Model 4700

GPIB Remote Controlled
AC Watt (Hour) Meter Calibration System

KROHN-HITE CORPORATION

Operating Manual

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Model 4700
OPERATORS
MANUAL

Serial No._____

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4700 SYSTEM

OPERATORS MANUAL

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SCHEMATICS AND LAYOUTS

4701A SCHEMATICS

Control Board Displays	CB-4736A
Control Board Switches	CB-4737A
MPU	CB-4721
MPU - IO	CB-4722
MPU-488 & 4702 INTERFACE	CB-4723
Sinewave Osc. and Amps Phase Shifter	B-4195L
PWM DACS	B-4193F
Volts AGC Circuitry	B-4194D
Comparators	CB-4196G
Power Amp	B-4192D
Power Supply	B-4200C
Reference Drawing	930727A

4702 SCHEMATICS

Power Supply Control Circuitry	B-4210F
Current Source	B-4211D

SYSTEM SCHEMATICS

Block Diagram	B-4190A
Connections to Watt-hour Meter Under Test	FIG.3.1.0

CALIBRATION & TEST POINT LAYOUTS

4701A MPU Board Calibration &	CB-4741A
4701A Mother Board Calibration	B-4274E
4702 Mother Board	B-4251A

WARRANTY

The Krohn-Hite Corporation (K-H) warrants to the original purchaser each instrument manufactured by them to be free from defects in material and workmanship. This warranty is limited to servicing, repairing and/or replacing any instrument or part thereof returned to the K-H factory for that purpose in accordance with the instructions set forth below; and furthermore to repair or replace all materials, except tubes, fuses, transistors and other semiconductor devices which shall within one year of shipment to the original purchaser be returned to the K-H factory and upon examination be deemed defective.

K-H instruments may not be returned to the factory under the terms of this warranty without the prior authorization of the K-H Service Department. All instruments returned to K-H for service hereunder should be carefully packed and shipped. All transportation charges shall be paid by the purchaser.

K-H reserves the right to discontinue instruments without notice and to make changes to any instrument at any time without incurring any obligation to so modify instruments previously sold.

This warranty is expressly in lieu of all other obligations or liabilities on the part of K-H. No other person or persons is authorized to assume in the behalf of K-H any liability in the connection with the sale of its instruments.

> CAUTION: The instrument you have purchased is a precision instrument manufactured under exacting standards. Any attempts to repair, modify or otherwise tamper with the instrument by anyone other than an K-H employee or authorized representative may result in this warranty becoming void.

FACTORY SERVICE REQUEST
AND
AUTHORIZATION

WARRANTY SERVICE

Instruments may be returned only on prior authorization. Please obtain a RETURN AUTHORIZATION NUMBER either directly from the factory or from an authorized K-H Representative. (See General Information below.)

CHARGEABLE REPAIRS

If requested, an estimate of charges will be submitted prior to repairs. We suggest that you request a RETURN AUTHORIZATION NUMBER to facilitate handling.

GENERAL INFORMATION

A) Please provide the following information in order to expedite the repair:

1) Indicate MODEL

2) Serial Number

3) Complete description of the trouble:

Symptoms, measurements taken, equipment used, lash-up procedures, attempted repairs, suspected location of failure and any other pertinent information.

B) Freight Charges must be PREPAID.

C) The RETURN AUTHORIZATION NUMBER should be noted on your documentation.

D) See Packing Suggestions - next page.

PACKING SUGGESTION

Although your K-H instrument is built for laboratory, production environment and some field environment, it is NOT ruggedized. Therefore...

1. Be sure the carton is STRONG enough to carry the weight of the instrument, e.g. use double wall corrugation.

2. Be sure the carton is LARGE enough to allow for sufficient packing material, e.g., at least 2 inches all around the instrument. The packing material should be able to be compressed and then return to its approximate original volume.

3. For better handling, the shipment should always be by AIR FREIGHT (expect for short distances). You might use either UPS "blue label" or common air freight carrier, second day air.

   Please do not bounce it across the country in a truck. It may not hurt it, but it certainly is not going to do a laboratory instrument much good.

4. QUESTIONS? Just contact us. We will be pleased to help you.

SECTION I

1.0.0 DESCRIPTION AND SPECIFICATIONS

1.1.0 General Description

1.1.1 The EDC Model 4701 is a controller and voltage source, which is, used in conjunction with the E.D.C. Model 4702 current source.

1.1.2 The resultant two unit system forms a wattmeter or watt-hour meter calibrator with independent control of frequency, voltage amplitude, current amplitude and phase angle.

1.1.3 The system may be controlled manually with the 4701 front panel controls or via the IEEE-488 bus.

1.1.4 The 4701 accepts an optical pickup input for timing of a preset number of meter disk revolutions, or a TTL pulse input from an electronic watt-hour meter.

1.1.5 The system has a specified accuracy and is traceable to N.I.S.T.

1.1.6 The system is overload and short-circuit proof.

1.2.0 Output Specifications

1.2.1 FREQUENCY:

Setability: 50, 60 or 400 Hz

Accuracy: $\pm$0.001%

1.2.2 VOLTAGE: (4701)

Setability: 10x, 11x, 12x, 20x, 21x, 22x, 23x, 24x, 25x, 26x, 27x, or 48x volts.
(Where x is an integer ranging from 0 to 10.)

Accuracy: . $\pm$0.05% of setting 01% of Full Scale. (Full Scale = 480V)

Power Output: 20 Watts minimum at any setting.

1.2.3 CURRENT: (4702)

Setability: 100, 50, 30, 15, 10, 5, or 2.5 Amps or 10% of the above currents, or 0 current for the "Creep" test.

Accuracy: . ±0.05% of setting ±0.01% of full scale
(Full scale = 100 A for 100% setting and
(Full scale = 10 A for 10% setting).

Compliance Voltage:
10A Range - 5.0 VAC rms.
100A Range - 0.5 VAC rms.

Power Output: 50 Watts at full scale output.
At other settings it is proportional to percentage of full scale, e.g. the power output at 50A on the 100A range is 25W.

1.2.4 SYSTEM ACCURACY AT UNITY POWER FACTOR

. ±0.07% of Setting ±0.014% of Full Scale

Full Scale = 480V x 100A = 48 kw* for 100% Current Setting
Full Scale = 480V x 10A = 4.8 kw* for 10% Current Setting

* Simulated

1.2.5 STABILITY

Observed bounce:. ±0.01%
Long term stability (6 months): ±0.02%

Note: In the Model 4702, Current Amplifier, there may be output current drift due to self heating on prolonged settings exceeding 50 Aac equal to ±0.02%

1.2.6 PHASE ANGLE:

Setability: . ±69° in 1° increments
Accuracy: ±0.05°

1.2.7 Distortion: 0.5%

1.2.8 Load Regulation: 0.005%

1.2.9 Line Regulation: 0.0025%

1.3.0 General Specification

1.3.1 Power: Switch Selectable
115 or 230 V. 10% 50-60 Hz

		4701	4702
1.3.2	Power Consumption:	120 W	200 W
1.3.3	Net Weight:	20 lbs; 9.1 kg	42 lbs; 19.1 kg
1.3.4	Shipping Weight:	25 lbs; 11.3 kg	50 lbs; 22.7 kg
1.3.5	Dimensions:	19"w x 31/2"h x 221/2d 482 x 89 x 571.5mm	19"w x 7"h x 13.75"d 482 x 177 x 349mm

1.3.6 Temperature: Calibration 23° ±1°C
Ambient 20° to 30°C
Operating Limit 10° to 50°
Storage -40° to 85°C

SECTION II

2.0.0 INSTALLATION

2.1.0 Mounting

The system is designed for mounting in a standard 19" rack. It is recommended that nylon washers be placed under the rack mounting screws to prevent scratching the mounting ears.

When rack mounting is required, use a rack support for each instrument. When the 4701, watt-hour meter and current source are set one above the other, place the current source above the watt-hour meter for better ventilation.

2.2.0 Mating Connectors Normally Supplied With System

	Description	Qty	EDC Part No.
2.2.1	AC Power Cord	2	17251/CB117
2.2.2	Male 25 Pin "D" Interconnecting Cable	1	BMM6R/CB-122
2.2.3	100 Amp Male Connectors Mfr: Superior Electric Co.	Red 1 Blk 1	PP250GR/CT216 PP250GB/CT217
2.2.4	Voltage Output Connector	1	MS-3106A-14S-6P /CT124
2.2.5	Cable Clamp for Above	1	97-3057-6/CT122
2.2.6	Optical Pickup Cable Mount Socket MFR: Switchcraft	1	TA5FL/OD143

2.3.0 IEEE-488 BUS (GPIB) Cables

A one or two meter IEEE Std. 488 cable may be obtained from EDC. It is EDC part number 3045-1 or 3045-2.

2.4.0 110/230 Line

2.4.1 A 110/230 line switch is located on the rear panel of each instrument, 4701 and 4702. Set the switch to the position correct for the line voltage the system will be connected to.

SECTION III

3.0.0 SYSTEM OPERATION

3.1.0 System Interconnections

The system is connected to the watt-hour meter under test as shown in FIG. 3.1.0.

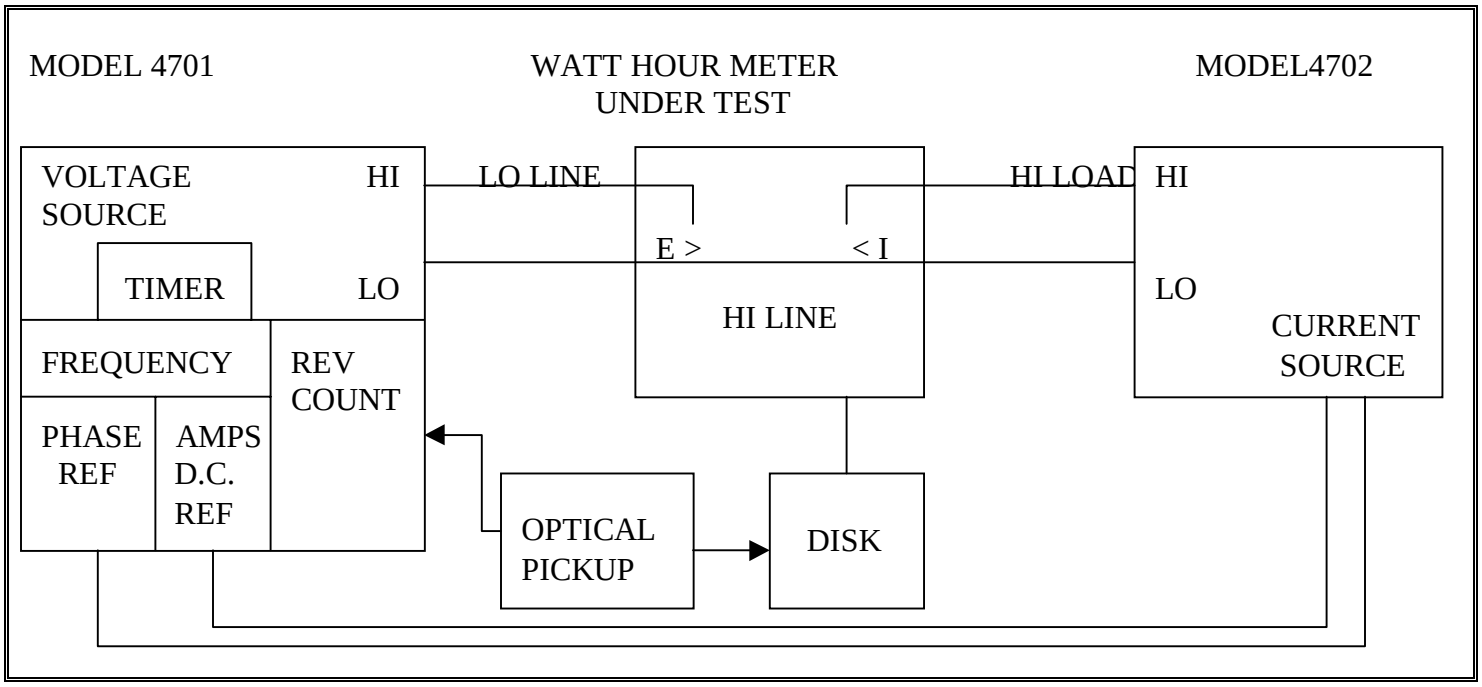


FIG 3.1.0

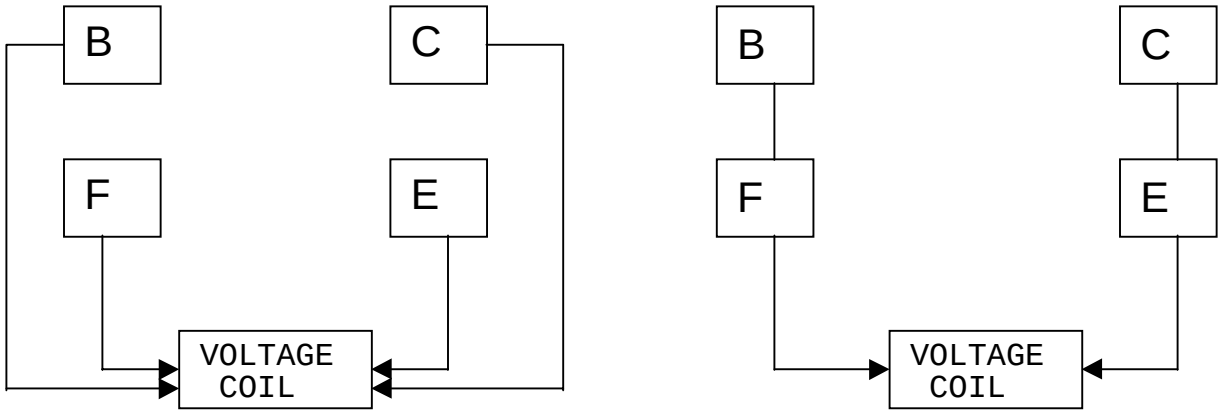
3.1.1. 4701 Voltage Output Connector

The connector pinout is:

A - Chassis Ground
B - HI Out
F - HI Sense
C - Lo Out
E - Lo Sense

If the voltage input of the watt-hour meter under test is high impedance, short pin B to pin F and short pin C to pin E. If the voltage input to the watt-hour meter under test draws appreciable current the remote sense capability should be used.

ONE OF THE CONFIGURATIONS SHOWN BELOW MUST BE USED.



A
(FOUR WIRE BETWEEN 4701 AND LOAD)
CORRECT FOR LARGE LOADS

FIG 3.1.1

B
(TWO WIRE BETWEEN 4701 AND LOAD)
CORRECT FOR SMALL LOADS
INCORRECT FOR LARGE LOADS

NOTICE

THE SENSING CIRCUIT MUST BE COMPLETE. PLEASE REFER TO DRAWING 930727 IN THE REAR OF THIS MANUAL.

3.1.2 4702 Current Output Connections

3.1.2.1 High Current Connections

For 100% Amps settings, the large output terminals must be used. No. 1/0 AWG wire is suitable. The flexible welding cable is convenient for many applications.

3.1.2.2 Lo Current Connections

For 10% Amps settings, the small output terminals must be used. No. 18 AWG wire or larger is suitable for the lower currents.

CAUTION:
ONLY ONE SET OF OUTPUT TERMINALS MAY BE USED AT ONE TIME.

3.1.3 4701 to 4702 Interconnection

Interconnect the two units with the 25 pin male "D" cable provided with the system.

3.1.4 4701 Optical Trigger Input

A contact closure, a TTL level or an optically derived level may be used as a trigger. The system triggers on a high to low transition of the input. The mating cable mount socket is a Switchcraft No. TA5FL.

The pinout is shown below.

OPTICAL TRIGGER INPUT CONNECTOR (TA5FL) PINOUT

PIN 1 - INPUT
PIN 2 - +5 V
PIN 4 - DIGITAL GROUND

3.2.0 Front Panel Controls and Annunciators

All of the system front panel controls and annunciators are located on the 4701 except the 4702 power switch.

3.2.1 Power Switches

Rocker with indicator - one on each unit.

3.2.2 Reset - Run - Remote Switch

The RESET and RUN positions are local modes where the system is programmable by the other front panel controls. In the REMOTE position the system is programmable via the IEEE-488 Bus. In the remote mode the annunciator and indicators display the programmed values. The RESET positions resets the timer to zero. The next high to low transition on the trigger input will start the counter.

3.2.3 Disk Revolutions Switch

Settable from 1-12 with indicator. The third trigger input will start the counter counting real time in increments of 10 ms. After "N" disk revolutions the counter will stop.

3.2.4 Standby Switch

In the standby mode the voltage and current outputs are shut off.

3.2.5 Volts Switches

The coarse switch selects the first two digits of 10x, 11x, 12x, 20x, 21x, 22x, 23x, 24x, 25x, 26x, 27x or 48x volts. The FINE switch selects x which is an integer ranging from 0 to 10. A 3 digit indicator displays the voltage.

3.2.6 Amps Switches

The SET switch selects 0.0, 2.5, 5, 10, 15, 30, 50 or 100 Amps. The % switch selects either 10% or 100% of the above values. A 3 digit indicator displays the amperage.

3.2.7 Phase Switches

The first two switches select a phase angle between 0 and 69 . The third switch determines whether the current lags or leads the voltage. A two digit indicator and a LEAD-LAG annunciator displays the selected settings.

3.2.8 Frequency Switch

The frequency may be set at 50, 60 or 400 Hz. An annunciator displays the selected frequency.

3.2.9 Mode Annunciator

An annunciator above the STANDBY switch displays SEC (seconds), and the mode, LOC (local), REM (remote), LLO (local lock out).

3.3.0 Remote Programming Via the IEEE-488 Bus (GPIB)

3.3.1 Introduction: The EDC model 4701 is compatible with the IEEE Std. 488/1978. The applicable reference publication is: IEEE Standard Digital Interface for Programmable Instrumentation (IEEE Std. 488/1978).

Publisher: The Institute of Electrical and Electronics Engineers, Inc.
345 East 47th Street
New York, NY 10017

The <GP-IB> makes it possible for a user to connect various instruments and components together into a functional system. However, this system will not work without the proper software.

The operating system software offers a set of functions and commands which the user can assemble into a written program. Once written, the user's application program, in conjunction with the operation system software, will allow the various instruments on the <GP-IB> to generate signals, take measurements, and allow the instrument controller to manage the resulting information.

All commands sent over the <GP-IB> must be expressed in the controller's own language such as BASIC, FORTRAN, etc.

There are three steps that MUST be taken when using the <GP-IB> to make the system operate. The user MUST:

a. Understand what tasks must be performed.
b. Use the controller's language.
c. Know what kind of information the instruments are capable of exchanging.
d. READ THE CONTROLLER PROGRAMMING MANUAL THOROUGHLY!!!

3.3.2 The interface capabilities of the 4701 are SH1, AH1, T6, L4, SR1, RL0, PP2, DC0, DT0, E1, (See para. 3.3.19 for PP2 exception.)

3.3.3 Interface Messages: The EDC 4701 will respond to the following interface messages:

"MLA". - My Listen Address. Upon receipt of this message, the instrument will enter its listener active state and be ready to accept a string of data bytes. ATN must be true.

"UNL". Unlisten. Upon receipt of this message, the instrument will enter its listener idle state and will not listen to any subsequent data byte strings. ATN must be true.

"IFC". Interface Clear. Upon receipt of this command the instrument will enter its listener idle state.

"Power-On" Clear. On "Power-On", and remote mode, the instrument will be in the listener idle state and its analog output will be 0.

The instrument will also go to its listener idle state when in the local mode.

3.3.4 There are several groups of commands which the 4701 will act upon, when received over the bus.

A. Normal messages to program the unit's output to a specified voltage and current.

B. Normal messages to program the unit's output to a specified frequency and phase angle.

C. Messages requesting specific responses on the condition of the 4701.

D. Serial Poll in response to a SRQ.

E. Parallel Poll to indicate device status.

F. Interface Clear (IFC)

3.3.5 Setting the Instrument's Address: The EDC 4701 bus address is set with a "dip switch" located on the MPU board.

NOTE: THE BUS ADDRESS IS DISPLAYED UPON GOING FROM REMOTE TO LOCAL, AND THE DISPLAYED ADDRESS IS THE DEVICE NUMBER THE MODEL 4701 WILL RESPOND TO. HOWEVER, IF THE ADDRESS SWITCH IS CHANGED WHILE IN THE REMOTE MODE, THE DISPLAY WILL NOT INDICATE THE NEW ADDRESS, ALTHOUGH THE INSTRUMENT WILL NOW RESPOND TO THE NEW ADDRESS.

3.3.5.1 Use switches 1 through 5. They are arranged in BINARY code.

SW1 = Bit 1
SW2 = Bit 2
SW3 = Bit 4
SW4 = Bit 8
SW5 = Bit 16
ON = True
OFF = False
Binary numbers 0 through 30 are acceptable.

DO NOT SET ALL 5 SWITCHES TO "ON".

3.3.6 The output voltage amplitude and frequency of the Model 4701 are individually controlled over the bus, as are the amplitude and phase shift of the current output of the 4702. Simplified commands will program the outputs to the correct levels and frequency. The best range of voltage and current are selected, assuring the output will be at the level which gives the best performance.

3.3.7 When the Model 4701 is first placed into the remote mode, the outputs are reduced to zero and a complete message string must be sent across to set each parameter i.e.; Voltage, Current, and Frequency. Load will default to 100% or Heavy Load. Revolutions will be set at 1. Phase will default to 0°.

3.3.8 The data to be sent for the various functions are outlined in table 3.3.0.

3.3.9 A complete message string might look like this:

"E125A2D+55F060R009RU"

Which translates to:

125VAC,10amps,55°Leading,60Hz,9Revolutions,Run

3.3.10 To program the 4701 to execute an elapsed time test the bus message "RU" must be sent. Even though this message may be sent by itself, prior data must have been sent to set up the voltage, current, phase, load, frequency and number of revolutions.

3.3.11 The elapsed time count is stored in an elapsed time register and may be accessed over the bus with the "?ET" command. When the unit is placed in the TALK mode, it will respond with "ET=nnn.nnSECS". n =0-9.

3.3.12 Several other commands are available to permit the logging of the elapsed time reading with time and date of the test. See table 3.3.0.

3.3.13 The last elapsed time reading is stored in the elapsed time register, and may be read over the bus at any time prior to another elapsed time test.

3.3.14 Data Byte String Format. In general, the 4701 may be programmed by sending over one function, or several functions in the same data string. The separator is the alpha prefixes to each function, eliminating the need for delimiters within the string.

3.3.15 Each function is programmed with its ASCII identifier plus a quantity, with the exception of the CURRENT byte.

3.3.16 The CURRENT Byte is restricted to its alpha character plus a digit from 0 to 7. These digits represent the test currents available in the 4701/4702 system. (See Table 3.3.16)

CURRENT BUS CODES

ASCII CHARACTER	100% AMPS OUT	10% AMPS OUT
0	0.0	0.0
1	2.5	0.25
2	5.0	0.50
3	10.	1.0
4	15.0	1.5
5	30.0	3.0
6	50.0	5.0
7	100.0	10.0

TABLE 3.3.16

3.3.17 The output will change to a new value after receiving the end of message terminator.

NOTE: THE 4701 MUST RECEIVE AN END OF MESSAGE TERMINATOR TO ACT ON THE MESSAGE. IT WILL RECOGNIZE CR LF, LF, OR EOI SENT WITH THE LAST BYTE, AS A TERMINATOR.

3.3.18 The EDC Model 4701 responds per IEEE 488 (GPIB)-1978 convention to a Serial Poll. A Serial Poll conducted in response to a SRQ sent to the 4701, will result in the 4701 transmitting over the bus the following status byte:

DI1-DI7 false, DI8 true

3.3.19 The EDC Model 4701 does not permit the Parallel Poll Configure, (PPC) command as implemented in the IEEE-488 (GPIB)-1978 convention. However, the unit may be configured by transmitting an ASCII "P", followed by the PPR byte. The EDC Model 4701 will respond to Parallel Polling from that point.

3.3.20 Talk Enable Modes. The controller may request specific status information from the EDC Model 4701. The messages to be sent to the EDC Model 4701 prior to sending an MTA are listed in table 3.3.2

3.3.21 Upon receipt of any of the above messages, and upon receipt of MTA, the EDC Model 4701 will respond with the appropriate information as listed in the table.

3.3.22 When the "what's wrong", (?), message is received, one of the following messages will be sent to the controller when the 4701 is placed in the talk mode.

"COMMAND ERROR"
"NOTHING WRONG"
"DATA ERROR"
"NO DATA PROGRAMMED"
"FREQUENCY ERROR"
"NO FREQUENCY DATA"
"VOLTAGE ERROR"
"NO VOLTAGE DATA"
"CURRENT ERROR"
"NO CURRENT DATA"

3.3.23 The "What's Wrong" request may be sent at any time, the EDC Model 4701 will respond with, "NOTHING WRONG" or one of the messages of Para 3.3.22. It is also used when the controller responds to an SRQ and the 4701 response signifies an error condition.

TALK MODES:

TO READ:	SEND:	RESPONSE:
1. VOLTS	?E	125VAC
2. AMPS	?A	10AMPS
3. FREQUENCY	?F	60HZ
4. *WATTS	?W	
5. *VARS	?V	
6. ELAPSED TIME	?T	ET=987.65SECS
6a. with TIME	?TT	AS 6 WITH TIME
6b. with DATE	?TD	AS 6 WITH DATE
6c. with D&T	?TC	AS 6 WITH DATE & TIME
7. REVOLUTIONS	?R	REVS=100
8. REAL TIME	?TI	10:25AM
9. *% ERROR	?%	
10. *Kh	?K	
11. *SERIAL #	?SN	
12. *MODEL	?MO	
13. LAST MESSAGE OVER THE BUS	?LM	LAST STRING RECEIVED
14. WHATS WRONG	?	SEE PARA. 3.3.22
15. REPORT	?S	CURRENT DEVICE SETTINGS
16. LEAD/LAG	?D	LEAD - LAG SETTINGS

TABLE 3.3.23

*= FOR FUTURE USE WITH KEYBOARD OPTION

3.4.0 Measurements With The System

The general Watt-Hour Meter equation is:

$$T = \frac{3600\ N\ K_h}{VI\cos\theta}$$

Where:

V is the voltage in volts.

I is the current in amperes.

θ is the phase angle.

cos θ is the power factor.

N is the number of disk revolutions.

K_h is the meter constant, and

T is the elapsed time in seconds.

If T_{th} is the theoretical elapsed time and T_{ob} is the observed elapsed time, then the meter error, E, is:

$$E = \frac{T_{th} - T_{ob}}{T_{th}}\ X\ 100\%$$

For example: if K_h= 1, N = 1, V= 110 V, I = 10A
and cos θ = °, then:

$$T_{th} = \frac{3600}{1100\ x\ ‰} = 6.55\ \text{sec.}$$

if T_{ob} = 6.62 sec., then:

Or $$E = \frac{6.55 - 6.62}{6.55}\ X\ 100\% = -1.07\%$$

1.07% SLOW

3.5.0 Power Error As A Function Of The Phase Angle Error

The power is given by $P = VI \cos \theta$

Therefore:

$$\frac{dP}{d\theta} = -VI \sin \theta$$

or: $dP = -VI \sin\theta \ d\theta$

or:

$$\frac{dP}{P} = \frac{-VI \sin \theta \ d\theta}{VI \cos \theta} = -\tan \theta \ d\theta$$

Percent error =

$$\frac{dP}{P} x\,100\% = -\tan \theta \ d\theta \ x\,100\%$$

At 60, the percent power error, for 0.1◦ phase error =

$$\frac{-1.732 \, x \, 0.1° \, x \, 2\pi \ RAD}{360°} \ X \ \ 100\% = 0.302\%$$

At 0° a 0.1° phase error would produce a negligible power error.