Description

GENERAL

The Model 33A AC-DC Meter Calibrator is a compact and accurate apparatus for the calibration of a wide range of AC and DC current and voltage indicating instruments and fulfills all requirements of Spec. MIL-C-45662A. The unit is designed for operation in a horizontal plane. The two TBS standard instruments, power supplies, rectifiers, switches, controls, precision components and safety interlocking circuitry are enclosed in an aluminum cabinet 12" high x 15½" deep x 21" wide (excluding carrying handles).

The top control panel incorporates the AC and DC taut band reference indicating instruments, coarse and fine amplitude controls, range and function selectors, safety bar interlock, equipment on-off switch, emf and current output terminals, circuit breakers and indicating lamps. An insulated work area measuring 6 inches by 11 inches is provided on the operating panel for placement of the meter being calibrated.

All controls and terminals are clearly marked utilizing red markings for AC functions and black for DC. The cabinet and panel are painted a two-tone gray color selected for minimum operator eye fatigue. A detachable aluminum cover provides storage area for the removable line power cord and plug.

The Model 33A supplies emf's ranging from 0.2 millivolt DC to 1000 volts DC in eighteen full scale ranges and from 2 millivolts AC to 1000 volts AC in nine full scale ranges. Current from .02 milliampere DC to 10 amperes DC is covered by eighteen full scale ranges, and nine full scale ranges provide .02 ampere AC to 10 amperes AC. Nominal accuracy of the equipment is ±0.35% of full scale and ±0.45% of full scale at downscale points, DC and AC at 50 - 400 Hz; within ±0.7% at full scale at 1000 Hz.

CALIBRATION DATA

The calibration data supplied with the Model 33A Meter Calibrator were determined using reference standards having an accuracy of 0.06% traceable to the National Bureau of Standards. Each full scale range is certified at full load and also under no-load conditions where applicable. The scale tracking error of each meter is determined and presented on the calibration data.

PROTECTIVE AND SAFETY FEATURES

The Model 33A incorporates a unique Safety Bar for the protection of operating personnel. The pressure sensitive bar is located adjacent to the standard meters on the control panel of the equipment. The bar must be depressed by the operator during calibration processes to obtain an output at the terminals. If the bar is released at any time, the line voltage supply to the calibrator will be automatically interrupted, and all circuits will be de-energized.

Instruments under test are protected against accidental overload by means of interlocks which de-energize the calibrator if range or function selectors are changed without first reducing the coarse amplitude control to zero. After the interlocks have been tripped it is necessary to return the coarse amplitude control to zero to re-energize the calibrator.

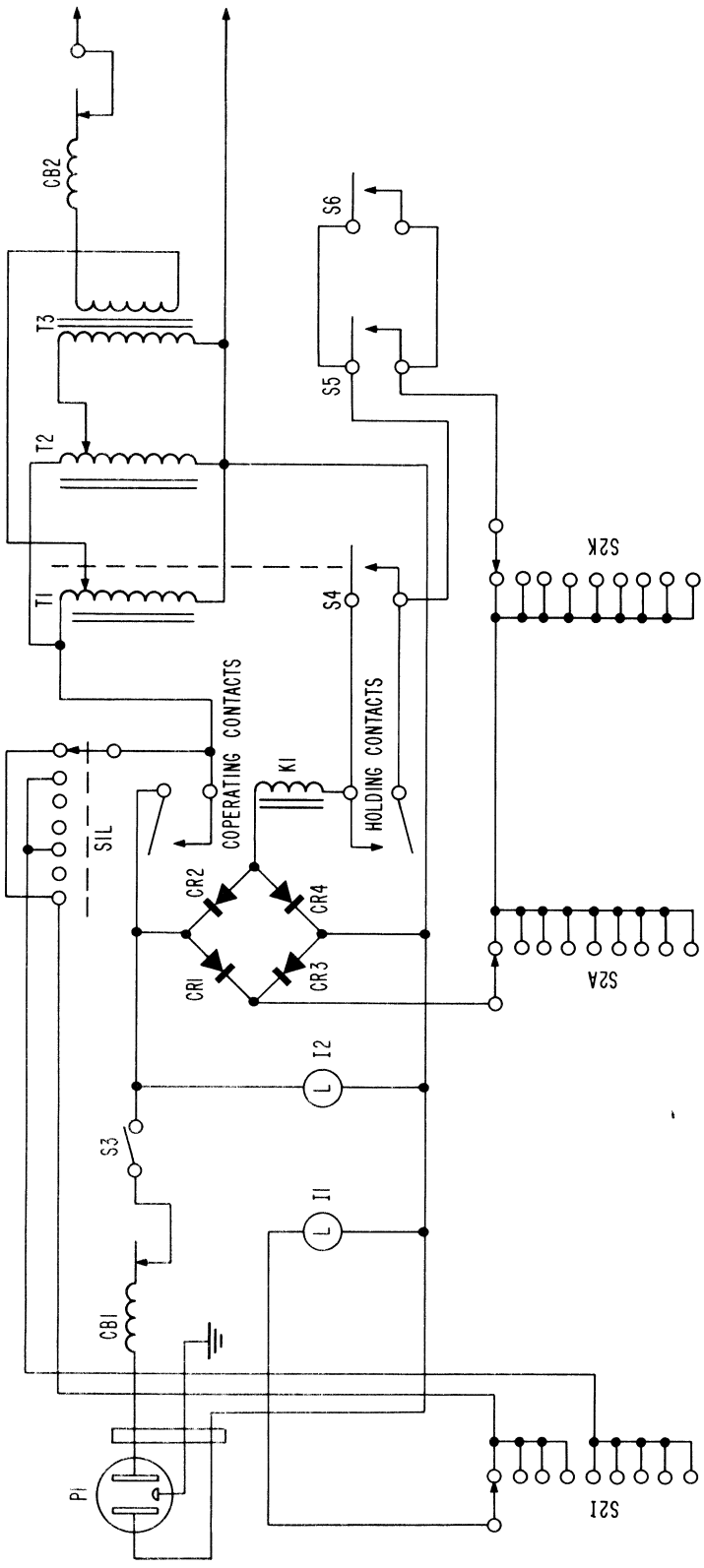
A red indicator located near the potential and current terminals and associated with the range and function selectors glows when ranges and functions having possible dangerous potentials are in use.

Theory of Operation

AMPLITUDE CONTROL AND PROTECTIVE INTERLOCK CIRCUITRY

See diagram on page 3. Line voltage is applied to the calibrator through power cable and three conductor male plug (P1). Voltage from the low or ground side of the power line is conducted to the "common" side of all transformers, indicator lamps and interlock circuitry by a common lead. The high side of the line connects to EQUIPMENT switch (S3) through thermal circuit breakers CB1. Placing EQUIPMENT switch (S3) in ON position applies line voltage to the amber indicator lamp (I2) and bridge rectifier consisting of four diodes (CR1), (CR2), (CR3) and (CR4).

The rectifier energizes control relay (K1) when actuator switches (S4) and (S5) or (S6) are closed. Switch (S4) is mechanically coupled to the control arm of the COARSE AMPLITUDE control (T1). Switches (S5) and (S6) operate when the SAFETY BAR is pressed. With the SAFETY BAR actuated and COARSE AMPLITUDE control turned fully counter-clockwise, the coil circuit of relay (K1) is closed, and the relay becomes energized. The operating contacts and holding contacts of the relay close and allow power to be applied to the amplitude control circuits. The COARSE control may be operated in a clock-wise manner without losing relay energizing current because the holding contacts are in parallel with the COARSE AMPLITUDE actuating switch. The SAFETY BAR must be depressed throughout all calibration operations, since releasing the bar will de-energize the relay and cause loss of power to the amplitude controls. Both amplitude controls are 3-terminal variable transformers connected across the line and feeding the appropriate power transformer depending on the function selected. The FINE control operates through a step-down transformer (T3) and has a total emf adjustment approximately one fifteenth that of the COARSE control.



Simplified Schematic Diagram - Amplitude Control and Protective Interlock Circuitry.

Operator safety is enhanced by mandatory use of the SAFETY BAR. The bar must be closed to allow operation of the equipment. Releasing the bar results in de-energization of the calibrator. When calibrating thermocouple type instruments, the COARSE and FINE AMPLITUDE controls should be returned to zero before releasing the bar to prevent possible transient overloads from damaging the thermocouple instrument under test. The red indicator lamp (I1) operates in conjunction with deck (S21) of the RANGE SELECTOR and deck (S1L) of the FUNCTION SELECTOR. The lamp glows when ranges and functions having possible dangerous voltages are in operation.

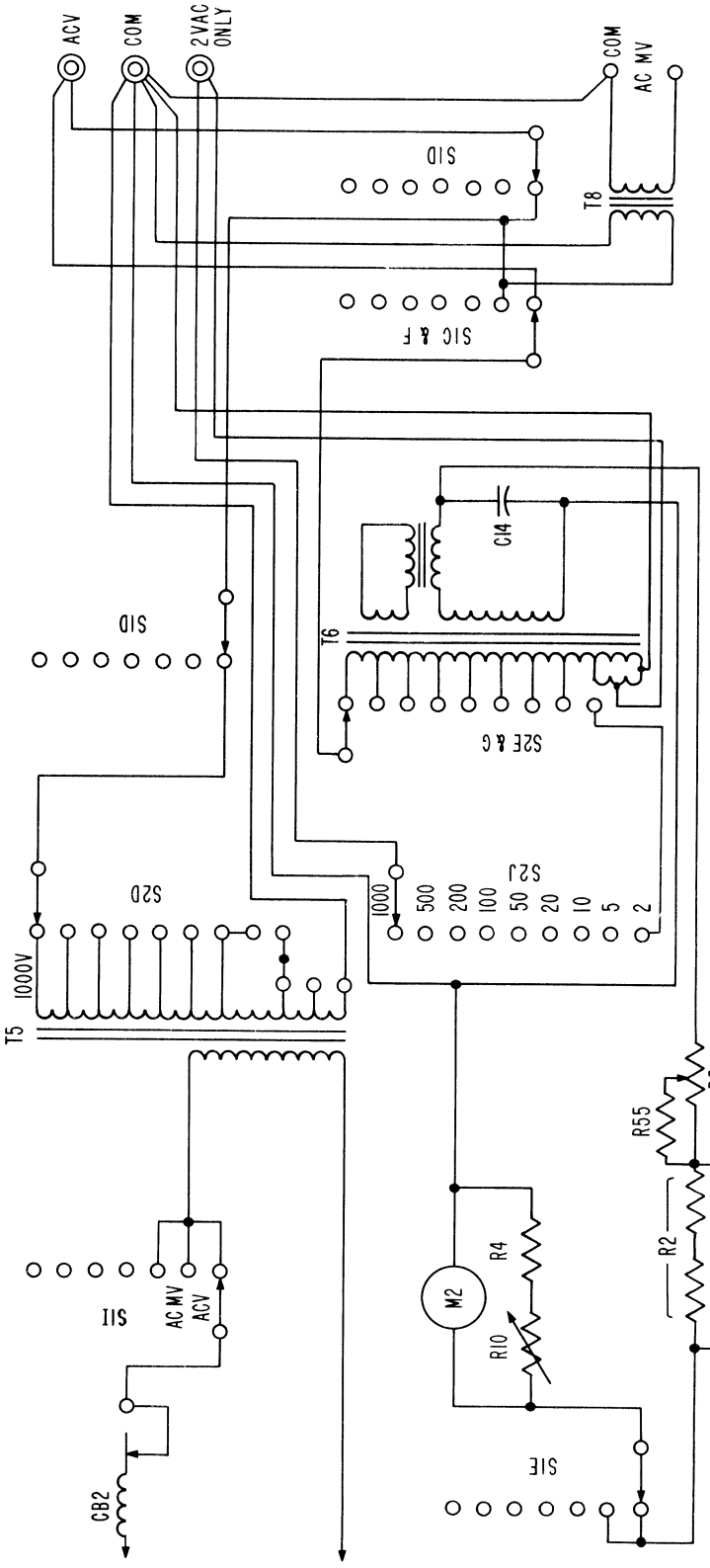
If position of the RANGE or FUNCTION SELECTOR is changed while the calibrator is energized (standard meters showing voltage or current applied to the output terminals), the equipment will immediately become de-energized in the same manner as when the SAFETY BAR is released. The COARSE AMPLITUDE control must then be returned to zero position to re-energize the calibrator. Deck (S2A) of RANGE SELECTOR and deck (S1K) of the FUNCTION SELECTOR serve as interlock connection for their respective switches.

AC VOLTS AND AC MILLIVOLTS

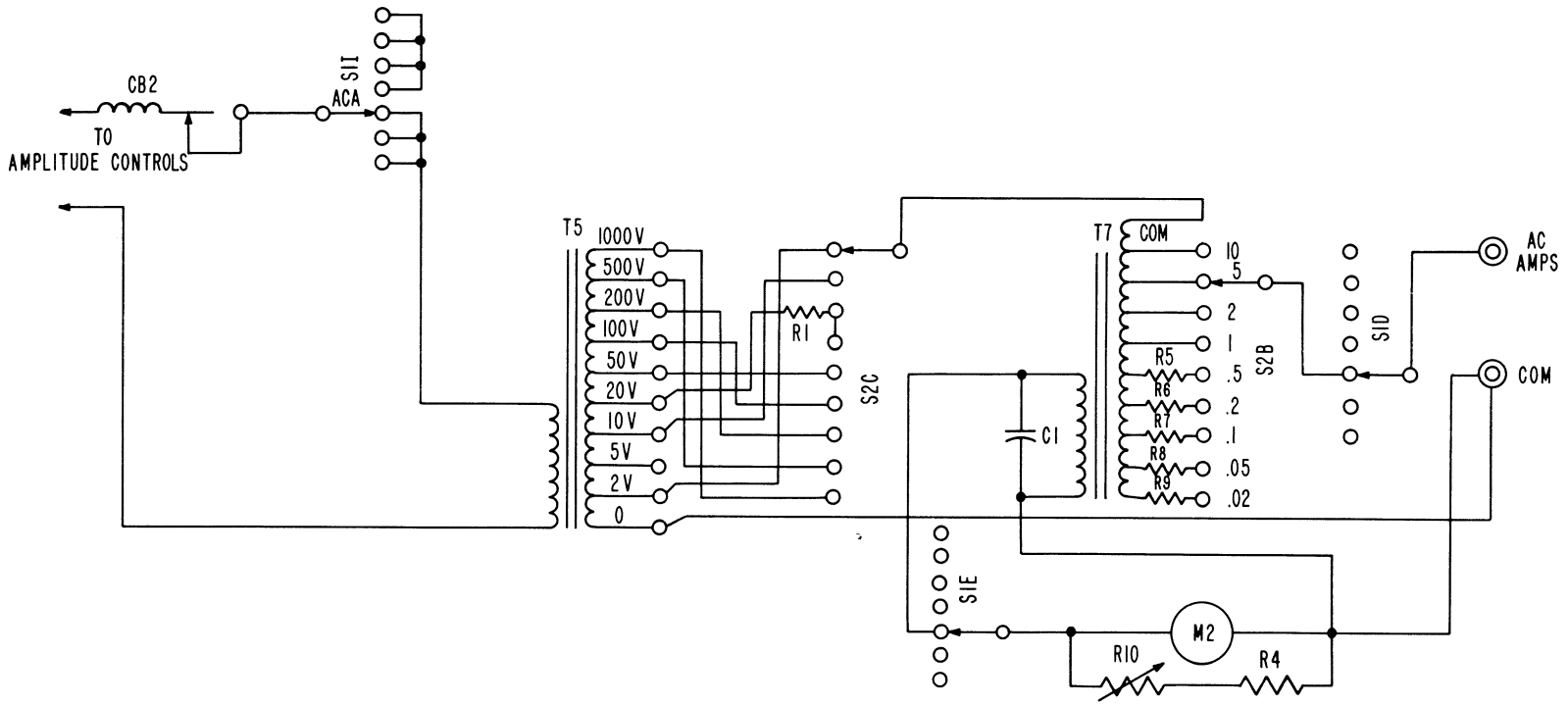
The basic components used in AC voltage calibrations are the power transformer, meter potential transformer, standard meter and associated switches and amplitude controls. See diagram on page 5. Power is fed from the amplitude controls to power transformer (T5) through deck (S11) of the FUNCTION SELECTOR. Appropriate emf is selected from the power transformer (T5) by deck (S1D) of the RANGE SELECTOR and fed to the special output terminals. An exception to this switching arrangement is the two-volt range which is fed to the 2 VOLTS ONLY terminal on the panel through deck (S2J) of the RANGE SELECTOR. The compensated meter potential transformer (T6) measures the emf applied to the output terminals through decks (S2E and S2G) of the RANGE SELECTOR, with the exception of the two-volt range which is connected directly to the VOLTS ONLY terminal. The equipment standard meter is connected directly to the 2 VOLTS ONLY terminal. The equipment standard meter is connected across the meter winding of the potential transformer. Capacitor (C14) is a compensating component connected across the meter winding of the potential transformer.

A network of resistors and capacitors associated with the meter and an integral part of the meter assembly are used to match the meter to the potential transformer. Variable resistor (R3) is used to set the voltage sensitivity of the meter to match the potential transformer during final calibration.

The primary of the millivolt transformer (T8) is connected to the appropriate taps on the power transformer (T4) and potential transformer (T6) by means of decks (S1C, F,) of the FUNCTION SELECTOR and decks (S2E, G, D, J) of the RANGE SELECTOR. The output winding is connected to the AC MILLIVOLTS terminals. The ratio of the windings of the millivolt transformer is 1000 to 1; with a measured 1000 volts applied to the primary winding a potential of 1000 millivolts (1 volt) will exist across the secondary winding. Except for a 2-volt potential at the 2 VOLTS ONLY terminal, voltage to the AC VOLTS terminals is disconnected when the FUNCTION SELECTOR is in the AC MILLIVOLTS position.



Simplified Schematic Diagram - AC Volts and AC Millivolts.



Simplified Schematic Diagram - AC Amperes.

AC AMPERES

See diagram on page 6. The basic components of the AC amperes circuit are a power transformer, current transformer, standard meter, range and function selectors. Controlled emf from the amplitude controls is applied to the primary of power transformer (T5) through deck (S11) of the FUNCTION SELECTOR. The appropriate output from the power transformer is selected by deck (S2C) of the RANGE SELECTOR and applied to the current transformer (T7). Deck (S2B) of the RANGE SELECTOR is used to pick up the appropriate tap from the current transformer for the range in use. Current is fed to the output terminals through deck (S1D) of the FUNCTION SELECTOR and from the common terminal of the power transformer. The standard meter is connected to the meter winding of the current transformer. Capacitor (C1) is used as a frequency compensating component. Variable resistor (R10) is used to match the standard meter (M2) to the current transformer during final calibration of the Model 33A.

DC VOLTS

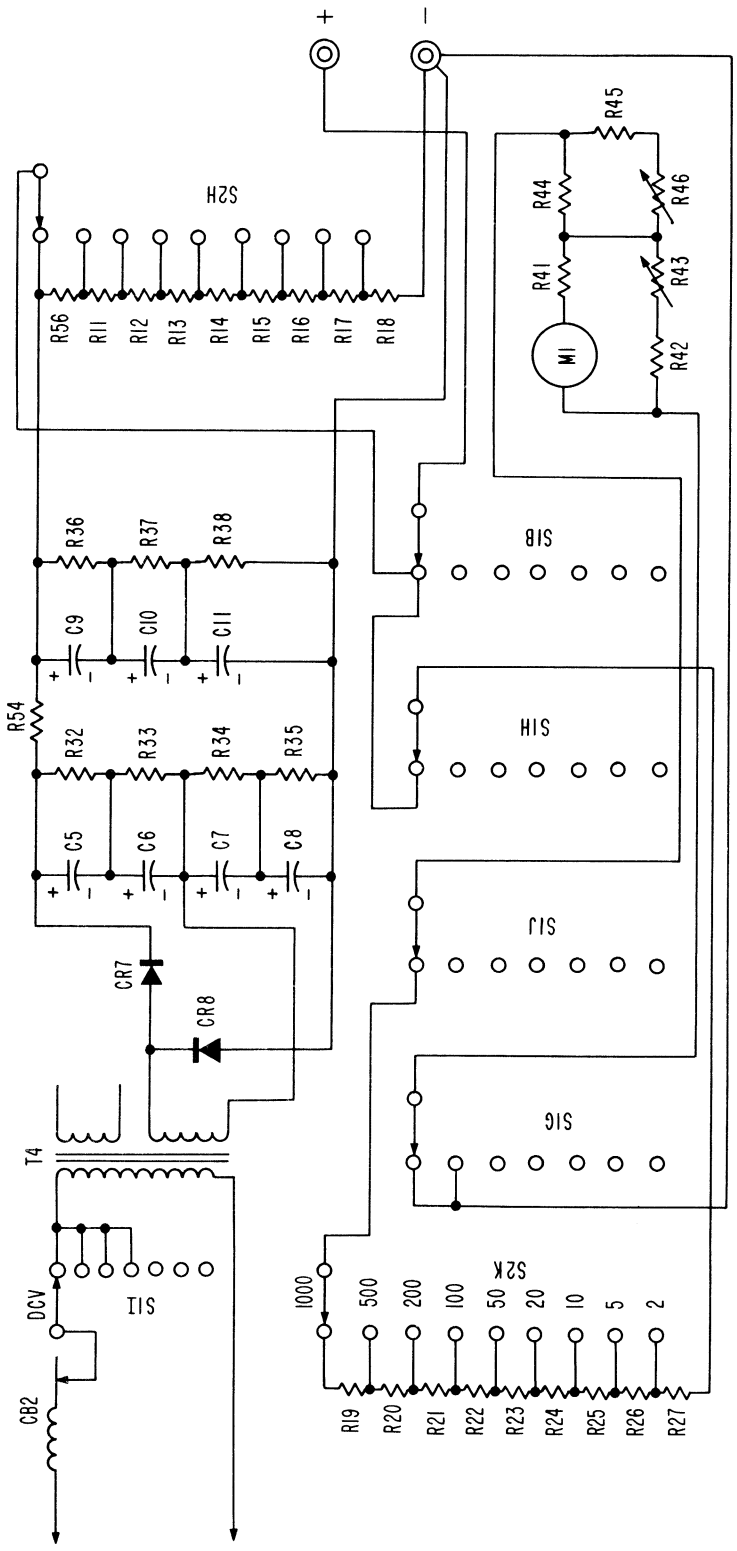
The basic components of the DC voltage circuit consist of a power transformer, rectifier and filter circuit, voltage divider, precision multiplier, standard meter, range and function selectors. See diagram on page 8.

Power from the amplitude controls is applied to the power transformer (T4) through deck (S11) of the FUNCTION SELECTOR. The output from the secondary winding is rectified and doubled by the circuit consisting of rectifiers (CR7) and CR8), filter capacitors (C5 through C11), filter resistor (R54) and equalizing resistors (R32 through R38). The filtered DC output is applied to the voltage divider resistors (R56 and R11 through R18). The appropriate voltage from the divider is selected by deck (S2H) of the RANGE SELECTOR and applied to the + output terminal through deck (S1B) of the FUNCTION SELECTOR. The same emf as that applied to the output terminals is also connected to the precision meter multiplier through deck (S1H) of the RANGE SELECTOR. The precision multiplier resistors (R19 through R27) act to extend the basic range of the standard meter (M1). The appropriate tap on the multiplier is selected by deck (S2K) of the RANGE SELECTOR and is connected to the meter through deck (S1J) of the FUNCTION SELECTOR. The low or - side of the meter is connected to the negative output terminal through deck (S1G) of the FUNCTION SELECTOR. A network of precision resistors (R41 through R46) is a part of the meter assembly. Variable resistor (R43) is adjusted to set the meter to required milliampere sensitivity during final calibration of the Model 33A.

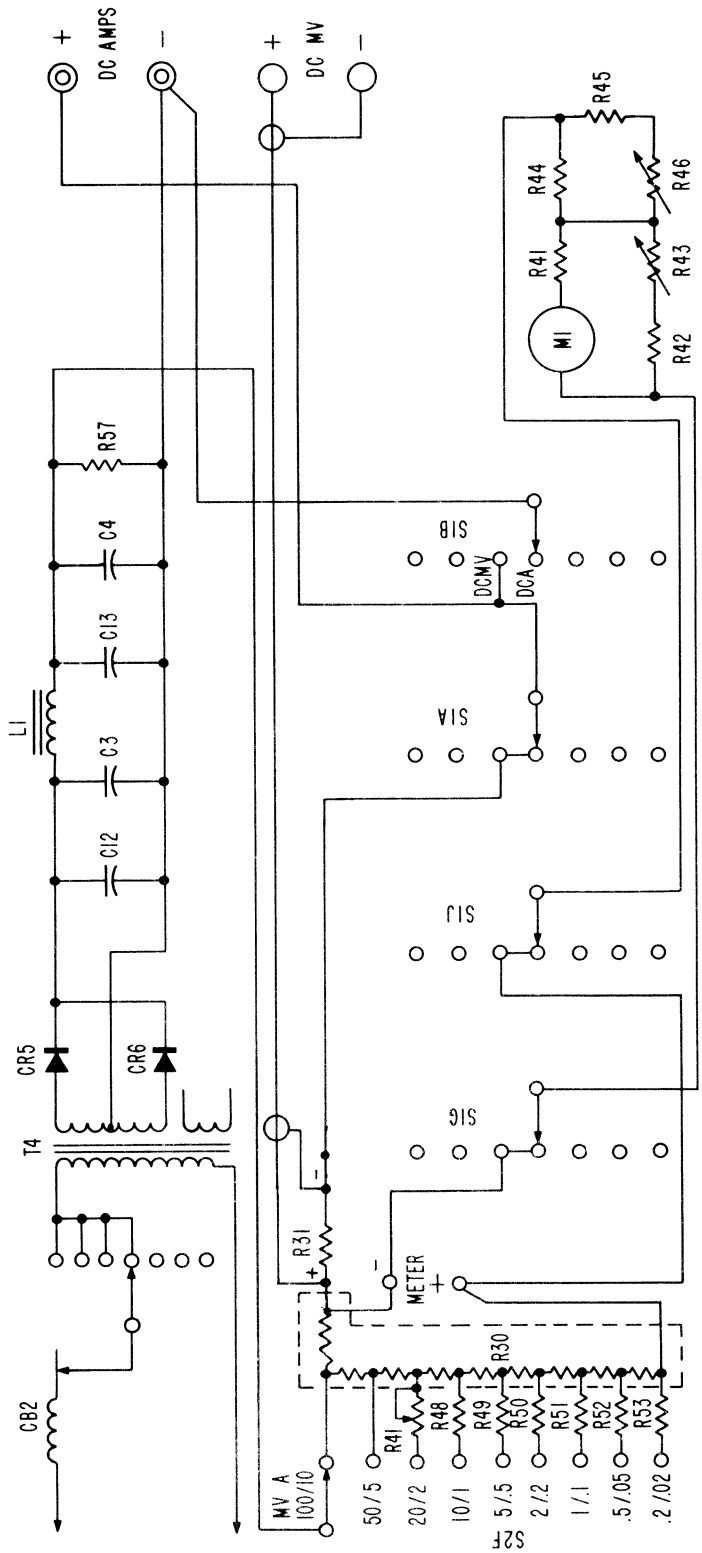
DC AMPERES AND DC MILLIVOLTS

The basic components for the DC current circuit are a power transformer, rectifier and filter network, precision shunt, standard meter, range and function selectors and a 4-terminal precision resistor for millivoltmeter calibrations. See diagram on page 9.

Power from the amplitude control circuit is applied to the primary of the power transformer (T4) through deck (S11) of the FUNCTION SELECTOR. The output from the transformer is rectified by the full-wave rectifier (CR5 and CR6). The rectified emf is filtered by the network consisting of filter capacitors (C3, 4 and C12, 13) and filter choke L1. The negative side of the supply is connected



Simplified Schematic Diagram - DC Volts.



Simplified Schematic Diagram - DC Amperes and DC Millivolts.

directly to the - DC AMPERES terminal, and the positive side is connected to the appropriate tap on the precision shunt (R30) through deck (S2F) of the RANGE SELECTOR. Current flows through the shunt, the 4-terminal millivolt resistor (R31) and to the positive DC AMPERES terminal through deck (S1A) of the FUNCTION SELECTOR. The precision shunt is operated as a 4-terminal resistor for any range, and the voltage drop across it is applied to the standard meter (M1) through decks (S1C) and (S1J) of the FUNCTION SELECTOR. A network of precision resistors (R41 - R46) matches the meter to the shunt. Variable resistor (R46) is used to set the meter to the precise parameters required during final calibration of the Model 33A.

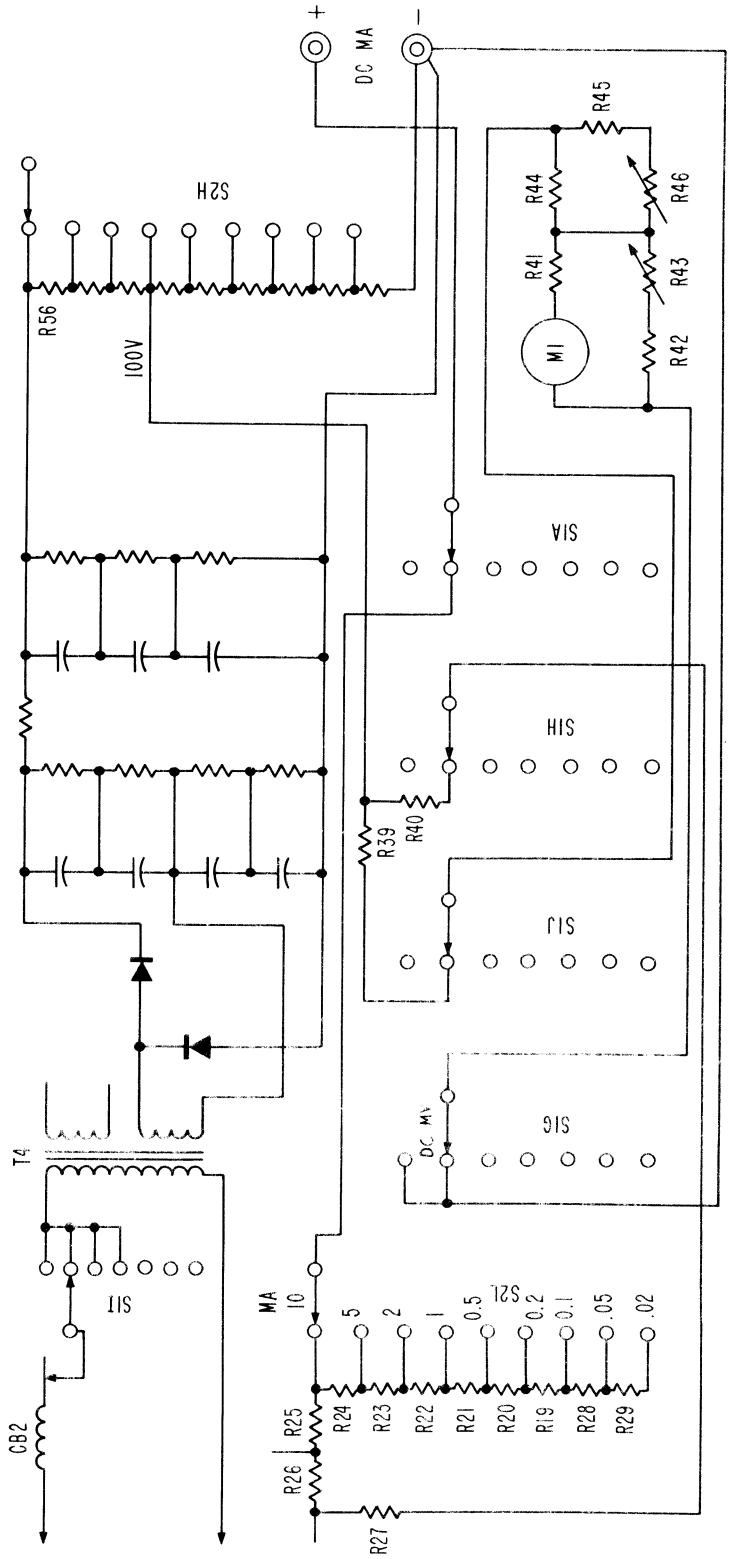
When the equipment is set to operate in the DC millivolts position, the function of the components is the same as that stated for DC amperes operation, except that a short-circuit is connected across the DC AMPERES terminals by action of deck (S1B) of the FUNCTION SELECTOR. The millivolt shunt is a 4-terminal resistor of known value. Applying a known current through it will result in a known emf being across its potential terminals. The known emf is applied to the DC MILLIVOLTS terminals of the Model 33A.

DC MILLIAMPERES

The basic circuit consists of a power transformer, voltage doubling and filter network, voltage divider, precision current divider, standard meter and a meter multiplier precision resistor.

Power from the amplitude controls is applied to the primary of the power transformer (T4) through deck (S11) of the FUNCTION SELECTOR. The output voltage from the transformer is rectified, doubled and filtered by the network consisting of rectifiers (CR7 and CR8), filter capacitors (C5 through C11), filter resistor (R54) and equalizing resistors (R32 through R38). The negative side of the supply is connected to the - DC MILLIAMPERES terminal. The positive side of the supply is connected to the top of the voltage divider circuit, resistor (R56) and resistors (R11 through R18). A tap is permanently connected to the 100-volt point on the divider and applies emf to the standard meter (M1) through precision multiplier resistor (R39) and deck (S1J) of the FUNCTION SELECTOR. A milliampere divider circuit consisting of precision resistors (R19 through R27) and (R40) is also connected to the 100-volt tap through deck (S1H) of the FUNCTION SELECTOR. Output to the positive DC MILLIAMPERES is selected by deck (S2L) of the RANGE SELECTOR. The negative side of the standard meter circuit is connected to the supply through deck (S1G) of the FUNCTION SELECTOR. In this manner, a precise 100 volts are applied to the precision divider string and the milliammeter under test in a series circuit. Ohm's Law, where a known emf across a known resistance results in a known current is applicable here. The proportion of the resistance of the precision divider to the resistance of the meter under test is great enough so that the resistance added by the meter under test results in negligible error.

For example; assume that a milliammeter having a full-scale sensitivity of 1 milliampere and a resistance of 50 ohms is to be calibrated. On this range, a circuit resistance of exactly 100,000 ohms is connected from the 100-volt tap, and the circuit is completed by the 50-ohm milliammeter being tested. By Ohm's Law, a current of 1 milliampere will flow through a 100,000-ohm resistance connected across 100 volts. In this case however, 100,050 ohms will be across the 100-volt source (100,000 ohms in the divider and 50 ohms in the meter). The computed current in this case will be 0.9995 milliampere; an error of 0.05%.



Simplified Schematic Diagram - DC Milliamperes.

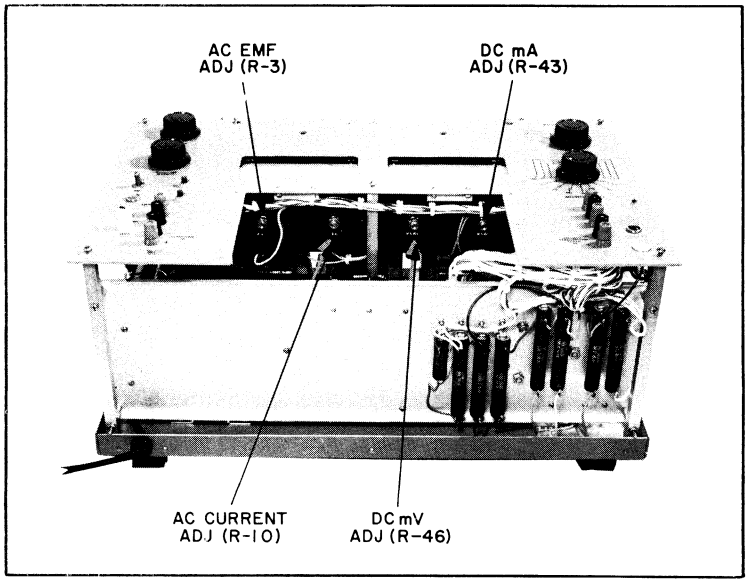
Maintenance

GENERAL PREVENTIVE MAINTENANCE

The only components requiring periodic inspection and care are the function and range switches and the coarse and fine amplitude controls. Dirty or oxidized switch contacts usually show up as erratic motion of either standard meter pointer when brought to reading. The switch contacts should be cleaned with a good grade of contact cleaner and coated with a very light film of white petroleum jelly as required. The elapsed time between cleaning periods will generally be one year, except where the instrument is used in an environment having some degree of sulphur or corrosive content in the air. In this event, cleaning may be required on a six-month basis. The contact area of the amplitude controls should be cleaned at the same time the switches are serviced. In this case, a clean cloth should be used to remove any corrosion from the area covered by the rotation of the wiping contact. No solvents should be used for cleaning the variable amplitude transformers.

ACCESS TO INTERIOR

The equipment wrap-around case is removed from the chassis by unscrewing the twelve round-head #10 screws located, three to a side, on the lower edge of the case, then lifting it straight up and off the chassis. All switches and most electrical parts are then accessible. In certain cases it may be necessary to remove the recessed test meter area to facilitate service. The six round-head #8 screws, three on each side of the meter test area, are removed, and the test plate can be slid out of the panel. Meter adjustments are located on the rear of the meters.



Trouble Shooting Chart

SYMPTOM	CAUSE	REMEDY
a. Amber pilot lamp does not glow when equipment switch is placed in on position and no response is indicated in standard or test meter when amplitude controls are advanced.	Circuit breakers CB1 or CB2 may be tripped.	Depress breaker push button. Should lock in down position.
	Open circuit breaker.	Check continuity of breaker with ohmmeter; breaker push button should be locked down. Note: the breakers are of the thermal type and require a few seconds of cooling time after tripping to enable locking to closed position. Replace if breaker is found defective.
	Defective equipment switch.	Check continuity with ohmmeter. Replace switch if no continuity is apparent with switch in on position.
b. Amber pilot lamp glows when equipment is turned on but no indication apparent on standard meters or test meter.	Open interlock circuit.	Interlock circuits must be closed; mechanical operation of the safety bar interlocks can be ascertained by listening for actuation click when bar is pressed. Coarse amplitude control interlock mechanical operation can be checked by listening for actuation click as interlock is engaged when control is turned fully counter-clockwise. Electrical continuity of interlock circuit should be checked.

Trouble Shooting Chart (Continued)

SYMPTOM	CAUSE	REMEDY
b. Amber pilot lamp glows when equipment is turned on but no indication apparent on standard meters or test meter.	Defective relay K1 or relay supply rectifier.	Relay coil resistance approximately 10,000 ohms. Rectifier output 115 volts DC with line emf of 115 volts.
	Defective amplitude control circuit.	Check continuity of variable and step-down transformers.
c. DC current section functions but DC voltage section inoperative.	Defective high voltage rectifier CR7-CR8.	Check resistance of rectifiers. Forward resistance approx. 40,000 ohms, back resistance infinite.
	Defective filter circuit.	Check resistors R54 and R32 through R38. Check filter capacitors C5 through C11.
	Defective power transformer.	Check continuity of transformer T4.
d. DC output voltage low.	Defective voltage doubler circuit.	Check as described in c. above.
e. DC voltage section functions but DC current is inoperative.	Defective current rectifier.	Check resistance of diodes CR5 and CR6. Forward resistance approximately 600 ohms, back resistance should be infinite.

Trouble Shooting Chart (Continued)

SYMPTOM	CAUSE	REMEDY
f. DC current low, cannot make full scale with minimum burden across output terminals.	Faulty rectifier or filter circuit.	Check as described in e. above.
g. Circuit breaker CB1 trips when equipment is placed in on position; amplitude controls in full counter-clockwise position.	Short circuit in wiring or switching circuits associated with interlock circuitry.	Check for shorted circuits and/or components in interlock circuitry.
Circuit breaker CB1 or CB2 trips when amplitude controls are advanced.	Shorted component or circuit in amplitude circuit, power transformer or rectifiers.	Check for shorted transformer windings, rectifiers, capacitors and for short circuit in voltage output circuits.
h. Instability in DC voltage or current output.	Faulty rectifier, intermittent connection in transformer or wiring or dirty switch contact.	Trace intermittent connection by voltage drop test technique. Clean switch contacts associated with circuit in question. Switches should be cleaned and lubricated as described in preventive maintenance paragraph page 12.

Trouble Shooting Chart (Continued)

SYMPTOM	REMEDY
i. Calibration errors	The precision components in the Model 33A are protected against damage from overload conditions by means of design parameters inherent in the calibrator. Changes in the standard meter parameters can occur with time, but these variations can be compensated by adjustment of the calibration adjustment resistors built into each meter circuit. **The original full-scale voltage and current sensitivity of each meter are recorded in the calibration data (part of this manual). These parameters will vary from unit to unit, and resetting of a meter to its original sensitivity should not be attempted unless the original data are available. Adjustment of meter parameters can be made as follows:** An RFL Model 1605, 1605A or equivalent accuracy (±0.04%) instrument is recommended as calibration equipment for performing the meter parameter adjustment or for over-all recertification of the Model 33A AC-DC Meter Calibrator. The equipment case must be removed to enable adjustment of the meters. Detailed instructions for adjusting the AC meter are given on page (s) 17-18 and on page (s) 19-20 for the DC meter. The meter adjustment potentiometers are located on the rear of the meters (see photo on page 12). Use an insulated tool for all adjustments to reduce danger of shock by inadvertently coming into contact with a high potential circuit. It is advisable to place an insulated shield of some type around the sides and front of the unit while the case is removed; heayy cardboard is sufficient. This is to prevent personnel from accidentally coming into contact with high voltage circuits.

i. Calibration errors (cont.)

AC Meter Adjustment

CURRENT SECTION Adjustment of current section will affect both voltage and current sensitivity. Voltage adjustment will affect only voltage sensitivity.

1. Connect the Model 1605 Calibration Standard in series with the AC meter and the current transformer (T7). This may be accomplished by disconnecting a lead from either of the terminals marked " meter " on the transformer. The Calibration Standard is connected to the transformer terminal and to the lead previously connected to the terminal.

2. Set the Calibration Standard to read the required current determined from the calibration data supplied with the Model 33A.

3. Place the Model 33A FUNCTION SELECTOR to AC CURRENT and the RANGE SELECTOR to the 1-ampere position.

4. Loosen the locknut on the AC current adjustment (R10) on rear of AC meter assembly. One turn is usually sufficient.

5. Energize the Model 33A and adjust amplitude controls until the Model 1605 Calibration Standard indicates required current, this will be somewhere in the range of 100 milliamperes; the exact value is determined from the meter parameter data included in the Model 33A calibration data. Adjust R10 until the AC standard meter indicates exactly full scale deflection. Reduce amplitude controls to zero (full counter-clockwise rotation) and lock potentiometer locknut.

6. Recheck full scale sensitivity to ensure that tightening of locknut did not disturb the calibration.

7. Disconnect the Model 1605 from the Model 33A and reconnect the meter lead to the meter terminal on the current transformer.

Trouble Shooting Chart (Continued)

SYMPTOM	REMEDY
i. Calibration errors (cont.) AC Meter Adjustment	VOLTAGE SECTION 1. Connect the Model 1605 Calibration Standard to the AC VOLTS common terminal on the Model 33A panel and to terminal #2 of TB1 on the rear of the AC standard meter. 2. Set the Calibration Standard to read the required emf as determined from the Model 33A calibration data. This will be approximately 50 volts, but will vary depending on the individual unit. 3. Place the Model 33A Function Selector to AC VOLTS and RANGE SELECTOR to the 10-volt position. 4. Loosen locknut on R55 located on the rear of the AC standard meter assembly. 5. Energize the Model 33A and adjust amplitude controls until the Calibration Standard indicates the required voltage. Adjust R55 until AC standard meter indicates exactly full scale deflection. Reduce amplitude controls to zero and tighten locknut on R55. 6. Recheck full scale sensitivity to ensure that tightening of locknut did not disturb the calibration. 7. Disconnect the Model 1605 Calibration Standard from the Model 33A Calibrator.

i. Calibration errors (cont.) DC Meter Adjustment	MILLIAMPERE ADJUSTMENT Adjustment of voltage or current calibration potentiometers affects both voltage and current sensitivity. Adjust in order given. 1. An external 1000-ohm precision resistor (0.05% accuracy or better) is required for setting up the milliampere sensitivity. The resistor should preferably be of the four terminal type, two current terminals and two potential terminals. 2. Disconnect the red lead from the positive terminal of the DC Meter assembly board. Connect one end of the 1000-ohm external resistor to the positive terminal of the assembly board. Connect other end of the external resistor to the positive DC VOLTS terminal on the panel. Connect the Model 1605A Calibration Standard potentiometer terminals to the emf terminals of the external 1000-ohm resistor observing polarity; i.e. the positive potentiometer connection should connect to the resistor side which is connected to the positive DC VOLTS panel terminal. Set the Model 1605 potentiometer to read the current as determined from the meter parameter data in the Model 33A calibration data. This is a function of the voltage drop across the external resistor. For example: if the current sensitivity of the meter is designated as 950 microamperes it means that the emf drop across the resistor will be 0.950 volt; i.e. E = .00095 x 1000. 3. Set the FUNCTION SELECTOR to DC VOLTS and the RANGE SELECTOR to the 2-volt position. 4. Loosen locknut on MA ADJ (R43) located on rear of the DC meter assembly board. 5. Energize the Model 33A and adjust amplitude controls until the Model 1605 potentiometer indicates the required value of emf. Adjust MA ADJ potentiometer until the Model 33A DC meter indicates exactly full scale deflection. Reduce amplitude controls to zero and tighten locknut. Recheck full scale sensitivity to ensure that tightening locknut did not disturb the calibration. Reduce amplitude to zero. 6. Disconnect external meter and replace red lead to positive terminal of meter assembly board.

Trouble Shooting Chart (Continued)

SYMPTOM	REMEDY
i. Calibration errors (cont.) DC Meter Adjustment	MILLIVOLT ADJUSTMENT 1. Connect potentiometer of the Model 1605 Calibration Standard across the positive and negative terminals located on the assembly board of the Model 33A DC Meter. Observe polarity. 2. Set the FUNCTION SELECTOR to DC VOLTS and the RANGE SELECTOR to the 2-volt position. 3. Loosen locknut on MV ADJ potentiometer (R46) on DC meter assembly board. 4. Set Model 1605 potentiometer to read required voltage as determined from meter parameter values of Model 33A calibration data. 5. Energize the Model 33A and adjust the amplitude controls until Model 1605 Calibration Standard indicates required emf. Adjust MV ADJ until DC meter indicates exactly full scale. 6. Reduce amplitude controls to zero and tighten MV ADJ locknut. Recheck full scale deflection to ensure that tightening locknut did not disturb calibration. Reduce amplitude controls to zero. Note: Since there is some interaction between the MV ADJ and the MA ADJ controls, it is advisable to recheck the milliampere sensitivity after adjusting the millivolt sensitivity. It may be necessary to trim up either control in certain cases, to ensure that the original meter parameters are reached in both millivolt and milliampere sensitivity.

C14	CAPACITOR, fixed mylar: .09 μF, 200 V DC nominal value.	Frequency compensation for potential transformer.	
CB1, CB2	CIRCUIT BREAKER, 2 A.	Overload protection.	HA-11665
L1	CHOKE, swinging, .01 hy at 10 A.	DC current supply filter choke.	HB-18459
CR1, CR2, CR3 & CR4	DIODE, silicon.	Relay supply rectifier.	HA-18687* (2)
CR5 & CR6	DIODE, silicon 20 A, 55 PIV.	DC current supply rectifier.	HA-18612* (1)
I1	LAMP, red indicator.	High voltage warning indicator	HA-18610
I2	LAMP, amber indicator.	Equipment On indicator.	HA-18624
M1	METER ASSEMBLY, DC.	DC standard meter including resistors R41, R42, R43, R44, R45 and R46.	HC-23890-B
M2	METER ASSEMBLY, AC.	AC standard meter including resistors R2, R3, R4, R10 and capacitor C2.	HC-23889-B
R1	RESISTOR, fixed WW, 5 ohms, ±5%, 50 w.	Current limiting resistor for 1 and 2 A. AC range.	H-1100-32

Table of Replaceable Parts (Continued)

SYMBOL NO.	DESCRIPTION	FUNCTION	RFL PART NO.
R5	RESISTOR, fixed WW, 50 ohms, ±5% 50 w.	Current limiting resistor for 0.5 A AC range.	H-1100-381
R6	RESISTOR, fixed WW, 100 ohms, ±5%, 50 w.	Current limiting resistor for 0.2 A AC range.	H-1100-382
R7	RESISTOR, fixed WW, 500 ohms, ±5%, 50 w.	Current limiting resistor for 0.1 A AC range.	H-1100-383
R8	RESISTOR, fixed WW, 4000 ohms, ±5%, 50 w.	Current limiting resistor for .05 A AC range.	H-1100-384
R9	RESISTOR, fixed WW, 10,000 ohms, ±5%, 50 w.	Current limiting resistor for .02 A AC range.	H-1100-385
R11	RESISTOR, fixed WW, 15 K ohms, ±5%, 25 w.	Part of voltage divider.	H-1100-387
R12	RESISTOR, fixed WW, 5000 ohms, ±5%, 10 w.	Part of voltage divider.	H-1100-396
R13	RESISTOR, fixed WW, 2500 ohms, ±10%, 10 w.	Part of voltage divider.	H-1100-258

R14	RESISTOR, fixed WW, 1500 ohms, ±5%, 10 w.	Part of voltage divider.	H-1100-397
R15	RESISTOR, fixed WW, 500 ohms, ±5%, 5 w.	Part of voltage divider.	H-1100-388
R16	RESISTOR, fixed WW, 300 ohms, ±5%, 5 w.	Part of voltage divider.	H-1100-389
R17	RESISTOR, fixed WW, 150 ohms, ±5%, 5 w.	Part of voltage divider.	HA-12865
R18	RESISTOR, fixed WW, 120 ohms, ±5%, 5 w.	Part of voltage divider.	H-1100-390
R19	RESISTOR, fixed precision; 500 K ohms, ±0.1%, 1 w.	Part of DC meter multiplier.	H-1600-239
R20	RESISTOR, fixed precision; 300 K ohms, ±0.1%, 1 w.	Part of DC meter multiplier.	H-1600-240
R21	RESISTOR, fixed precision; 100 K ohms, ±0.1%, 1 w.	Part of DC meter multiplier.	H-1600-248
R22	RESISTOR, fixed precision; 50 K ohms, ±0.1%, 1 w.	Part of DC meter multiplier.	H-1600-247
R23	RESISTOR, fixed precision; 30 K ohms, ±0.1%, 1 w.	Part of DC meter multiplier.	H-1600-246
R24	RESISTOR, fixed precision; 10 K ohms, ±0.1%, 1 w.	Part of DC meter multiplier.	H-1600-245
R25	RESISTOR, fixed precision; 5000 ohms, ±0.1%, 1 w.	Part of DC meter multiplier.	H-1600-244
R26	RESISTOR, fixed precision; 3000 ohms, ±0.1%, 1 w.	Part of DC meter multiplier.	H-1600-243

Table of Replaceable Parts (Continued)

SYMBOL NO.	DESCRIPTION	FUNCTION	RFL PART NO.
R27	RESISTOR, fixed precision; 1905 ohms, ±0.1%, 1w.	Part of DC meter multiplier.	H-1600-232
R28	RESISTOR, fixed precision; 1 megohm, ±0.1%, 1 w.	Part of DC milliampere divider.	HA-17064
R29	RESISTOR, fixed precision; 3 megohm, ±0.1%, 2 w.	Part of DC milliampere divider.	H-1600-238
R30 & R31	RESISTOR ASSEMBLY, precision shunt.	DC current shunt and DC millivolt shunt.	HC-18635
R32 to R38	RESISTOR, fixed composition; 100K ohms, ± 10%, 2 w.	DC voltage filter network equalizing resistors.	H-1009-583
R39	RESISTOR, fixed precision; 100 K ohms, ±0.1%, 1 w.	Part of DC milliamperes meter multiplier.	H-1600-226
R40	RESISTOR, fixed precision; 95 ohms, ±0.1%, 1 w.	Part of DC milliamperes meter multiplier.	H-1600-237
R47	RESISTOR, adjustable WW; 1 ohm, 10%, 25 w.	Current limiting resistor for the 2 A, DC range.	H-1100-34
R48	RESISTOR, fixed WW; 2.2 ohms, 5%, 10 w.	Current limiting resistor for the 1 A, DC range.	H-1100-391
R49	RESISTOR, fixed WW; 4.7 ohms, 5%, 10 w.	Current limiting resistor for the 0.5 A, DC range.	H-1100-392

R50	RESISTOR, fixed WW; 10 ohms, 5%, 5 w.	Current limiting resistor for the 0.2 A, DC range.	H-1100-393
R51	RESISTOR, fixed WW; 20 ohms, 5%, 3 w.	Current limiting resistor for the 0.1 A, DC range.	H-1100-360
R52	RESISTOR, fixed WW; 40 ohms, 5%, 3 w.	Current limiting resistor for the .05 A, DC range.	H-1100-394
R53	RESISTOR, fixed WW; 100 ohms, 5%, 3 w.	Current limiting resistor for the .02 A, DC range.	H-1220-33
R54	RESISTOR, fixed WW; 5000 ohms, 5%, 50 w.	DC voltage supply filter resistor.	H-1100-395
R56	RESISTOR, fixed WW; 15 K ohms, 5%, 50 w.	Part of voltage divider.	H-1100-386
R57	RESISTOR, fixed WW; 100 ohms, 5%, 5 w.	Current bleeder resistor. All DC ranges.	H-1100-300
CR7 & CR8	RECTIFIER, silicon 0.375 A, 2000 V.	DC voltage supply rectifier.	HA-18613* (1)
K1	RELAY, 115 V DC, d.p.d.t.	Interlock relay.	HA-18614
S1	SWITCH, rotary; 7 position, 6 section, 12 pole, non-shorting.	Function selector.	HB-18606
S2	SWITCH, rotary; 9 position, 6 section, 12 pole, non-shorting.	Range selector.	HB-18607

Table of Replaceable Parts (Continued)

SYMBOL NO.	DESCRIPTION	FUNCTION	RFL PART NO.
S3	SWITCH, toggle; s.p.s.t.	Equipment on-off switch.	HA-3709
S4, S5, S6	SWITCH, sensitive.	Safety interlock actuators.	HA-6429
T1	TRANSFORMER, variable.	Coarse amplitude control.	HB-18615
T2	TRANSFORMER, variable.	Fine amplitude control.	HB-18615
T3	TRANSFORMER, step-down.	Fine amplitude control ratio.	HA-8782
T4	TRANSFORMER, power.	Supply transformer for DC voltage and current.	HB-18456
T5	TRANSFORMER, power.	Supply transformer for AC voltage and current.	HB-18458
T6	TRANSFORMER, potential.	AC meter potential transformer.	HB-18474
T7	TRANSFORMER, current.	AC meter current transformer.	HC-18471
T8	TRANSFORMER, millivolt.	AC millivolt ratio transformer.	HB-18457