Runs, But There is Still a Problem:		
Overspeed Trips (Light ON) at Wrong Speed	B	32
Overspeed Trips Intermittently (Light ON and OFF) With Engine Running	B	32
Overspeed Will Not Trip (Light OFF) During 75% Overspeed Verify Test	B	32
Starter Motor Cranking Stops at Wrong Speed	C	34
Starter Motor Will Not Disengage	C	35
Engine Will Not Shut Down:		
Engine RPM is Above Oil Step RPM Setting and Engine Oil Pressure is Lower Than Preset Value (35 psi), But No Engine Shutdown	D	36
Engine RPM is Below Oil Step RPM Setting and Engine Oil Pressure is Lower Than Preset Value (15 psi), But No Engine Shutdown	D	36
Normal Shutoff Switch in OFF Position (While Operating at Any Speed Greater than Crank Terminate), But No Engine Shutdown	A	31
Overspeed Trips (Light ON), But No Engine Shutdown	B	33

SYSTEM TROUBLESHOOTING CHARTS AND PROCEDURES



NOTE B. Do Not Leave Starter Motor Engaged With Engine Running. Engines that have electric starter motor(s), or a DC actuated air starter motor, automatically disengage when crank termination rpm is reached. Positive (+) battery voltage is removed from the engine mounted or remote mounted starter controls when the normally closed crank termination contacts open. To perform test measurements, **one** of the methods that follow may be necessary to disengage the starter motor:

1. Disconnect wire at speed switch terminal ESS-2.
2. Manually disengage by installing a toggle switch to control the electric starter motor magnetic switch (install the switch in series with the magnetic switch coil lead).
3. Manually disengage by installing a toggle switch to control the air starter solenoid valve (install the switch in series with either of the solenoid valve leads).

NOTE: For wiring diagrams and schematics, make reference to Wiring Diagrams Section.

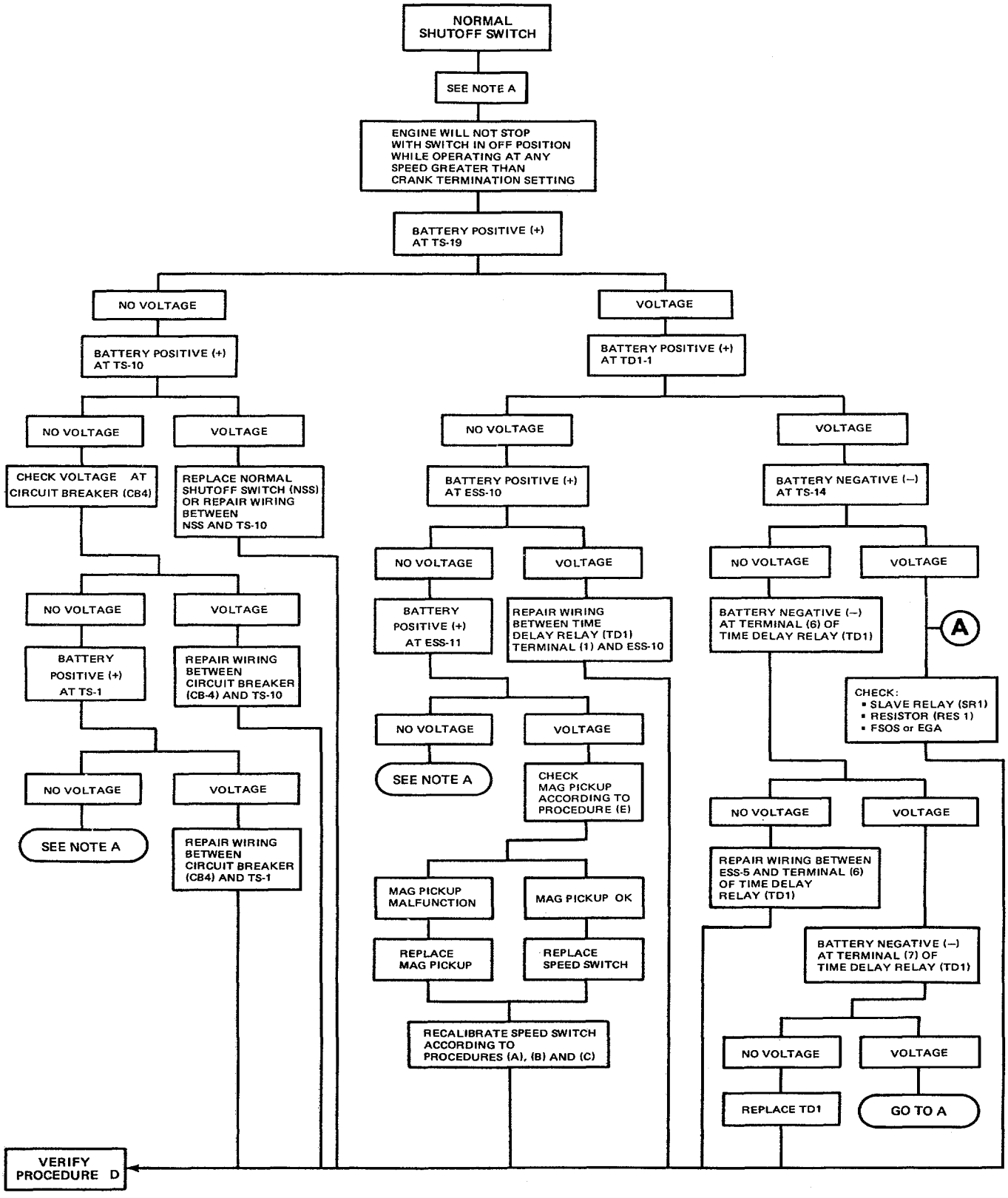

NORMAL SHUTOFF SWITCH
SEE NOTE A
ENGINE WILL NOT STOP WITH SWITCH IN OFF POSITION WHILE OPERATING AT ANY SPEED GREATER THAN CRANK TERMINATION SETTING
BATTERY POSITIVE (+) AT TS-19
NO VOLTAGE
VOLTAGE
BATTERY POSITIVE (+) AT TS-10
BATTERY POSITIVE (+) AT TD1-1
NO VOLTAGE
VOLTAGE
NO VOLTAGE
VOLTAGE
CHECK VOLTAGE AT CIRCUIT BREAKER (CB4)
REPLACE NORMAL SHUTOFF SWITCH (NSS) OR REPAIR WIRING BETWEEN NSS AND TS-10
BATTERY POSITIVE (+) AT ESS-10
BATTERY NEGATIVE (–) AT TS-14
NO VOLTAGE
VOLTAGE
NO VOLTAGE
VOLTAGE
NO VOLTAGE
VOLTAGE
BATTERY POSITIVE (+) AT TS-1
REPAIR WIRING BETWEEN CIRCUIT BREAKER (CB-4) AND TS-10
BATTERY POSITIVE (+) AT ESS-11
REPAIR WIRING BETWEEN TIME DELAY RELAY (TD1) TERMINAL (1) AND ESS-10
BATTERY NEGATIVE (–) AT TERMINAL (6) OF TIME DELAY RELAY (TD1)
A
CHECK:
• SLAVE RELAY (SR1)
• RESISTOR (RES 1)
• FSOS or EGA
NO VOLTAGE
VOLTAGE
NO VOLTAGE
VOLTAGE
NO VOLTAGE
VOLTAGE
SEE NOTE A
REPAIR WIRING BETWEEN CIRCUIT BREAKER (CB4) AND TS-1
SEE NOTE A
CHECK MAG PICKUP ACCORDING TO PROCEDURE (E)
REPAIR WIRING BETWEEN ESS-5 AND TERMINAL (6) OF TIME DELAY RELAY (TD1)
MAG PICKUP MALFUNCTION
MAG PICKUP OK
BATTERY NEGATIVE (–) AT TERMINAL (7) OF TIME DELAY RELAY (TD1)
REPLACE MAG PICKUP
REPLACE SPEED SWITCH
RECALIBRATE SPEED SWITCH ACCORDING TO PROCEDURES (A), (B) AND (C)
NO VOLTAGE
VOLTAGE
REPLACE TD1
GO TO A
VERIFY PROCEDURE D

CHART A.

TROUBLESHOOTING (OVERSPEED)

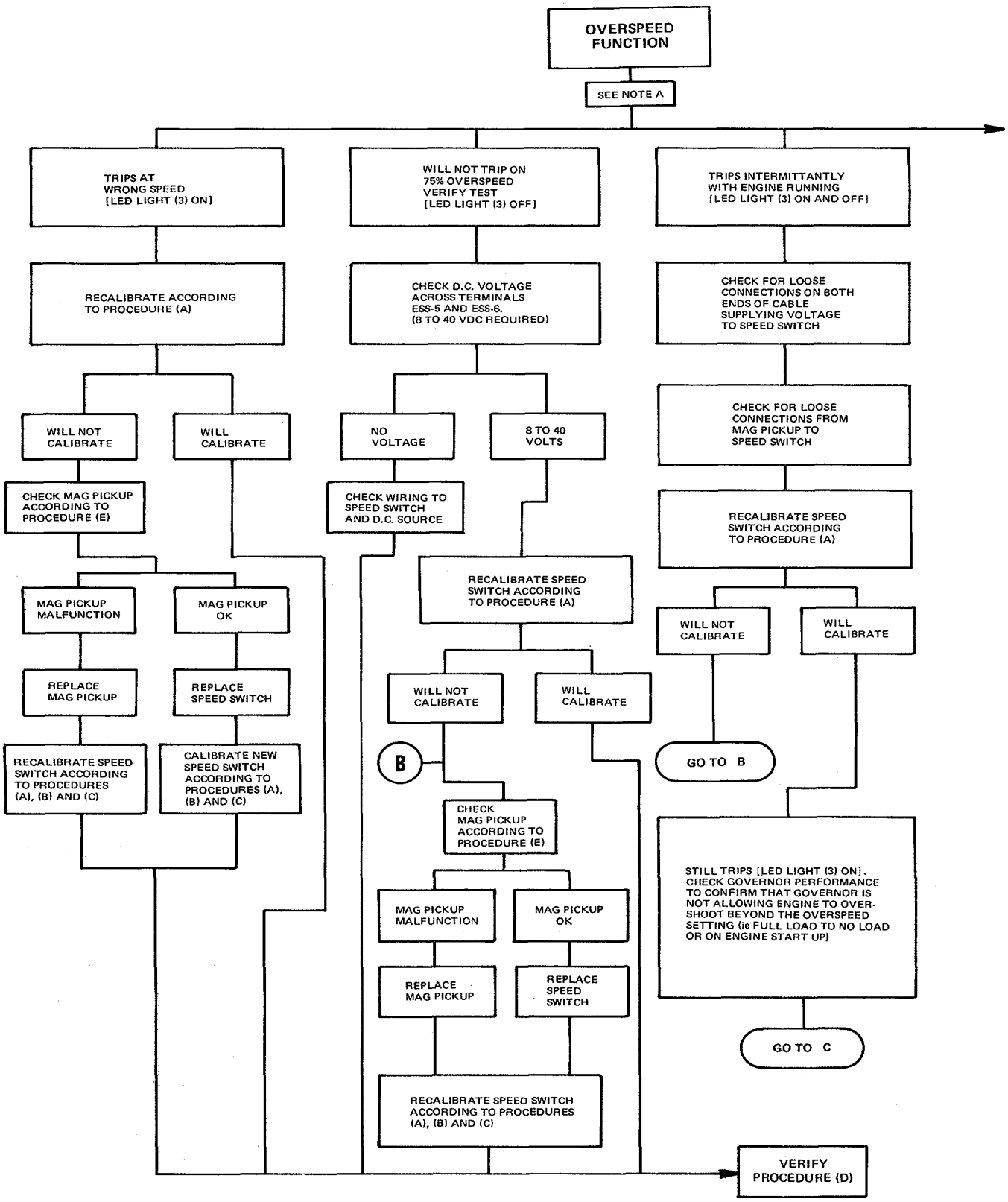


CHART B.

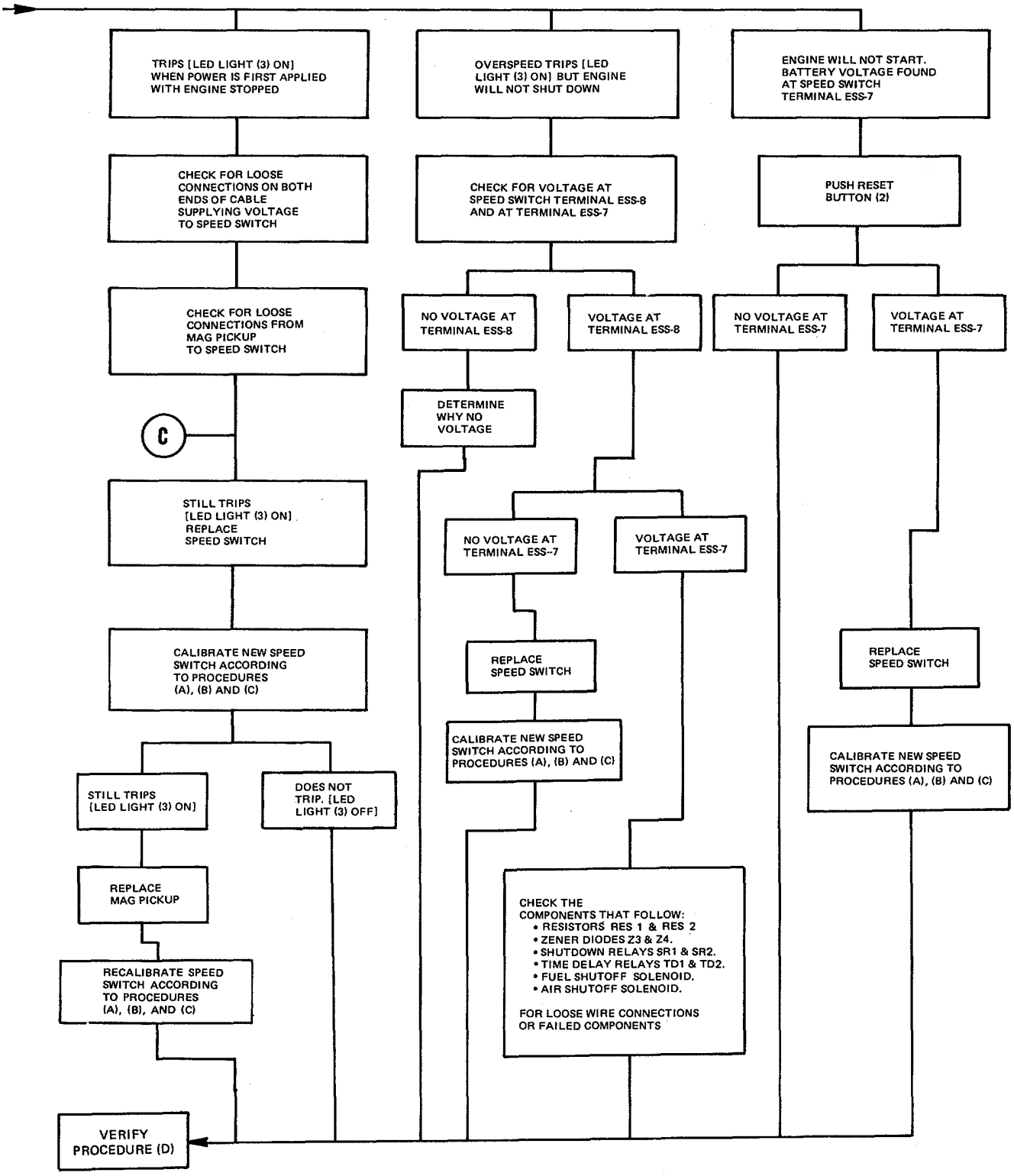


CHART B (Continued)

TROUBLESHOOTING (CRANK TERMINATE)

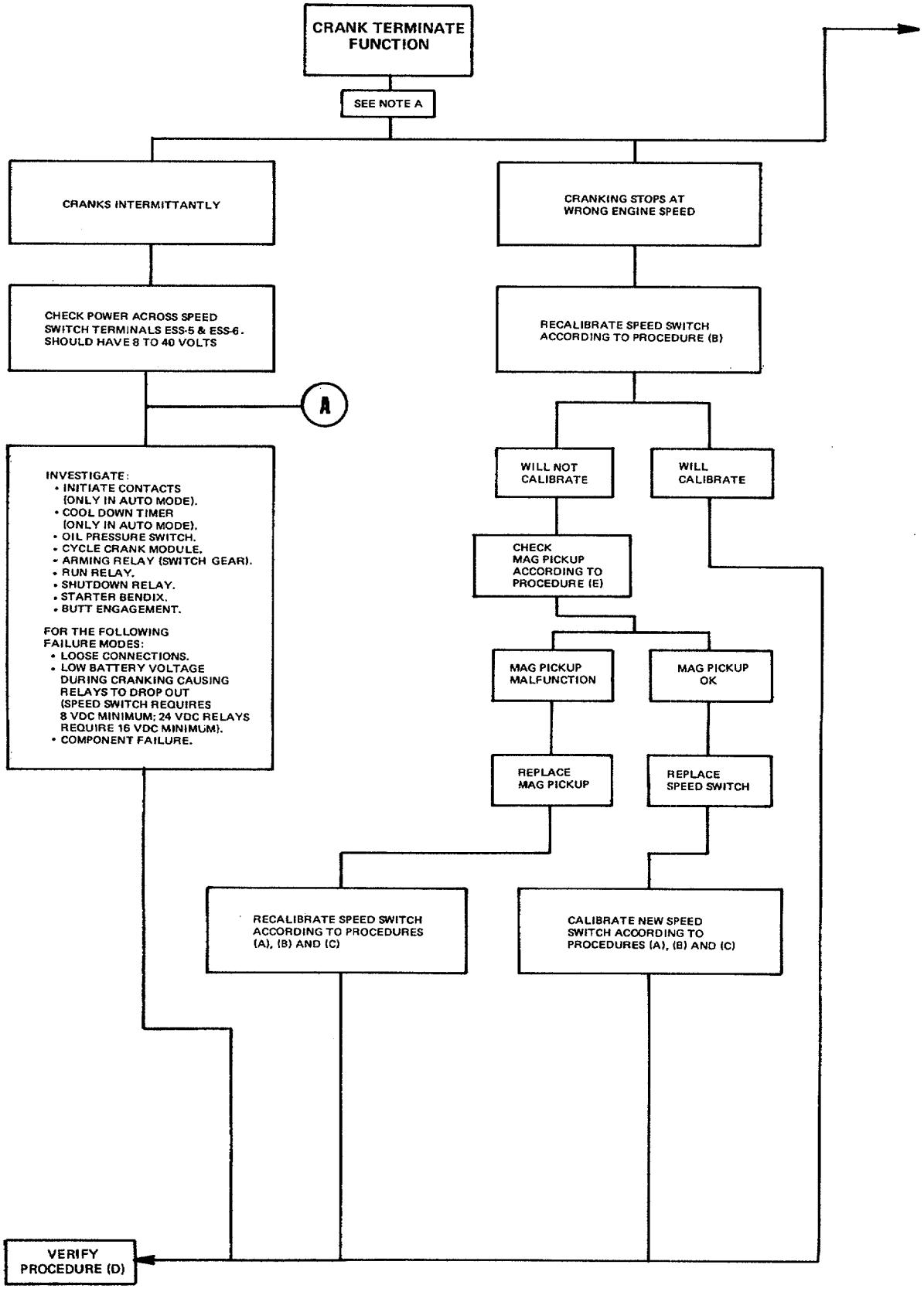


CHART C.

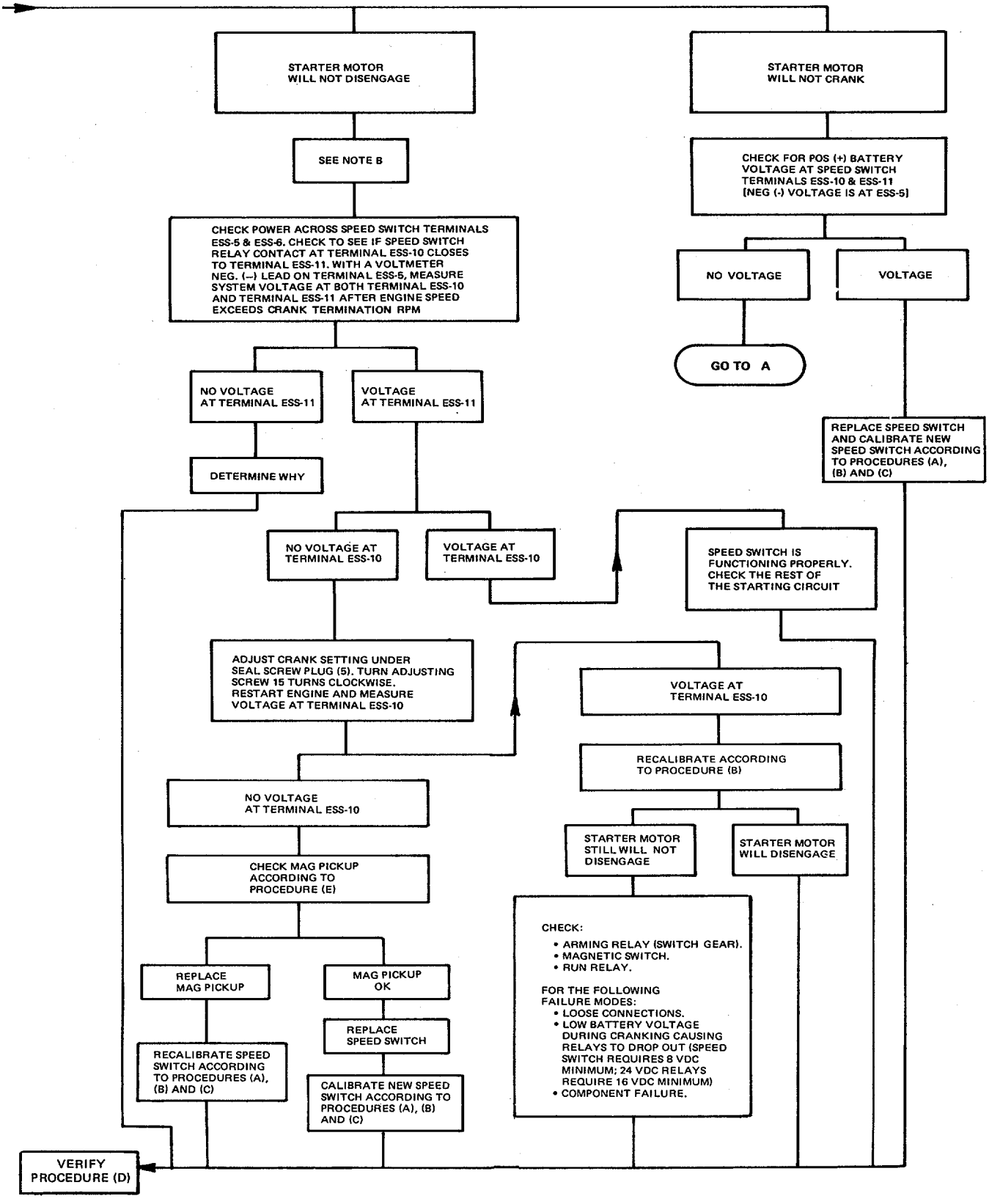


CHART C (Continued)

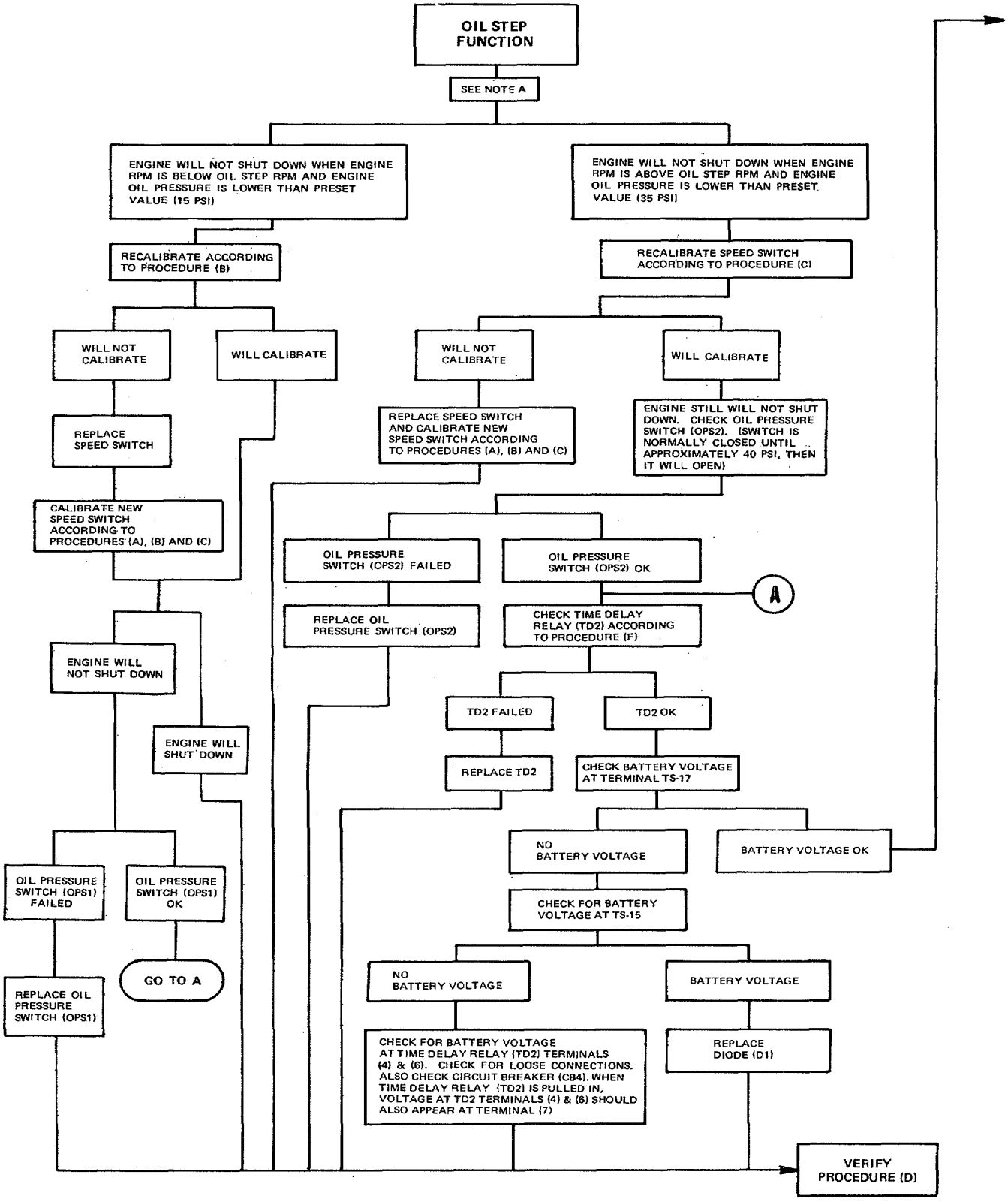

OIL STEP FUNCTION
SEE NOTE A
ENGINE WILL NOT SHUT DOWN WHEN ENGINE RPM IS BELOW OIL STEP RPM AND ENGINE OIL PRESSURE IS LOWER THAN PRESET VALUE (15 PSI)
ENGINE WILL NOT SHUT DOWN WHEN ENGINE RPM IS ABOVE OIL STEP RPM AND ENGINE OIL PRESSURE IS LOWER THAN PRESET VALUE (35 PSI)
RECALIBRATE ACCORDING TO PROCEDURE (B)
RECALIBRATE SPEED SWITCH ACCORDING TO PROCEDURE (C)
WILL NOT CALIBRATE
WILL CALIBRATE
WILL NOT CALIBRATE
WILL CALIBRATE
REPLACE SPEED SWITCH
REPLACE SPEED SWITCH AND CALIBRATE NEW SPEED SWITCH ACCORDING TO PROCEDURES (A), (B) AND (C)
ENGINE STILL WILL NOT SHUT DOWN. CHECK OIL PRESSURE SWITCH (OPS2). (SWITCH IS NORMALLY CLOSED UNTIL APPROXIMATELY 40 PSI, THEN IT WILL OPEN)
CALIBRATE NEW SPEED SWITCH ACCORDING TO PROCEDURES (A), (B) AND (C)
OIL PRESSURE SWITCH (OPS2) FAILED
OIL PRESSURE SWITCH (OPS2) OK
A
REPLACE OIL PRESSURE SWITCH (OPS2)
CHECK TIME DELAY RELAY (TD2) ACCORDING TO PROCEDURE (F)
ENGINE WILL NOT SHUT DOWN
TD2 FAILED
TD2 OK
ENGINE WILL SHUT DOWN
REPLACE TD2
CHECK BATTERY VOLTAGE AT TERMINAL TS-17
NO BATTERY VOLTAGE
BATTERY VOLTAGE OK
OIL PRESSURE SWITCH (OPS1) FAILED
OIL PRESSURE SWITCH (OPS1) OK
CHECK FOR BATTERY VOLTAGE AT TS-15
GO TO A
NO BATTERY VOLTAGE
BATTERY VOLTAGE
REPLACE OIL PRESSURE SWITCH (OPS1)
CHECK FOR BATTERY VOLTAGE AT TIME DELAY RELAY (TD2) TERMINALS (4) & (6). CHECK FOR LOOSE CONNECTIONS. ALSO CHECK CIRCUIT BREAKER (CB4). WHEN TIME DELAY RELAY (TD2) IS PULLED IN, VOLTAGE AT TD2 TERMINALS (4) & (6) SHOULD ALSO APPEAR AT TERMINAL (7)
REPLACE DIODE (D1)
VERIFY PROCEDURE (D)

CHART D.

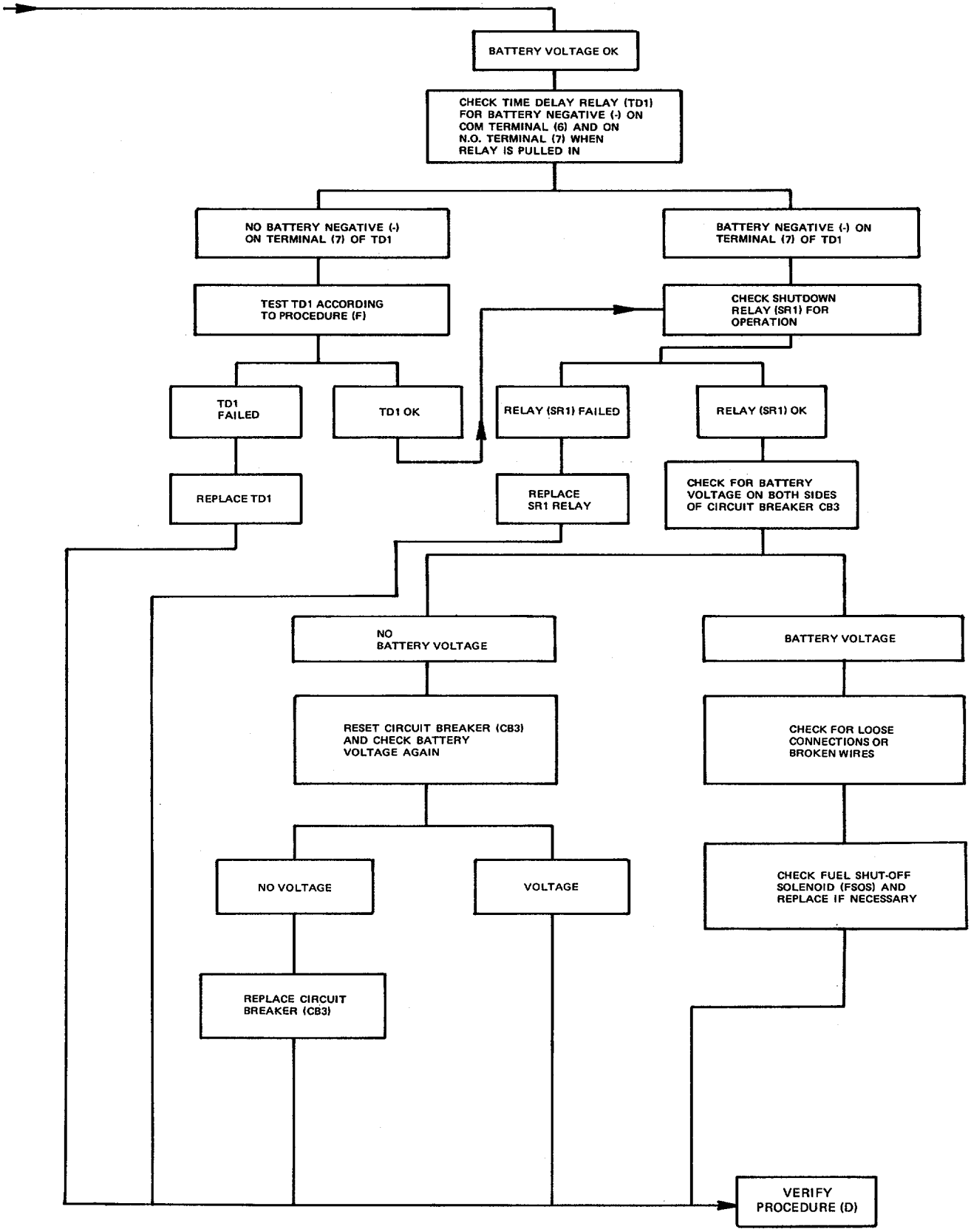
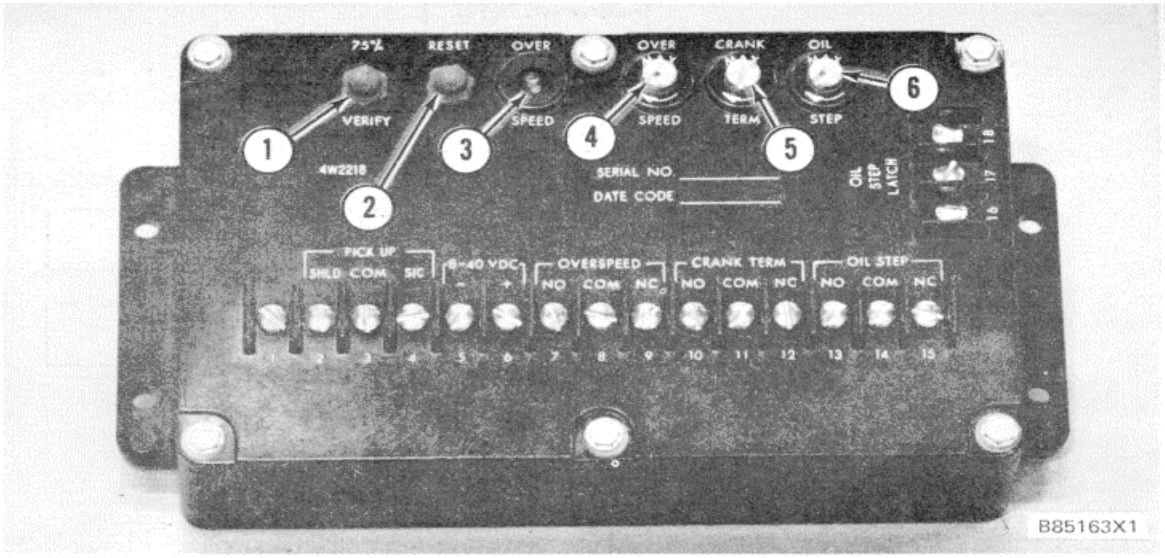


CHART D (Continued)

PROCEDURE A



4W2218 ELECTRONIC SPEED SWITCH (ESS)

1. Verify button. 2. Reset button. 3. "LED" overspeed light. 4. Seal screw plug (overspeed). 5. Seal screw plug (crank terminate). 6. Seal screw plug (oil step).

OVERSPEED SETTING CALIBRATION

1. Remove lockwire and seal from seal screw plugs (4), (5) and (6). Remove seal screw plug (4) from access hole for overspeed adjustment screw.

2. Use a small screwdriver and lightly turn overspeed adjustment potentiometer twenty turns in the direction of "MAX ARROW" (clockwise).

NOTE: The overspeed adjustment screw is made so that it can not cause damage to the potentiometer, or be removed, if the adjustment screw is turned too many turns in either direction.

3. Run engine at 75% of desired overspeed setting rpm. Make reference to the SPEED SPECIFICATION CHART (Part of PROCEDURE D).

4. With engine at 75% of overspeed setting rpm, push VERIFY button (I) and hold in. Turn overspeed adjustment potentiometer in the direction opposite of "MAX ARROW" counterclockwise) slowly until "LED" overspeed light (3) comes on. Engine will shutdown if speed switch is connected to the fuel shutoff solenoid and/or air inlet shutoff solenoid.

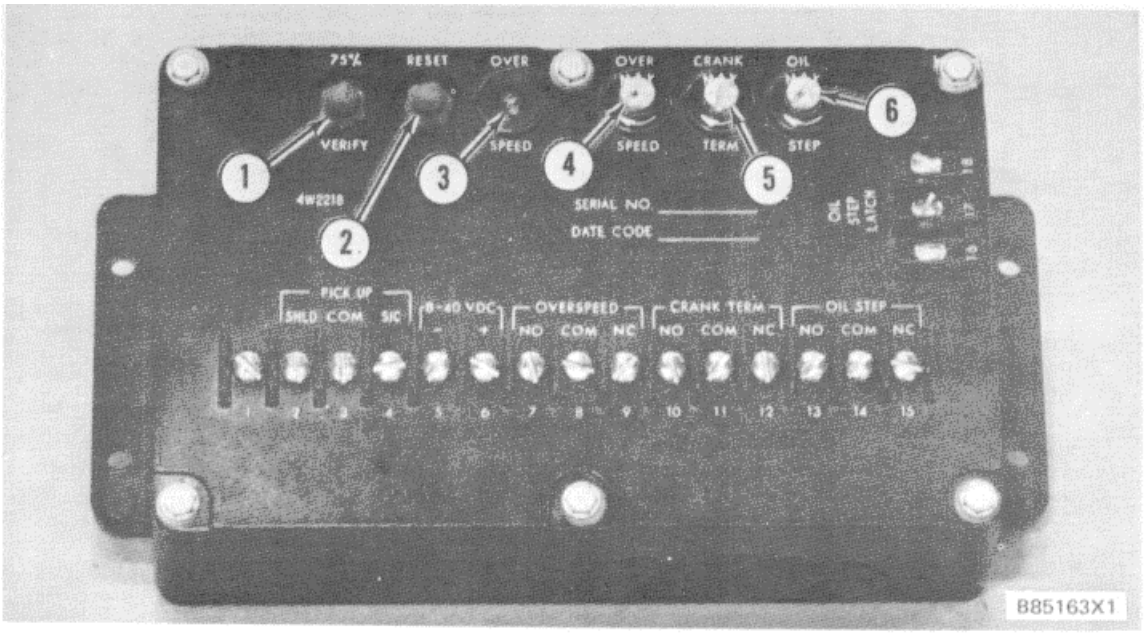
5. To reset speed switch, push in reset button (2). Air inlet shutoff must be manually reset.

6. Slowly turn overspeed adjustment potentiometer approximately one turn clockwise and do Steps 3, 4 and 5 again.

NOTE: More adjustment may be needed to get the correct setting. Turn adjustment potentiometer clockwise to increase, speed setting, and counterclockwise to decrease speed setting. Turn adjustment potentiometer very slowly only a small amount at a time until adjustment is correct.

7. When the speed setting is correct, install seal screw plug (4) in overspeed adjustment access hole. Tighten screw to a torque of 0.20 + 0.03 N-m (2 +.3 lb. in.). Install the lockwire and seal (if crank termination and oil step adjustments are complete).

PROCEDURE B



4W2218 ELECTRONIC SPEED SWITCH (ESS)

1. Verify button. 2. Reset button. 3. "LED" overspeed light. 4. Seal screw plug (overspeed). 5. Seal screw plug (crank terminate). 6. Seal screw plug (oil step).

CRANK TERMINATE SPEED ADJUSTMENT

1. Remove lockwire and seal from seal screw plug (4), (5) and (6). Remove seal screw plug (5) from the access hole for crank terminate adjustment screw.

2. Use a small screwdriver and lightly turn the crank terminate adjustment potentiometer twenty turns in the direction of "MAX AR-ROW" (clockwise).

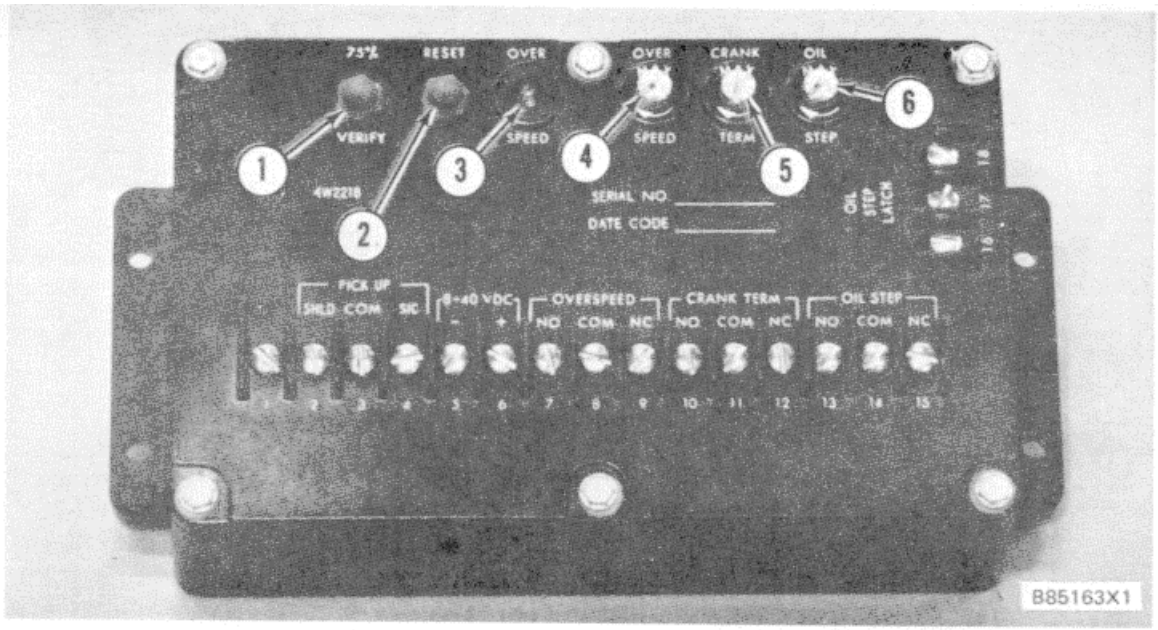
NOTE: The crank terminate adjustment screw is made so that it can not cause damage to the potentiometer, or be removed, if the adjustment screw is turned too many turns in either direction.

3. Turn the crank terminate adjustment potentiometer twelve turns in a direction opposite of "MAX ARROW" (counterclockwise) for an approximate crank terminate setting.
4. Connect a voltmeter (6V7070 Multimeter or a voltmeter of same accuracy) with the positive lead at ESS-12 and the negative lead at ESS-5. Start the engine and make a note of the speed at which the system voltage is canceled (this is the speed at which the DC starter system disengages). See the SPEED SPECIFICATION CHART (Part of PROCEDURE D) for the correct crank terminate speed.

NOTE: If setting is not correct, do Steps 5, 6 and 7.
If setting was correct, go to Step 7.

5. Stop the engine and turn the crank terminate adjustment potentiometer one full turn in the correct direction (clockwise to increase and counterclockwise to decrease).
6. With the voltmeter still connected as in Step 4, start the engine and make a note of the speed at which the system voltage is canceled (this is the speed at which the DC starter system disengages). If needed, make more small adjustments until the crank terminate speed is correct.
7. Install seal screw plug (5) in crank terminate adjustment access hole. Tighten to a torque of 0.20 ± 0.03 N-m (2 ± .3 lb. in.). Install the lockwire and seal (if overspeed and oil step adjustments are complete).

PROCEDURE C



4W2218 ELECTRONIC SPEED SWITCH (ESS)

1. Verify button. 2. Reset button. 3. "LED" overspeed light. 4. Seal screw plug (overspeed). 5. Seal screw plug (crank terminate). 6. Seal screw plug (oil step).

OIL STEP CALIBRATION

1. Remove the lockwire and seal from seal screw plugs (4), (5) and (6). Remove seal screw plug (6) from access hole for the oil step adjustment screw.

2. Use a small screwdriver and lightly turn oil step adjustment potentiometer 20 turns in the direc- tion opposite of "MAX ARROW" (counter- clockwise). This will lower the oil step speed setting to its lowest value.

NOTE: The oil step adjustment screw is made so it can not cause damage to the potentiometer, or be removed, if the adjustment screw is turned too many turns in either direction.

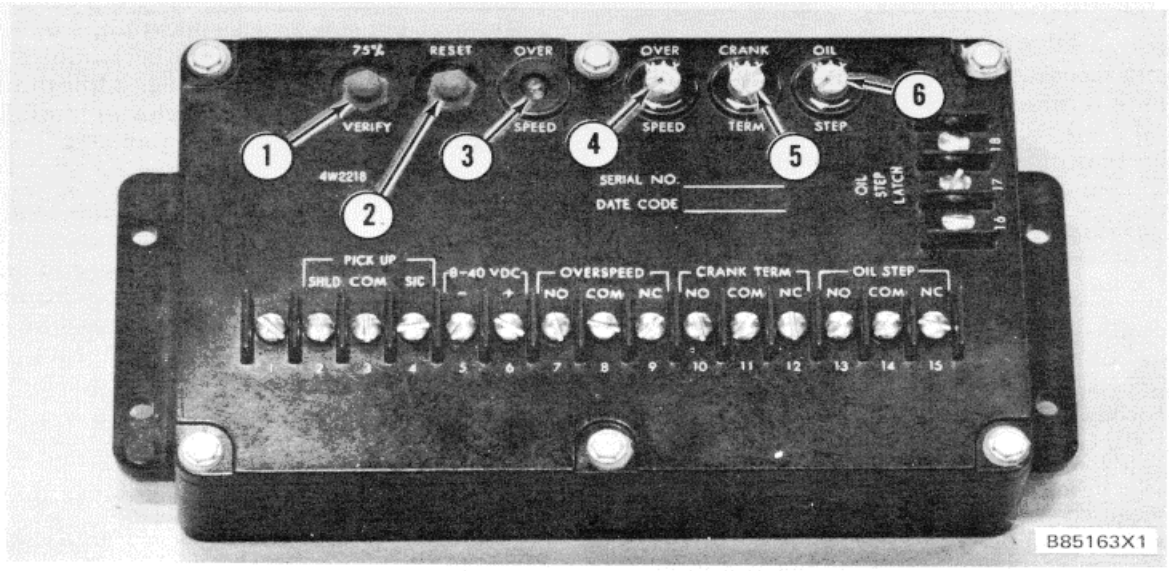
3. Use a 6V7070 Multimeter (or a voltmeter of same accuracy) to check for positive (+) voltage at terminal ESS-13 [negative (-) voltage is at terminal ESS-5].

4. Make reference to SPEED SPECIFICATION CHART (Part of PROCEDURE D). For a particular engine rating, find the specified rpm in column for Oil Step Speed Setting. Run the engine at this specified rpm.

5. With the engine running, look into the oil step adjustment access hole. A red "LED" (light emitting diode) light will be on. After an 8 to 10 second delay, positive (+) voltage will be seen at terminal ESS-13. Now turn the oil step adjustment potentiometer clockwise until the red light in the oil step access hole goes out. When the light goes out, this indicates that the oil step rpm setting is above the present running rpm of the engine. Slowly turn the adjustment poten- tiometer counterclockwise until the light comes back on. After an 8 to 10 second delay, positive (+) voltage will be seen at terminal ESS-13.

6. When the oil step setting is correct, install seal screw plug (6) into the adjustment access hole for the oil step function. Tighten plug to a torque of 0.20 ± 0.03 N-m (2 + .3 lb. in.). If all other adjustments are complete (overspeed and crank terminate), install lockwire and seal.

PROCEDURE D



4W2218 ELECTRONIC SPEED SWITCH (ESS)

1. Verify button. 2. Reset button. 3. "LED" overspeed light. 4. Seal screw plug (overspeed). 5. Seal screw plug (crank terminate). 6. Seal screw plug (oil step).

OVERSPEED VERIFY TEST

1. Run the engine at rated speed and push verify button (l) in for a moment. This will cause the speed switch to activate and shutdown the engine.

NOTE: Any time the engine speed is 75% or more of the overspeed setting, the engine will shutdown if the verify button is pushed.

EXAMPLE: For an engine with a rated speed of **1800** rpm, the overspeed setting is 2125 rpm (see SPEED SPECIFICATION CHART and Note E). The overspeed verify test will shutdown the engine at 75% (+ 25 rpm) of the overspeed setting of 2125 rpm. In this example, 75% of 2125 rpm is approximately 1600 rpm. If the verify button is pushed at an engine speed of approximately 1600 rpm or above, the engine will shutdown.

The "LED" overspeed light (3) will come on and stay on until the reset button is pushed after an overspeed switch shutdown. To restart the engine, push in reset button (2) for a moment. This will reset the speed switch, and the "LED" overspeed light (3) will go off. The air inlet shutoff lever must now be manually reset before the engine can be started.

NOTE C: To verify overspeed shutdown system operation, push in the VERIFY button for a moment. The engine must shutdown at *75%* or more of overspeed setting.
NOTE D: Input Voltage: Maximum 40 VDC; Minimum 8 VDC.
NOTE E: The engine overspeed setting rpm is 118% of rated engine rpm.

SPEED SPECIFICATION CHART (RPM)				
TYPICAL RATED ENGINE SPEED	**OVERSPEED SETTING (±25) NOTE E**	**75% OVERSPEED VERIFY (+ 25) NOTE C**	**OIL STEP SPEED SETTING**	**CRANK TERMINATE**
1800	2125	1600	1125	600
1600	1890	1415	1125	600
1500	1775	1325	1125	600
1300	1535	1150	750	400
1200	1415	1060	750	400
1000	1180	885	750	400
900	1065	800	750	400

PROCEDURE E

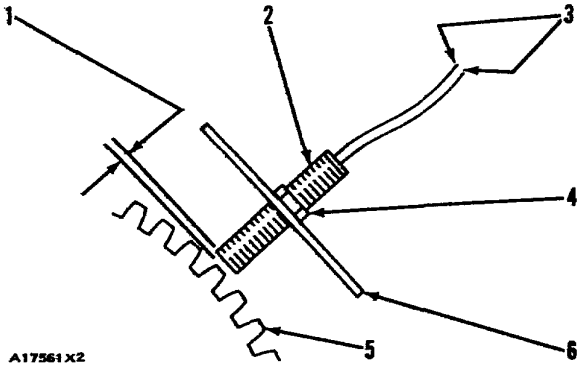
MAGNETIC PICKUP VERIFY

1. Connect a 6V7070 Multimeter (or a voltmeter of same accuracy) to electronic speed switch common terminal (ESS-3) and signal terminal (ESS4). Set the meter voltage scale to a scale greater than *1.5* VAC. Start the engine and run at idle rpm or 600 rpm (whichever is greater).

If the measured voltage is 1.5 VAC or **more**, the operation of the magnetic pickup is correct. If measured voltage is **less** than 1.5 VAC, go to Step 2.

2. Disconnect the wiring from the magnetic pick- up and connect the voltmeter to magnetic pick- up connector terminals I and 2. Set the volt- meter voltage scale to a scale greater than 1.5 VAC. Start the engine and run at idle rpm or 600 rpm (whichever is greater).

If the measured voltage is 1.5 VAC or **more**, repair or replace the wiring between the magnetic pickup and the electronic speed switch. If the measured voltage is **less** than 1.5 VAC, go to Step 3.



MAGNETIC PICKUP

1. Clearance dimension. 2. Magnetic pickup. 3. Wires. 4. Locknut. 5. Gear tooth. 6. Housing.

3. Remove magnetic pickup (2) from the engine flywheel housing (earlier location, front drive housing) and turn the flywheel until a gear tooth (5) is directly in the center of the threaded opening for the magnetic pickup. Install the magnetic pickup again in the threads of housing (6).

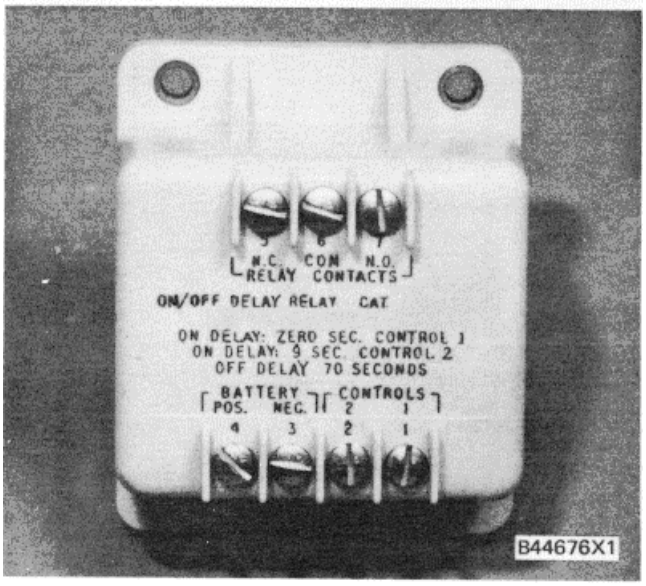
By hand, turn in a clockwise direction until the end of the magnetic pickup just makes contact with the gear tooth (5). Now turn the magnetic pickup back out 1/2 turn (180° in the counterclockwise direction) to get the correct air gap [clearance dimension (1)]. Now tighten locknut (4) to a torque of 68 ± 13 N•m (50 + 10 lb. ft.).

NOTE: Do not let the magnetic pickup turn while locknut is tightened.

Do Step 2 again. *If* voltage is still **less** than 1.5 VAC, replace the magnetic pickup.

PROCEDURE F

ON/OFF TIME DELAY (RELAY)



ON/OFF TIME DELAY (RELAY)

Performance Check (either TD1 or TD2 relays can be checked with methods that follow)

A. Items Required For Check:

1. Battery or any D.C. source of 8 to 40 volts.
2. Voltmeter (6V7070 Multimeter or one of same accuracy).
3. Stop watch.

B. Bench Or Installed Test

Connect or verify source voltage to relay terminals 3 (-) and 4 (+) [if bench testing, also connect positive (+) voltage to relay terminal 6]. All connections must be maintained until tests are complete.

NOTE: There will be voltage when the relay is closed. When relay is open, there will be no voltage [voltage may be positive (+) or negative (-) when relay is tested on engine; when bench testing, voltage will always be positive (+)].

1. Use the voltmeter to verify chart that follows:

Terminals	Relay Position
5	Closed
7	Open

2. (a) Apply positive (+) source voltage to terminal I (either relay) and immediately verify the chart that follows (do not leave voltage on terminal 1 for more than 60 seconds):

Terminals	Relay Position
5	Open
7	Closed

(b) Remove positive (+) source voltage from terminal 1. Use a stop watch and check the time from the moment of removal to verify chart that follows:

Terminals	Delay Time to Function	
	0 to 60 Secs.	After 80 Secs.
5	Open	Closed
7	Closed	Open

3. (a) Apply positive (+) source voltage to terminal 2.

NOTE: If bench testing, Step 3 can be used with either relay. When installed on engine, Step 3 can only be checked with TD2. **Do not apply positive (+) voltage to terminal 2 of TD1, or a direct short will result.**

Check the time from the moment voltage is applied to verify chart that follows (do not leave voltage on terminal 2 for more than 60 seconds):

Terminals	Delay Time to Function	
	0 to 8 Secs.	After 10 Secs.
5	Closed	Open
7	Open	Closed

(b) Remove positive (+) source voltage from terminal 2. Check the time from the moment of removal to verify chart that follows:

Terminals	Delay Time to Function	
	0 to 60 Secs.	After 80 Secs.
5	Open	Closed
7	Closed	Open

4. Remove wire from terminal 4 and verify chart that follows:

Terminals	Relay Position
5	Closed
7	Open

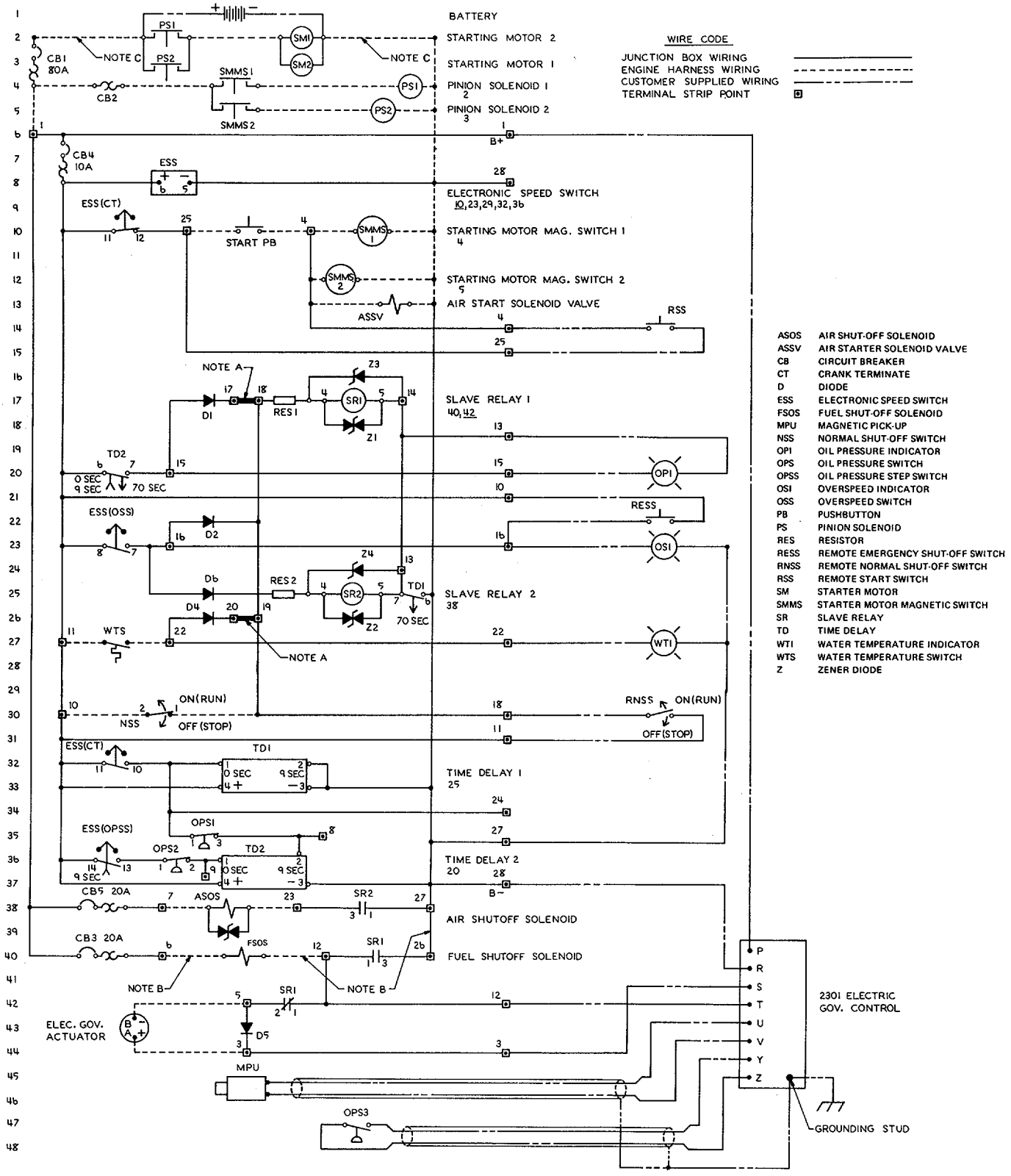
ELECTRIC SHUT-OFF WIRING DIAGRAMS

COMPONENT ABBREVIATIONS (REF 5N360)

ALT	ALTERNATOR
AMM	AMMETER
ASOS	AIR SHUT-OFF SOLENOID
ASSV	AIR START SOLENOID VALVE
B-	BATTERY NEGATIVE
B+	BATTERY POSITIVE
BATT	BATTERY
CB	CIRCUIT BREAKER
CT	CRANK TERMINATE
D	DIODE
EGA	ELECTRIC GOVERNOR ACTUATOR
EGC	ELECTRIC GOVERNOR CONTROL
ESS	ELECTRIC SPEED SWITCH
FSOS	FUEL SHUT-OFF SOLENOID
HWTAS	HIGH WATER TEMPERATURE ALARMSWITCH
LOPAS	LOW OIL PRESSURE ALARM SWITCH
LWTAS	LOW WATER TEMPERATURE ALARMSWITCH
MGOPG	MARINE GEAR OIL PRESSURE GAGE
MGOPSU	MARINE GEAR OIL PRESSURE SENDING UNIT
MGOTAS	MARINE GEAR OIL TEMPERATURE ALARM SWITCH
MPU	MAGNETIC PICK-UP
NSS	NORMAL SHUT-OFF SWITCH
OPG	OIL PRESSURE GAGE
OPI	OIL PRESSURE INDICATOR
OPS	OIL PRESSURE SWITCH
OPSS	OIL PRESSURE STEP SWITCH
OPSU	OIL PRESSURE SENDING UNIT
OSI	OVERSPEED INDICATOR
OSS	OVERSPEED SWITCH
PB	PUSH BUTTON
PP	PRELUBE PUMP
PPMS	PRELUBE PUMP MAGNETIC SWITCH
PPPS	PRELUBE PUMP PRESSURE SWITCH
PS	PINION SOLENOID
RES	RESISTOR
RESS	REMOTE EMERGENCY SHUT-OFF SWITCH
RNS	REMOTE NORMAL SHUT-OFF SWITCH
RSS	REMOTE START SWITCH
SM	STARTER MOTOR
SMMS	STARTER MOTOR MAGNETIC SWITCH
SR	SLAVE (SHUTDOWN) RELAY
TD	TIME DELAY
TM	TACHOMETER
TS	TERMINAL STRIP
WTG	WATER TEMPERATURE GAGE
WTI	WATER TEMPERATURE INDICATOR
WTS	WATER TEMPERATURE SWITCH
WTSU	WATER TEMPERATURE SENDING UNIT
Z	ZENER DIODE

WIRE COLOR CODE ABBREVIATIONS

B	BLACK
BR	BROWN
B/W	BLACK WITH WHITE STRIPE
CU	COPPER (BARE WIRE)
DK BL	DARK BLUE
DK GR	DARK GREEN
GR	GREEN
LT BL	LIGHT BLUE
O	ORANGE
O/B	ORANGE WITH BLACK STRIPE
P/B	PINK WITH BLACK STRIPE
PU/W	PURPLE WITH WHITE STRIPE
R	RED
W	WHITE
W/O	WHITE WITH ORANGE STRIPE
W/R	WHITE WITH RED STRIPE
Y	YELLOW
Y/BR	YELLOW WITH BROWN STRIPE



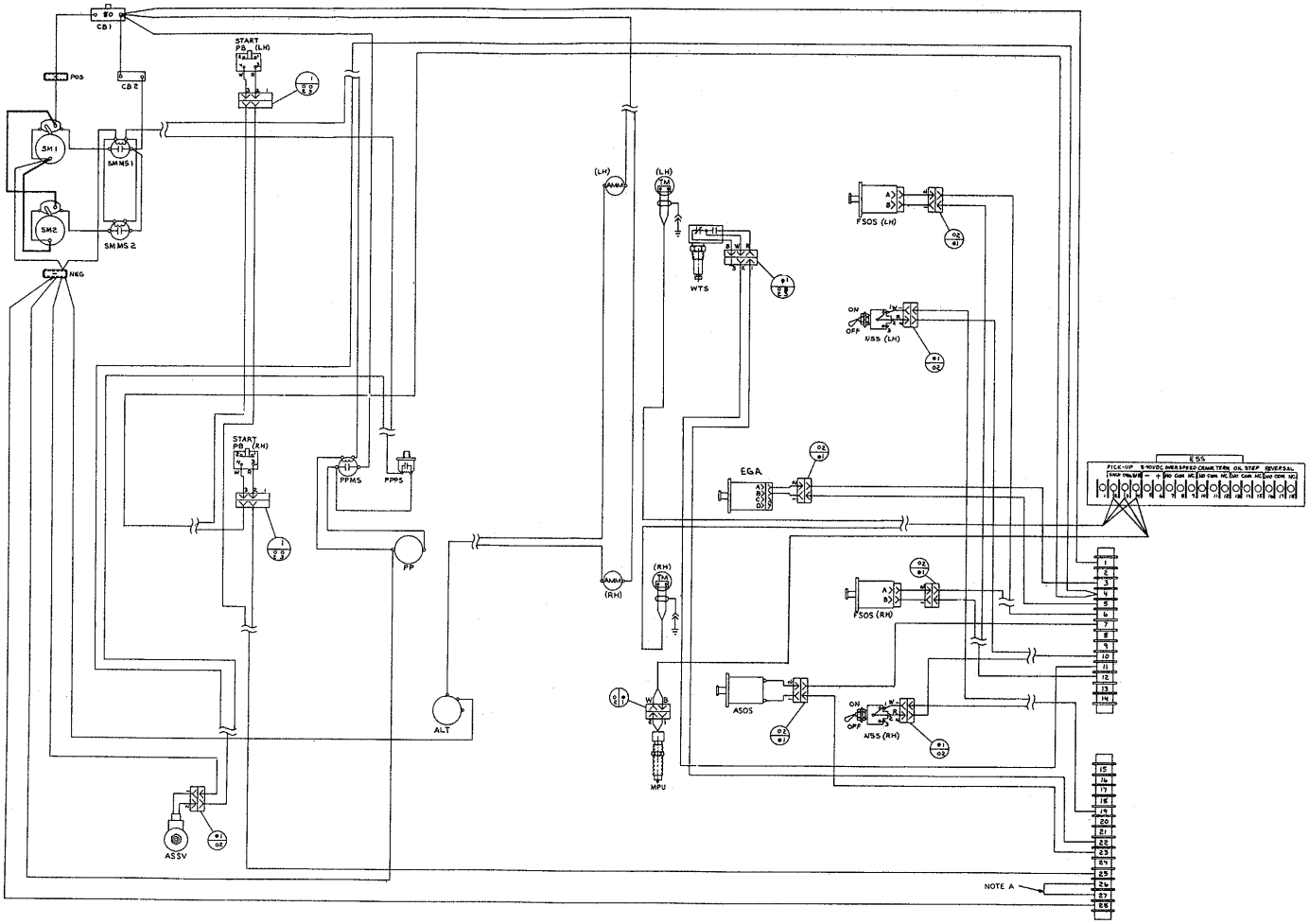
ASOS	AIR SHUT-OFF SOLENOID
ASSV	AIR STARTER SOLENOID VALVE
CB	CIRCUIT BREAKER
CT	CRANK TERMINATE
D	DIODE
ESS	ELECTRONIC SPEED SWITCH
FSOS	FUEL SHUT-OFF SOLENOID
MPU	MAGNETIC PICK-UP
NSS	NORMAL SHUT-OFF SWITCH
OPI	OIL PRESSURE INDICATOR
OPS	OIL PRESSURE SWITCH
OPSS	OIL PRESSURE STEP SWITCH
OSI	OVERSPEED INDICATOR
OSS	OVERSPEED SWITCH
PB	PUSHBUTTON
PS	PINION SOLENOID
RES	RESISTOR
RESS	REMOTE EMERGENCY SHUT-OFF SWITCH
RNSS	REMOTE NORMAL SHUT-OFF SWITCH
RSS	REMOTE START SWITCH
SM	STARTER MOTOR
SMMS	STARTER MOTOR MAGNETIC SWITCH
SR	SLAVE RELAY
TD	TIME DELAY
WTI	WATER TEMPERATURE INDICATOR
WTS	WATER TEMPERATURE SWITCH
Z	ZENER DIODE

ELECTRIC PROTECTIVE SYSTEM SCHEMATIC

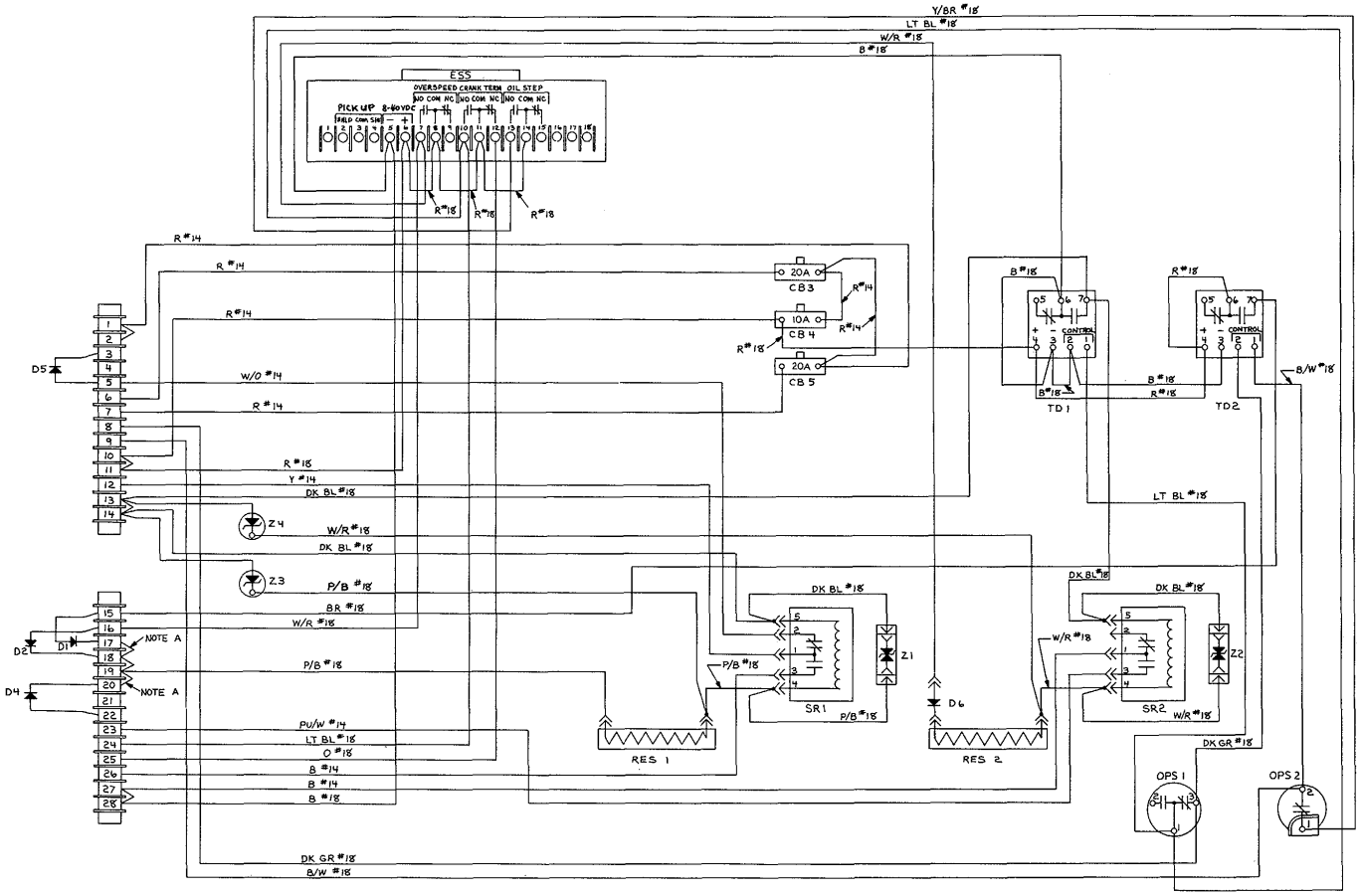
NOTE A: Terminal strip jumpers between terminals TS17 & TS18 and TS19 & TS20 are not required when alarms are used for low oil pressure and high water temperature.

NOTE B: The terminal strip wire between terminals TS26 & TS27 is in the wiring harness when a 3161, UGSD or UG8L governor is installed. When a 2301 governor is used, no wire is required; also, no fuel shutoff solenoid is used between TS6 & TS12.

NOTE C: This wire is provided by customer if electric starter motor(s) are not used.

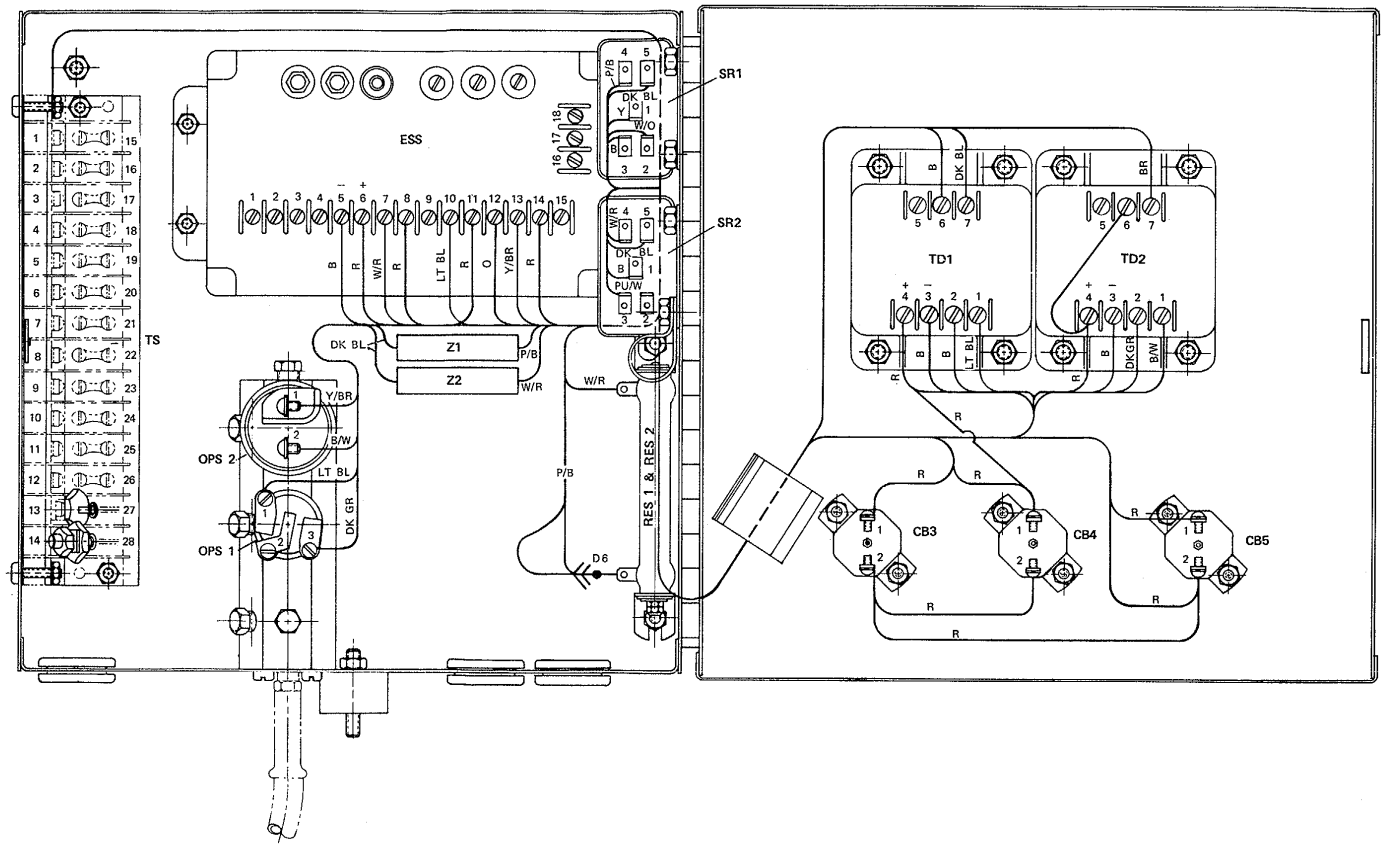


3500 ENGINE WIRING DIAGRAM (REF 5N8944)
(All Possible Combinations)
NOTE A: Jumper required only with 3161, UG8D and UG8L governors.

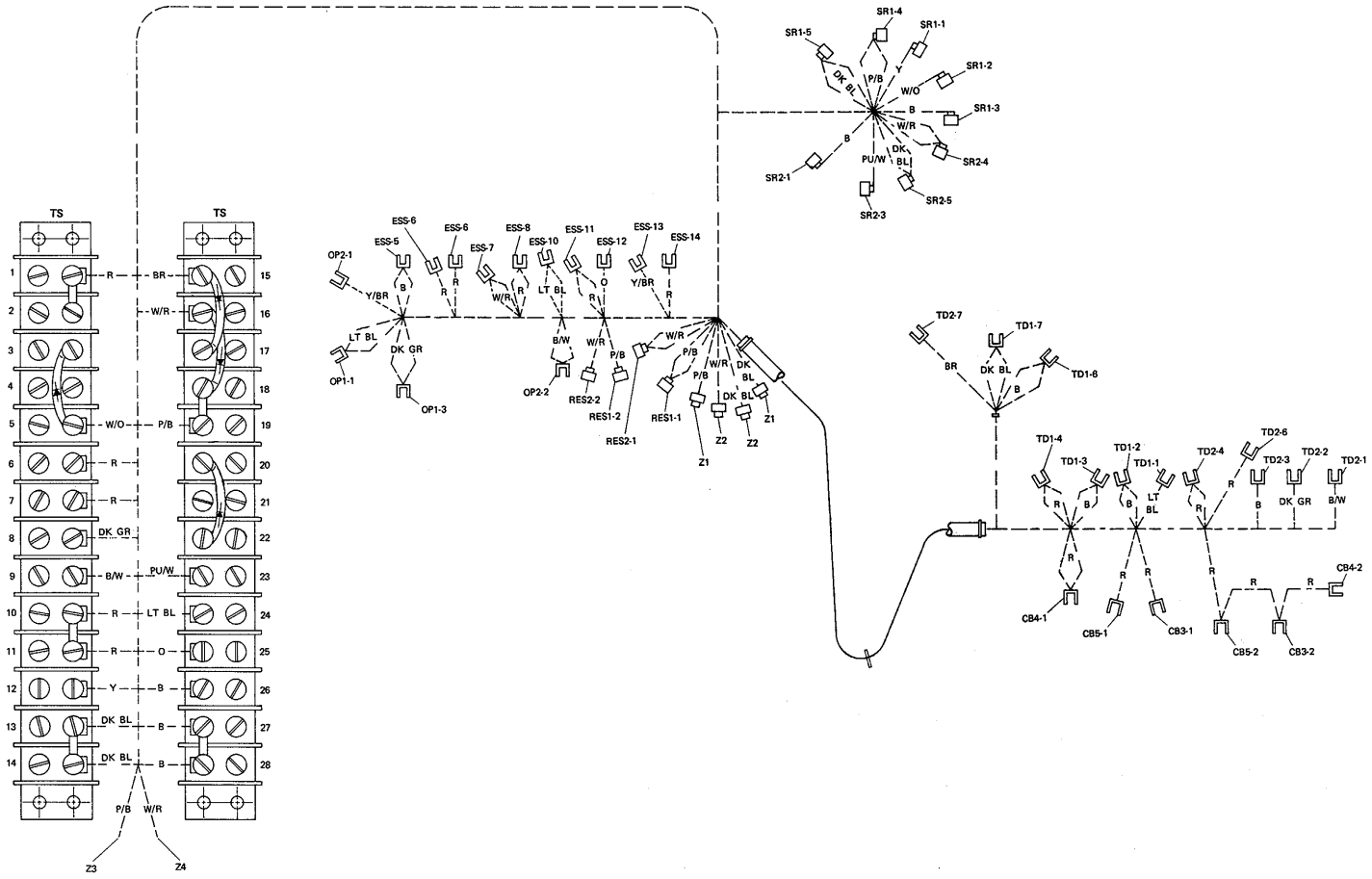


TYPICAL JUNCTION BOX WIRING DIAGRAM (REF 5N8944)

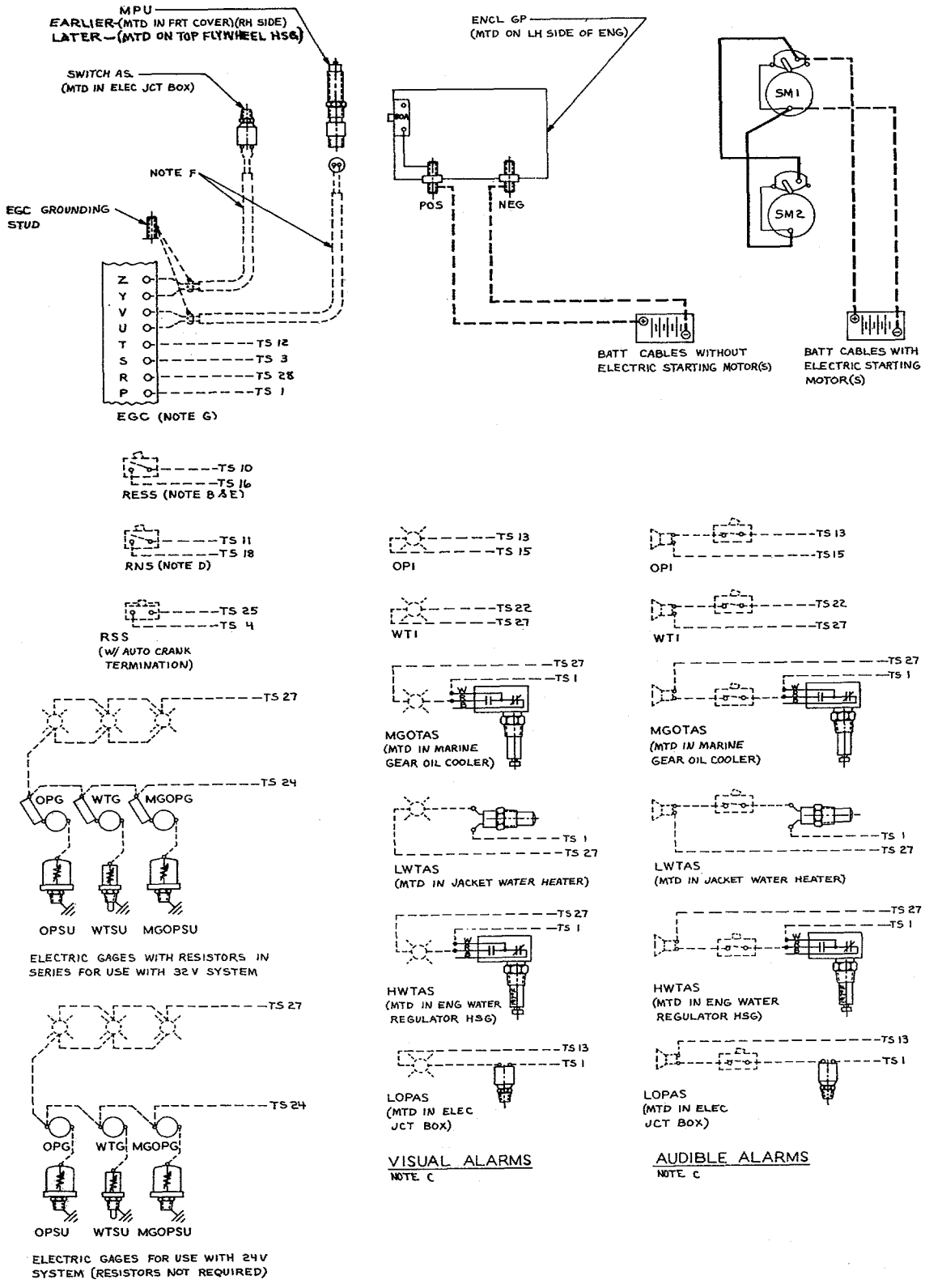
NOTE A: Terminal strip jumpers between terminals TS17 & TS18 and TS19 & TS20 are not required on Marine Engines which have alarms only for low oil pressure and high water temperature.



JUNCTION BOX (REF 4W2635)



JUNCTION BOX WIRING HARNESS (REF 4W2636)



CUSTOMER WIRING WITH ELECTRIC PROTECTIVE SYSTEM (NOTE A)

SEE NOTES ON PAGE THAT FOLLOWS

NOTE A: Wire, cable and components shown with dotted lines are to be added by customer. See wire and cable gage charts for size selection.

NOTE B: Do not use remote emergency switch for normal engine shutdown. The use of emergency switch requires manual reset of air shut-off at top of air inlet housing.

NOTE C: Caterpillar alarm and prealarm contacts are rated for a maximum of 3 amps inductive at the charging system voltage.

NOTE D: Switch to be a single pole, normally open switch (may be latching if desired) with a minimum contact rating of .5 amp inductive at the charging system voltage.

NOTE E: Switch to be a single pole, normally open switch (may be latching if desired) with a minimum contact rating of 1 amp inductive at the charging system voltage.

NOTE F: Magnetic pick-up and oil pressure switch to be wired to electric governor control (Woodward 2301) with a two conductor shielded cable (Belden Corp. type 8780 or equivalent). Shields are to be grounded at electric governor control grounding stud. Each shield should not have more than one ground connection.

NOTE G: Woodward 2301 Electric Governor Control terminal identification chart:

SYMBOL	FUNCTION	STAND-BY TS NO.	LOAD SHARING TS NO.
P	Batt +	2	12
R	Batt -	1	13
S	EGA +	6	17
T	EGA -	5	16
U	Mag Pick-up	7	18
V	Mag Pick-up	8	19
Y	Oil Pressure Speed Limiter	9	14
Z	Oil Pressure Speed Limiter	10	15



Caterpillar, (

operation & maintenance

3508, 3512 and 3516 Industrial Engines

23Z1-UP	27Z1-UP	68Z1-UP	73Z1-UP
24Z1-UP	65Z1-UP	70Z1-UP	49Y1-UP
25Z1-UP	67Z1-UP	71Z1-UP	95Y1-UP

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Foreword

This guide contains operation instructions and lubrication and maintenance information.

The operation section is a reference for the new operator and a refresher for the experienced one. Read — study — and keep it handy.

Illustrations guide the operator through the correct procedures of checking, starting, operating and stopping the engine.

The maintenance section is a guide to equipment care. The illustrated, step-by-step instructions are grouped by servicing intervals. Topics without specific intervals are listed under "When Required." Topics in the "Lubrication and Maintenance Chart" are referenced to detailed instructions that follow.

Use the service meter to determine servicing intervals. Calendar intervals shown (daily, weekly, monthly, etc.) may be used instead of service meter intervals if they provide more convenient servicing schedules and approximate the indicated service meter reading.

Under extremely severe, dusty or wet operating conditions, more frequent lubrication than is specified in the "Lubrication and Maintenance Chart" may be necessary.

Perform service on topics at multiples of the original requirement. For example, at Every 500 Service Hours or 3 Months, also service those topics listed under Every 250 Service Hours or Monthly, Every 50 Service Hours or Weekly and Every 10 Service Hours or Daily.

Some photographs in this publication may show details or attachments that may be different from your engine.

Continuing improvement and advancement of product design may have caused changes to your engine which may not be covered in this publication. Each publication is reviewed and revised, as required, to update and include these changes in later editions.

Whenever a question arises regarding your engine or this publication, please consult your Caterpillar dealer for the latest available information.

Engine Identification

Caterpillar engines are identified with SERIAL NUMBERS and ARRANGEMENT NUMBERS. In some cases MODIFICATION NUMBERS are also used. These numbers are shown on the serial number plate mounted on the engine. The Specification Section at the back of the Parts Book indicates the location of the serial number plate.

Caterpillar dealers need all of these numbers to determine which components were included on the engine when it was assembled at the factory. This permits accurate identification of replacement part numbers.

Ordering Parts

Quality Caterpillar replacement parts are available from Caterpillar dealers throughout the world. Their parts stocks are up to date and include all parts normally required to protect your investment in Caterpillar engines. When ordering parts, your order should specify the quantity, part number, part name and serial number, arrangement number and modification number of the engine for which the parts are needed. If in doubt about the part number, please provide your dealer with a complete description of the needed item.

Safety

Warning Plates and Decals

Read and understand all Warning plates and decals before operating, lubricating or repairing this equipment. Do not attempt any repairs you do not understand.

General

Do not allow unauthorized personnel on or near the engine while it is being serviced Do not wear loose clothing and jewelry whenever working around engines or machinery.

Stop engine before making adjustments or repairs to the engine or driven equipment unless specified otherwise.

Attach a "DO NOT OPERATE" tag on the start switch, start button or air start knob, before servicing the engine. These tags, Form SEHS7332, are available from your Caterpillar dealer.

Be sure the remote starting and the automatic start-stop systems are inoperative on engines being serviced. Remove the starter key.

Disconnect and tape the battery ground lead before working on an engine to prevent accidental starting.

To prevent injury, install guards over all exposed drive shafts, pulleys, any application with exposed rotating parts.

Always use tools that are in good condition and be sure you understand how to use them before performing any service work. Remove all tools, electrical cords and any other loose items from the engine before starting.

Engine speeds, temperatures and load are the best indications of performance.

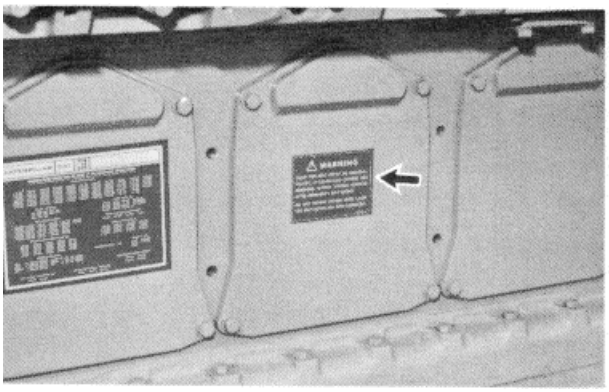
Rely on your instruments, record and compare readings to detect developing abnormalities.

Wear a hard hat, face shield, clothing, shoes, respirator or other protective items when necessary.

When using pressure air, wear protective glasses and protective clothing.

Wear ear protective devices to prevent hearing damage, if working inside an enclosed engine room with engine running.

Fire or Explosion



A flash fire may result in personal injury if crankcase covers are removed within 15 minutes after an emergency shutdown.

Fire may result from lubricating oil or fuel sprayed on hot surfaces causing personal injury and property damage. Inspect all lines and tubes for wear or deterioration.

They must be routed, supported or clamped securely. Tighten all connections to the recommended torque.

Keep all exhaust manifold and turbocharger shields in place to reduce fire hazard.

Collect drained liquids and wipe up all oil, fuel or coolant spills.

Store oily rags in proper containers. Do not leave rags on engine.

Never store flammable liquids near the engine.

Keep all lubricants stored in properly marked containers.

Never put maintenance fluids into glass containers.

Safety

Provide adequate and safe waste oil disposal.

Oil and fuel filters must be properly installed and tightened when being changed.

Diesel fuel and all lubricants are flammable. Do not weld on pipes or tubes that contain oil. Clean them thoroughly with nonflammable solvent before welding.

Do not smoke while refueling.

Loose or damaged lines, or tubes that allow oil, fuel or coolant to leak can cause overheating and/or fire.

Do not bend or strike high pressure lines. Do not install bent or damaged lines and tubes. Do not replace steel tubes with copper tubes.

Do not allow debris, dirt and foreign material to accumulate around or on the engine. Overheating or fire could result.

Wiring must be kept in good condition, properly routed and firmly attached. Routinely inspect wiring for wear or deterioration. Loose, unattached, or unnecessary wiring must be eliminated. All wires and cables must be of the recommended gauge and fused if necessary. Do not use smaller gauge wire or bypass fuses. Tight connections, recommended wiring and cables properly cared for will help prevent arcing or sparking which could cause a fire.

Batteries must be kept clean, covers on all cells, recommended cables and connections used and battery box covers in place when operating.

Do not smoke when observing battery electrolyte level. Batteries give off flammable fumes.

Never disconnect any charging unit circuit or battery circuit cable from the battery when charging unit is operating. A spark can cause the flammable vapor mixture of hydrogen and oxygen to explode.

When starting from an external power source attach the ground cable last, and remove it first, to prevent sparks from occurring near the battery. Attach the ground cable from the booster source to the starter ground terminal.

Always have a fire extinguisher on hand and know how to use it. Inspect and have it serviced as recommended on its instruction plate or decal.

Burns

To prevent personal injury, do not step up on engine to remove the radiator filler cap. Use an adequate ladder.

Always inspect the cooling system with the engine stopped and cool.

Extreme caution should be used whenever draining a lubricant. The lubricant may be hot and could cause personal injury.

Relieve all pressure in air, oil, fuel or water systems before any lines, fittings or related items are disconnected or removed. Be alert for possible pressure when disconnecting any device from a system that utilizes pressure. Do not check for pressure leaks with your hand.

Do not touch any part of an operating engine. Allow the engine to cool before any repairs are performed on the engine.

Use caution when removing cover plates. Gradually loosen (do not remove) the last two bolts or nuts located at opposite ends of the cover or device. Pry cover loose to relieve any spring or other pressure, before removing the last bolts or nuts.

Use caution when removing radiator filler cap, grease fittings, pressure taps, breathers or drain plugs. Hold a rag over the cap or plug to prevent being sprayed or ½ splashed by liquids under pressure.

Stop any fuel or oil leak as soon as it is discovered.

Cooling system conditioner contains alkali; do not drink, or let conditioner contact skin or get in eyes.

Battery electrolyte contains acid. Avoid contact with skin or eyes.

Preparing to Start

Be sure all protective guards and covers are installed if an engine must be started to make adjustments or checks. To help prevent an accident caused by parts in rotation, work carefully around them.

Do not disable or bypass automatic shutoff circuits. They are provided to prevent personal injury and equipment damage.

Never start an engine with the governor linkage disconnected.

Make provisions for shutting off air supply to stop the engine if there is an overspeed on start-up after servicing the engine.

Inspect engine for potential hazards.

See the "Lubrication and Maintenance" section of this guide for adjustment, or the Service Manual for repairs.

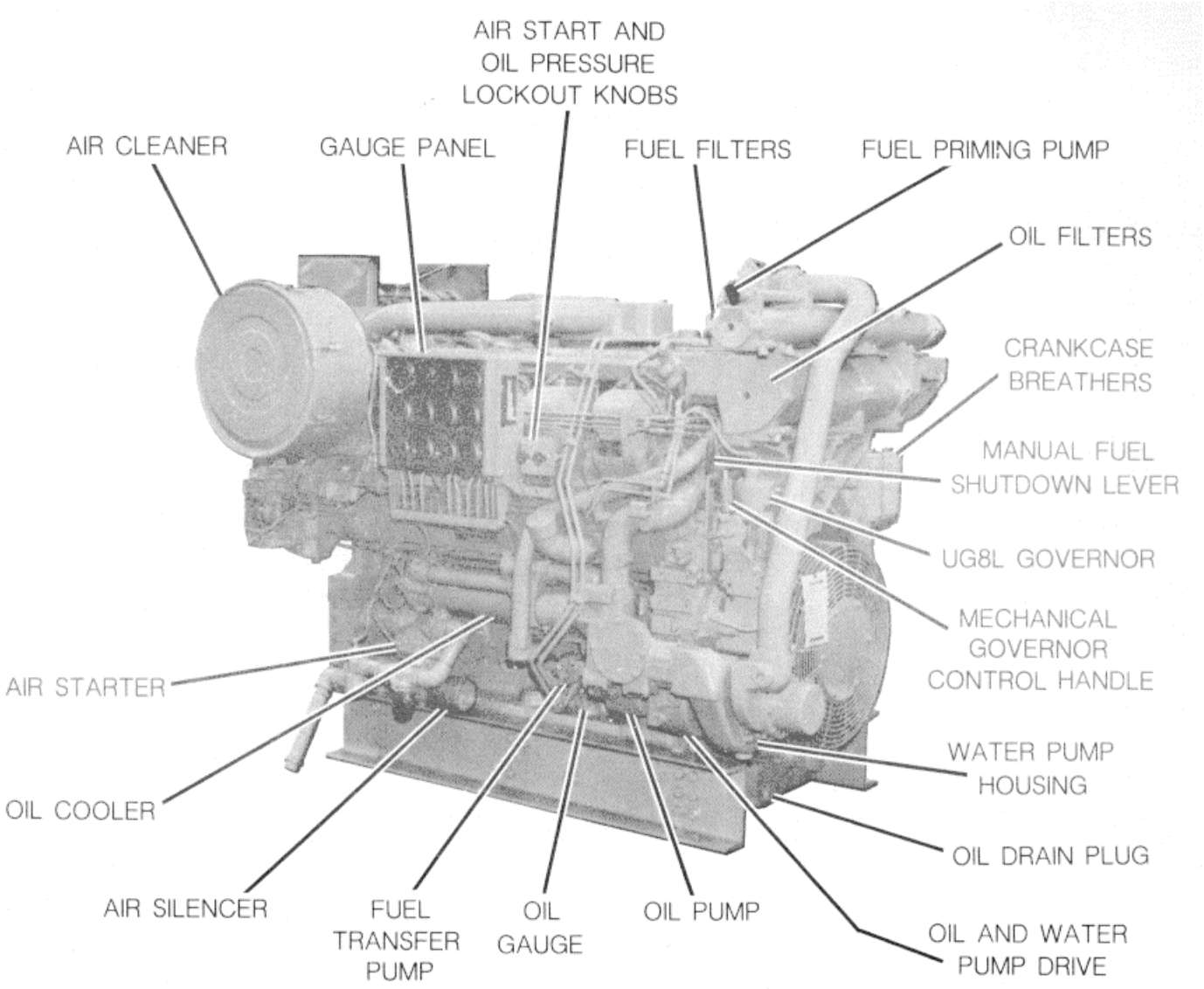
Starting

Do not start the engine or move any of the controls if there is a warning tag attached to the controls.

Make sure no one is working on, or close to the engine or engine driven components before starting it.

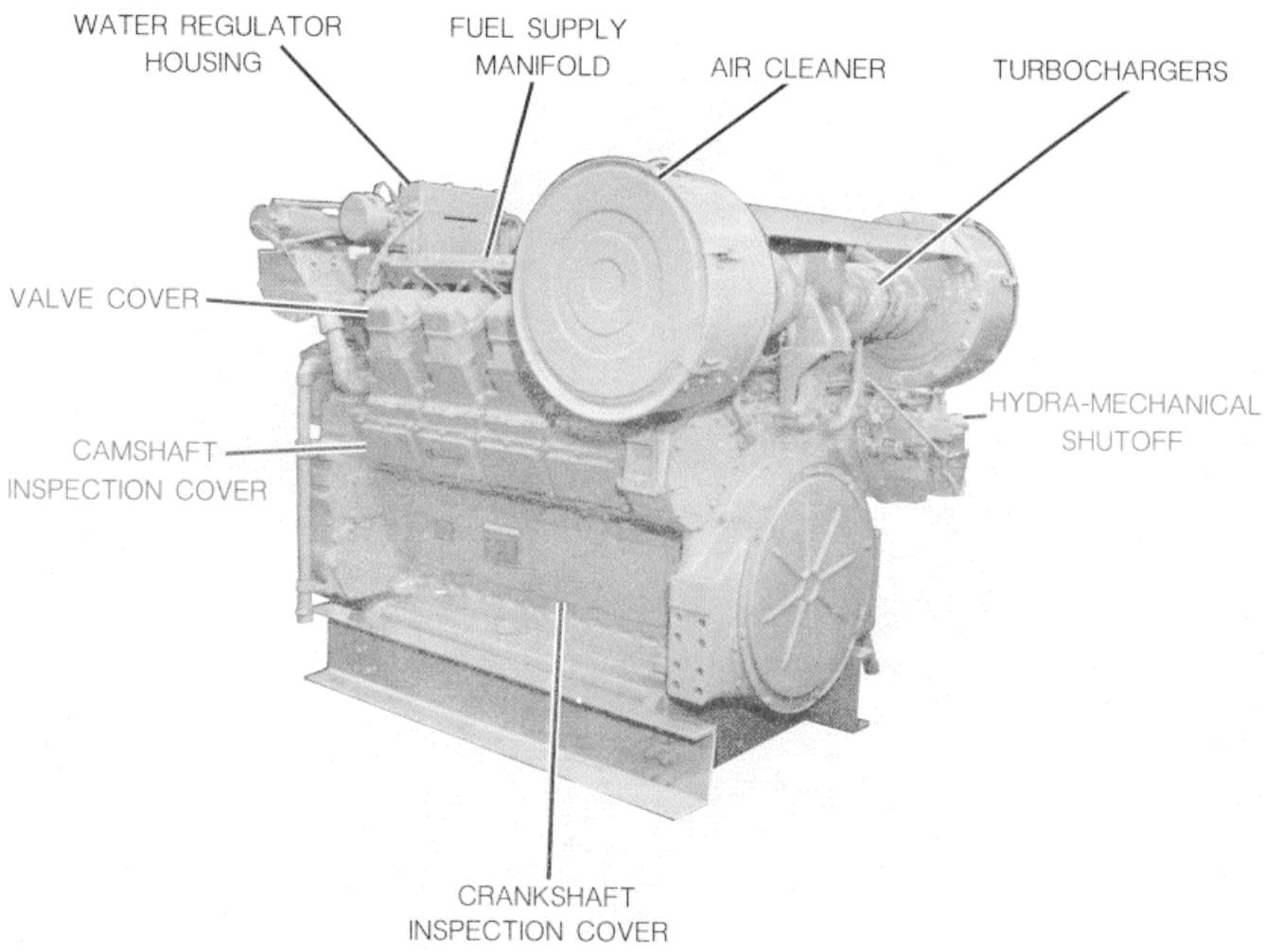
Start and operate engine in well ventilated area. If it is necessary to operate in a closed area, vent exhaust to the outside.

Operation Section



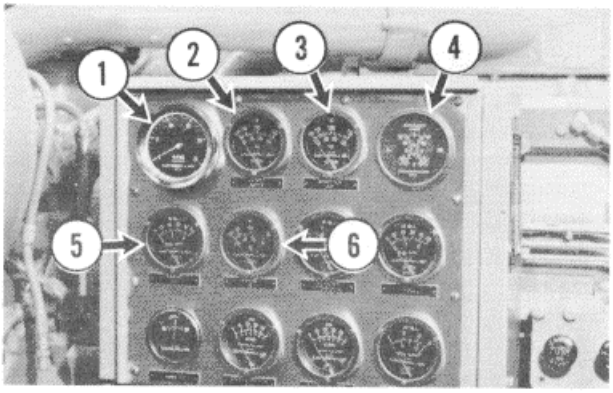
3508 INDUSTRIAL ENGINE

Model Views



3508 INDUSTRIAL ENGINE

Gauges

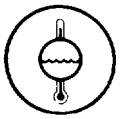




1. Tachometer - Indicates engine RPM. When the governor control lever is moved to the full speed position without load, the engine is running at high idle.

When the governor control lever is moved to the full speed position and load is applied, the engine will slow slightly to full load speed.

The engine can be operated between these two speed limits for long periods of time without shortening engine life. The high idle RPM, 1980, and the full load RPM, 1800, are stamped on the engine's Altitude Information Plate.



2. Engine Jacket Water Temperature - Indicates engine water temperature. The water temperature reading may vary according to load, but should never exceed the boiling temperature for the pressurized system being used. Engine jacket water temperature range is 800 to 100°C (175° to 210° F).

3. Inlet Air Temperature – Indicates inlet air temperature. As the inlet air temperature increases, the air expands, less fuel is burned in the cylinders, and less horsepower is developed. As a result, at full load governor position with a full load, the engine may be overloaded. Maximum inlet air temperature is 1150°C (235° F).

4. Exhaust Temperature – Indicates exhaust gas temperature. The temperature readings are taken from both the left and right banks. The two readings will vary slightly from each other. Maximum exhaust temperature is approximately 480°C (900° F).

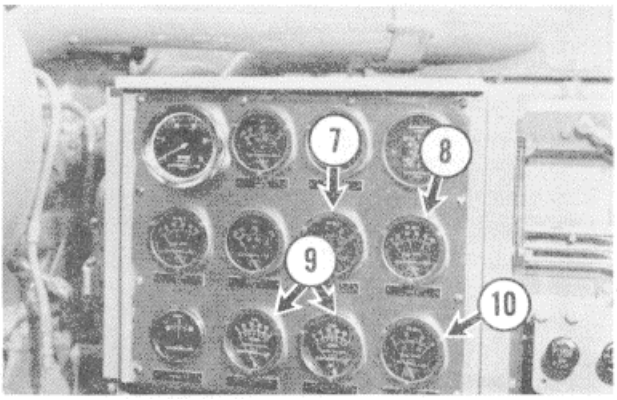


5. Engine Oil Pressure – Indicates engine oil pressure. The oil pressure reading will be greatest after starting a cold engine. Oil pressure will decrease as the engine warms while idling. As the engine speed is increased to full load speed, oil pressure will increase and stabilize. Minimum engine oil pressure is 345 kPa (50 psi), at rated speed.



6. Engine Oil Temperature - Indicates engine oil temperature. The purpose of the oil is to lubricate all moving parts inside the engine, and to cool the pistons and bearings. The oil cooler transfers the heat in the oil to the engine jacket water.

If the cooling system cannot remove the necessary heat from the water, the engine oil cannot be properly cooled. Above normal oil temperature indicates a heat problem has occurred in the lubrication and/or cooling system. A problem can occur with cylinder heads, liners, pistons or bearings. Maximum oil temperature is 110°C (2300F).



7. Oil Filter Differential Pressure - Indicates the difference of oil pressure between the inlet side (dirty side) and the outlet side (clean side) of the oil filter. As the element becomes plugged, the difference in pressure between the two sides of the element will increase. Oil filter maximum pressure differential is 105 kPa (15 psi).



8. Fuel Pressure – Indicates pressure of the filtered fuel. The fuel pressure range is 345 to 520 kPa (50 to 75 psi).



9. Air Cleaner Differential Pressure – Indicates the difference of air pressure between the inlet side (dirty side) and the engine side (clean side) of the air filter element. As the element becomes plugged, the difference in pressure between the two sides of the element will increase. Maximum air cleaner pressure differential is 762 mm (30 in.) H20.

10. Fuel Filter Differential Pressure - Indicates the difference of fuel pressure between the inlet side and the outlet side of the fuel filter elements. As the element becomes plugged, the difference in pressure between the two sides of the element will increase. Maximum fuel filter differential pressure is 105 kPa (15 psi).

Shutoff and Alarm System Components

Emergency Shutoff Controls

Emergency shutoff controls may be electrically, mechanically or hydraulically operated. Familiarize yourself with the types and locations of the shutoff controls, the conditions which cause each control to function, and the resetting procedure required to start your engine.

The operation of all electrical shutoff controls is similar. A critical operating condition actuates a switch to stop the engine. The shutoff control may require resetting before the engine can start.

The shutoff controls should be tested every 1000 hours by authorized Caterpillar dealer personnel. Every 500 hours, the Hydra-Mechanical Shutoff can be tested remotely by engine personnel.

Do not use an emergency shutoff control for a normal stopping procedure.

Always determine the cause of the shutdown, and have the necessary repairs made before restarting the engine. See the "Troubleshooting" section of this guide.

Alarm Switches

Alarm switches are set at a less critical temperature, pressure, or level limit than the shutoff controls. The purpose of the alarm switch is to warn the operator that an unsafe operating condition is starting to occur. Corrective measures must be taken to avoid possible damage to the engine.

When an alarm is activated, corrective measures must be taken before the situation becomes an emergency.

Each alarm switch is electrically connected to an indicator light, bell or horn. The alarm will continue until the condition is corrected. Then the light will turn off and the bell or horn will be silenced.

To silence the bell or horn while repairs are being made, a two-way switch and a red indicator light may be installed. The red indicator light will come on when the alarm is turned off.

The red light will stay on, to indicate that the engine is not protected, if the switch is left in the OFF position after the repairs have been made.

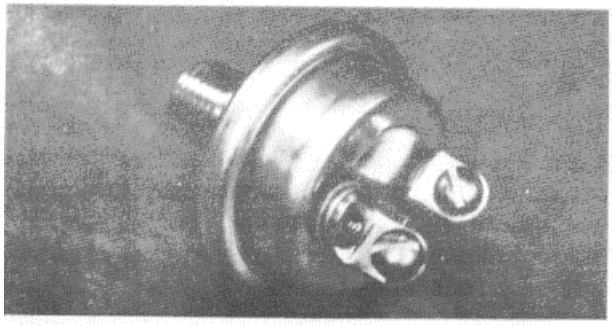
Testing Alarms

All alarms on the engine should be tested twice a year for proper operation by referring to the Service Manual or authorized Caterpillar dealer personnel.

NOTICE

During testing abnormal operating conditions must be simulated. Perform the tests correctly to prevent possible damage to the engine.

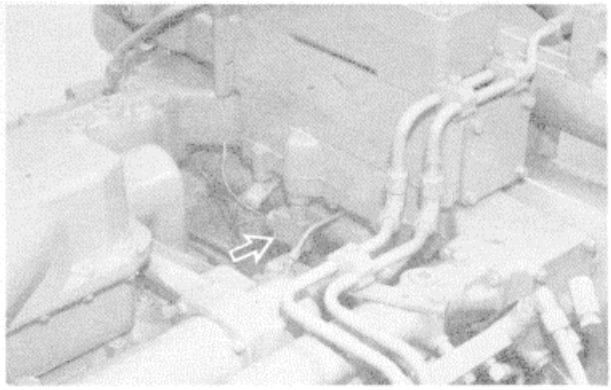
Pressure Switch



This low oil pressure switch is used in the oil system to shut the engines down when oil pressure drops below system pressure.

Shutoff and Alarm System Components

Electrical High Water Temperature Shutoff

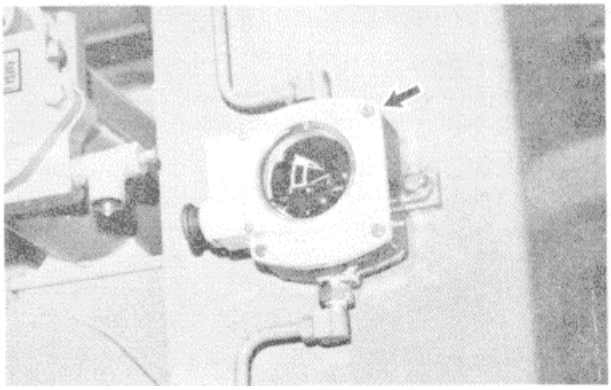


The shutoff switch is located in the water temperature regulator housing. Excessive water temperature closes the switch. No resetting procedure is required. The switch opens as the coolant cools.

NOTICE

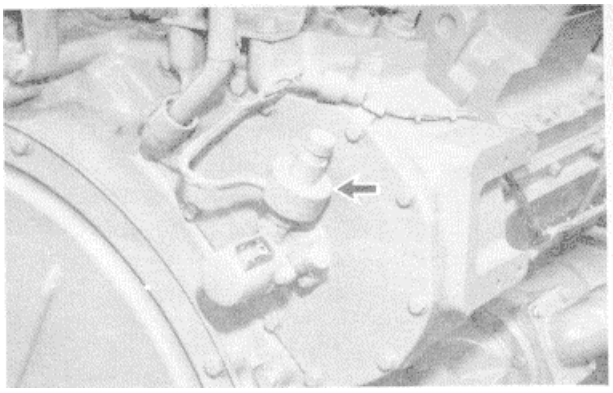
The sensing element must be submerged in the coolant to operate. The shutoff cannot actuate if the coolant level is low.

Coolant Level Alarm



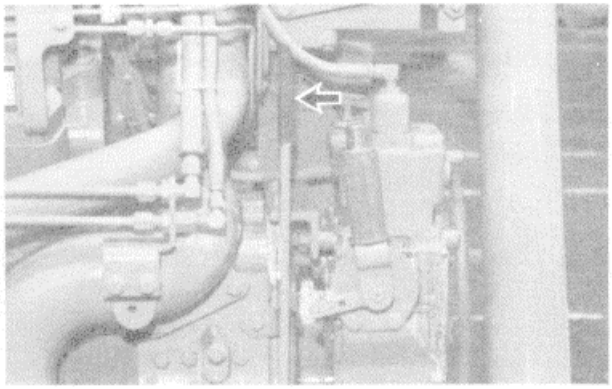
The expansion tank has a low coolant level gauge, which is used to determine when the coolant is low. When the coolant is near the LOW mark, coolant must be added to the expansion tank to avoid engine overheating or possible engine damage.

Electrical Overspeed Shutoff



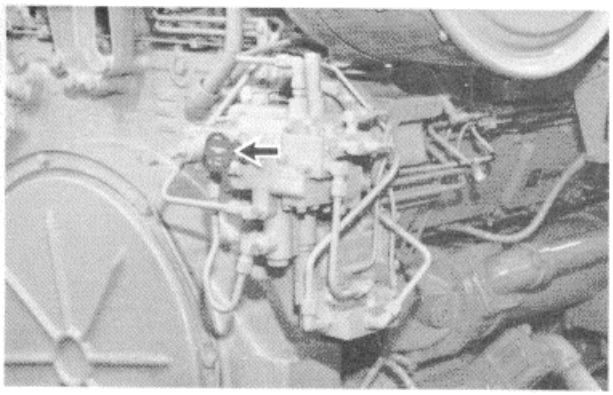
This shutoff has an overspeed switch which works through the governor shutoff solenoid and the air inlet shutoff solenoids. If the engine should overspeed, fuel and air will be cut off to stop the engine.

Manual Fuel Shutoff Lever

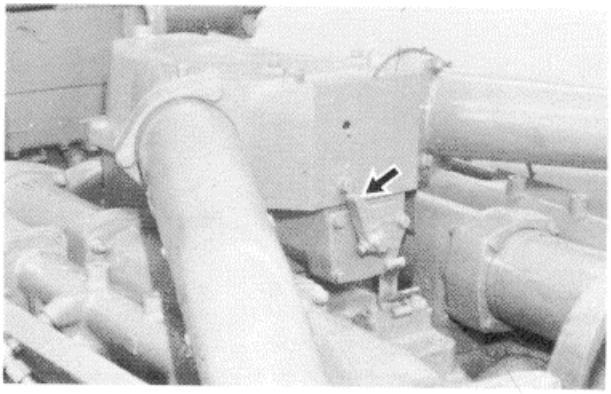


A manual shutdown lever is provided to override the governor control of the engine. This shutdown will only move the fuel control linkage to the fuel-off position. It does not shut off the air inlet.

Hydra-Mechanical Shutoff (HMSO)



The HMSO will automatically stop the engine if there is an overspeed, low oil pressure or high coolant temperature. The fuel rack and the air inlet shutoff will activate when the engine overspeeds.

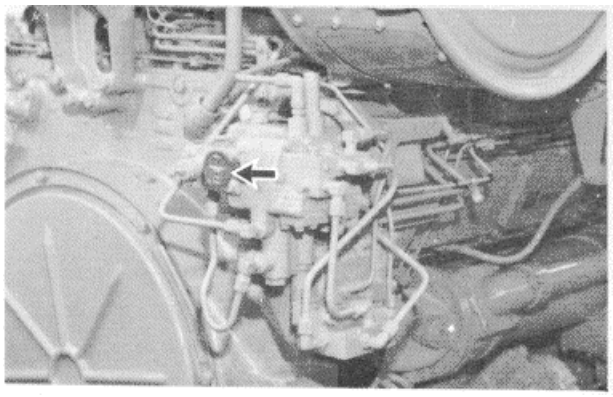


The fuel rack will reset automatically, but the air inlet shutoff must be reset to the RUN position manually.

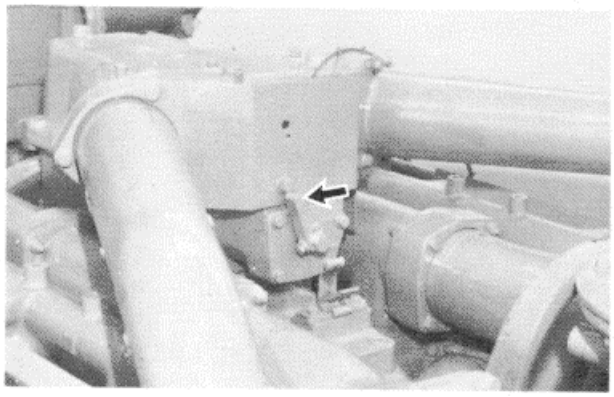
The HMSO uses lubrication oil from the engine. It has an oil pump that supplies pressure to the shutoff system. There is a sump in the valve which must be refilled, if it was drained, before starting the engine.

The HMSO can also be used as an emergency manual shutoff.

Test the operation of the HMSO every 500 hours. Use the following procedure.



1. Pull out the red emergency knob while observing the air inlet shutoff valve.



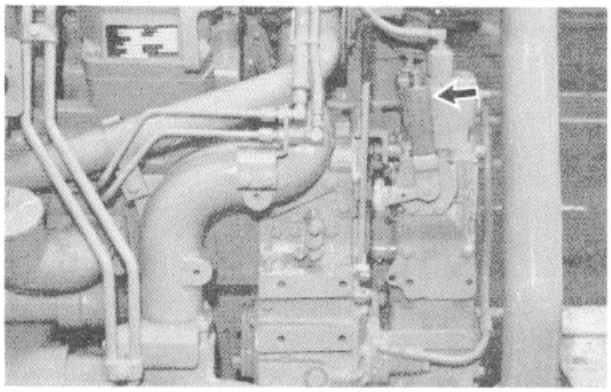
2. The air inlet shutoff knob must move to the STOP position and shut off the air supply to the engine. The engine must stop.

3. Push in the red emergency knob to reset the HMSO.

4. Move the air shutoff knob to the RUN position to open the air inlet valve.

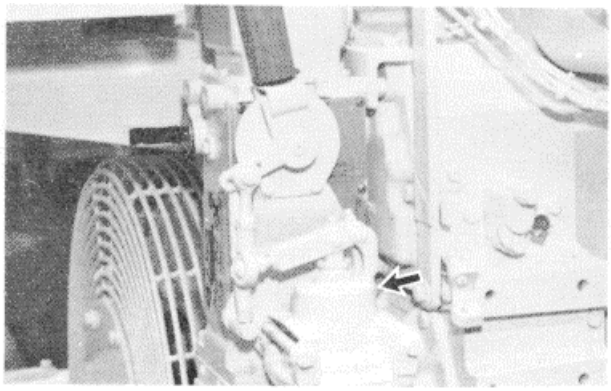
Consult your Caterpillar dealer if the HMSO or the air inlet shutoff did not operate correctly.

Mechanical Governor Control



The mechanical governor control is used to control engine speed remotely. It will manually move the governor speed control lever.

Air Actuated and Hydra-Mechanical Governor Controls



The dipstick gauge shows the amount of oil in the governor. This governor is equipped with speed droop, however, it must be adjusted inside the governor. See the Service Manual for adjusting speed droop

The air actuated governor control is attached directly to the UG8L Governor. This is connected to the governor speed control lever, used to control engine speed.

3161 Lever-Type Governor (3516 Industrial Engines)

The 3161 lever-type governor has an air-fuel ratio control to limit smoke and provides pneumatic speed setting. The 3161 uses engine oil for lubrication and actuation.

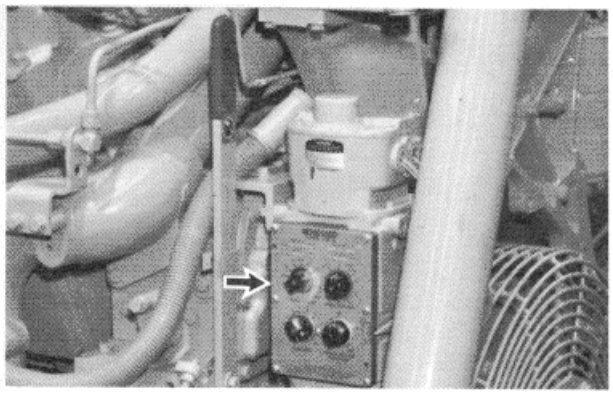
3161 Dial-Type Governor (3516 Gen. Set Engines)

The 3161 dial-type governor has speed setting control and external droop adjustment but will not have a load limit control. It will have a 24-32 volt DC permanent magnet, synchronizing motor for remote control of engine speed. This governor will allow paralleling with other hydra-mechanical governors or electronic governors.

EG3P and EG1OP Actuator

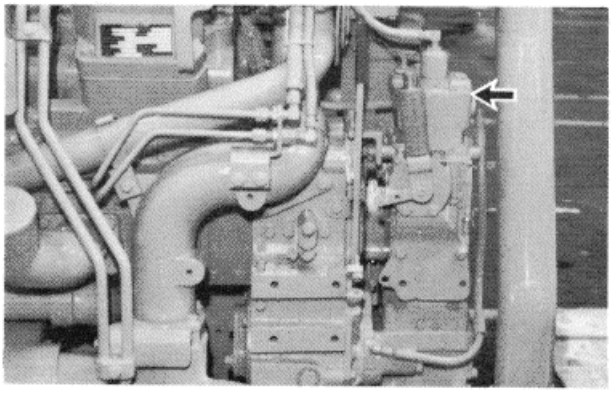
The EG3P and EG1OP Actuator controls the fuel rack linkage with hydraulic power using the engine oil supply.

UG8D Governor (3508/3512 Gen. Set Engines)



The UG8D Governor will have, as standard equipment, either the 24V to 32V shutdown solenoid to be used with electric shutoffs or the hydra-mechanical shutoff system. The UG8D Governor has no smoke limiter but does have the usual adjustments for droop, load limit and speed override.

UG8L Governor (3508/3512 Industrial Engines)



The UG8L Governors have 10% regulation and a boost-acutated smoke limiter. The UG8L Governor also has either a hydraulic/pneumatic shutoff cylinder or an electric shutoff solenoid that moves the fuel control linkage to the fuel-off position. The hydraulic/pneumatic cylinder is normally for use with the hydra-mechanical protection device. This governor is equipped with speed droop, however, it must be adjusted inside the governor. See Service Manual for adjusting speed droop.

Woodward 2301 Electronic Governors (Gen. Set Engines Only)

The 2301 Nonparallel Control gives exact engine speed control. The system measures engine speed constantly and makes necessary corrections to the engine fuel setting through an actuator connected to the fuel system.

The 2301 Parallel Control has two functions: Exact engine speed and kilowatt load sharing. The system measures engine speed constantly and makes necessary corrections to the engine fuel setting through an actuator connected to the fuel system.

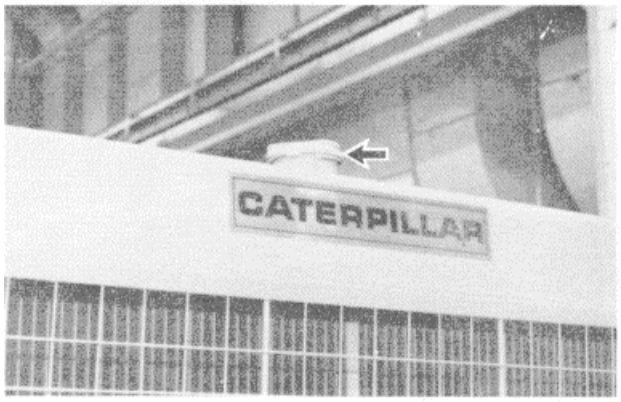
The actuator is connected to the fuel system by linkage. It changes the electrical input from the control box to mechanical output that changes the engine fuel setting. For example, if the engine speed was more than the speed setting, the control box will decrease fuel to the engine.

Before Starting the Engine

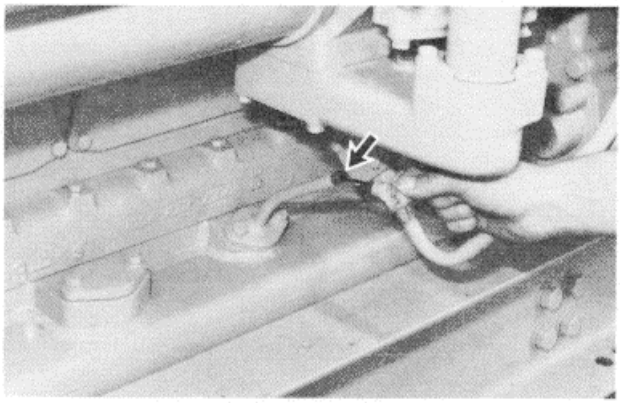
Perform required periodic maintenance before starting the engine. Make a walk-around inspection of the installation. It only takes a few minutes to make minor corrections. This can prevent major repairs at a later date.

NOTICE

All valves in fuel return line must be open before and during engine operation to prevent high fuel pressure. High fuel pressure may cause filter housing failure or other damage.

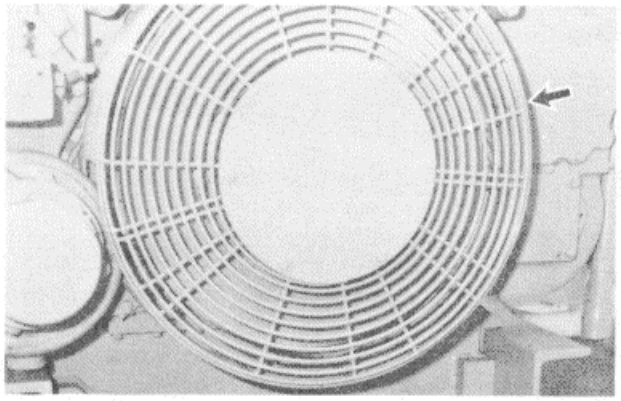


1. Inspect the coolant level. The level should be to the bottom of the filler neck. Operate the engine until it is at operating temperature. Add coolant if necessary. Install filler cap.

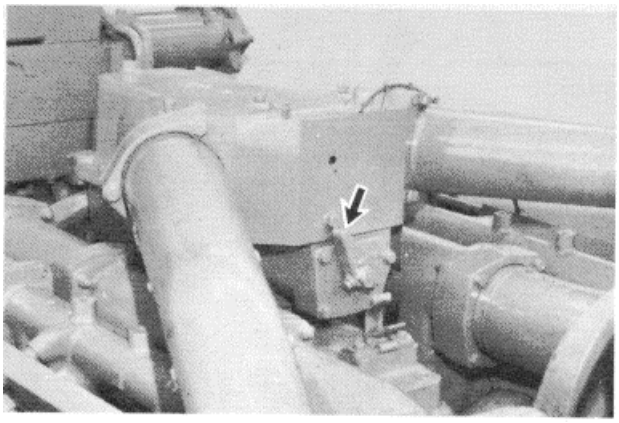


2. Measure the crankcase oil level. Check dipstick for correct level. The oil level must be between the FULL and the ADD marks on the ENGINE STOPPED side of the dipstick. Add oil if necessary.

3. Disconnect any battery chargers that are not protected against the starter current drain.



4. All guards must be in place. Repair or replace all guards that are damaged or missing.



5. Make sure air inlet shutoff valve is in the RUN position.

6. Make sure fuel lines are properly clamped and tight. Check for loose fittings or leaks.

Starting the Engine

Direct Electric Starting

NOTICE

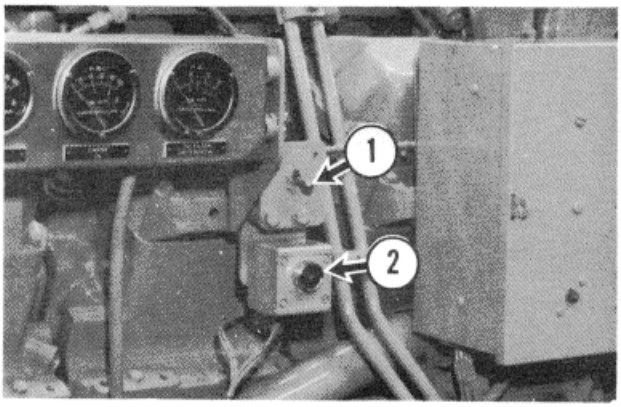
Do not engage starter when flywheel is turning.

Do not start engine under load.

Above 0 ° C (32 ° F)

1. Place the transmission in NEUTRAL. Open the main electrical circuit breaker on generator sets.

2. Move the throttle to low idle engine speed.



3. Turn the starter switch to START or move toggle switch ① to the ON position, press button ② to START. If the engine does not start after 10 seconds, move the fuel shutoff lever to shut off the fuel; then continue to crank for 10 seconds. This will clear the cylinders of fuel.

4. As soon as the engine starts, allow the engine to idle for three to five minutes, or until the water temperature gauge has begun to rise.

5. Do not apply load to the engine or increase engine speed until the oil pressure gauge indicates normal.

NOTICE

If oil pressure does not raise within 15 seconds after the engine starts, stop the engine and make necessary corrections.

6. Operate the engine at low load until all systems reach operating temperatures. Check all gauges during the warmup period.

Below 0 ° C (32 ° F)

⚠ WARNING

Ether is poisonous and flammable.

Do not store replacement cylinders in living areas.

Do not smoke while changing cylinders.

Use only in well ventilated areas.

Use with care to avoid fires.

Avoid breathing of vapors or repeated contact with skin.

Do not puncture or burn cylinders.

Discard cylinders in a safe place.

Keep ether container away from heat, sparks, open flame, or open sunlight. It may explode.

If an aerosol container is used, follow instructions on the container.

Do not store or use at temperatures above 93° C (200°F).

Use ether sparingly while cranking the engine.

NOTICE

If starting fluid is necessary, spray starting fluid into the air cleaner inlet. Spray starting fluid only while cranking the engine. Otherwise, damage to engine can result.

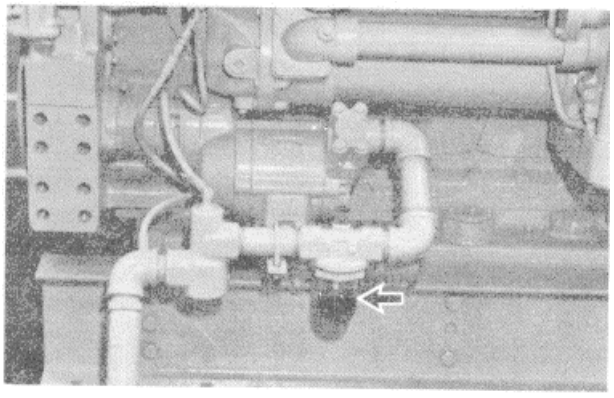
If the engine fails to start within 30 seconds, release the starter switch or button and wait two minutes to allow the starting motor to cool before using it again.

Heating of jacket water and crankcase oil, use of starting aid fluid and/or use of extra battery capacity may be required to assist starting in cold temperatures.

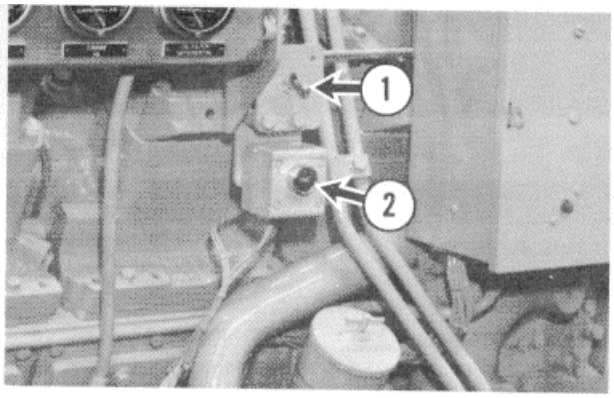
Air Starting

1. Open and close the bleed valve on the bottom of the air tank to drain condensation and oil carryover.

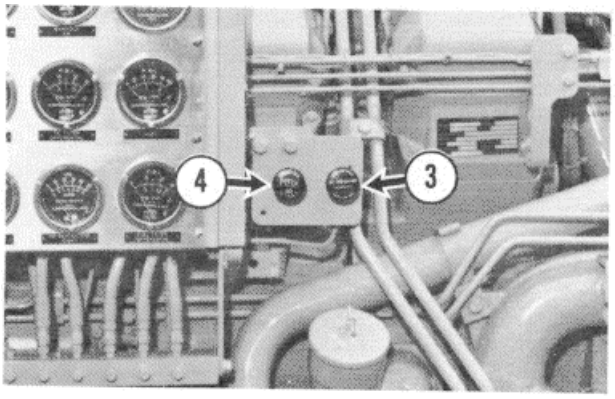
2. Check the air supply pressure. The air starter must have 690 kPa (100 psi) to operate properly.



3. Check the oil level in the air lubricator. Keep jar at least half full. Add oil if necessary. See the Lubrication and Maintenance Chart for the proper oil to use.



4. Move toggle switch ① to the ON position and push the air control valve ② in to crank the engine. As soon as the engine starts, release the valve; or



push in the oil pressure lockout knob ③ and hold. Push air control valve knob ④ in to crank the engine. As soon as the engine starts, release the air control valve knob ④ and the oil pressure lockout knob ③.

Starting From External Electrical Source

⚠ WARNING

Always wear protective glasses when working with batteries.

Prevent sparks near the batteries. They could cause vapors to explode. Do not allow cable ends to contact each other or the engine.

Batteries give off flammable fumes that can explode.

Electrolyte is an acid and can cause personal injury if it contacts skin or eyes.

NOTICE

Before attaching the booster cables, move toggle switch at the engine to the OFF position.

When using booster cables, be sure to connect in parallel: NEGATIVE (-) to NEGATIVE (-) and POSITIVE (+) to POSITIVE (+).

Do not allow the free end of booster cables to touch the engine. This helps avoid sparks.

This engine has a 24 or 32 Volt starting system. Use only equal voltage for boost starting. The use of a welder or higher voltage will damage the electrical system.

Starting the Engine

Connect one end of cable to the POSITIVE (+) (ungrounded) terminal of the battery of the engine. Connect the other end to the POSITIVE (+) terminal of the power source.

Connect one end of the second cable to the NEGATIVE (-) terminal of the power source. Connect the other end to the starter ground terminal of the engine.

Start the engine.

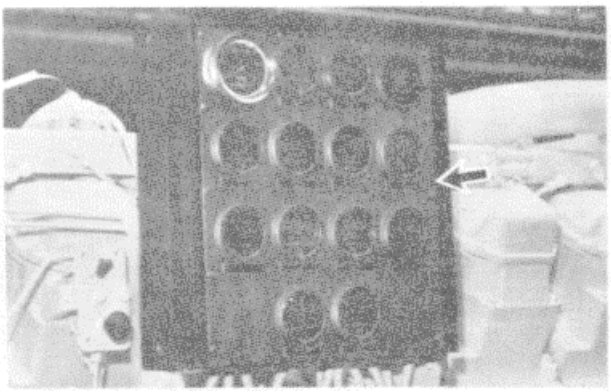
Disconnect the cable from the starter ground terminal first. Disconnect the other end from the NEGATIVE (-) terminal of the power source. Disconnect the cable from the POSITIVE (+) terminal of the battery. Disconnect the other end from the POSITIVE (+) terminal of the power source.

After Starting the Engine

NOTICE

If oil pressure does not raise within 15 seconds after the engine starts, stop the engine and make necessary corrections.

1. Do not apply a load to the engine, or increase the speed, until oil pressure gauge indicates normal. Oil pressure should raise to normal within 15 seconds after the engine starts.



2. Operate the engine at low load until all systems reach operating temperatures. Check all gauges during the warmup period.

Stopping the Engine

NOTICE

Stopping the engine immediately after it has been working under load, can result in overheating and accelerated wear of the engine components. Follow the stopping procedure, outlined below, to allow the engine to cool. Excessive temperatures in the turbocharger centerhousing will cause oil coking problems.

1. Reduce engine speed to low idle.

2. Shift into NEUTRAL. On generators, open the main electrical circuit breaker.

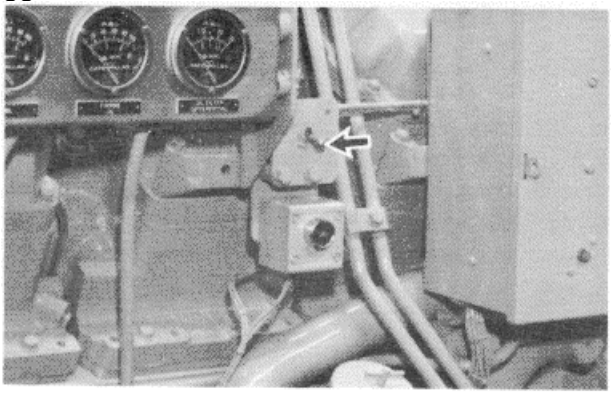
3. Increase engine speed to no more than half engine speed. Idle for at least five minutes to cool the engine.

4. Reduce engine speed to low idle.

5. Check the crankcase oil level while the engine is idling. Maintain the oil level between the ADD and FULL marks on the CHECK WITH ENGINE RUNNING side of the dipstick.

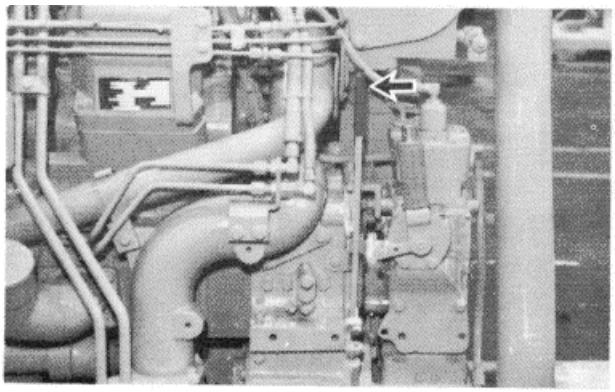
6. The engine may be stopped by using one of the following engine mounted controls:

Toggle Switch



Move toggle switch to the OFF position.

Manual Fuel Shutoff Lever



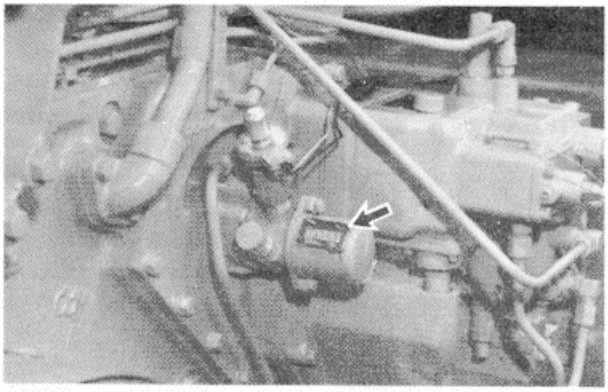
Pull the red handle lever out to shut off the fuel supply to the engine.

After Stopping the Engine

1. Fill the fuel tank.

2. If below freezing temperatures are expected, allow the engine jacket water expansion tank to cool; then check the coolant for proper antifreeze protection. Add permanent-type antifreeze if required. See the Operation and Maintenance Procedures.

3. Repair any leaks, perform minor adjustments, tighten loose bolts, etc.



4. Observe the service meter reading. Perform periodic maintenance as instructed in the Lubrication & Maintenance Chart.

5. Perform the required periodic maintenance on all other equipment as outlined in the equipment manufacturer's instructions.

Lifting Engine and Attachment

NOTICE

When it is necessary to remove a component on an angle, remember that the capacity of an eyebolt is less as the angle between the supporting members and the object becomes less than 900. Eyebolts and brackets should never be bent and should only have stress in tension.

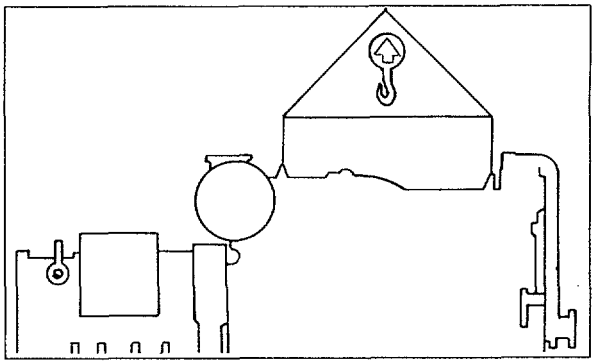
Use a hoist to remove heavy components. Lift the engine by using an adjustable lifting beam. All supporting members (chains and cables) should be parallel to each other, and as near perpendicular as possible to the top of the object being lifted.

Some removals require the use of lifting fixtures to obtain proper balance and to provide safe handling.

Lifting eyes are designed for the arrangement as sold. Alterations to lifting eyes and/or arrangement weight make the lifting devices obsolete.

If you make alterations, you are responsible for providing adequate lifting devices.

Engine With or Without Generator



To remove the engine only or the engine and generator together, use the two lifting eyes on the engine.

Engine Storage

If the engine is not started for several weeks, the lubricating oil drains from the cylinder walls and piston rings. This lack of oil permits the piston rings to rust. This causes metal-to-metal contact between the piston rings, the pistons and the cylinder liners when the engine is started. This metal-to-metal contact will result in shorter engine life. To prevent excessive engine wear:

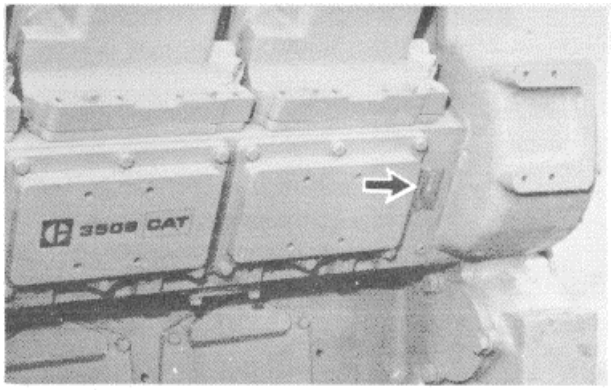
1. Be sure all lubrication points mentioned in the Lubrication and Maintenance Chart are serviced.

2. If freezing temperatures can be expected, check the cooling system for adequate protection against freezing. A 50-50 solution of permanent-type antifreeze and approved water treated with the proper amount of coolant conditioner, will give protection below -29°C (-20°F).

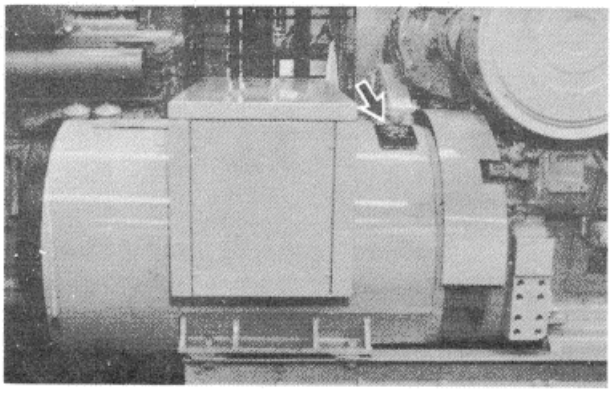
If it will be impossible to start the engine every week, consult your Caterpillar dealer for instructions to prepare your engine for longer storage periods.

Maintenance Section

Serial Number Locations



Engine



Generator

Maintenance Recommendations

Cooling System

⚠ WARNING

Check coolant only when engine is stopped and filler cap is cool enough to touch. Remove filler cap slowly to avoid steam. Allow coolant and components to cool before draining.

NOTICE

Never add coolant to an overheated engine. Allow the engine to cool first.

Check the specific gravity of the antifreeze solution frequently in cold weather to ensure adequate protection.

If the engine is to be stored in, or shipped to, an area with below freezing temperatures, the cooling system must be protected against freezing to the lowest expected ambient temperature.

All water is corrosive at engine operating temperature. The cooling system should be protected with a 3% to 6% concentration of cooling system conditioner at all times regard- less of the concentration of antifreeze, or by using Caterpillar Coolant Conditioner Elements.

Do not use Caterpillar Cooling System Conditioner or Coolant Conditioner Elements with Dowtherm 209 Full-Fill coolant. Follow the instructions provided with the Dowtherm 209 Full-Fill coolant.

Coolant should be drained and replaced "Every 2000 Service Hours or 1 Year." However, when cooling system conditioner additions are made every 250 service hours as recommended, the drain period can be extended to "4000 Service Hours or 2 Years."

A 3% to 6% concentration of Caterpillar Cooling System Conditioner can be maintained by adding .50 liter (1 pint) for each 15 liters (4 gallons) of coolant used.

Premix antifreeze solution to provide protection to the lowest expected ambient temperature. Pure undiluted antifreeze will freeze at -23°C (-10°F).

Acceptable water for use in the ethylene glycol-type antifreeze and water mixture is shown on the chart below.

Acceptable Water		
Water Content	**50% or More Antifreeze**	**Less Than 50% Antifreeze**
Chlorides	100 ppm or less	50 ppm or less
Sulfates	100 ppm or less	50 ppm or less
Hardness as $CaCo_3$	200 ppm or less	100 ppm or less
Dissolved Solids	500 ppm or less	250 ppm or less
pH	6.5 or higher	6.5 or higher

ppm = parts per million

Use clean water that is low in scale forming mineral. Do not use softened water. Add Caterpillar Cooling System Conditioner, Caterpillar Coolant Conditioner Elements, or equivalent, to the water to provide corrosion protection.

Filling at over 20 liters (5 U.S. gallons) per minute can cause air pockets in the cooling system.

After draining and refilling the cooling system, run the engine with the filler cap off until the coolant reaches normal operating temperature and the coolant level stabilizes. Add coolant as necessary to fill the system to the proper level.

Never use both the liquid cooling system conditioner and coolant conditioner elements at the same time.

Operate with a thermostat in the cooling system all year-round. Cooling system problems can arise without a thermostat.

Fuel System

NOTICE

Fill the fuel tank at the end of each day of operation to drive out moist air and to prevent condensation. Do not fill the tank to the top. The fuel expands as it gets warm and may overflow.

Do not fill fuel filters with fuel before installing them. Contaminated fuel will cause accelerated wear to fuel system parts.

After changing fuel filters, open fuel supply and return valves that were closed. The fuel system will bleed air back through the return.

Drain water and sediment from any fuel storage tank weekly, and before the tank is refilled. This will help prevent water or sediment from being pumped from the storage tank into the engine fuel tank.

Use only fuel as recommended in the "Fuel, Coolant and Lubricant Specifications" section of this guide.

Air Intake System

As the air cleaner elements become plugged, the difference of air pressure between the inlet side (dirty side) and the engine side (clean side) will increase. Service the air cleaners when the air cleaner restriction gauge registers 762 mm (30 inches) H_20.

The primary element can be cleaned up to six times before replacement. The element, when cleaned, should be thoroughly checked for rips or tears in the filter material. Replace the primary element every year even though it has not been cleaned six times.

Scheduled Oil Sampling

Use scheduled oil sampling to monitor engine and maintenance requirements. Each oil sample should be taken when the oil is hot and well mixed, to ensure the sample is representative of the oil in the compartment.

S.O.S. Interval Chart	
Compartment	**Interval**
Engine Crankcase	At Oil Change

Consult your Caterpillar dealer for complete information and assistance in establishing a scheduled oil sampling program for your engine.

Electrical System

⚠ WARNING

Prevent sparks near the batteries. They could cause vapors to explode. Do not allow cable ends to contact each other or the engine.

NOTICE

When boost starting an engine, follow the instructions in "Starting the Engine" in the "Operation Section" of flywheel to properly start the engine.

This engine has a 24 or 32 volt starting system. Use only equal voltage for boost starting. The use of a welder or higher voltage will damage the electrical system.

General

NOTICE

Accumulated grease and oil on an engine or deck is a fire hazard. Remove this debris with steam cleaning or high pressure water, at least every 1000 hours or each time any significant quantity of oil is spilled on an engine.

Wipe all fittings, caps and plugs before servicing.

Keep a close watch for leaks. If leaking is observed, find and correct the source of the leak.

Check the fluid levels more frequently than the recommended periods if leaking is suspected or observed.

Fuel, Coolant and Lubricant Specifications

Fuel Specifications

Types of Fuel

Caterpillar Diesel Engines have the ability to burn a wide variety of fuels. These fuels are divided into two general groups, preferred and permissible.

The preferred fuels provide maximum engine service life and performance. They are distillate fuels. They are commonly called fuel oil, furnace oil, diesel fuel, gas oil, or kerosene.

The permissible fuels are crude oils or blended fuels. Use of these fuels can result in higher maintenance costs and reduced engine service life.

See "Fuels for Caterpillar Diesel Engines," Form SEHS7067, for a detailed summary of preferred and permissible fuels and their specifications.

Cetane Requirement

The minimum fuel cetane number recommended for the engine is 40.

Fuel Cloud Point

Fuel waxing can plug the fuel filters in cold weather. The fuel cloud point must be below the temperature of the surrounding air to prevent filter waxing and power loss. Fuel heating attachments are available from your Caterpillar dealer to minimize fuel filter waxing.

Fuel Sulfur Content

The percent of sulfur in the fuel will affect the engine oil recommendations. If the fuel has over 0.5% sulfur content, the CD engine oil must have a TBN of 20 times the percentage of fuel sulfur. Your oil supplier should be able to furnish the correct oils.

Engine Coolant Specifications

Use a mixture of approved fill water and antifreeze, and Cooling System Conditioner.

"Know Your Cooling System" Form SEBD0518, can provide more detailed specifications.

Fill Water

Always add conditioner to water. Never use plain water only.
Acceptable water for use in the ethylene glycol-type antifreeze and water mixture is shown on the chart below:

Acceptable Water		
Water Content	**50% or More Antifreeze**	**Less Than 50% Antifreeze**
chlorides	100 ppm or less	50 ppm or less
Sulfates	100 ppm or less	50 ppm or less
Hardness as CaCo3	200 ppm or less	100 ppm or less
Dissolved Solids	500 ppm or less	250 ppm or less
pH	6.5 or higher	6.5 or higher

ppm = parts per million

Antifreeze

Use ethylene glycol-type antifreeze. Use the correct amount to provide freeze protection to the lowest expected operating environment.

Conditioner

Use Caterpillar Cooling System Conditioner or equivalent. Follow the instructions on the container.

On a new or reconditioned engine add 1 liter (1 quart) of Caterpillar Cooling System Conditioner, or equivalent, for each 30 liters (8 U.S. gallons) so that the cooling system will have a 3%/o to 6% concentration of conditioner.

If the engine is not equipped with spin-on Coolant Conditioner Elements, add .50 liter (1 pint) of Caterpillar Cooling System Conditioner for each 15 liters (4 U.S gallons) of coolant used to maintain the 3% to 6%.

Lubricant Specifications

The abbreviations listed below, follow S.A.E. J754 nomenclature. The classifications follow S.A.E. J183 classifications. The MIL specifications are U.S.A. Military Specifications. These definitions will be of assistance in purchasing lubricants. The specific classifications for this engine are found on the "Recommended Lubricants" Chart.

Engine Oils (CD)

Use oils that meet Engine Service Classification CD or MIL-L-2104C.

Consult the "EMA Lubricating Oils Data Book," Form SEBU5939, for a listing of CD oil brands.

NOTICE

The percentage of sulfur in the fuel will affect the engine oil recommendations. If the fuel has over 0.5% sulfur content, the CD engine oil must have a TBN of 20 times the percentage of fuel sulfur. Your oil supplier should be able to furnish the correct oils.

Air Lubricator Oil (CD)

Use SAE10 or 10W nondetergent oil for temperatures above 0°C (32°F). Use diesel fuel for temperatures below 0°C (32°F). NOTE: Change oil and filter element after first 50 hours of operation for new or reconditioned engines.

Lubricating Grease (MPG)

Use Multipurpose-type Grease (MPG). Multipurpose-type grease which contains 3% to 5% molybdenum disulfide is preferred. NLGI No. 2 Grade is suitable for most temperatures. Use NLGI No. 1 or No. 0 Grade for extremely low temperatures.

Refill Capacities-
Approximate

Compartment or System	Liters	U.S. Gallons	Imperial Gallons
ENGINE CRANKCASE			
3508 Industrial	104 227	27 59	22 42
3512 Industrial	152 312 613	40 81 162	33 68 134
3516 Industrial	204 401 842	53 106 219	44 88 182
COOLING SYSTEM			
3508 Engine Only 3512 Engine Only 3516 Engine Only	114 148 205	30 39 54	25 33 45

Engine Specifications

3508 Engines

Engine Specifications	
Operating Range (rpm) 68Z1-UP, 70Z1-UP	900-1300
Operating Range (rpm) 95Y1-UP, 23Z1-UP	1500-1800
Number of Cylinders	8
Stroke	190 mm (7.5 in.)
Firing Order	1-2-7-3-4-5-6-8
Rotation (viewed from flywheel)	Counterclockwise

3512 Engines

Engine Specifications	
Operating Range (rpm) 65Z1-UP, 67Z1-UP	900-1300
Operating Range (rpm) 49Y1-UP, 24Z1-UP	1500-1800
Number of Cylinders	12
Stroke	190 mm (7.5 in.)
Firing Order	1-12-9-4-5-8- 11-2-3-10-7-6
Rotation (viewed from flywheel)	Counterclockwise

3516 Engines

Engine Specifications	
Operating Range (rpm) 71Z1-UP, 73Z1-UP	900-1300
Operating Range (rpm) 25Z1-UP, 27Z1-UP	1500-1800
Number of Cylinders	16
Stroke	190 mm (7.5 in.)
Firing Order	1-2-5-6-3-4-9-10- 15-16-11-12-13-14-7-8
Rotation (viewed from flywheel)	Counterclockwise

Recommended Lubricant Viscosities

Recommended Lubricant Viscosities
For Use At Outside Temperatures From —30°C (—22°F) to +50°C (+122°F)*

Outside Temperature	**°C**	—30	—20	—10	0	+10	+20	+30	+ 40	+ 50
	°F	—22	— 4	+14	+32	+50	+68	+86	+104	+122
Engine Crankcase **CD**			SAE 5W-20							
			SAE 10W							
			SAE 10W-30							
				SAE 15W-40						
					SAE 30					
						SAE 40				
Outside Temperature	**°C**	—30	—20	—10	0	+10	+20	+30	+ 40	+ 50
	°F	—22	— 4	+14	+32	+50	+68	+86	+104	+122

*When operating below —30°C (—22°F) refer to the Cold Weather Operation Guide, Form SEBU5338, available from your Caterpillar dealer.

Lubrication and Maintenance Chart

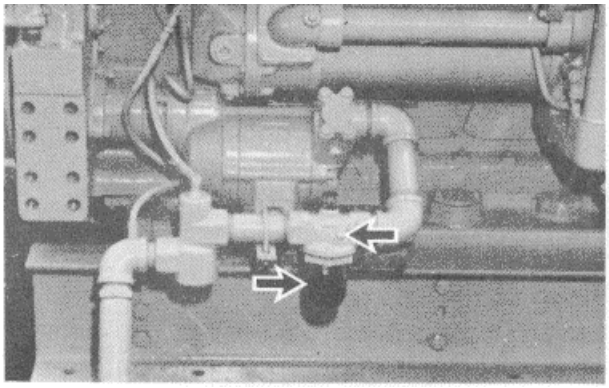
Item	Service	Lube.	Page
When Required			
Air Starter	Fill motor air lubricator and adjust oiler feed.	CD	38
Every 10 Service Hours or Daily			
Walk-Around Inspection	Inspect engine.		39
Clutch Throwout Collar and Engagement Shaft Bearings	Check clutch adjustment and lubricate fittings.	MPG	47
Cooling System	Check coolant level.		48
Woodward UG8L Governor	Measure oil level.		49
Engine Crankcase	Measure oil level.	CD	49
Fuel Tank	Drain water and sediment.		50
Every 50 Service Hours or Weekly			
Zinc Rods	Inspect and replace rods if necessary.		51
Batteries	Check electrolyte level.		52
Every 100 Service Hours or 2 Weeks			
Clutch Bearing	Lubricate fitting.	MPG	53
Every 250 Service Hours or Monthly			
Alternator Belts	Inspect - replace and/or adjust.		54
Fan Pulley Bearing	Lubricate fitting.	MPG	55
Cooling System	Coolant conditioner.		55
Engine Crankcase 3508 Engines -104 liter (27 gal.) 3512 Engines -152 liter (40 gal.) 3516 Engines -204 liter (53 gal.)	Change oil and filters. The percent of sulfur in the fuel will affect the engine oil recommendations. If the fuel has over 0.5% sulfur content, the CD engine oil must have a TBN of 20 times the percentage of fuel sulfur. Your oil supplier should be able to furnish the correct oils.	 CD CD CD	 56 56 56

Item	Service	Lube.	Page
Every 500 Service Hours or 3 Months			
Emergency Shutoff Controls	Test for proper operation.		59
Engine Crankcase 3508 Engines - 227 liter (59 gal.)	Change oil and filters. See fuel sulfur note under Every 250 Service Hours or Monthly.	**CD**	59
3512 Engines - 312 liter (81 gal.)		**CD**	59
3516 Engines - 401 liter (106 gal.)		**CD**	59
Every 1000 Service Hours or 6 Months			
Shutoff Controls	Check for proper operation.		60
Woodward UG8L Governor	Change oil.		60
Governor Air Actuator	Lubricate fittings.	**MPG**	64
Engine Crankcase Breathers	Clean.		64
Engine Crankcase 3512 Engines - 613 liter (162 gal.)	Change oil and filters. See fuel sulfur note under Every 250 Service Hours or Monthly.	**CD**	65
3516 Engines - 842 liter (219 gal.)		**CD**	65
Every 2000 Service Hours or 1 Year			
Engine Valve Lash	Adjust if necessary. Inspect valve rotators.		66
Cooling System	Change coolant.		66

When Required

Air Starter

Filling Air Lubricator



NOTICE

Never allow the air lubricator jar to become empty. The starting motor will be damaged by **lack of** proper lubrication.

The vanes of the starting motor are lubricated with a fine oil mist from the motor oiler while the motor is operating.

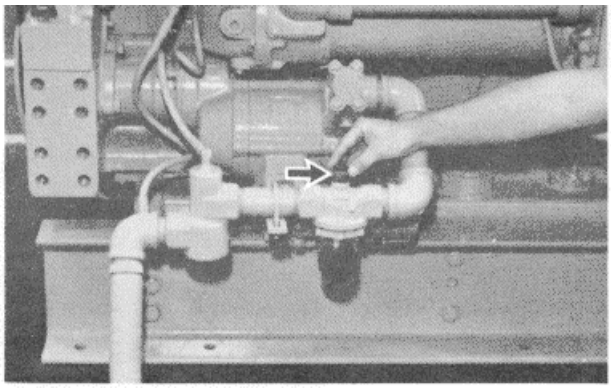
When the air lubricator jar becomes half empty**,** remove the oil filler plug and fill the jar with clean oil.

Adjusting Oiler Feed Adjust the oiler to release four drops of oil per minute into the starting motor air stream.

1. Be sure the fuel supply line valve to the engine is closed.

2. Crank the engine.

3. Count the drops of oil released per minute into the air stream.



a. Turn the valve needle (the uppermost knob is the oiler) counterclockwise to increase the number of drops per minute.

b. Turn the valve needle clockwise to decrease the number of drops per minute.

Walk-Around Inspection

Inspect Engine

1. Make sure lines are properly clamped and tight. Check for loose fittings or leaks.

2. All guards must be in place. Repair or replace missing or damaged guards.

3. Disconnect any battery chargers that are not protected against the starter current drain. Check condition of batteries and the level of electrolyte.

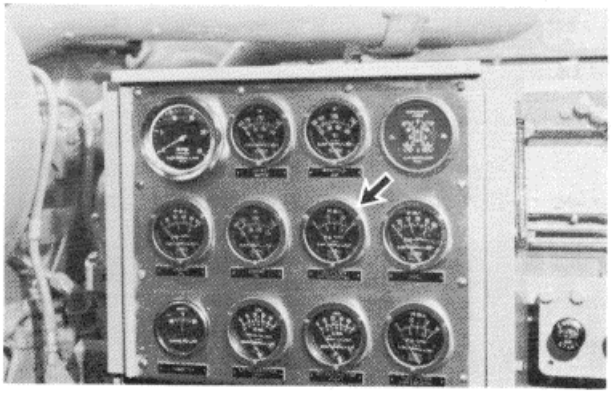
4. Check for coolant, fuel or oil leaks on or below engine.

5. Check condition of all belts. Replace if necessary.

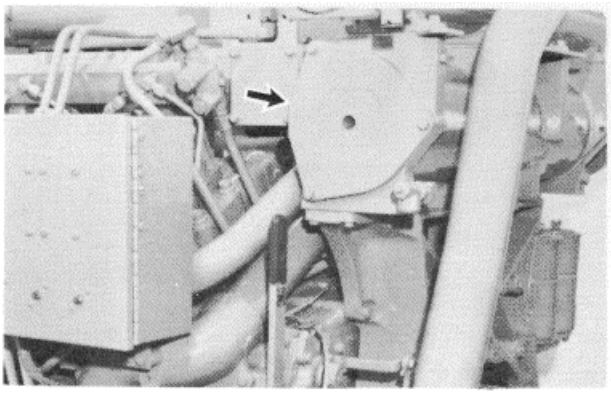
6. Check condition of gauges. Replace if cracked or not calibrated to "O."

7. While operating, frequently observe the engine oil pressure gauge, the fuel pressure gauge, the fuel filter differential pressure gauges, the oil filter differential pressure gauges, and the air cleaner differential pressure gauges.

Engine Oil Filter



The engine oil filter elements should be changed when the oil filter differential pressure gauge registers 105 kPa (15 psi) when engine is at rated speed, and is at operating temperature.



For changing engine oil filter elements see topic entitled "Engine Crankcase." NOTE
: Follow the Lubrication and Maintenance Chart under normal operation.

Fuel System

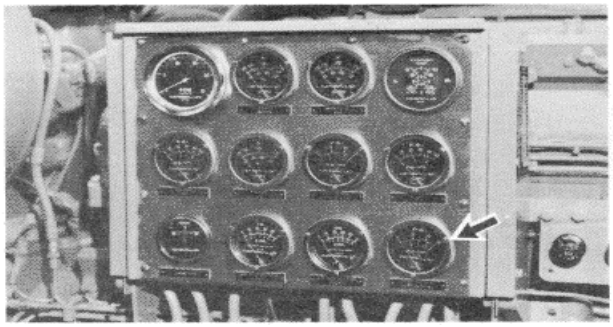
⚠ WARNING

Fuel leaked or spilled onto hot surfaces or electrical components can cause a fire.

Disconnect the battery when changing fuel filters.

NOTICE

Do not fill fuel filter housings with fuel before installing elements. Contaminated fuel will cause accelerated wear to fuel system components.

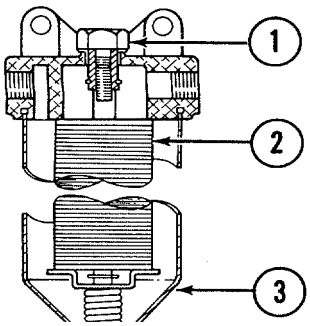


The final fuel filter elements should be replaced when the fuel filter differential pressure gauge registers 105 kPa (15 psi), when engine is at rated speed and operating temperature. The primary fuel filter should be cleaned each time the elements are changed.

Cleaning the Primary Fuel Filter

1. Stop the engine.

2. Close the fuel supply line valve.



3. Loosen nut (1) on the cover and remove case (3).

4. Remove filter element (2). Clean the element and case in clean nonflammable solvent.

5. Inspect and install the two cover gaskets. Install new gaskets if necessary.

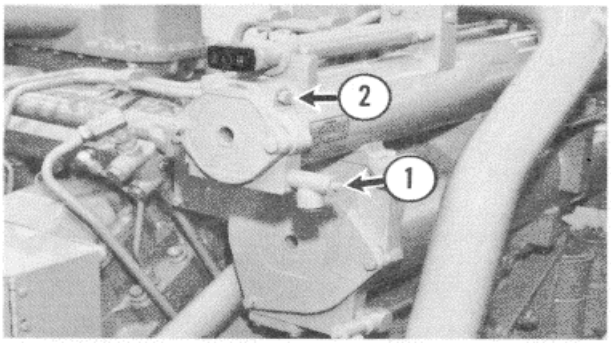
6. Install the cleaned filter element and case.

7. Open fuel supply line valve.

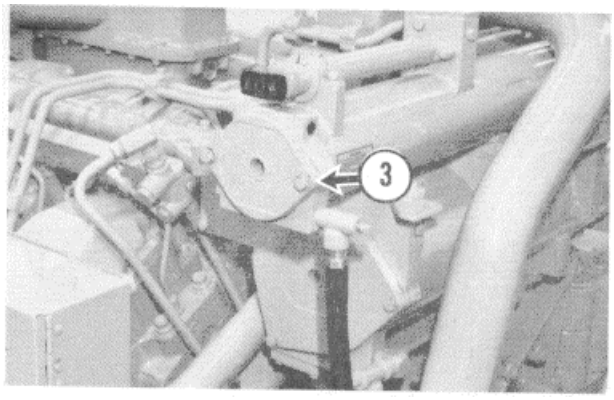
8. Prime the fuel system. See "Priming the Fuel System."

Changing Final Fuel Filters

1. Close the fuel supply line valve.

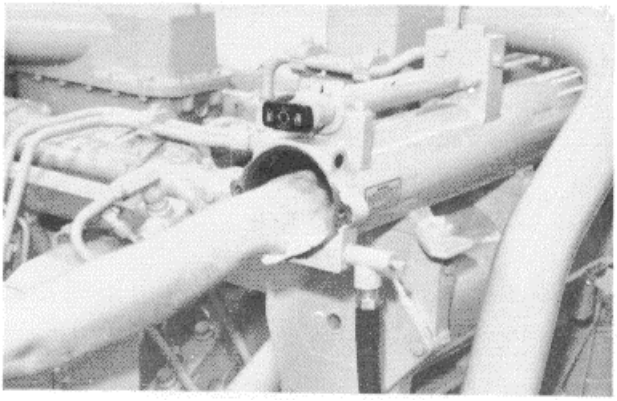


2. Attach one end of the drain hose to drain valve (1). Put the other end of the hose in a container to catch the fuel. Open drain valve (1). Remove vent plug (2) and drain the fuel filter housing.

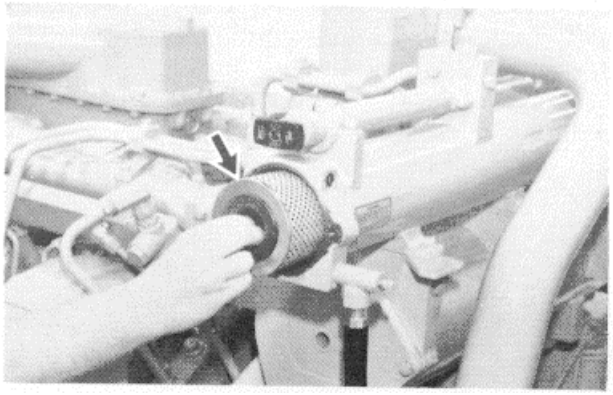


3. Remove cover (3) from each end of the filter housing.

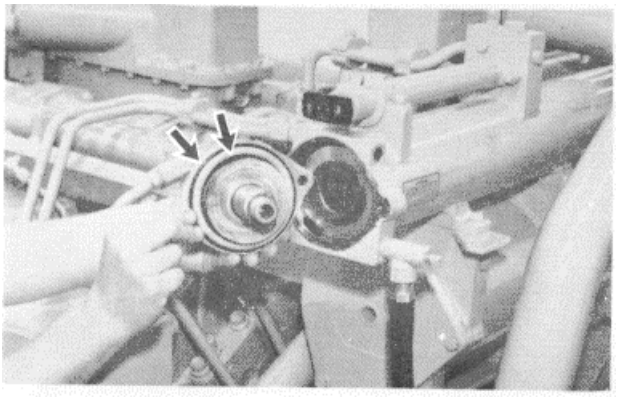
4. Remove the five used filter elements from inside the filter housing.



5. Wipe all sediment from inside the filter housing.



6. Install new filter elements.



7. Inspect the cover O-ring seal. Install new seal if necessary.

8. Install the cover.

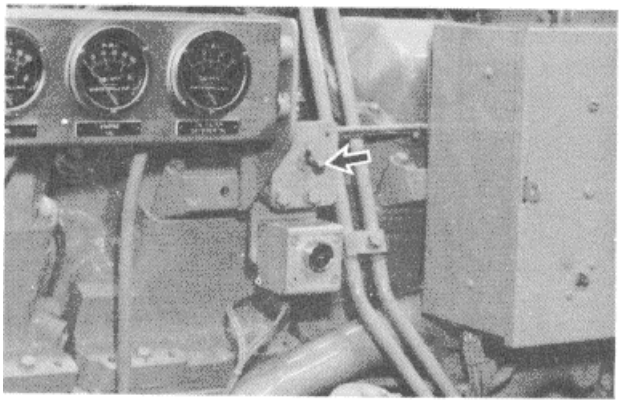
9. Install vent plug (2), close drain valve (1) and remove the drain hose.

10. Open the fuel supply line valve.

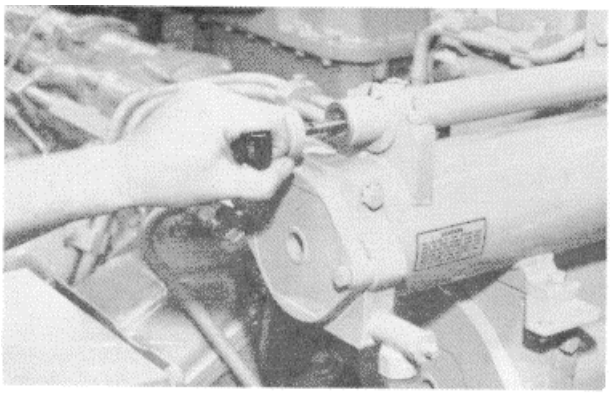
11. Prime the fuel system. See "Priming the Fuel System."

Priming the Fuel System

1. Open the fuel supply line valve.



2. Move the ON/OFF switch at the engine, to the OFF position.



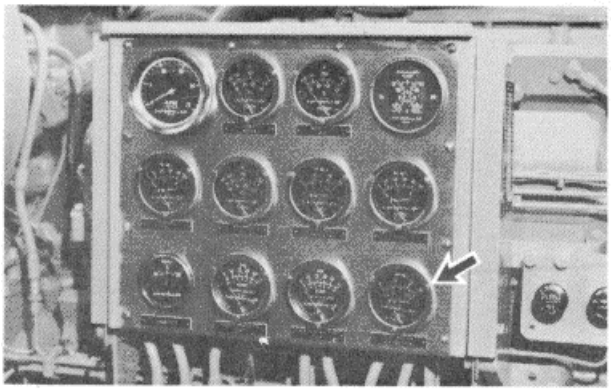
3. Turn the pump handle knob counterclockwise. Release the lock plate from the retainer on the fuel priming pump.

4. Operate the fuel priming pump until the air in the fuel system has been pumped through the fuel return line to the fuel tank.

Duplex Fuel Filters

The duplex fuel filter system will allow continuous operation while the fuel filters are being changed.

NOTE: Under normal operation, the main fuel filters are to be used, until they need to be replaced. The auxiliary filters can be transferred to during continuous engine operation while the main filters are being changed.



When the fuel filter differential gauge registers 105 kPa (’15 psi), the main fuel filter elements should be replaced.

Changing the Main Final Fuel Filters

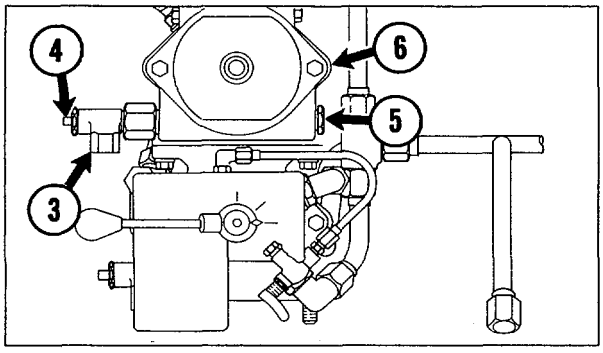
⚠ WARNING

Fuel leaked or spilled onto hot surfaces or electrical components can cause a fire.

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1. Open fill valve (1) for five minutes minimum.

2. Close fill valve (1) and rotate control valve 2 to the (Auxiliary Run position.



3. Attach one end of the drain hose to drain valve (3). Put the other end of hose in a container to catch the fuel. Open drain valve stem 4. Remove vent plug 5 and drain the fuel filter housing.

4. Remove cover () from the end of the filter housing.

5. Remove the five used filter elements from inside the filter housing.

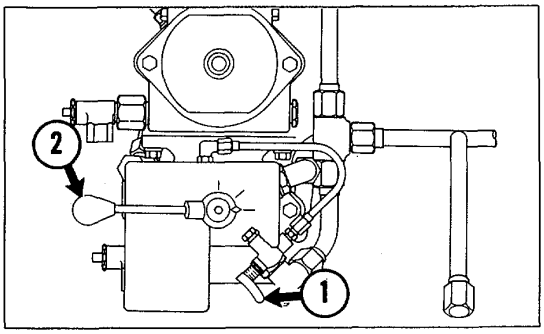
6. Wipe all sediment from inside the filter housing.

7. Install five new filter elements.

8. Inspect the cover O-ring seal. Install new seal if necessary.

9. Install cover (6).

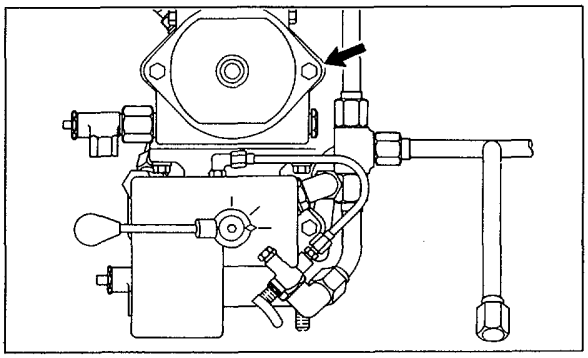
10. Make sure vent plug (5) is installed, and drain valve stem (4) is closed.



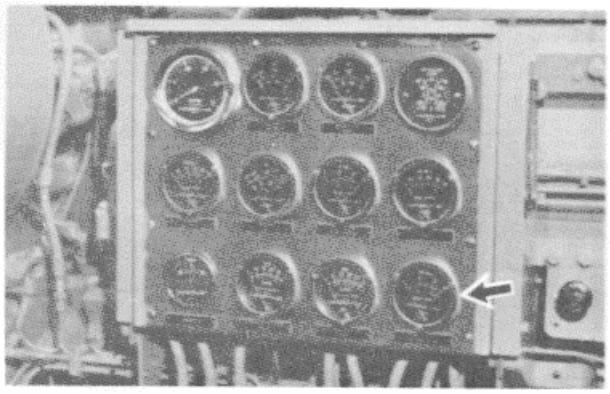
11. Open fill valve (1) for minimum of five minutes.

12. Close fill valve (1) and rotate control valve (2) to the Main Run position.

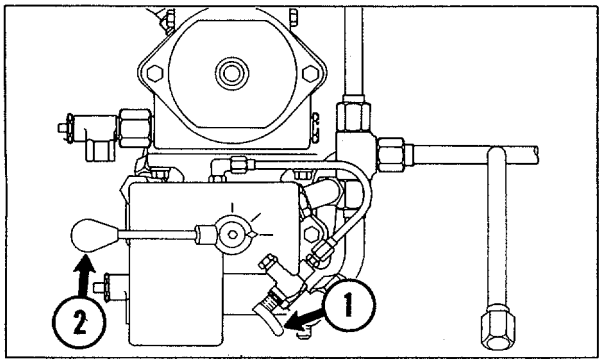
Changing Auxiliary Final Fuel Filters



If the main final fuel filters have been used and there are no replacement filters, the auxiliary filters may be used for a maximum of 100 hours engine operation.



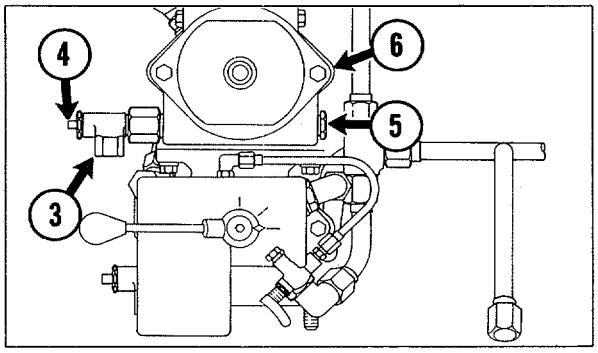
The auxiliary filters must be replaced when the fuel filter differential gauge registers 105 kPa (15 psi). NOTE: Engine must be shut down to change the auxiliary filters, if the main fuel filters are empty.



1. To change the auxiliary filters when the control valve is in the Auxiliary Run position, open fill valve 1 for minimum of five minutes.

2. Close fill valve 1 and rotate control valve 2 to the Main Run position.

To change the auxiliary filters when the control valve is in the Main Run position, proceed to step 3.



3. Attach one end of drain hose to drain valve 3. Put the other end of the hose in a container to catch the fuel. Open drain valve stem 4. Remove vent plug 5 and drain the fuel filter housing.

4. Remove cover 6 from the end of the filter housing.

5. Remove the two used filter elements from inside the filter housing.

6. Wipe all sediment from inside the filter housing.

7. Install two new filter elements.

8. Inspect the cover O-ring seal. Install new seal if necessary.

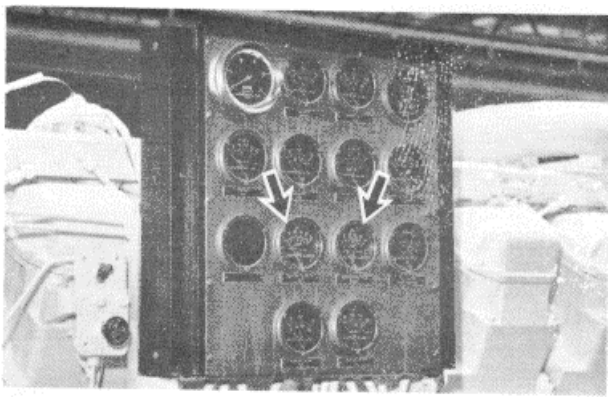
9. Install cover 6.

10. Make sure that vent plug 5 is installed, and drain valve stem 4 is closed.

11. Open fill valve 1 for minimum of five minutes.

12. Close fill valve 1 and leave control valve 2 in the Main Run position, for normal operation.

Air Cleaners



Observe gauges for both left and right air cleaners.

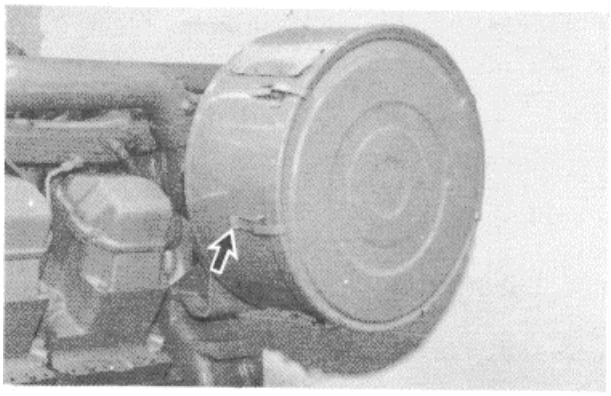
If air cleaner restriction gauge registers 762 mm (30 inches) H20, clean or replace air cleaner elements.

NOTICE

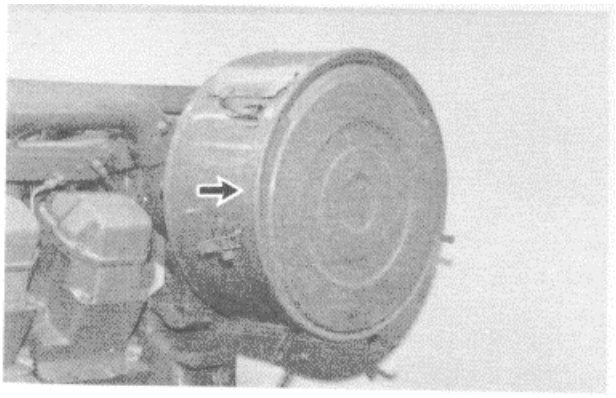
Service the air cleaners with engine stopped.

Keep spare filter elements on hand for replacement.

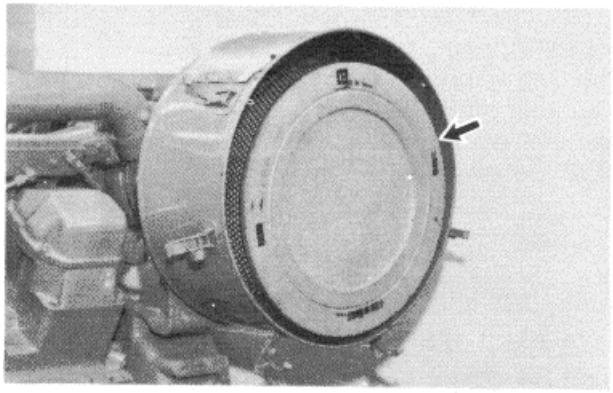
Changing Air Cleaner Elements



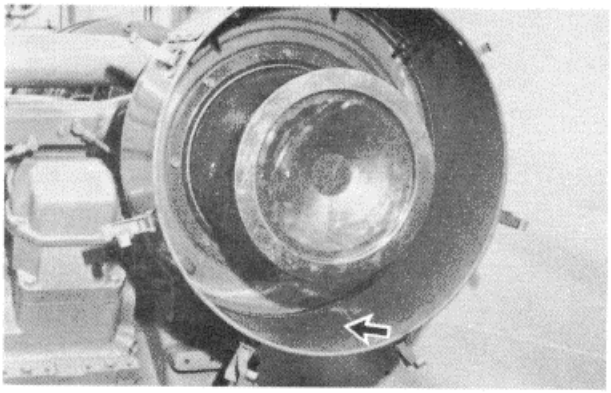
1. Release the cover fasteners from around the filter housing.



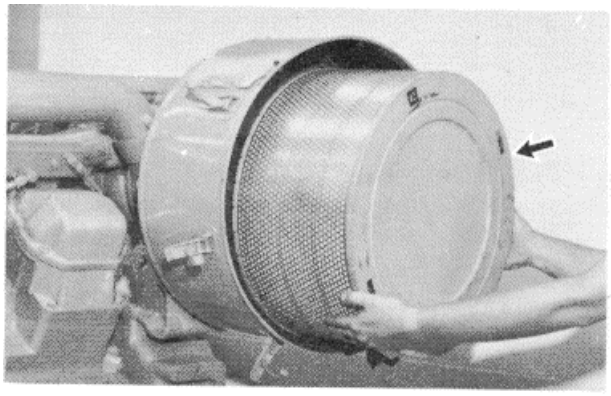
2. Remove the cover.



3. Remove the element.

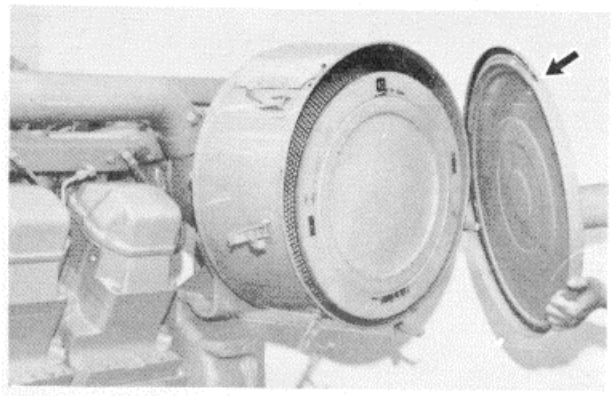


4. Clean the inside of the housing.



5. Install the new or cleaned element.

The primary element can be cleaned up to six times before replacement. The element, when cleaned, should be thoroughly checked for rips or tears in the filter material. Replace the primary element every year even though it has not been cleaned six times.



6. Install the cover and fasten it.

7. Repeat steps 1 thru 6 for the air cleaner on the other side of the engine.

Cleaning Air Cleaner Elements

⚠ WARNING

When using pressure air, wear protective face shield and clothing. Use 205 kPa (30 psi) maximum air pressure for cleaning purposes.

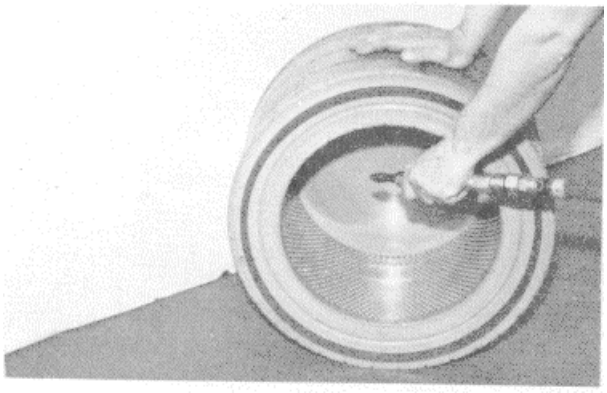
NOTICE

Do not clean elements by bumping or tapping them.

Inspect element after cleaning. Do not use an element with damaged pleats, gaskets or seals.

Element can be cleaned with pressure air.

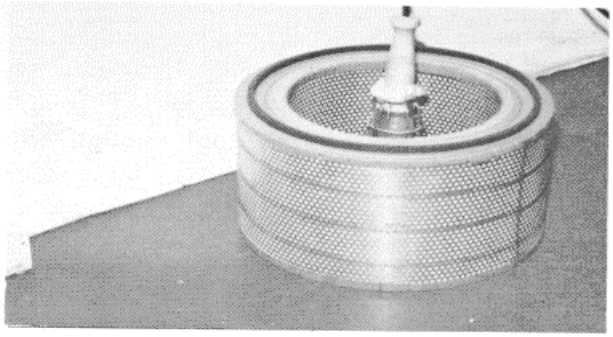
Pressure Air 205 kPa (30 psi) Maximum



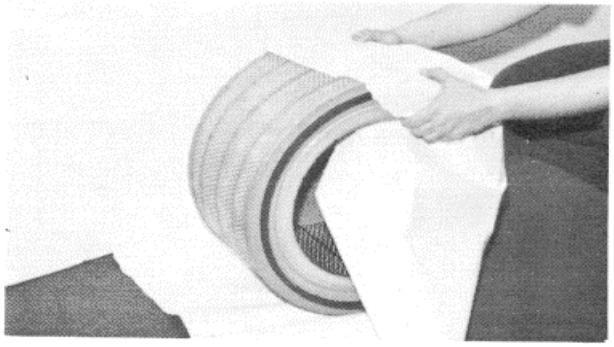
1. Direct air along pleats inside of element, outside of element and then inside of element.

2. Inspect element after cleaning.

Inspecting Elements



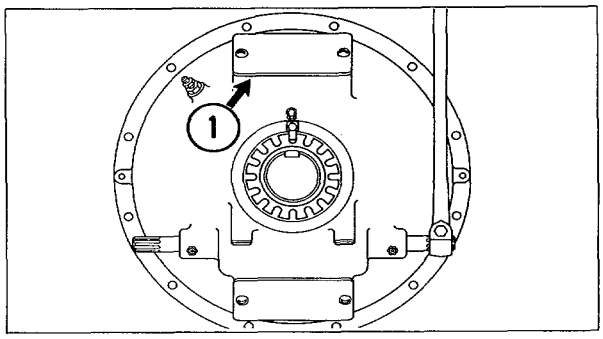
1. Insert a light inside a dry and cleaned element. Discard an element with rips or tears.



2. Wrap and store elements in a clean, dry place.

Clutch Throwout Collar and Engagement Shaft Bearings

Check Clutch Adjustment



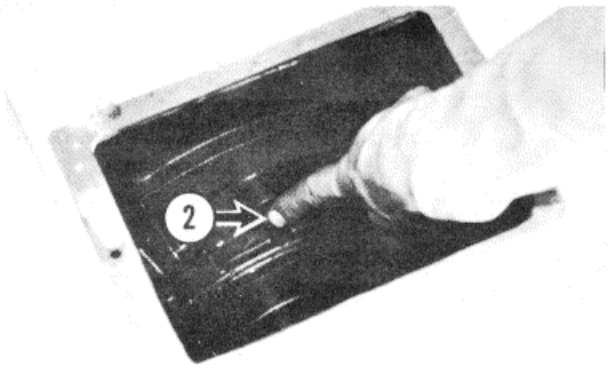
⚠ WARNING

If the clutch is damaged to the point of a burst failure, expelled pieces can cause personal injury to anyone in the immediate area. Proper safeguards must be followed to prevent accidents.

Do not operate engine with cover plate ① removed as personal injury may result.

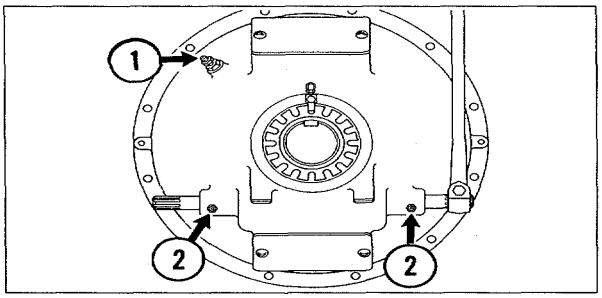
When clutch is disengaged, the hand lever must fall behind the vertical position. If the clutch slips, overheats or operating lever disengages, adjustment is necessary.

To adjust: Remove cover plate ①.



Rotate clutch until lock pin ② can be reached. Disengage lock pin and turn adjusting ring clockwise to increase engagement torque and counterclockwise to decrease engagement torque. Turn adjusting ring so that 345 ± 50 N.m (254 ± 35 lb ft) torque or 636 ± 90 N (143 ± 20 lb) force at 540 mm (21.3 in) length on lever, is required to engage the clutch.

Lubricate Fittings



1. Lubricate clutch throwout collar ①.

2. Lubricate engagement shaft bearing ②.

Cooling System

Check Coolant Level

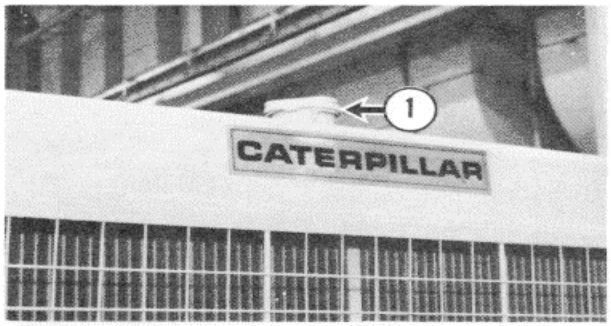
⚠ WARNING

At operating temperature, engine coolant is hot and under pressure.

Check coolant level only when engine is stopped and filler cap is cool enough to touch with your hand.

Remove filler cap slowly to relieve pressure.

Steam can cause personal injury.



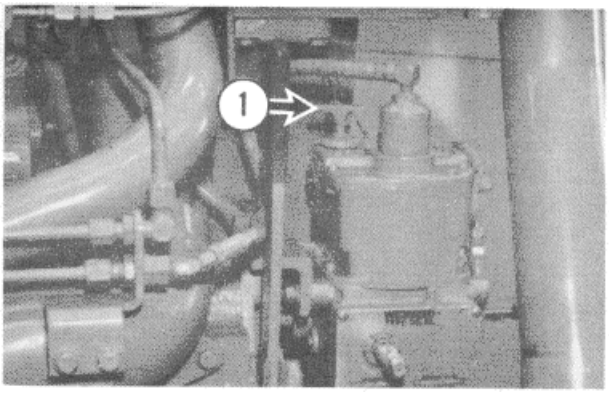
1. Remove filler cap O slowly to relieve pressure. Inspect condition of cap gasket. Replace cap if necessary.

2. Maintain coolant level to the bottom of the filler tube. Install the filler cap.

3. Inspect for leaks or damaged hoses. Make repairs if necessary.

Woodward UG8L Governor

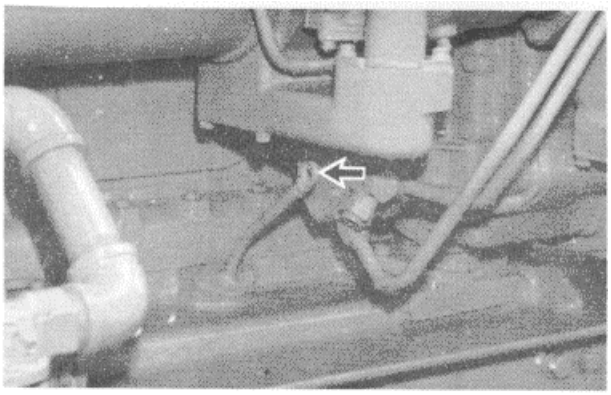
Measure Oil Level



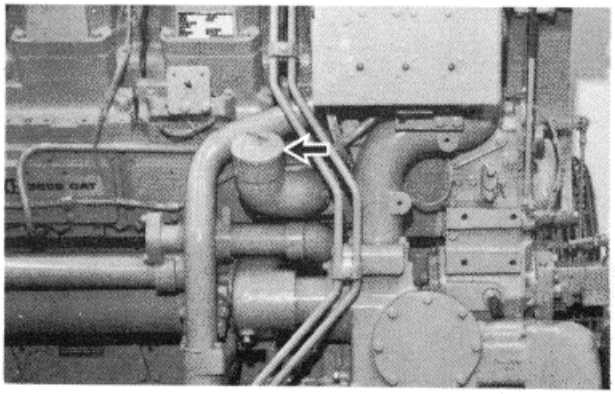
Maintain oil level at the FULL mark on dipstick gauge ①.

Engine Crankcase

Measure Oil Level



1. Measure engine oil level.



2. Maintain oil level to FULL mark on the ENGINE STOPPED side of dipstick. Add oil if necessary.

Every 10 Service Hours or Daily

Fuel Tank

Drain Water and Sediment

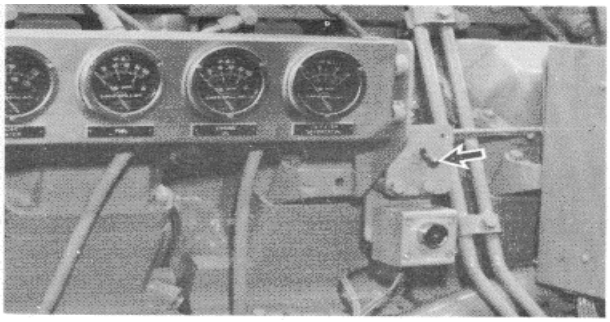
Open drain valve. Allow water and sediment to drain into a container. Close drain valve. Wipe up spills.

Every 50 Service Hours or Weekly

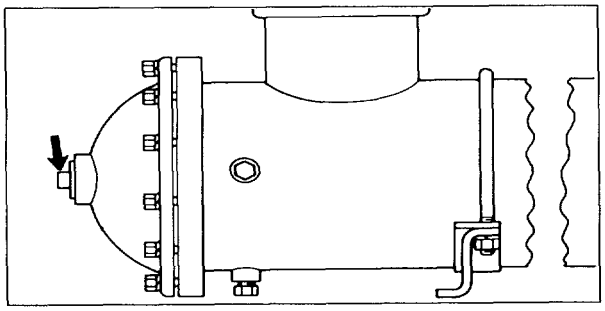
Zinc Rods

Inspect

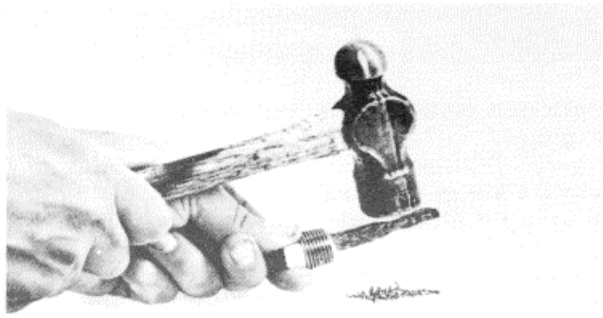
All zinc rod locations, heat exchanger, water pump piping, etc.



1. Move the ON/OFF switch at the engine to the OFF position.



2. Remove all the plugs. They are painted red for easy identification.



3. Tap the zinc rods lightly with a hammer. If the rod has deteriorated, or if it flakes when tapped, install a new zinc rod.

Installing New Zinc Rods



1. Unscrew or drill the existing rod from the plug base.

2. Install a new rod in the plug base.

3. Install the plug.

Every 50 Service Hours or Weekly

Batteries

Check Electrolyte Level

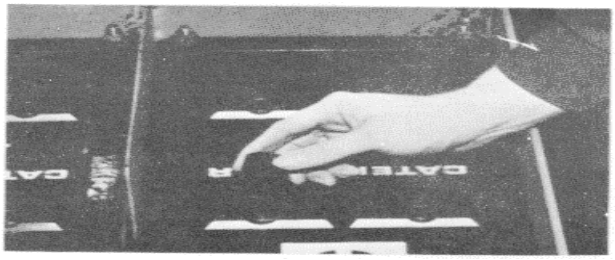
⚠ WARNING

Batteries give off flammable fumes that can explode.

Electrolyte is an acid and can cause personal injury if it contacts skin or eyes.

Do not smoke when observing battery electrolyte level.

Always wear protective glasses when working with batteries.



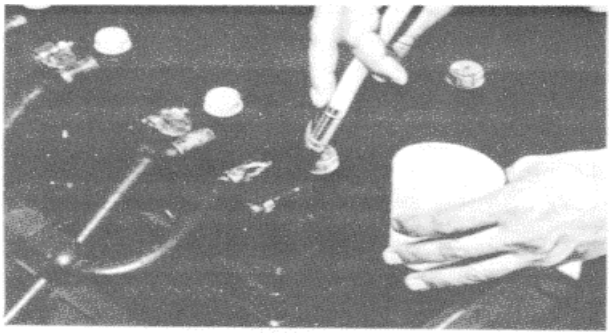
1. Remove fill caps. Maintain electrolyte to bottom on fill plug openings.

If addition of water is necessary, use distilled water. If distilled water is not available use clean water that is low in minerals. Do not use artificially softened water.

At proper charging rate, batteries should not require more than 30 cc (1 ounce) water per cell per week.

Keep batteries clean.

Cleaning Batteries



1. Loosen and remove cable clamps from all battery terminals.

2. Clean all battery terminals.

3. Clean all cable clamps.

4. Install and tighten cable clamps to battery terminals.

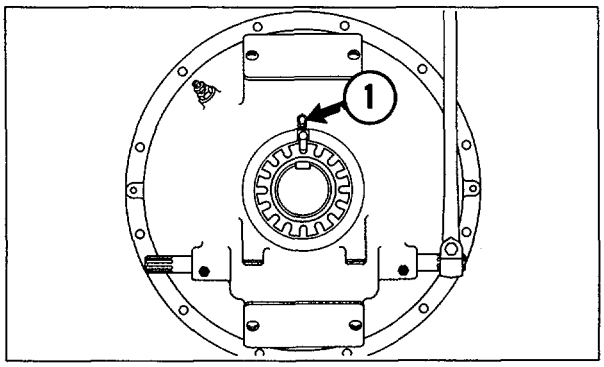
5. Coat cable clamps and terminals with grease.

Every 100 Service Hours or 2 Weeks

Clutch Bearing

Lubricate Fitting

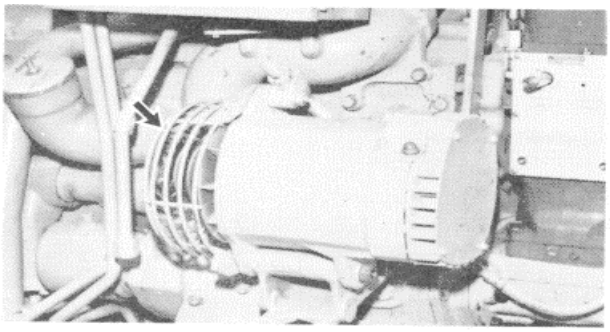
1. Lubricate clutch bearing ①.



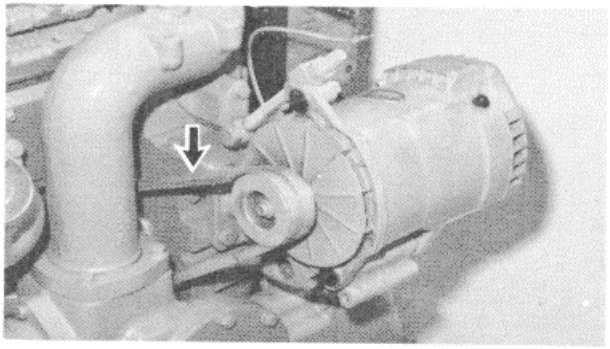
Every 250 Service Hours or Monthly

Alternator Belts

Inspect Belt



1. Remove belt guard.

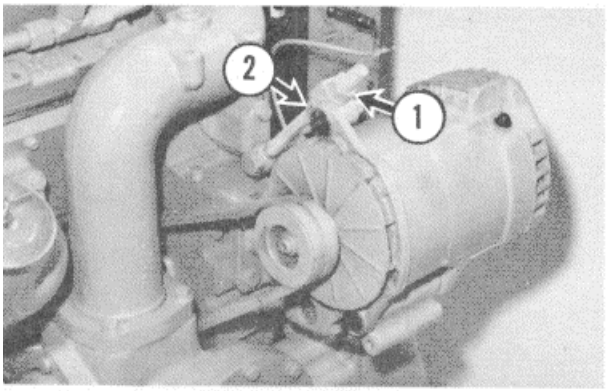


2. Inspect the belts for wear. Replace belts if worn, cracked or frayed.

When belt replacement is necessary, belts must be replaced in complete matched sets. Never replace only one belt. The new belt will carry all of the load and consequently, fail rapidly.

3. If belts do not require replacement or adjustment, install the belt guard. If belts require adjustment or replacement, do not install the belt guard. See "To Adjust" below when belt adjustment and/or replacement is necessary.

To Adjust



1. Apply a 110 N (25 pound) force perpendicular to the belt, midway between the driving and driven pulley. Measure the belt deflection.

Proper belt deflection is 15 to 20 mm (.6 to .8 inch). Adjust the belt tension as required.

2. Loosen locknut ① on the belt tightener rod.

3. Turn adjustment nut ② until correct belt deflection is obtained.

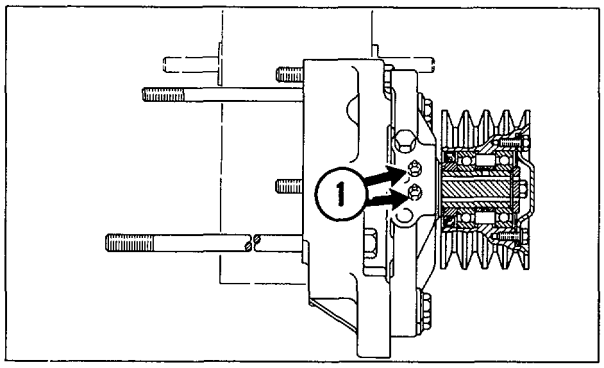
4. Tighten locknut ①.

5. Check the belt adjustment.

6. Install the belt guard.

Fan Pulley Bearing

Lubricate Fitting



Lubricate fan pulley bearing ①.

Cooling System

Add Coolant Conditioner

⚠ WARNING

At operating temperature, the engine coolant is hot and under pressure.

Check the coolant level only when the engine is stopped and the filler cap is cool enough to touch with your hand.

Remove the filler cap slowly to relieve pressure.

Steam can cause personal injury.

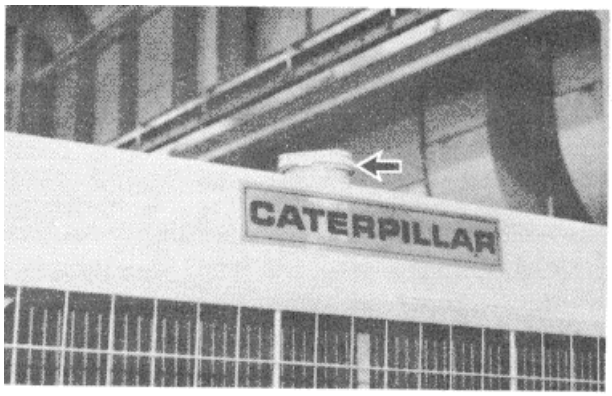
Cooling System Conditioner contains alkali. Avoid contact with skin and eyes to prevent personal injury.

NOTICE

All water is corrosive at engine operating temperature. Use either Caterpillar Cooling System Conditioner, or Coolant Conditioner Element to treat either plain water or ethylene glycol antifreeze solution. Never use both the cooling system conditioner and the coolant conditioner element at the same time.

Do not use Caterpillar Cooling System Conditioner or Coolant Conditioner Elements with Dowtherm 209 Full-Fill coolant. Follow recommendations provided with Dowtherm 209 Full-Fill coolant.

Add .5 liter (1 pint) of Caterpillar Cooling System Conditioner for each 15 liters (4 U.S. gallons) of coolant used. This will maintain the required 3% to 6% concentration of conditioner.



1. Remove filler cap slowly to relieve pressure.

It may be necessary to drain enough coolant to allow for the addition of cooling system conditioner.

2. Add Caterpillar Cooling System Conditioner.

3. Inspect filler cap gasket. Replace cap if damaged.

4. Install filler cap.

Engine Crankcase

3508 Engines With 104 Liter (27 Gal.) Capacity Oil Sump

3512 Engines With 152 Liter (40 Gal.) Capacity Oil Sump

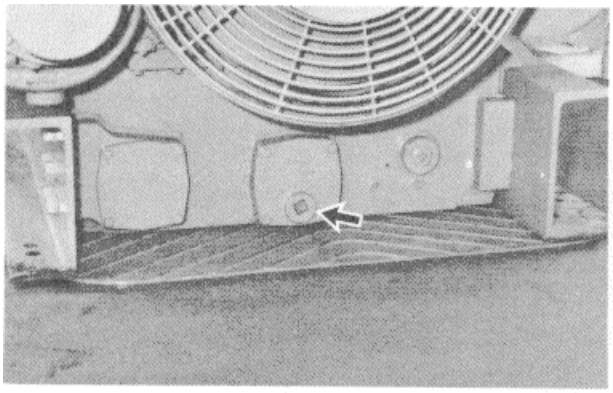
3516 Engines With 204 Liter (53 Gal.) Capacity Oil Sump

⚠ WARNING

Use caution when draining oil or changing filters. Hot oil or components can cause burns if they contact skin.

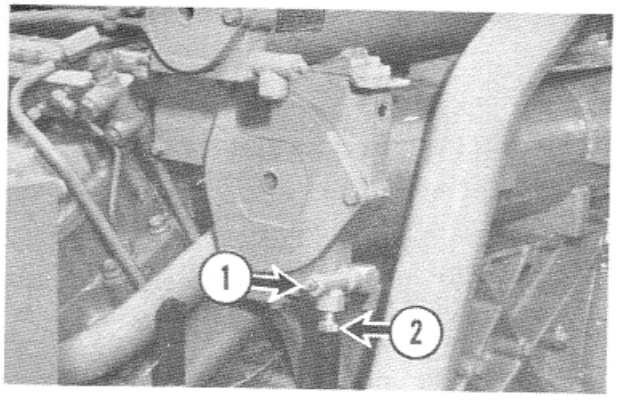
Change Oil and Filters - Clean Suction Screen

With the oil warm and the engine stopped, drain the crankcase.



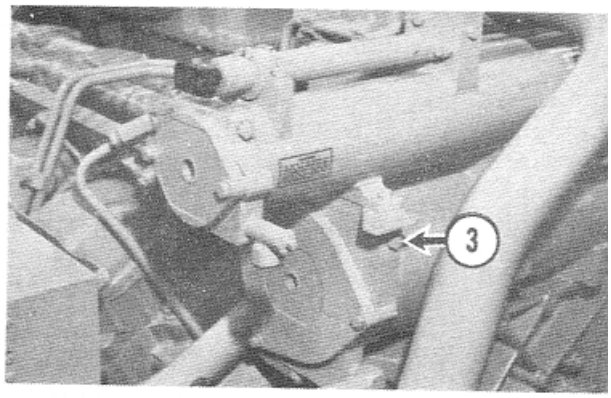
1. Remove the oil pan drain plug. Allow the oil to drain.

2. Clean and install the drain plug.

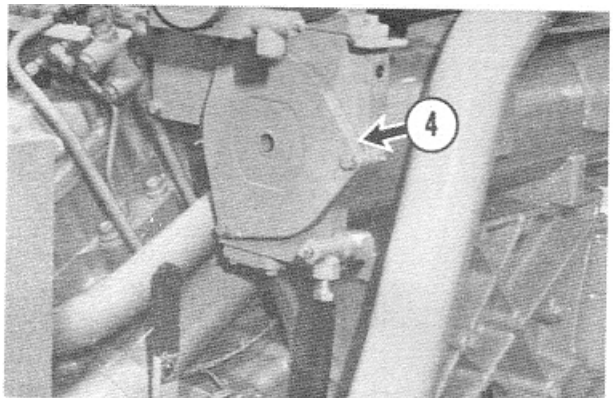


3. Attach one end of hose ②) to drain valve ①. Put the other end of hose ②in a container to catch the oil.

4. Open oil filter housing drain valve ①

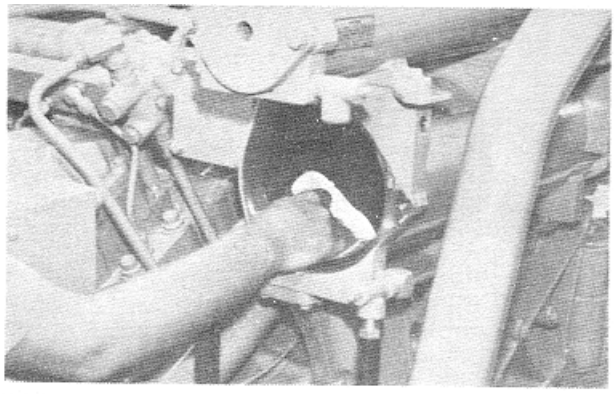


5. Remove vent plug ③from the side of the filter housing.

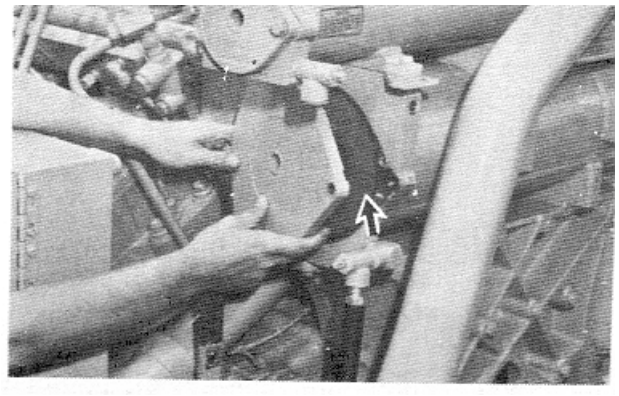


6. Remove cover ④

7. Remove the three oil filter elements.



8. Wipe out the oil filter housing with a clean rag.



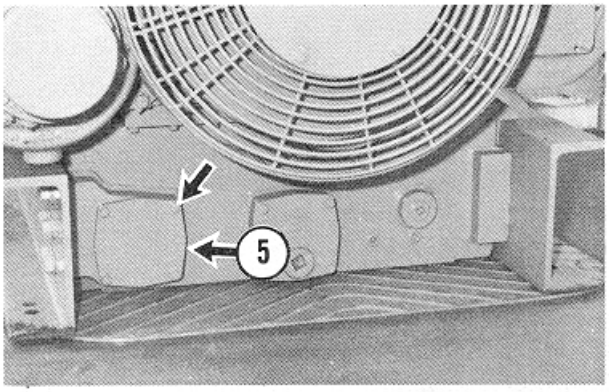
9. Install three new filter elements.

10. Inspect the cover O-ring seal. Install new seal if necessary.

11. Install cover ④

12. Close the filter housing drain valve ①

13. Remove the drain hose.



NOTE: The suction screen cover is on left hand side of small capacity oil pans (250 hour service only).

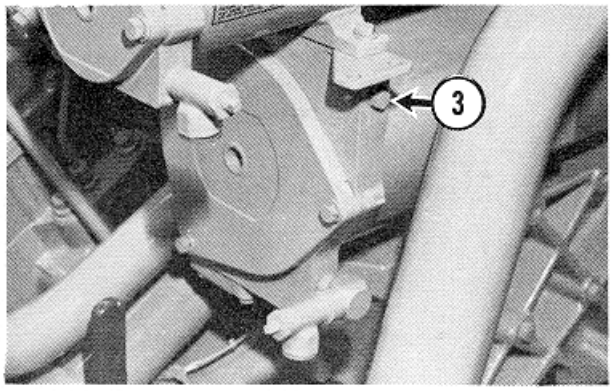
14. Remove four bolts and cover ⑤) from the right front side of oil pan.

15. Remove suction screen and clean.

16. Inspect O-ring seals. Install new seals if necessary.

17. Install the suction screen and cover⑤

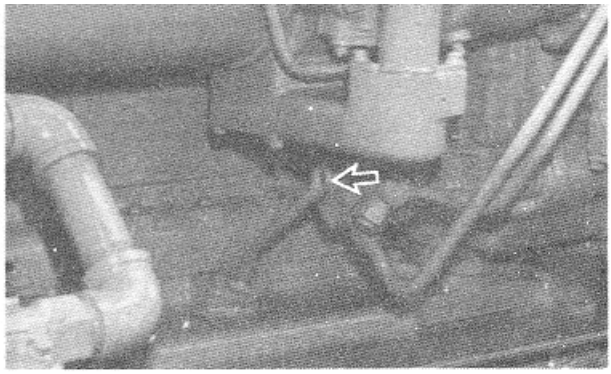
18. If a prelube pump is available, fill the oil filter housing and the oil cooler with oil.



19. If prelube pump is not available, then proceed with filling the crankcase. See "Refill Capacities" and "Fuel, Coolant and Lubricant Specifications."

20. Clean and install vent plug ③into the filter housing.

21. Crank the engine with the fuel supply line closed until 70 kPa (10 psi) oil pressure shows on the gauge. Open the fuel supply line valve. Then start and run the engine. Inspect for leaks. Reduce engine speed to low idle.

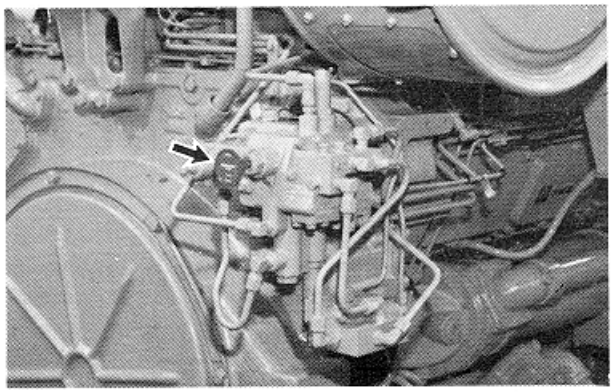


22. Maintain oil level to the FULL mark on ENGINE RUNNING side of dipstick. Stop the engine.

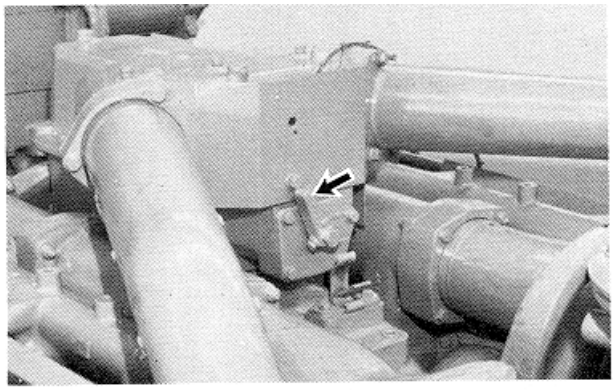
Every 500 Service Hours or 3 Months

Emergency Shutoff Controls

Test for Proper Function



The Hydra-Mechanical Shutoff should be tested to ensure proper operation and protection to the engine. Refer to "Engine Controls - Standard and/or Attachment" in the Operation Section.



Check air inlet valve to make sure it closes during testing.

Engine Crankcase

3508 Engines 227 Liter (59 Gal.) Capacity Oil Sump

3512 Engines 312 Liter (81 gal.) Capacity Oil Sump

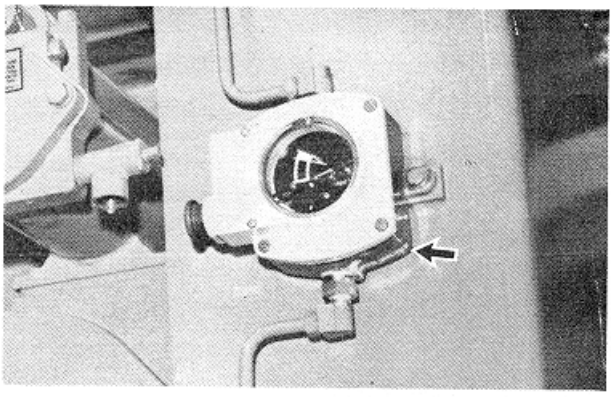
3516 Engines 401 Liter (106 Gal.) Capacity Oil Sump

Refer to "Engine Crankcase" at the Every 250 Service Hours or Monthly interval for procedure to change oil and filters.

Every 1000 Service Hours or 3 Months

Shutoff Controls

Check for Proper Operation



The engine protective shutoff controls must be checked for proper operation. They are the coolant level alarm, low oil pressure switch, electrical high water temperature shutoff, electrical overspeed shutoff and the manual fuel shutoff lever. Refer to "Shutoff and Alarm System Components" in the "Operation Section" for information on these controls. This will ensure that if a malfunction should occur, the engine will stop without being damaged.

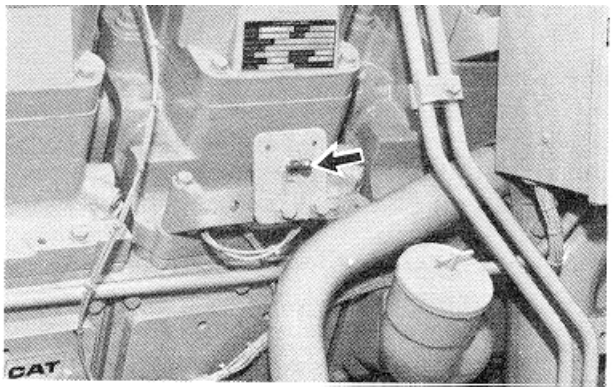
Have the checks made by a qualified mechanic. Consult your authorized Caterpillar engine dealer, or refer to the Service Manual for your engine.

Woodward UG8L Governor

Change Oil

⚠ WARNING

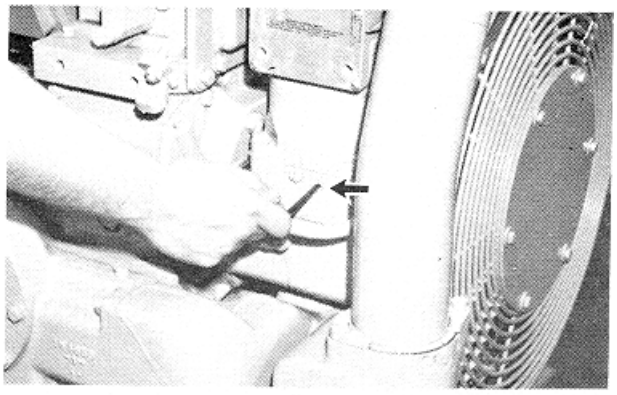
To prevent personal injury be sure the engine cannot be started. Disconnect the ground cable from the battery terminal.



1. Move the ON/OFF switch to the OFF position.

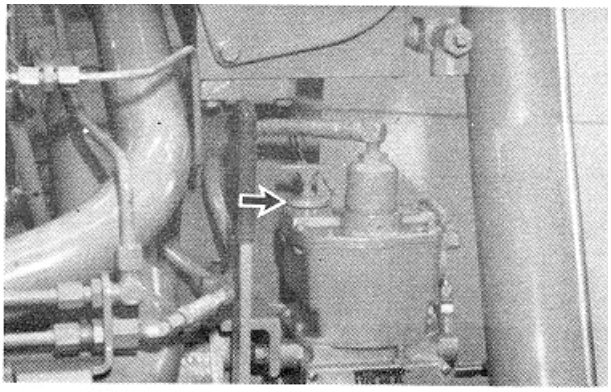
2. Close the fuel tank fuel supply valve.

3. Disconnect the ground cable from the battery terminal.



4. Remove the drain plug. Allow oil to drain.

5. Clean and install the drain plug.



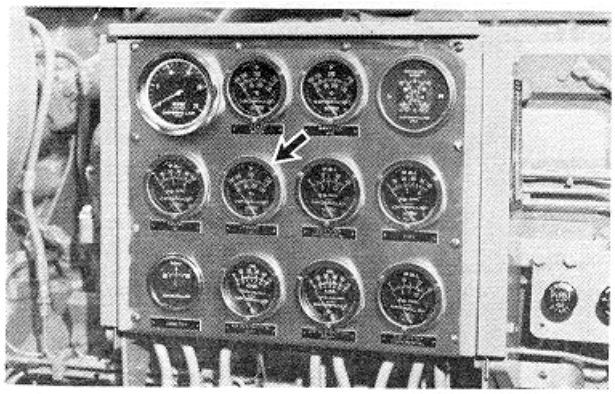
6. Fill the governor, with clean oil, to the FULL mark on the dipstick. Refer to the Lubrication and Maintenance Chart for proper oil.

7. Connect the ground cable to the battery.

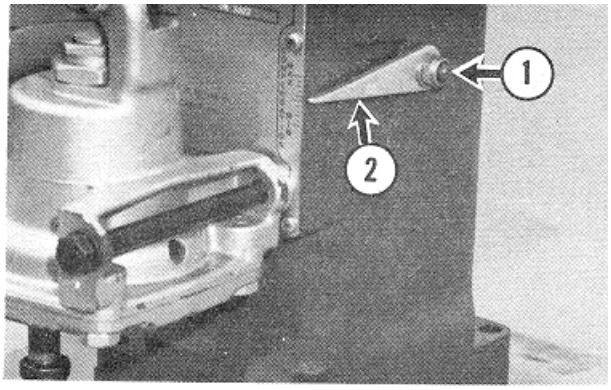
8. Open the fuel tank supply valve.

9. Use the procedure that follows to bleed the governor.

Bleed Air From the Governor

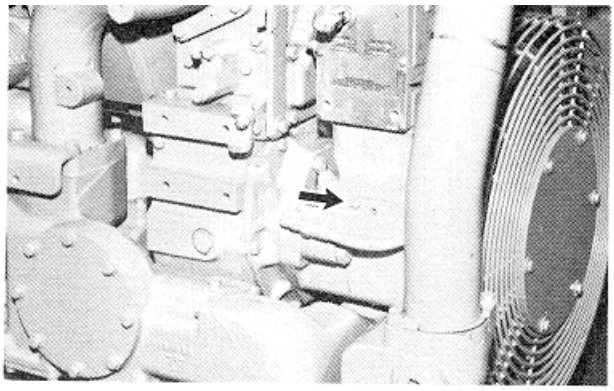


1. Start the engine and allow the engine to reach normal operating temperature.

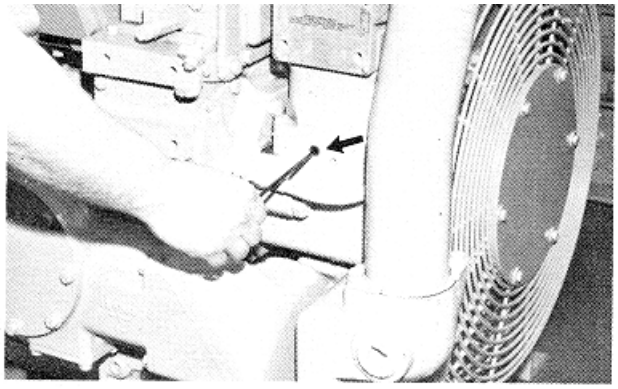


2. Loosen nut ①on the side of the governor which holds compensation adjusting pointer②

3. Manually move pointer ②to the extreme upper position. Tighten nut ①This will allow the governor to be purged of air.

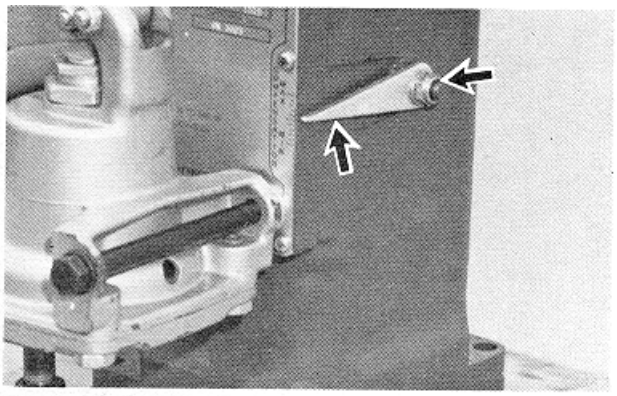


4. Remove the plug from the base of the governor.



5. Use a wide blade screwdriver to turn the needle valve three or more turns counterclockwise.

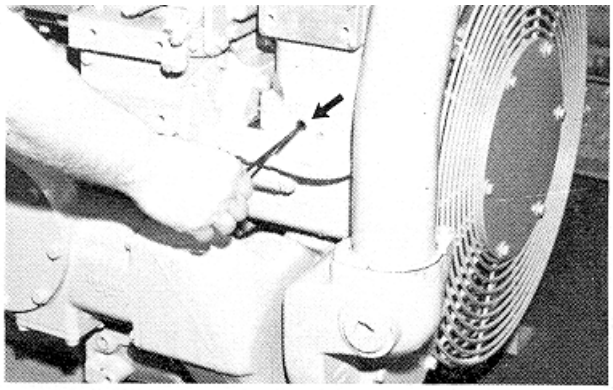
6. Allow the engine to surge for approximately 30 seconds.



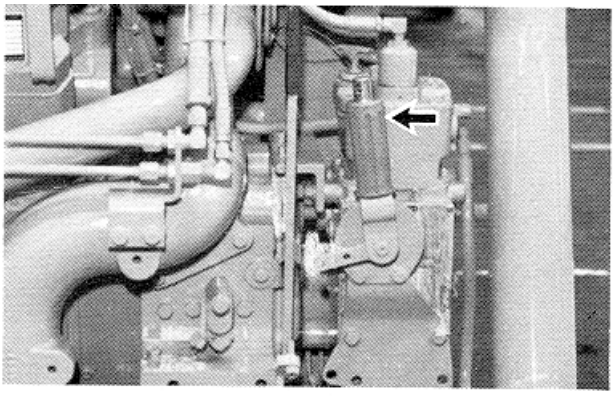
7. Loosen the nut and move the compensation adjusting pointer to the extreme downward position. Tighten the nut.

8. Slowly turn the needle valve clockwise until the surging stops.

9. It should now take less than one turn from this point to close the valve completely.



10. Open the valve to the same position where the surging had stopped.



11. Manually move the governor linkage to disturb the engine speed.

If the engine speed stabilizes, and the needle valve is only 1/2 to 3/4 turn open, the governor is properly adjusted. Install the base plug.

If more than a 3/4 turn is required to stop engine surging, proceed with the following steps.

12. Raise the pointer two divisions on the pointer scale.

13. Turn the needle valve counterclockwise three or more turns.

14. Allow the engine to surge approximately 30 seconds.

15. Gradually turn the needle valve clockwise until surging just stops.

16. Note the portion of a turn required to close the needle valve.

17. Open the valve exactly to the same position surging stopped.

18. Manually move the governor linkage to disturb the engine speed. The engine speed should stabilize with the needle valve opened 1/2 to 3/4 turn.

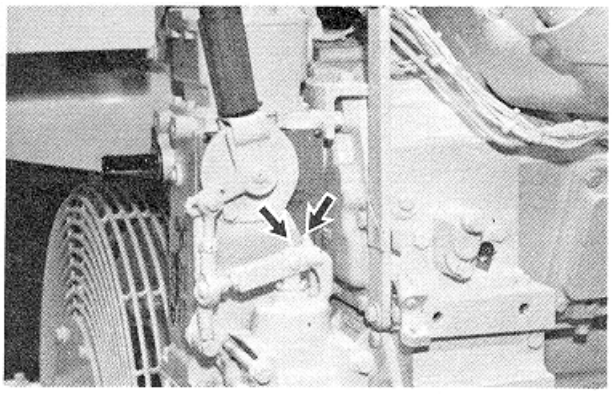
19. A valve opened less than 1/2 of a turn produces a slow response to load changes. A valve opened more than 3/4 of a turn produces excessive speed response to load change. If the engine does not stabilize between 1/2 to 3/4 turn open, raise the pointer two divisions and repeat steps 12 through 19.

20. When the engine speed stabilizes, install the base plug.

Every 1000 Service Hours or 6 Months

Governor Air Actuator

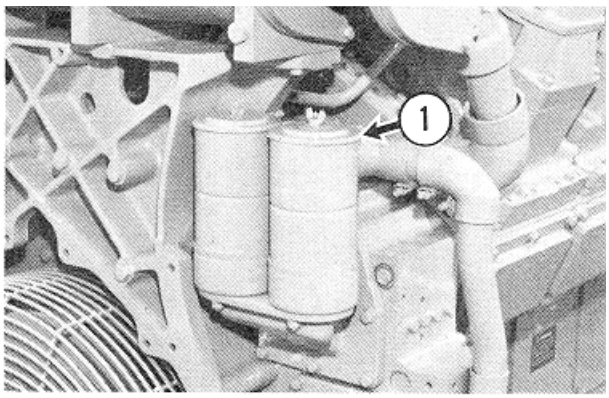
Lubricate Fittings



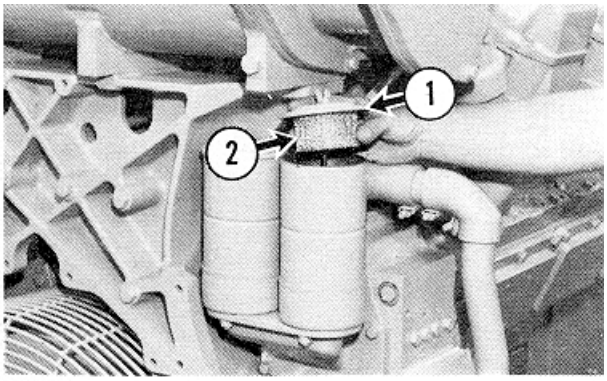
1. Lubricate governor air actuator.

Engine Crankcase Breathers

Clean



1. Remove cover assembly ① from each breather.



2. Remove mesh ②from each breather.

3. Clean mesh elements in clean nonflammable solvent.

4. Install mesh elements ②in the breathers.

5. Install cover assembly ①onto each breather.

3512 Engines With 613 Liter (162 Gal.) Capacity Oil Sump

3516 Engines With 842 Liter (219 Gal.) Capacity Oil Sump

Refer to "Engine Crankcase" at the Every 250 Service Hours or Monthly interval for procedure to change oil and filters.

Every 2000 Service Hours or 1 Year

Engine Valve Lash

Measure Valve Lash (Clearance)

⚠ WARNING

To prevent possible injury when rotating the flywheel, do not use the starter motor to turn the flywheel.

NOTICE

With the engine stopped and cold, measure the valve clearance. Always turn the flywheel in the direction of normal rotation.

Valve Clearance Check

When the valve clearance is checked, adjustment is not necessary if the measurement is in the range given in the Valve Clearance Check chart.

Valve Clearance Check	
Intake	0.32 to 0.48 mm (.013 to .019 in.)
Exhaust	0.68 to 0.84 mm (.027 to .033 in.)

Valve Clearance Setting

If the measurement is outside of the range given for valve clearance check, adjustment is necessary. Set the clearance to the nominal clearance given in the "Valve Clearance Setting" chart. Refer to the Service Manual or your Caterpillar dealer for the valve adjustment procedures.

Valve Clearance Setting	
Intake	0.40 mm (.016 in.)
Exhaust	0.76 mm (.030 in.)

Cooling System

Change Coolant

⚠ WARNING

At operating temperature, engine coolant is hot and under pressure.

Check coolant level only when engine is stopped and filler cap is cool enough to touch with your hand.
Remove filler cap slowly to relieve pressure.

Steam can cause personal injury.

Cooling System Conditioner contains alkali. Avoid contact with skin and eyes to prevent personal injury.

Use all cleaning solutions with care.

NOTICE

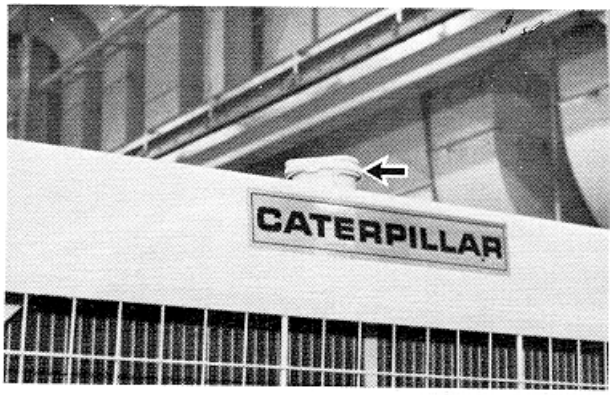
All water is corrosive at engine operating temperature. Use Caterpillar Cooling System Conditioner to treat either approved plain water or ethylene glycol solution.

Do not use Caterpillar Cooling System Conditioner or Coolant Conditioner Elements with Dowtherm 209 Full-Fill coolant. Follow recommendations provided with Dowtherm 209 Full-Fill coolant.

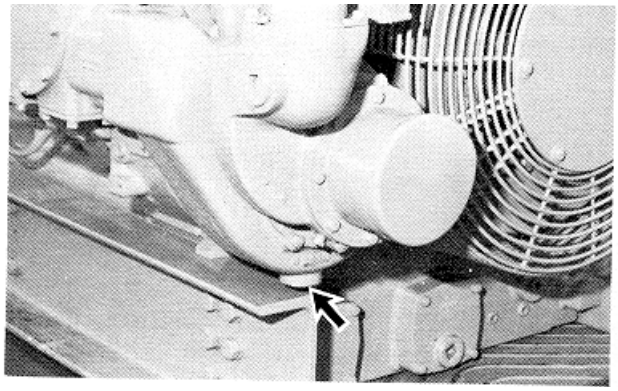
If the engine is to be shipped to, or stored in, an area with temperatures below $0^{O}C$ ($32^{O}F$), the cooling system must be protected to the lowest expected ambient temperature.

Clean the cooling system if there is a scale buildup, oil in the coolant, if the coolant is muddy, if engine overheating or foaming is observed. Refer to "Clean the Cooling System."

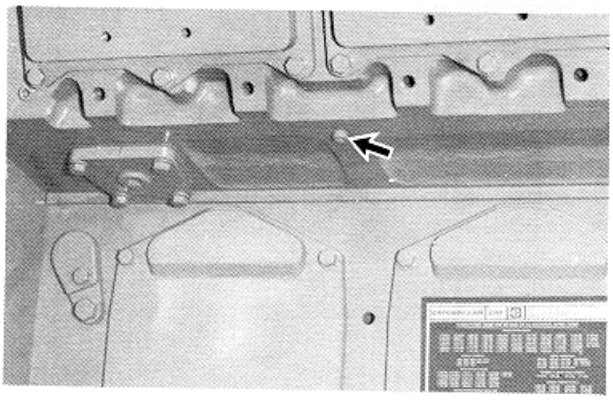
NOTE: If cooling system conditioner has been added at Every 250 Service Hours as recommended, the coolant change period can be extended to 4000 Service Hours.



1. Remove the filler cap slowly to relieve pressure.



2. Remove the drain plug on bottom of water pump housing.



3. Remove the block drain plugs. Allow coolant to drain.

4. Clean and install all drain plugs.

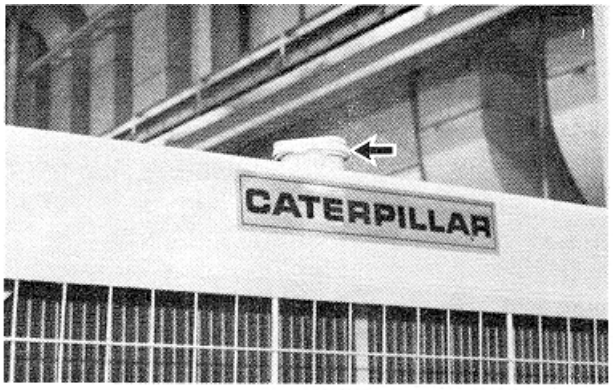
5. Fill the system with a solution of approved water, antifreeze and 1 liter (1 quart) of Caterpillar Cooling System Conditioner for each 30 liters (8 U.S. gallons) of coolant added. See "Refill Capacities" for amount of solution needed.

NOTE: The addition of .5 liter (1 pint) of conditioner per 15 liters (4 U.S. gal.) of water will give the system a 3% to 6% concentration of conditioner.

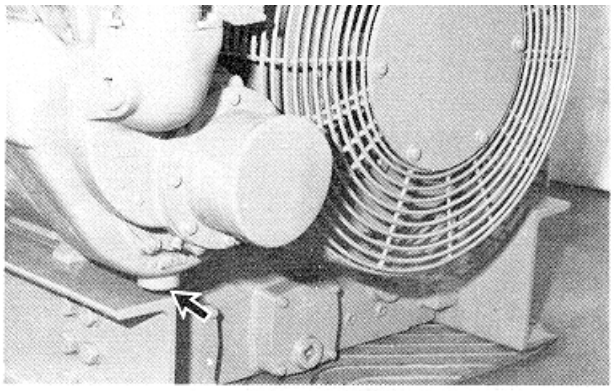
Add solution slowly at 20 liters (5 U.S. gal.) or less per minute to avoid air locks.

6. Start the engine with the filler cap off. Operate the engine until the thermostat opens and coolant level stabilizes. Fill the cooling system to the bottom of fill tube. Install the filler cap.

Clean the Cooling System



1. Remove the filler cap slowly to relieve pressure.



2. Remove the drain plug. Allow coolant to drain. Install the drain plug when all of solution is drained.

3. Fill the cooling system with a cleaning solution. Use a commercially available cleaner or 1 Kg (2 lb.) sodium bisulfate per 38 liters (10 gal.) of water.

4. Start and operate engine for ½ hour. Stop engine and drain the cleaning solution.

5. With the engine stopped, flush the system with water until draining water is clear.

6. Install the drain plug. Fill the system with a neutralizer. Use a commercially available neutralizer or 250 grams (1/2 lb.) sodium carbonate crystals per 38 liters (10 gal.) of water.

7. Operate engine for ten minutes. Stop the engine and drain the neutralizer.

8. With the engine stopped, flush the system with water until drain water is clear. Install the drain plug.

9. Fill the system with clean water and operate the engine for five minutes. Remove the drain plug, drain the cooling system and install the drain plug.

10. Repeat Step 9 until water drained is clear.

11. Mix a solution of water, antifreeze and cooling system conditioner. See "Refill Capacities" for amount of coolant needed.

12. Add solution slowly at 20 liters (5 U.S. gal) or less per minute to avoid air locks.

13. Start and operate the engine with the filler cap removed until the thermostat opens and the coolant level stabilizes. Fill the system to the bottom of fill tube.

14. Stop the engine.

15. Install the filler cap.

Troubleshooting Section

Troubleshooting

On the following pages there is a list of possible problems. To correct a problem, make reference to the CAUSE and CORRECTION.

If problems are encountered, they should be corrected promptly to maintain engine operation.

This list of problems, causes, and corrections, will only give an indication of where a possible problem can be, and what repairs may be needed. Remember that a problem is not normally caused only by one part, but by the relation of one part with other parts.

This list can not give all possible problems and corrections. The serviceman must find the problem and its source, then make the necessary repairs.

Troubleshooting Index

1. **Engine will not turn when start switch is on**
2. **Engine will not start**
3. **Starting motor does not turn**
4. **Air starting motor turns slowly**
5. **Alternator gives no charge**
6. **Alternator charge rate is not regular**
7. **Alternator has noise**
8. **Misfiring or running rough**
9. **Not enough power**
10. **Stall at low rpm**
11. **Sudden changes in rpm**
12. **Loud combustion noise**
13. **Valve train noise**
14. **Loud valve train noise**
15. **Too much valve lash**
16. **Little or no valve clearance**
17. **Valve rotocoil or spring lock is free**
18. **Noise in engine**
19. **Too much vibration**
20. **Too much white or blue smoke**
21. **Oil at the exhaust**
22. **Too much lubrication oil used**
23. **Too much black or gray smoke**
24. **Fuel consumption too high**
25. **Low oil pressure**
26. **Coolant in oil**
27. **Oil in cooling system**
28. **Coolant is too hot**
29. **Engine has early wear**
30. **Exhaust temperature too high**

1. Engine will not turn when start switch is on

Cause	Correction
Battery has low output.	Make reference to Item 3.
Wiring or switches have defect.	Make reference to Item 3.
Starting motor solenoid has a defect.	Make reference to Item 3.
Starting motor has a defect.	Make reference to Item 3.
Oil pressure switch for prelubrication pump has a defect.	Make a replacement of defective switch.
Prelubrication oil pump has a defect.	Repair or replace pump components as needed.
Inside problem prevents engine crankshaft from turning.	If the crankshaft can not be turned after disconnecting the driven equipment, remove the fuel injectors and check for fluid in the cylinders while turning the crankshaft. If fluid in the cylinders is not the problem, the engine must be disassembled to check for other inside problems. Some of these inside problems are bearing seizure, piston seizure or wrong pistons installed in the engine.

2. Engine will not start

Cause	Correction
Slow cranking speed.	Make reference to Items 3, 4 and 5.
Dirty fuel filter.	Install new fuel filter.
Dirty or broken fuel lines.	Clean or install new fuel lines as necessary.
Fuel pressure is low.	At starting rpm, the minimum fuel pressure from fuel transfer pump must be 20 kPa (3 psi). If fuel pressure is less than 20 kPa (3 psi) change the fuel filter element. Look for air in the fuel system. If fuel pressure is still low, check the fuel control valve and the fuel transfer pump for correct operation.
No fuel to cylinders.	Put fuel in tank. "Prime" (remove the air and/or low quality fuel from the fuel system).

2. Engine will not start (cont'd)

Cause	Correction
Bad quality fuel.	Remove the fuel from the fuel tank. Install a new fuel filter element. Put a good grade of clean fuel in the fuel tank.
Wrong fuel injection timing.	Make adjustment to timing.

3. Starting motor does not turn Deleted.

4. Air starting motor turns slowly Deleted.

5. Alternator gives no charge Deleted.

6. Alternator charge rate is not regular Deleted.

7. Alternator has noise Deleted.

8. Misfiring or running rough

Cause	Correction
Fuel pressure is low.	Make sure there is fuel in the fuel tank. Look for leaks or bad bends in the fuel line between fuel tank and fuel transfer pump. Look for air in the fuel system, sticking, binding or defective fuel control valve. Check fuel pressure. The outlet pressure of the fuel transfer pump must be a minimum of 140 kPa (20 psi) at full load speed. If fuel pressure is lower than the above pressure, install a new fuel filter element. If fuel pressure is still low, check the fuel transfer pump.
Air in fuel system.	Find the air leak in the fuel system and correct it. If air is in the fuel system it will generally get in on the suction side of the fuel transfer pump.

8. Misfiring or running rough (cont'd)

Cause	Correction
Leak or break in fuel line between fuel manifold and cylinder head.	Install a new fuel line.
Wrong valve clearance.	Make adjustment.
Wrong fuel injection timing.	Make adjustment to timing.

9. Not enough power

Cause	Correction
Bad quality fuel.	Remove the fuel from the fuel tank. Install a new fuel filter element. Put a good grade of clean fuel in the fuel tank.
Fuel pressure is low.	Make sure there is fuel in the fuel tank. Look for leaks or bad bends in the fuel line between fuel tank and fuel transfer pump. Look for air in the fuel system, sticking, binding or defective fuel control valve. Check fuel pressure. The outlet pressure of the fuel transfer pump must be a minimum of 140 kPa (20 psi) at full load speed. If fuel pressure is lower than the above pressure, install a new fuel filter element. If fuel pressure is still low, check the fuel transfer pump.
Leaks in air inlet system.	Check the pressure in the air intake manifold. Look for restrictions in the air cleaner.
Governor linkage.	Make adjustment to get full travel of linkage. Install new parts for those that have **damage** or defects.
Wrong valve clearance.	Make adjustment.
Wrong fuel injection timing.	Make adjustment to timing.
Power setting too low.	Make an adjustment of the power setting to specifications shown on the engine information plate.
Turbocharger has carbon deposit.	Inspect and repair turbocharger as necessary.

10. Stall at low rpm

Cause	Correction
Fuel pressure is low.	Make sure there is fuel in the fuel tank. Look for leaks or bad bends in the fuel line between fuel tank and fuel transfer pump. Look for air in the fuel system, sticking, binding or defective fuel control valve. Check fuel pressure. The outlet pressure of the fuel transfer pump must be a minimum of 140 kPa (20 psi) at full load speed. If fuel pressure is lower than the above pressure, install a new fuel filter element. If fuel pressure is still low, check the fuel transfer pump.
Idle rpm too low.	Make adjustment to governor so idle rpm is the same as given on the engine information plate.
Engine accessories.	Check engine accessories for damage and correct adjustment. If necessary, disconnect the accessories and test the engine.

11. Sudden changes in rpm

Cause	Correction
Failure of governor or fuel injection pump.	Look for damaged or broken springs, linkage or other parts. Remove the governor.
	Check for free travel of the control linkages. Install new parts for those that have damage or defects.

12. Loud combustion noise

Cause	Correction
Bad quality fuel.	Remove the fuel from the fuel tank. Install a new fuel filter element. Put a good grade of clean fuel in the fuel tank.
Wrong fuel injection timing.	Make adjustment to timing.

13. Valve train noise

Cause	Correction
Broken valve spring(s) or locks.	Install new parts where necessary. Broken locks can cause the valve to slide into the cylinder. This will cause much **damage.**
Not enough lubrication.	Check lubrication in valve **compartment.** There must be a strong flow of oil at engine high rpm, but only a small flow of oil at low rpm.
	Oil passages must be clean, especially those sending oil to the cylinder head.
Damage in bridge for valves.	Make **a** replacement of the bridge and make an adjustment as necessary.
Too much valve clearance.	Make correct adjustment.

14. Loud valve train noise

Cause	Correction
Broken valve spring(s).	Make replacement of damaged parts.
Broken camshaft.	Make replacement of damaged parts. Clean engine thoroughly.

15. Too much valve lash

Cause	Correction
Not enough lubrication.	Check lubrication in valve compartment. There must be **a** strong flow of oil at engine high rpm, but only **a** small flow at low rpm. Oil passages must be clean, especially those sending oil to the cylinder head.
Rocker arm worn at face that makes contact with bridge.	If there is too much wear, install new parts or rocker arms. Make adjustment of valve clearance.
End of valve stem worn.	If there is too much wear, install new valves. Make adjustment of valve clearance.
Worn push rods.	If there is too much wear, install new push rods. Make adjustment of valve clearance.

15. Too much valve lash (cont'd)

Cause	Correction
Valve lifter worn.	If there is too much wear, install new valve lifters. Make adjustment of valve clearance.
Bridges for valves worn.	Make an adjustment or replacement as necessary.
Broken or worn valve lifters.	Clean engine thoroughly. Install new valve lifters.
Check camshaft for wear.	Check for. Free movement of valves or bent valve stem. Make adjustment of valve clearance.
Worn cams on camshaft.	Check valve clearance. Check for free movement of valves or bent valve stems. Install a new camshaft. Install new valve lifters. Make adjustment of valve clearance.

16. Little or no valve clearance

Cause	Correction
Worn valve seat or face of valve.	Reconditioning of cylinder head is needed. Make adjustment of valve clearance.

17. Valve rotocoil or spring lock is free

Cause	Correction
Broken locks.	Broken locks can cause the valve to slide into the cylinder. This will cause much damage.
Broken valve spring(s).	Install new valve spring(s).
Broken valve.	Replace valve and other damaged parts.

18. Noise in engine

Cause	Correction
Failure of bearing for connecting rod.	Inspect the bearing for the connecting rod and the bearing surface (journal) on the crankshaft. Install new parts where necessary.
Damaged gears.	Install new parts where necessary.
Defect in attachment.	Repair or install new components.

19. Too much vibration

Cause	Correction
Vibration damper or pulley is loose	Check vibration damper and pulley for damage. Tighten bolts or nuts. If vibration damper or pulley bolt holes have damage or wear, replace with new parts.
Vibration damper has a defect.	Install a new vibration damper.
Engine supports are loose, wrong, or have a defect.	Tighten all mounting bolts. Install new components if necessary.
Driven equipment is not in alignment or is out of balance.	Check alignment and balance. Correct if needed.
Misfiring or running rough.	Make reference to Item 8.

20. Too much white or blue smoke

Cause	Correction
Too much lubrication oil in engine.	Remove extra oil. Find where extra oil comes from. Put correct amount of oil in engine.
Misfiring or running rough.	Make reference to Item 8.
Wrong fuel injection timing.	Make adjustment to timing.
Worn valve guides.	Recondition cylinder head.
Worn piston rings.	Install new piston rings.
Failure of turbocharger oil seal.	Check inlet manifold for oil and repair turbocharger if necessary.

21. Oil at the exhaust

Cause	Correction
Too much oil in the valve compartment.	Be sure that there is plug in the end of the rocker shaft.
Worn valve guides.	Reconditioning of the cylinder head is needed.
Worn piston rings.	Inspect and install new parts as needed.

22. Too much lubrication oil used

Cause	Correction
Too much lubrication oil in engine.	Remove extra oil. Find where extra oil comes from.
	Fill engine with oil to the FULL mark on the dipstick. Then, check oil level while engine is running. Do not put too much oil in engine.
Oil leaks.	Find all oil leaks. Make repairs as needed. Check for dirty oil breather.
Oil temperature is too high.	Check operation of oil cooler. Install new parts if necessary. Clean the core of the oil cooler.
Too much oil in the valve compartment.	Be sure that there is a plug in the end of the rocker shaft.
Worn valve guides.	Recondition the cylinder head.
Worn piston rings.	Inspect and install new parts as needed.

23. Too much black or gray smoke

Cause	Correction
Not enough air for combustion.	Check air cleaner for restrictions.
Bad fuel injectors.	Install new fuel injectors.
Wrong fuel injection timing.	Make adjustments of timing.

24. Fuel consumption too high

Cause	Correction
Fuel system leaks.	Replacement of parts is needed at points of leakage.
Fuel and combustion noise (knock).	Make reference to Item 8 and Item 9.
Wrong fuel injection timing.	Make adjustment to timing.

25. Low oil pressure

Cause	Correction
Dirty oil filter or oil cooler.	Check the operation of bypass valve for the filter. Install new oil filter element if needed.
	Clean or install new oil cooler core. Remove dirty oil from engine. Put clean oil in engine.
Diesel fuel in lubrication oil.	Find the place where diesel fuel gets into the lubrication oil. Make repairs as needed. Drain the lubrication oil that has diesel fuel in it. Install a new oil filter element. Fill the engine with clean oil.
Too much clearance between rocker arm shaft and rocker arms.	Check lubrication in valve compartments. Install new parts as necessary.
Oil pump suction pipe has a defect.	Replace pipe.
Pressure regulating valve does not close.	Clean valve and housing. Install new parts as necessary.
Oil pump has a defect.	Repair or replace oil pump.
Too much clearance between crankshaft and crankshaft bearings.	Inspect the bearings and make replacement if necessary.
Too much clearance between camshaft and camshaft bearings.	Install new camshaft and camshaft bearings if necessary.
Defect in oil pressure gauge.	Install new gauge.

26. Coolant in oil

Cause	Correction
Failure of oil cooler core.	Install a new core for the oil cooler. Drain crankcase and refill with clean lubricant. Install new oil filter element.
Failure of cylinder head gasket.	Check cylinder liner projection. Install a new cylinder head gasket. Tighten the bolts holding the cylinder head.
Crack or defect in cylinder head.	Install a new cylinder head.
Crack or defect in cylinder block.	Install a new cylinder block.
Failure of, liner seals.	Replace seals.

27. Oil in cooling system

Cause	Correction
Defect in core of oil cooler.	Install a new core in the oil cooler.
Failure of cylinder head gasket.	Check cylinder liner projection. Replace head gasket.

28. Coolant is too hot

Cause	Correction
Not enough coolant in system.	Add coolant to cooling system. Check for leaks.
Pressure relief valve has a defect.	Check operation of pressure relief valve. Install a new pressure relief valve if necessary.
Combustion gases in coolant. system. Make repairs as needed.	Find out where gases get into the cooling
Water temperature regulators (thermostats) or temperature gauge has defects.	Check water temperature regulators for correct operation. Check temperature gauge operation. Install new parts as necessary.
Water pump has a defect.	Make repairs to the water pump as necessary.
Too much load on the system.	Reduce the load.
Wrong fuel injection timing.	Make adjustment to timing.

29. Engine has early wear

Cause	Correction
Dirt in lubrication oil.	Remove dirty lubrication oil. Install a new oil filter element. Put clean oil in the engine. Check oil filter bypass valve for a weak or broken spring.
Air inlet leaks.	Inspect all gaskets and connections. Make repairs if leaks are found.
Fuel leakage into lubrication oil.	This will cause high fuel consumption and low engine oil pressure. Make repairs if leaks are found. Install new parts where needed. Make reference to Items 24 and 25.

30. Exhaust temperature is too high

Cause	Correction
Air inlet system has a leak.	Check pressure in the air intake manifold. Look for restrictions at the air cleaner. Correct any leaks.
Exhaust system has a leak.	Find cause of exhaust leak. Make repairs as necessary.
Air inlet or exhaust system has a restriction.	Remove restriction.
Wrong fuel injection timing.	Make an adjustment to the timing.

Caterpillar Warranty

INDUSTRIAL, AGRICULTURAL, AND MARINE ENGINES, MARINE TRANSMISSIONS AND ELECTRICAL POWER GENERATION PRODUCTS

This warranty applies to the following products delivered to the first user on or after January 1, 1982.

Caterpillar warrants new engines for industrial, agricultural, and marine applications, marine transmissions and electrical power generation products ("products") sold by it (except products installed in on-highway vehicles, in machines manufactured by Caterpillar or in marine pleasure craft sold in the United States of America, to which different warranties apply) to be free from defects in material and workmanship subject to the following provisions.

Warranty Period

The warranty period is 12 months (24 months for standby electric generators and mobile agricultural machines) starting from date of delivery to the first user.

Caterpillar Responsibilities

If a defect in material or workmanship is found during the warranty period Caterpillar will provide through a Caterpillar dealer or other source approved by Caterpillar:

- New or repaired parts at Caterpillar's choice.
- Reasonable and customary labor during normal working hours needed to make the warranty repair.
- Labor needed to disconnect and reconnect the product from its attached equipment, mounting, and support systems.
- Reasonable travel expenses if Caterpillar chooses to perform the repair in the field.
- Usual and customary parts shipping charges to the approved source.
- Lubricating oil, filters, antifreeze and other service items made unusable by the warranty failure.

User Responsibilities

User is responsible for

- All costs for transporting the product or equipment in which the product is installed.
- Travel expenses for field repair of products in remote places.
- Premium or overtime labor costs.
- Any removal and installation costs beyond those required to disconnect and reconnect the product from its attached equipment, mounting, and support systems
- Parts shipping charges in excess of those which are usual and customary
- Costs to investigate performance complaints unless the problem is caused by a defect in Caterpillar material or workmanship
- Giving timely notice of a warrantable failure and promptly making the product available for repair.

Limitations

Caterpillar is not responsible for failures resulting from

- Any use or installation which Caterpillar judges improper
- Attachments, accessory items and parts not sold or approved by Caterpillar
- Abuse, neglect and improper repair
- User's unreasonable delay in making the product available after notice, for product improvements ordered by Caterpillar
- Caterpillar does not warrant items sold by it which are warranted by another maker

This warranty is expressly in lieu of any other warranties, express or implied, including any warranty of merchantability or fitness for a particular purpose. Remedies under this warranty are limited to the provision of material and services, as specified above. Caterpillar is not responsible for incidental or consequential damages.

As used in this warranty the term "Caterpillar" means Caterpillar Tractor Co. or one of its subsidiaries whichever last sold the product involved.

SELF5018-01 (1-82)

SECTION II.MAINTENANCE ALLOCATION CHART

(1) GROUP NUMBER	(2) COMPONENT ASSEMBLY	(3) MAINTENANCE FUNCTION	(4) MAINTENANCE CATEGORY C	O	F	H	D	(5) TOOLS AND EQUIPMENT	(6) REMARKS
01	Exhaust System								
	Manifold, Exhaust	Inspect		0.5					
		Replace			6.0				
		Repair			8.0				
02	Cooling, System								
	Hoses & Clamps	Inspect	0.2						
		Replace		2.0					
	Thermostat Engine	Inspect		0.5					
		Test		0.5					
		Replace		2.0					
	Heater, External	Inspect		0.5					
	Engine Block	Replace		4.0					
		Repair			6.0				
	Water Manifold Assy	Inspect		0.5					
		Replace			6.0				
		Repair			12.0				
	Pump Water	Inspect		0.2					
		Replace			4.0				
		Repair				8.0			
		Overhaul					10.C		
03	Fuel System	Inspect		0.5					
	Turbocharger	Replace			10.C				
		Repair				12.0			
		Overhaul					24.0		
	Lines & Fittings	Inspect		0.2					
		Replace		2.0					
		Repair		4.0					
	Filter, Fuel	Inspect		0.1					
		Replace		0.3					
	Pump, Fuel Reciprocating -	Inspect		0.3					
		Test			1.5				
	Pumps Fuel Injection	Replace			3.0				
		Repair				6.0			
		Overhaul					8.0		

SECTION II. MAINTENANCE ALLOCATION CHART

(1) GROUP NUMBER	(2) COMPONENT ASSEMBLY	(3) MAINTENANCE FUNCTION	(4) MAINTENANCE CATEGORY C	O	F	H	D	(5) TOOLS AND EQUIPMENT	(6) REMARKS
	Injectors, Fuel	Inspect		0.5					
		Test			1.0				
		Adjust			1.0				
		Replace			2.0				
		Repair				3.0			
04	Engine								
	Engine Assembly	Inspect		1.5					
		Test				8.0			
		Service	1.5						
		Replace			40.0				
		Repair		24.0					
		Overhaul					120.0		
	Filter, Oil	Inspect		0.2					
		Replace		0.5					
	Lube Oil Cooler	Inspect		0.2					
		Replace		4.0					
		Repair			8.0				
	Drive Mechanism Fuel Pump	Inspect		1.0					
		Replace			8.0				
		Repair				16.0			
	Pump, Oil	Inspect			2.0				
		Replace			5.0				
		Repair				10.0			
		Overhaul					12.0		
	Compression Release Mechanism	Inspect			2.0				
		Replace			4.0				
		Repair			8.0				
	Governor	Inspect			0.3				
		Test			2.0				
		Replace			2.0				
		Repair				10.0			
		Overhaul					16.0		
	Governor Drive	Inspect			2.0				
		Replace			4.0				
		Repair				8.0			
	Manifold, Intake	Inspect		0.5					
		Replace			4.0				
		Repair			6.0				

SECTION II. MAINTENANCE ALLOCATION CHART

(1) GROUP NUMBER	(2) COMPONENT ASSEMBLY	(3) MAINTENANCE FUNCTION	(4) MAINTENANCE CATEGORY C	O	F	H	D	(5) TOOLS AND EQUIPMENT	(6) REMARKS
	After Cooler	Inspect		0.5					
		Replace			8.0				
		Repair				12.0			
	Fly Wheel & Damper	Inspect			1.0				
		Replace			2.0				
	Rocker Arms	Inspect		0.3					
		Replace			1.5				
		Repair				3.0			
	Cylinder Head Assy	Inspect		0.5					
		Replace			4.0				
		Repair				10.0			
		Overhaul					16.0		
	Rods, Push	Inspect			1.0				
	Replace				1.0				
	Valves, Intake &	Inspect			1.0				
	Exhaust	Adjust			1.5				
		Replace				8.0			
		Repair				12.0			
	Lifters, Valve	Inspect			1.0				
		Replace			1.0				
	Oil Pan	Inspect		1.0					
		Replace				16.0			
		Repair				24.0			
	Pistons & Connecting	Inspect			2.0				
	Rods	Replace			12.0				
		Repair				20.0			
	Liners, Cylinder	Inspect			2.0				
		Replace			12.0				
		Repair				20.(			
	Camshaft & Bearings	Inspect			4.0				
		Replace				16.(			
	Crankshaft &	Inspect			2.5				
	Bearings	Replace				40.0			
		Repair					60.0		

SECTION II. MAINTENANCE ALLOCATION CHART

(1) GROUP NUMBER	(2) COMPONENT ASSEMBLY	(3) MAINTENANCE FUNCTION	(4) MAINTENANCE CATEGORY C	O	F	H	D	(5) TOOLS AND EQUIPMENT	(6) REMARKS
	Engine Block	Inspect		1.0					
		Test					8.0		
		Replace					40.0		
		Repair				24.0			
		Overhaul					80.0		

SECTION III. TOOL AND TEST EQUIPMENT REQUIREMENTS

REF. CODE	MAINT. CAT.	NOMENCLATURE	NATIONAL/NATO STOCK NUMBER	TOOL* NUMBER

By Order of the Secretary of the Army:

JOHN A. WICKHAM, JR.
General, United States Army
Chief of Staff

Official:

R. L. DILWORTH
Brigadier General, United States Army
The Adjutant General

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☆**U.S. GOVERNMENT PRINTING OFFICE: 1990 - 261-88/22713**

THE METRIC SYSTEM AND EQUIVALENTS

LINEAR MEASURE

1 Centimeter 10 Millimeters 0 01 Meters 0 3937 Inches
1 Meter 100 Centimeters 1000 Millimeters 39 37 Inches
1 Kilometer 1000 Meters 0 621 Miles

WEIGHTS

1 Gram 0 001 Kilograms 1000 Milligrams 0 035 Ounces
1 Kilogram 1000 Grams 2 2 Lb
1 Metric Ton 1000 Kilograms 1 Megagram 1 1 Short Tons

LIQUID MEASURE

1 Milliliter 0 001 Liters 0 0338 Fluid Ounces
1 Liter 1000 Milliliters 33 82 Fluid Ounces

SQUARE MEASURE

1 Sq Centimeter 100 Sq Millimeters 0 155 Sq Inches
1 Sq Meter 10,000 Sq Centimeters 10 76 Sq Feet
1 Sq Kilometer 1,000,000 Sq Meters 0 0386 Sq Miles

CUBIC MEASURE

1 Cu Centimeter 1000 Cu Millimeters 0 06 Cu Inches
1 Cu Meter 1,000,000 Cu Centimeters 35 31 Cu Feet

TEMPERATURE

5/9 (F 32) C
212 Fahrenheit is equivalent to 100 Celsius
90 Fahrenheit is equivalent to 32 2 Celsius
32 Fahrenheit is equivalent to 0 Celsius
9/5 C + 32 F

APPROXIMATE CONVERSION FACTORS

TO CHANGE	TO	MULTIPLY BY
Inches	Centimeters	2 540
Feet	Meters	0 305
Yards	Meters	0 914
Miles	Kilometers	1 609
Square Inches	Square Centimeters	6 451
Square Feet	Square Meters	0 093
Square Yards	Square Meters	0 836
Square Miles	Square Kilometers	2.590
Acres	Square Hectometers	0 405
Cubic Feet	Cubic Meters	0.028
Cubic Yards	Cubic Meters	0.765
Fluid Ounces	Milliliters	29 573
Pints	Liters	0.473
Quarts	Liters	0.946
Gallons	Liters	3.785
Ounces	Grams	28.349
Pounds	Kilograms	0.454
Short Tons	Metric Tons	0 907
Pound-Feet	Newton-Meters	1.356
Pounds per Square Inch	Kilopascals	6.895
Miles per Gallon	Kilometers per Liter	0.425
Miles per Hour	Kilometers per Hour	1.609

TO CHANGE	TO	MULTIPLY BY
Centimeters	Inches	0.394
Meters	Feet	3.280
Meters	Yards	1.094
Kilometers	Miles	0.621
Square Centimeters	Square Inches	0.155
Square Meters	Square Feet	10.764
Square Meters	Square Yards	1.196
Square Kilometers	Square Miles	0.386
Square Hectometers	Acres	2.471
Cubic Meters	Cubit Feet	35.315
Cubic Meters	Cubic Yards	1,308
Milliliters	Fluid Ounces	0.034
Liters	Pints	2.113
Liters	Quarts	1.057
Liters	Gallons	0.264
Grams	Ounces	0.035
Kilograms	Pounds	2.205
Metric Tons	Short Tons	1 102
Newton-Meters	Pound-Feet	0.738
Kilopascals	Pounds per Square Inch	0.145
Kilometers per Liter	Miles per Gallon	2.354
Kilometers per Hour	Miles per Hour	0.621

TEAR ALONG PERFORATED LINE

RECOMMENDED CHANGES TO EQUIPMENT TECHNICAL PUBLICATIONS



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