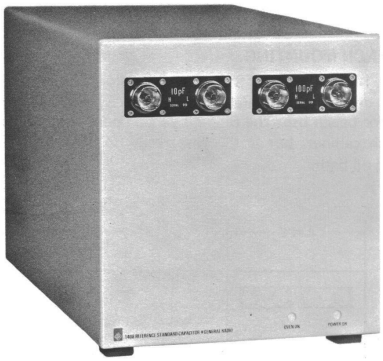
♦ PRECISION INSTRUMENTS FOR TEST AND MEASUREMENT ♦

1408 SERIES

Reference Standard Capacitor

Instruction Manual



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WARRANTY

We warrant that this product is free from defects in material and workmanship and, when properly used, will perform in accordance with applicable IET specifications. If within one year after original shipment, it is found not to meet this standard, it will be repaired or, at the option of IET, replaced at no charge when returned to IET. Changes in this product not approved by IET or application of voltages or currents greater than those allowed by the specifications shall void this warranty. IET shall not be liable for any indirect, special, or consequential damages, even if notice has been given to the possibility of such damages.

THIS WARRANTY IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESSED OR IMPLIED, INCLUDING BUT NOT LIMITED TO, ANY IMPLIED WARRANTY OF MERCHANTIBILITY OR FITNESS FOR ANY PARTICULAR PURPOSE.

WARNING

OBSERVE ALL SAFETY RULES
WHEN WORKING WITH HIGH VOLTAGES OR LINE VOLTAGES.

Dangerous voltages may be present inside this instrument. Do not open the case
Refer servicing to qulified personnel

HIGH VOLTAGES MAY BE PRESENT AT THE TERMINALS OF THIS INSTRUMENT

WHENEVER HAZARDOUS VOLTAGES (> 45 V) ARE USED, TAKE ALL MEASURES TO AVOID ACCIDENTAL CONTACT WITH ANY LIVE COMPONENTS.

USE MAXIMUM INSULATION AND MINIMIZE THE USE OF BARE CONDUCTORS WHEN USING THIS INSTRUMENT.

Use extreme caution when working with bare conductors or bus bars.

WHEN WORKING WITH HIGH VOLTAGES, POST WARNING SIGNS AND KEEP UNREQUIRED PERSONNEL SAFELY AWAY.

CAUTION

DO NOT APPLY ANY VOLTAGES OR CURRENTS TO THE TERMINALS OF THIS INSTRUMENT IN EXCESS OF THE MAXIMUM LIMITS INDICATED ON THE FRONT PANEL OR THE OPERATING GUIDE LABEL.

Introduction–Section 1

1.1 PURPOSE.

The Type 1408 Reference Standard Capacitors have been designed to bring to standards laboratories the improved accuracy of capacitor calibrations developed by the National Bureau of Standards. Capacitor values are 10-pF and 100-pF standards and allow measurements to parts in 10^7, with the capacitor temperature held constant to within .01°C. Refer to the back of the Calibration Certificate for specifications.

1.2 DESCRIPTION.

The Type 1408 Capacitors are based upon an NBS design and use a fused-silica dielectric with gold electrodes to provide the time and voltage stability required for calibrations to parts in 10^7. Two models of the standards are produced, air bath and oil bath.

The oil-bath models (Figure 1-1) allow the capacitor to be immersed in an oil-bath while connections are made to the low-contact-resistance gold-plated GR874® coaxial connectors 6 in. above the capacitor.

The air-bath models (Figure 1-2) are thermostatically controlled at a nominal 30°C. The bath has a long-term stability of .01°C; it changes by less than .01°C for a 6°C change in ambient temperature. The temperature control is by a 12-V system; batteries can be used during transportation.

1.3 ACCESSORIES SUPPLIED.

The accessories supplied with the 1408 Capacitors include two Type 1408-9601 Patch Cord Assemblies and a Type 4200-9622 Power Cord for each air-bath unit.

1.4 ACCESSORIES AVAILABLE.

The Type 1408 Capacitors, except the oil-bath unit, may be rack mounted by ordering the Type 0480-9725 Rack Adaptor Set. Extra Type 1408-9601 Patch Cord Assemblies

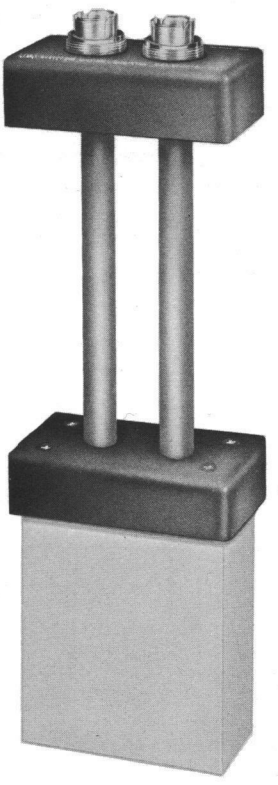

Figure 1-1. 1408 Standard; for use in oil bath.

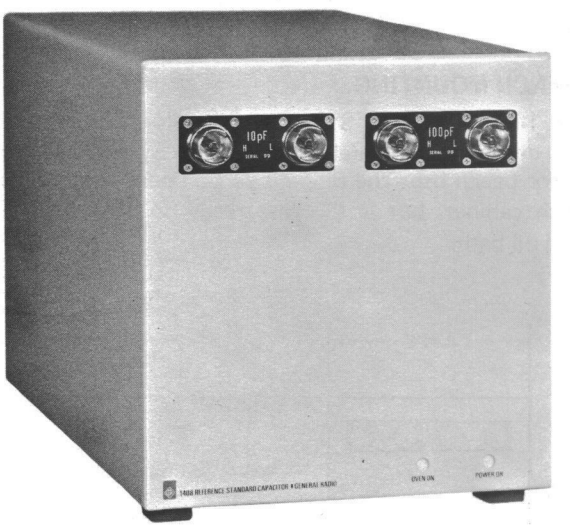

Figure 1-2. 1408 Standard with temperature-controlled air bath.

may be ordered if desired. For precision capacitor measurements, the GR 1621 Precision Capacitance Measurement System is available, which includes the Type 1616 Precision Capacitance Bridge, Type 1238 Detector and Type 1316 Oscillator. This system may be used with an external capacitance standard referenced to the National Bureau of Standards to measure a Type 1408 Reference Standard Capacitor.

A thermometer capable of reading .01°C increments would be necessary to check the temperature stability of either an oil- or air-bath unit under operating conditions. An absolute temperature can be measured with a platinum resistance thermometer or a relative temperature measurement can be made by measuring the resistance of wire with a known temperature coefficient and calculating the temperature change.

Installation—Section 2

2.1 DIMENSIONS.

The dimensions of the capacitors are shown in Figure 2-1.

2.2 BENCH MOUNTING.

The 1408 Reference Standard Capacitor, air-bath version, is delivered completely assembled in a metal cabinet, ready for bench use. The oil-bath version does not come in a bench cabinet, but is supplied ready to mount in an existing oil bath.

2.3 POWER CONNECTIONS.

The 1408 Capacitor, air-bath version, can be operated from either a 100- to 125-V or a 200- to 250-V, 50- to 60-Hz power line. Before connecting the 3-wire power cord to the line, set the slide switch on the rear panel to the proper setting as indicated by the position of the white line on the slide switch. The slide can be moved with a screwdriver blade. The 0.2-A fuse installed in the instrument is connected so that it will protect the instrument for either voltage.

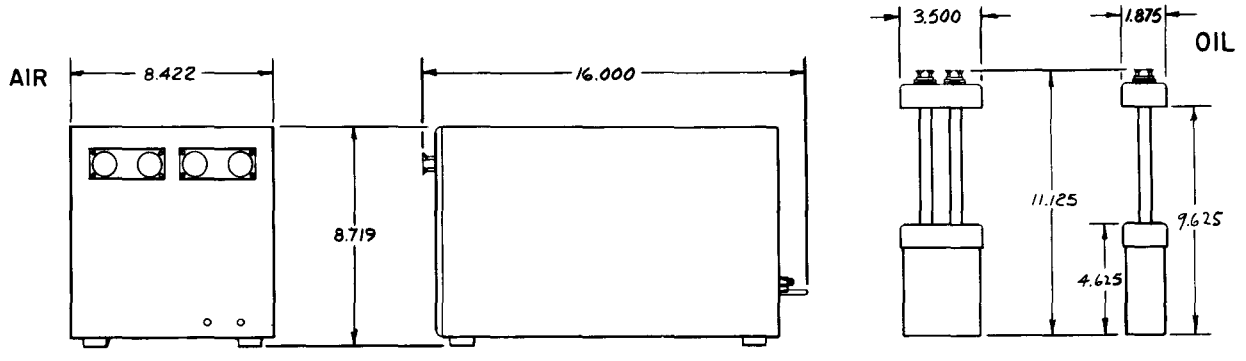

Figure 2-1. Dimensions in inches of the GR 1408 Reference Standard Capacitors.

Two battery terminals (Hayman Mfg. Co. Type DC101) are provided at the rear of the air-bath instrument to allow connection of a 12-V battery (at 0.4 A) for portable operation of the internal oven. An automobile-type 12-V battery is recommended for portable operation. The battery power is not used when the ac line power is connected to the unit. The mating connector is an AMP type 42566-2 (GR P/N 7920-0121).

The oil-bath unit does not have an ac or dc power supply since its temperature is controlled by an externally supplied and controlled oil bath.

2.4 RELAY-RACK MOUNTING.

2.4.1 Single Instrument and Blank Panel (Figure 2-2).

Rack Adaptor Set (P/N 0480-9725) is available to convert the convertible bench model (air-bath unit only) for use in an EIA standard RS-310 19-in. relay rack with universal mounting-hole spacing. Table 2-1 lists the parts included in the Rack Adaptor Set. The conversion procedure is as follows (Figure 2-2):

a. Loosen the two captive 10/32 screws in the rear of the cabinet, near the sides, until the instrument is free; slide the instrument forward, out of the cabinet.

b. Remove the four feet from the cabinet by pushing them outward.

c. Push out the plugs from the four bosses (C) on the sides of the cabinet, near the front. Use a hammer and a small punch inside the cabinet to push each plug outward. Do not damage the threads in the threaded holes.

d. Press the subpanel (D) into the blank panel (E), to form a liner for the latter.

e. Attach the short flange of the blank panel to the front of the cabinet (on either side of the cabinet, as desired) using two 5/16-in. screws (F). Note that the screws enter in opposite directions – one from inside the cabinet and one from the flange side, as shown.

Table 2-1

PARTS INCLUDED IN THE RACK ADAPTOR SET, P/N 0480-9725 (Figure 2-2)

Fig. 2-2 Ref.	No. Used	Item	GR Part No.
E	1	Blank Panel	0480-8935
D	1	Sub-Panel	0480-8955
Q	2	Rack Adaptor Assembly	0480-4905
H	1	Support Bracket	0480-8524
–	1	Hardware Set includes	0480-3080
F, J, K, L, M,		8 screws, Phillips head 10-32, 5/16-in.	
N		4 screws, Phillips head, 10-32, 9/16-in. with white nylon cup washers	

f. Pierce and push out the plug in the lower rear boss (G) on the side toward the blank panel only, as shown.

g. Attach one end of the support bracket (H) to the lower rear boss. The bracket must be placed so that the screw passes through a clearance hole, into a tapped hole. Lock the bracket in the position with a 5/16-in. screw (J).

h. Attach the other end of the support bracket to the lower, rear hole in the wide flange, as shown, using a 5/16-in. screw (K).

i. Attach one Rack Adaptor Assembly (Q, including handle) to the side of the cabinet opposite the blank panel, using two 5/16-in. screws (L). Again, note that the screws enter in opposite directions, one from inside the cabinet and one from outside. Use the upper and lower holes in the assembly.

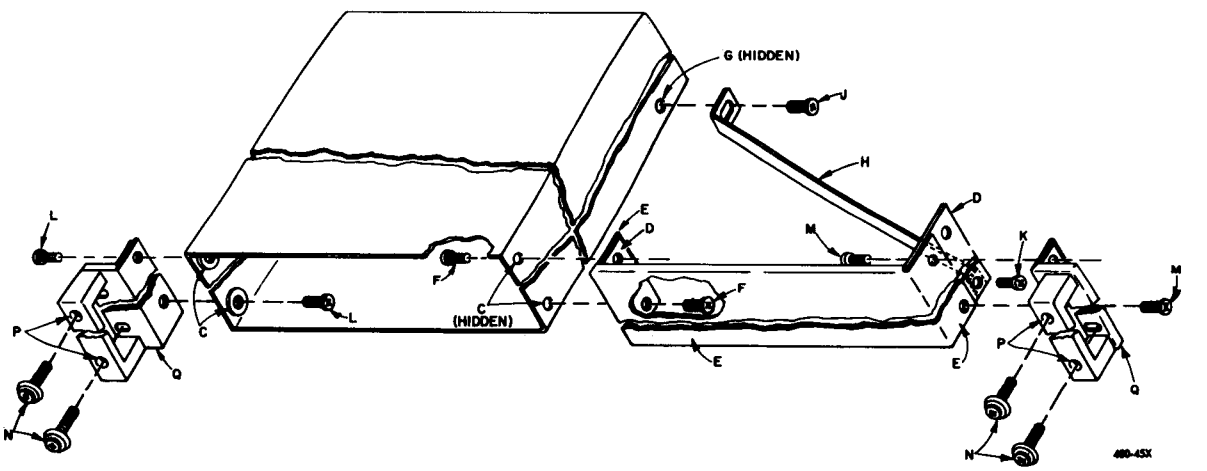

Figure 2-2. Method of mounting the air-bath capacitor and a blank panel in a relay rack.

j. Attach the other Rack Adaptor Assembly (Q, including handle) to the wide flange on liner (D) and the flange on the blank panel (E). Use two 5/16-in. screws (M) through the two holes in the flange that are nearest the assembly. Again, the screws enter in opposite directions.

k. Install the instrument in the cabinet and lock it in place with the two captive screws through the rear panel that were loosened in step a.

l. Place a straight edge across both the instrument panel and the blank panel. Loosen the screw (J) through the slot in the support bracket (H). Exert a slight pressure on the blank panel (E), so that it forms a straight line with the instrument panel, and tighten the screw (J) in the bracket, to lock the panels in this position.

m. Slide the entire assembly into the relay rack and lock it in place with the four 9/16-in. screws (N) with captive nylon cup washers. Use two screws on each side and tighten them by inserting a screwdriver through the holes (P) in the handles.

2.4.2 Rack-mounting Two Instruments.

Two instruments of the same panel size can be mounted side-by-side in a standard 19-in. relay rack. Use the mounting procedure, substituting the second instrument for the blank panel. Do not use the support bracket (H, Figure 2-2), but insert 3 screws through the bosses in the adjacent sides of the cabinets, two near the front (C) and one near the rear (G). The four feet must be removed from each cabinet to prevent interference with any instrument mounted directly below the capacitors. Use the four screws (N) with nylon washers to lock the instruments in the rack. The required hardware is listed below:

3 Screws, Phillips Head, 10-32, 5/16 in.

4 Screws, Phillips Head, 10-32, 9/16 in. with nylon washers

2.5 OUTPUT TERMINAL RELOCATION.

The H and L GR874 connectors are normally mounted on the front panel of the air-bath standard, but can be moved to the rear panel as follows:

NOTE

This procedure does not apply to the oil-bath version. Its terminals are fixed and cannot be moved.

a. Remove the instrument from its cabinet (paragraph 2.4.1 step a).

b. Push out the necessary pair(s) of snap cover plates from the rear panel, depending on whether 1 or 2 standards are in the chassis.

c. Remove the 8 Phillips-head screws from the 2 aluminum straps across the top of the oven insulation.

d. Remove the two straps and the piece of insulation just below them.

e. Remove the 4 Phillips-head screws that secure each connector to the front panel.

f. Move the connectors to the rear, reinsert the screws, and secure in place. There are 2 pairs of connectors, one for each of two possible capacitors in the open. One capacitor has the orange (H)—yellow (L) pair, while the other has the green (H)—violet (L) pair (note H and L labelling on the rear panel).

g. Push the snap cover plates removed in step b into the front-panel holes vacated by the connections.

h. Replace the oven insulation and secure the aluminum straps with their Phillips-head screws.

i. Reinstall the instrument cabinet.

2.6 OIL-BATH MOUNTING.

The oil bath model is designed to allow it to be placed upright in a temperature-controlled oil bath. It is not necessary to support the capacitor since the typical oil-bath circulation is not sufficient to tip the capacitor over. The oil level in the bath should be maintained at approximately a 6-in. depth above the tray.

2.7 PATCH-CORD ASSEMBLIES (P/N 1408-9601).

The Type 1408-9601 Patch-Cord Assemblies are 3-ft. coaxial patch cords with gold-plated GR874 connectors. The gold-plating reduces the contact resistance of a connection, thus the repeatability is improved as compared to the mating of 2 standard GR874 connectors. When using the patch cords to connect the standard to a bridge, such as in an external standard application, good repeatability is achieved at the standard since both connectors are gold plated. The same applies at the bridge, if both terminals are gold plated as in the GR 1616 Precision Capacitance bridge. This means that a measurement may be repeated more accurately time-after-time, even if the connecting patch cords are disconnected and reconnected between measurements.

2.8 RESIDUAL IMPEDANCES.

An equivalent circuit and typical values for the residual inductances and capacitances within the capacitor are shown in the specifications. These values are useful in determining when the error they contribute to the measured capacitance is negligible, as is usually the case at 1 kHz. If the error cannot be neglected, and corrections for the effects of the residuals must be made, measured values of the residuals for the particular capacitor in use should be used. When these errors are important, as for example, at frequencies higher than 1 kHz, other error sources must also be considered, such as the impedance of the cables between bridge and capacitor and the changes of the dielectric constant of the fused silica with frequency (see footnote 1, Section 4).

Operation–Section 3

3.1 GENERAL.

The Type 1408 Reference Standard Capacitor comes in two versions, oil-bath and air-bath. The operation of each version is described in the paragraphs that follow.

CAUTION

Do not apply greater than 500 V to the measurement terminals.

3.2 OIL-BATH VERSION.

To place the oil-bath version into operation, proceed as follows:

a. Mount the oil-bath capacitor in a temperature-controlled oil-bath, keeping the GR874 terminals above the oil level.

b. Connect the standard to the equipment it is to be used with by means of the 2 low-resistance patch-cord assemblies supplied.

c. Monitor the temperature of the oil bath. To make meaningful measurements of parts in 10^7, the oil-bath temperature must be known to within .01°C.

d. There are no adjustments to be made to the unit. It is now ready for operation.

3.3 AIR-BATH VERSION (AC OPERATION).

To place the ac air-bath version into operation, proceed as follows:

a. Set the rear-panel line-voltage switch to the proper position, depending on the line voltage.

b. Connect the 3-wire power cord between the rear-panel 3-wire power plug and a suitable power line.

c. The front-panel POWER ON lamp will glow and the OVEN ON lamp will glow if the oven temperature is below the nominal 30°C. At least 24 hour's warmup is necessary to establish stability for operation at the specified precision.

d. Connect the standard to the equipment to be used, with the 2 low-resistance patch-cord assemblies supplied.

e. There are no adjustments to be made to the unit. It is now ready for operation. A thermometer can be inserted through the hole in the top of the cabinet to monitor the oven temperature.

3.4 AIR-BATH VERSION (DC OPERATION).

To place the dc air-bath version (for portability) into operation, proceed as follows:

a. Connect a 12-V automobile-type battery (0.4 A) to the rear-panel EXTERNAL BATTERY 12 V + and – terminals. For transporting the unit in an automobile, connection may be made directly to the automobile's 12-V battery.

b. Perform steps c, d and e of paragraph 3.3 to complete the operation.

When transporting the unit, its operation will continue in any operating position, since the thermostat is a pressurized unit. Changes in capacitance value due to environmental temperature changes are stated in the specifications, while changes in orientation of the air-bath unit will not affect the capacitance value.

3.5 TEMPERATURE MEASUREMENT

For measurement of the air-bath capacitor temperature, a mercury-in-glass or a platinum resistance thermometer can be inserted through a hole near the center of the top of the cabinet into a brass block mounted between and against the capacitor cases. The hole in this block has a diameter of 0.312 in., 0.792 cm, and the depth of the hole from the cabinet top is 5.5 in., 14 cm.

The black insulation, which can be seen through the hole in the cabinet top, may appear to cover the hole, but there is a slit or cut in the insulation through which the thermometer can be inserted. Use a pencil point or thin rod to open this slit into a hole before inserting the thermometer.

If a thermometer at 23°C is inserted into the well, the capacitor temperature and capacitance are reduced until the thermometer is heated to the bath temperature. A typical change produced by a mercury-in-glass thermometer reaches a maximum 0.3 ppm reduction in capacitance about an hour after insertion. To avoid this change, heat the thermometer to 30°C in the hand before placing it in the hole.

3.6 TIME CONSTANTS

When the temperature of the air bath is changed suddenly or with a step function, for example, by a change in environment that is fast compared to the time constants or by a turning on or off of the power to the heater, the change with time, t, of the temperature, θ, of the capacitors and of the corresponding capacitance value can be described with good accuracy by two time constants, T_1 and T_2 in the equation

$$\theta = \theta_1 + (\theta_2 - \theta_1)\,(1 - e^{-t/T_1})\,(1 - e^{-t/T_2}),$$

where θ_1 is the initial temperature and θ_2 the final temperature and e = 2.718.

Typical magnitudes of the time constants for the air baths are:

When the bath is turned on: T_1 = 1.3 hrs. T_2 = 3.4 hrs.
When the bath is turned off: T_1 = 2.1 hrs. T_2 = 8.5 hrs.
When the bath is at operating temperature and the environment is changed:

T_1 = 1.6 hrs. T_2 = 2.8 hrs.

For times longer than the larger constant, T_2, a good approximation can be obtained from the simpler equation

$$\theta_2 - \theta = (\theta_2 - \theta_1)\, e^{-t/T_2},$$

which tells us the amount θ that time t differs from the final temperature, θ_2, when we know the applied step in temperature, $\theta_2 - \theta_1$. For example, if the bath starts at a room temperature θ_1 = 23°C and heats up quickly to θ_2 = 30°C, the difference, $\theta_2 - \theta$, at a time t = 7 T_2 is $7^\circ \times e^{-7}$ = .0064°C. When the capacitor temperature coefficient is about 12 ppm/°C and T_2 is 3.4 hrs, the capacitor will be about 0.08 ppm below its final value after 24 hours.

For information about changes in the interval between 0 and T_2 hours, the complete equation must be used. This will show that the changes near zero are very slow or the effective time constants are much larger than T_2. If, for example, the bath is turned off for 15 minutes and then turned on again, the capacitance will decrease, reach a minimum 0.35 ppm below its initial value about 15 minutes after the turn-on time, and then return to the initial value at a more rapid rate corresponding to T_2 = 2.8 hrs.

For the oil-bath capacitors, the simple equation with a single time constant is adequate to estimate the changes when, for example, the capacitor at room temperature is put into oil at a different temperature. The time constant, T, is 15 minutes for the 10-pF capacitor, 12 minutes for the 100 pF.

3.7 GROUNDING

The true ground for the capacitor is the outside contact of the GR874 Connectors. These connectors are not connected to the case of the capacitor and the case should not be used as a ground.

Theory–Section 4

4.1 GENERAL.

The fundamental design of the 10- and 100-pF standards is based upon the development at NBS by Cutkosky and Lee[1] of a 10-pF capacitor with time stability and small variations due to voltage change or shock, which permit calibration to parts in 10^7. The dielectric material used for such stability is a special grade of fused silica. It has the further advantages of low losses and low frequency dependence of its dielectric constant in the audio-frequency range.

4.2 DESIGN.

The two main considerations in the design of the fused-silica capacitors are the manner of applying the electrodes to the substrate and the manner of supporting the capacitor in its cell. It becomes apparent very quickly that the gap between these electrodes is critical. It has to be well defined and free of isolated particles of metal that could be attracted to the plated guard or electrodes by electrostatic forces, which would cause a dependence of the capacitance upon the voltage applied. The geometry of the support in the vicinity of the gap is the principal factor in the design of the cell as the direct capacitance is not completely within the fused silica but includes capacitance from the top face of one electrode through the gap to the other electrode.

Figure 4-1 shows the configuration of the electrodes and the supporting cell. The electrodes and guard are in the same plane on each face, and photo-etching techniques can be used both to generate the gaps and to adjust the capacitance by changing the area of an electrode. Since the electrode areas are not equal and the capacitance is defined mostly by the area of the smaller electrode, only one gap is now crucial.

The substrate is held between spring-loaded supports. As the distance between the plane of the gap and the holder above it changes so does the direct capacitance. Figure 4-2

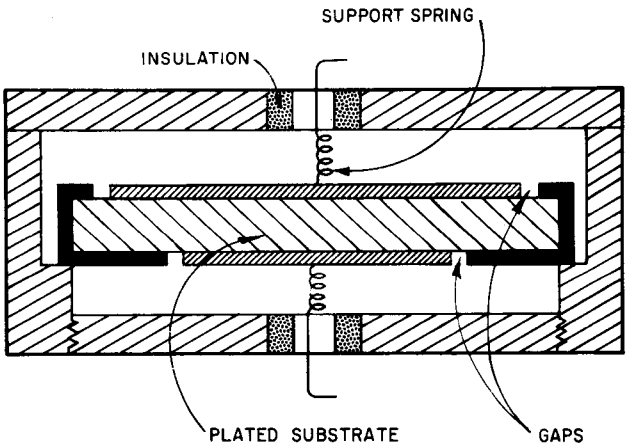

Figure 4-1. Substrate thickness is the only difference between 10- and 100-pF units.

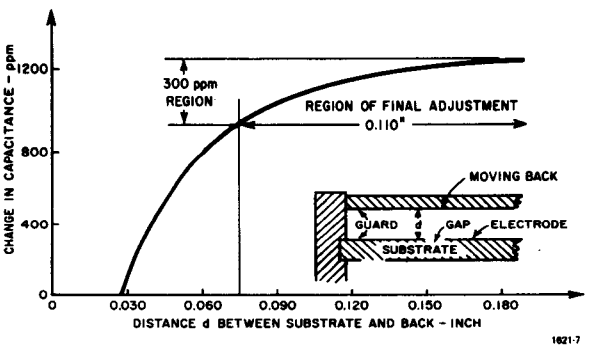

Figure 4-2. Effect upon capacitance of changes in back-substrate separation.

[1] Cutkosky, R. D. and Lee, L. H., "Improved Ten-Picofarad Fused-Silica Dielectric Capacitor," *NBS Journal of Research*, Vol. 69C, July-September, 1965.

shows the magnitude of this effect. When the back plate is close to the gap, the steep slope of the curve shows that the capacitance is sensitive to any accidental motion of the plate, but at separations greater than about 70 mils the capacitance is a more linear and less critical function of spacing. The position of the back plate can be adjusted over a small range in this region beyond 70 mils to provide a capacitance adjustment range of about 300 ppm, which is used to set the capacitance close to the nominal value.

4.3 CONSTRUCTION.

Figure 4-3 shows two coated and etched capacitor substrates. The coating consists of .0005 in. of pure gold. Both the thin substrate (.030-in. thick) for 100 pF and the thick one (0.300-in. thick) for 10 pF have a diameter of 2.727 in. The element is placed in a brass holder, and the capacitance is adjusted to ±100 ppm of nominal values. Contact to the electrodes is made through gold-coated phosphorbronze springs. Figure 4-4 shows the holder ready to be placed in a stainless-steel container, and also shows the assembled and sealed cell. This container is welded shut, evacuated, baked, back-filled with dry nitrogen, and sealed; connections to the capacitor are made via glass-to-metal feedthroughs.

The dielectric constant of fused silica has a temperature coefficient of approximately 12 ppm/°C. To make meaningful measurements at a level of a part of 10^7 one has to know the ambient temperature to within .01°C. This can be accomplished in an oil bath. The GR874 connectors, gold plated for lower contact resistance, are installed 6 in. above the capacitor to allow connection above the oil level. The normally simple measurement of this capacitor in an adequate oil bath is, however, complicated by the additional precision apparatus required to make the accurate temperature measurements needed to define the capacitance value. For that reason, an air bath was developed which can provide one or two capacitors with their own environment and, therefore, eliminate temperature measurements except in the case of the highest accuracy.

4.4 OVEN HEATER.

The oven-heating circuit is a 12-V system for maintaining the oven temperature to within ±.01°C. Figure 5-2 shows the circuit schematic and Figure 5-1 shows the etched-circuit board layout.

The circuit is a full-wave bridge rectifier with a supplemental external battery connection (A-J6 and A-J7). The A-DS1 lamp is the front panel POWER ON lamp, it glows whenever power is applied to the circuit by the ac line voltage or the dc battery voltage.

Anchor terminals 4 and 5 (AT4 and AT5) are the terminals for the thermostat. When the temperature is below the nominal 30°C, these terminals are open, turning Q3, Q2 and Q1 on. This allows A-DS2, the front panel OVEN ON lamp to light. When the temperature in the oven reaches the nominal 30°C, AT4 and AT5 are connected together through the thermostat causing the base of Q3 to go low and turning Q3, Q2 and Q1 off. This opens the circuit through A-DS2; thus, turning the OVEN ON lamp off.

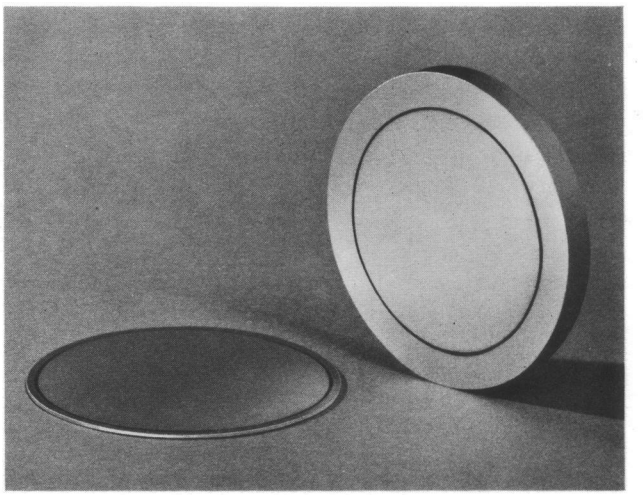

Figure 4-3. 100-pF and 10-pF substrate elements.

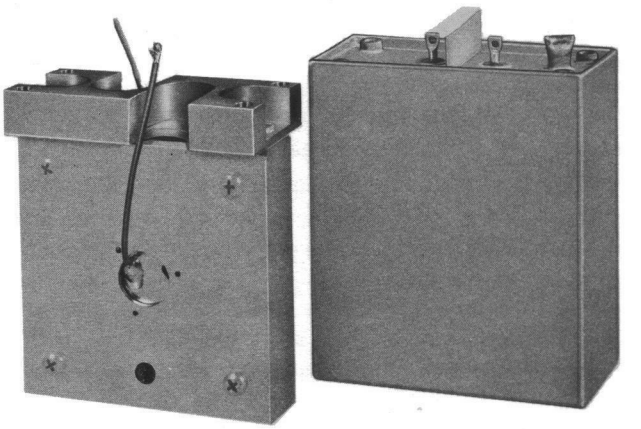

Figure 4-4. Capacitor brass holder and sealed assembled cell.

Service and Maintenance–Section 5

5.1 GR FIELD SERVICE.

The warranty attests the quality of materials and workmanship in our products. When difficulties do occur, our service engineers will assist in any way possible. If the difficulty cannot be eliminated by use of the following service instructions, please write or phone the nearest GR service facility (see back page), giving full information of the trouble and of steps taken to remedy it. Describe the instrument by type number (front panel), serial, and ID numbers (rear panel).

Instrument Return. Before returning an instrument to General Radio for service, please ask our nearest office for a "Returned Material" number. Use of this number in correspondence and on a tag tied to the instrument will ensure proper handling and identification. For instruments not covered by the warranty, a purchase order should be forwarded to avoid unnecessary delay.

For return shipment, please use packaging that is adequate to protect the instrument from damage, i.e., equivalent to the original packaging. Advice may be obtained from any GR office.

5.2 MEASUREMENT.

It is recommended that measurement of the 1408 Reference Standard Capacitor be made at a frequency of 1 kHz, using a GR 1616 Precision Capacitance Bridge (or GR 1621 Precision Capacitance-Measurement System) with an external standard calibrated with reference to an NBS standard. The procedure is as follows:

a. Connect the L terminal of the capacitor to be measured to the 3 TERMINAL UNKNOWN LOW terminal on the 1616 Bridge and the H terminal to the HIGH terminal with the 2 patch-cord assemblies (P/N 1408-9601) supplied with the capacitor.

b. Refer to the 1616 Instruction Manual for normal measurement procedures with an external standard.

This type of comparison measurement allows the capacitor being measured to be known to the precision of the external standard. Therefore, if the external standard is known to 0.1 ppm by NBS calibration, then the capacitor being measured can be determined to that precision.

However, if the external standard is known to say only 3 ppm, the capacitor being measured can be determined to a precision of 3 ppm, but the difference between the capacitors can be determined to the precision allowed by the bridge resolution.

A third possible way to achieve a measurement of the reference standard capacitor is to obtain measurements with the use of several external standards rather than just one. Then, by applying the appropriate statistics, a value for the capacitor being measured can be determined. This measurement approach has been used in the measurement of standard voltage cells*.

5.3 MAINTENANCE.

5.3.1 Oil-Bath Version.

The oil-bath version has its capacitor sealed in the dry-nitrogen atmosphere and thus maintenance is not possible without equipment for replacing and resealing the container. The gold plated GR874 connectors should be checked periodically for damage, but cleaning is not necessary. If any failures do occur, follow the procedures given in paragraph 5.1.

5.3.2 Air-Bath Version.

The capacitor(s) within this version should be treated the same as an oil-bath capacitor. However, the oven power supply and the associated wiring can be serviced if a malfunction occurs. The oven-heater-circuit description was given in paragraph 4.4 and its etched-circuit board and schematic diagram are shown in Figures 5-1 and 5-2, respectively.

*Dunn, Andrew F., "Maintenance of Laboratory Unit of Voltage," *IEEE Transactions on Instrumentation and Measurement,* Vol. IM-20, No. 1, Page 2 (February, 1971).
Cameron, J. M. and Eicke, W. G., "Designs for Surveillance of the Volt Maintained by a Small Group of Saturated Standard Cells", *NBS Technical Note 430* (October, 1967).

ELECTRICAL PARTS LIST

Ref Des	Description	GR Part No.	Fed Mfg Code	Mfg Part No.	Fed Stock No.
1408 Reference Standard Capacitor (AIR BATH)					
CAPACITOR					
C1	Electrolytic, 660 μF, +150-10%, 25 V	4450-6125	37942	TT, 660 μF, +150-10%	
DIODES					
CR1	Type 1N3253	6081-1001	79089	1N3253	5961-811-8372
CR2	Type 1N3253	6081-1001	79089	1N3253	5961-811-8372
CR3	Type 1N3253	6081-1001	79089	1N3253	5961-811-8372
CR4	Type 1N3253	6081-1001	79089	1N3253	5961-811-8372
CR5	Type 1N3253	6081-1001	79089	1N3253	5961-811-8372
CR6	Type 1N3253	6081-1001	79089	1N3253	5961-811-8372
FUSE					
A-F1	Slo-blo, 0.2 A	5330-0600	71400	MDL, .2 Amp	
JACKS					
A-J1	Jack	0874-4006	24655	0874-4006	
A-J2	Jack	0874-4006	24655	0874-4006	
A-J3	Jack	0874-4004	24655	0874-4004	
A-J4	Jack	0874-4004	24655	0874-4004	
A-J5	Power plug	4240-0600	24655	4240-0600	5935-816-0254
A-J6	Multiple plug	4220-0160	28520	DC101	
A-J7	Multiple plug	4220-0160	28520	DC101	
PILOT LIGHT					
A-DS1	Lamp, 14 V	5600-0309	71744	#330	6240-990-2164
A-DS2	Lamp, 14 V	5600-0309	71744	#330	6240-990-2164
RESISTORS					
R1	Comp., 100 kΩ, ±5%, 1/2 W	6100-4105	01121	RC20GF104J	5905-195-6761
R2	Comp., 1 k, ±5%, 1/2 W	6100-2105	01121	RC20GF102J	5905-195-6806
R3	Comp., 20 k, ±5%, 1/2 W	6100-3205	01121	RC20GF203J	5905-195-0649
R4	Comp., 10 k, ±5%, 1/2 W	6100-3105	01121	RC20GF103J	5905-185-8510
R5	Comp., 68 Ω, ±5%, 1/2 W	6100-0685	01121	RC20GF680J	5905-195-5571
R6	Comp., 68 Ω, ±5%, 1/2 W	6100-0685	01121	RC20GF680J	5905-195-5571
R11	Comp., 51 Ω, ±5% 2 W	6120-0515	01121	RC42GF510J	5905-252-5425
R12	Potentiometer, 250 Ω, ±10%, 2 W	6010-0200	01121	JU, 250 Ω ±10%	5905-055-5061
SWITCH					
A-S1	Slide	7910-0831	42190	4603	
TRANSFORMER					
A-T1		0745-4630	24655	0745-4630	
TRANSISTORS					
Q1	Type 40250	8210-1095	79089	40250	
Q2	Type 2N697	8210-1040	49956	2N697	5961-752-0150
Q3	Type 2N3414	8210-1047	24454	2N3414	5961-989-2749
1408 A Reference Standard Capacitor (10 pF OIL BATH) (10 pF and 100 pF OIL BATH)					
CONNECTORS					
A-J1 and A-J2		0874-4006	24655	0874-4006	

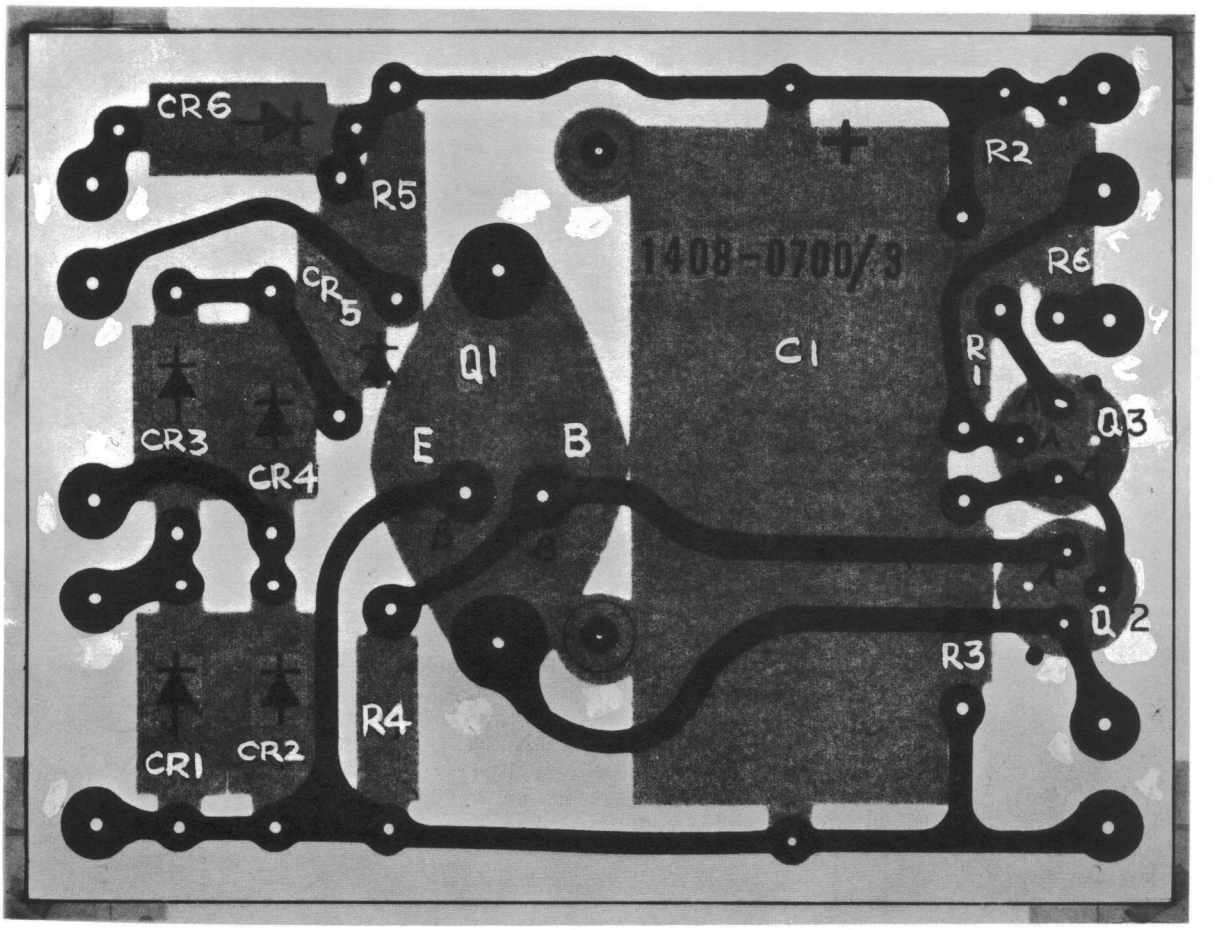

Figure 5-1. Oven-heater-circuit etched-circuit board (P/N 1408-4700).

MECHANICAL PARTS LIST

Qnt	Fig Ref	Description	GR Part No.	Mfg Part No.	Fed Stock No.
		1408 REFERENCE CAPACITANCE STANDARD (AIR BATH)			
		FRONT PANEL			
1	1.	Connector, A-J1, 10 pF H	0874-4006	0874-4006	
1	2.	Cabinet convertible bench:	1408-2040	1408-2040	
1		Gasket	5331-3092	5331-3092	
1	3.	Connector, A-J2, 10 pF L	0874-4006	0874-4006	
1	4.	Connector, A-J3, 100 pF H	0874-4004	0874-4004	
1	5.	Connector, A-J4, 100 pF L	0874-4004	0874-4004	
4	6.	Foot	5260-2060	5260-2060	
		REAR PANEL			
4	1.	Cover	0480-7000	0480-7000	
1	2.	Power plug, A-J5	4240-0600	4240-0600	5935-816-0254
1	3.	Slide switch, A-S1	7910-0831	4603	
1	4.	Fuse mounting device	5650-0100	HKP-H	5920-284-7144
2	5.	Multiple plug, A-J6, EXTERNAL BATTERY 12 V -; A-J7, EXTERNAL BATTERY 12 V +	4220-0160	DC101	

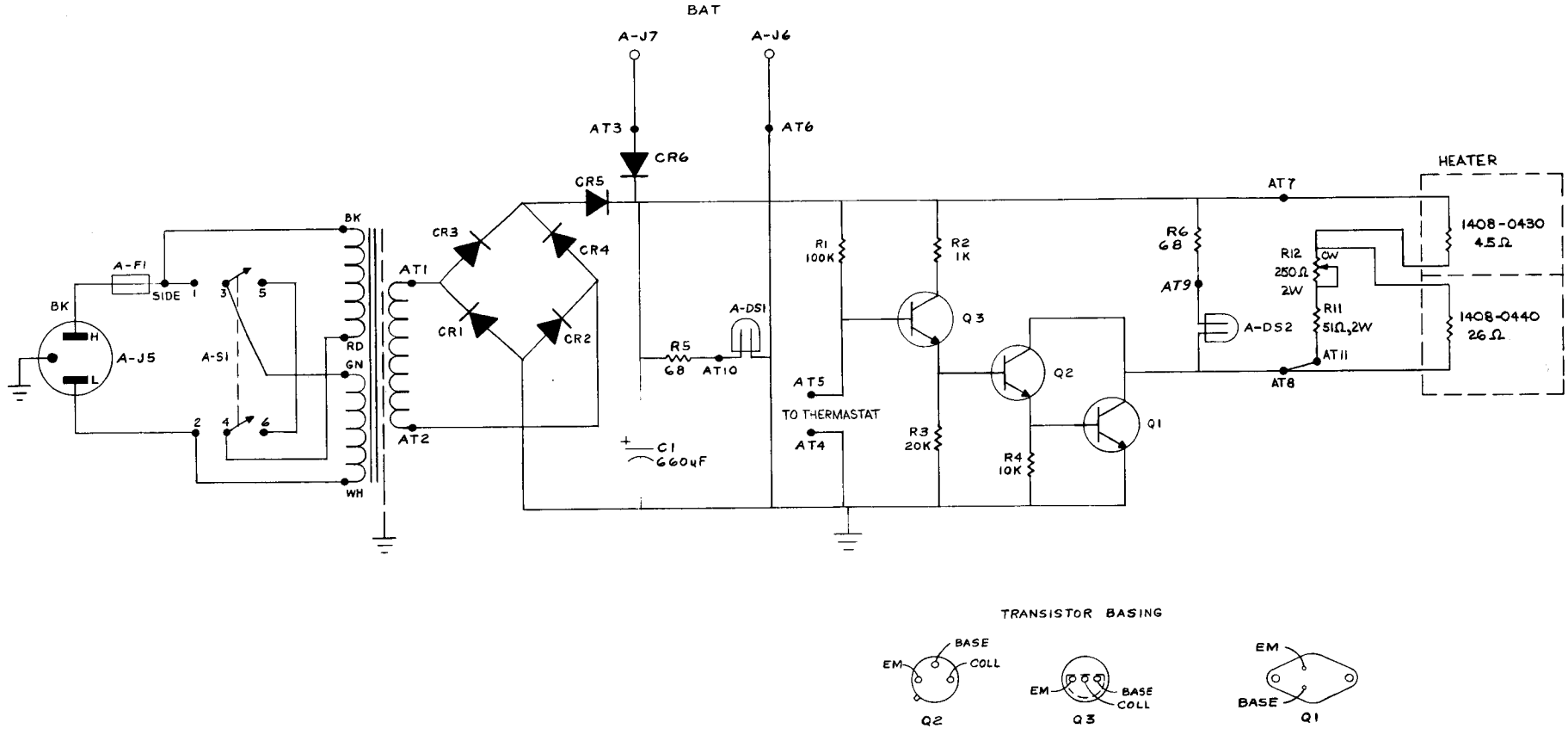

Figure 5-2. Oven-heater-circuit schematic diagram.

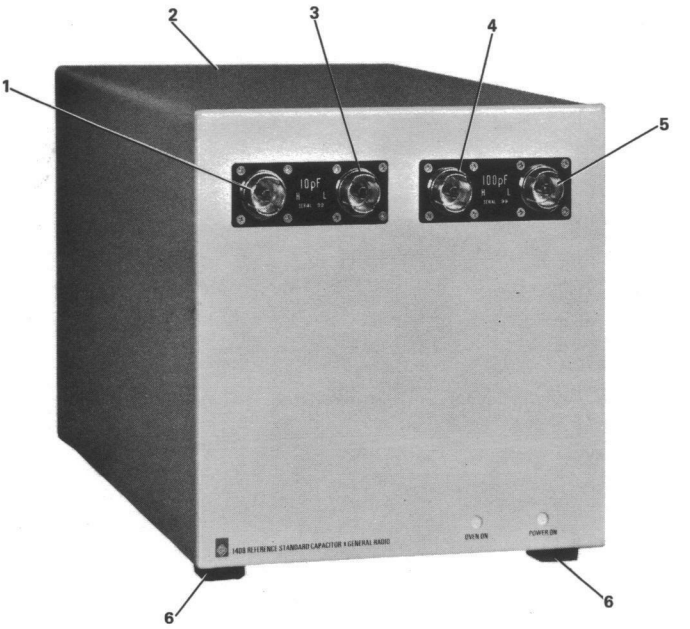

Figure 5-3. Front-panel mechanical parts.

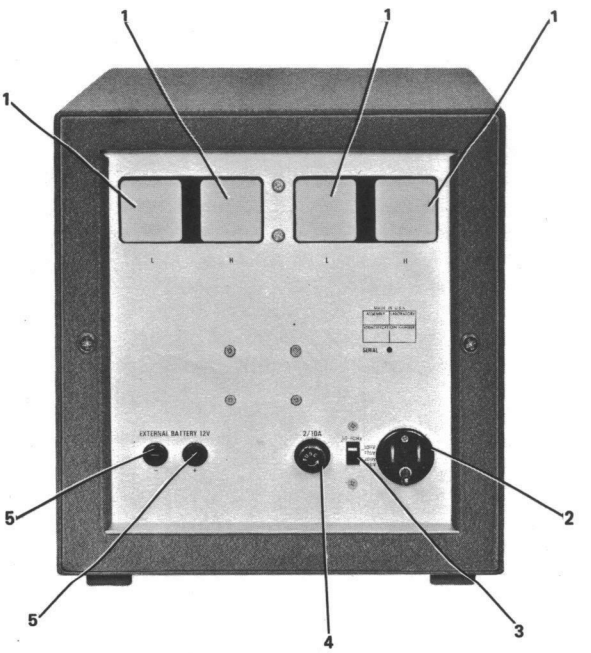

Figure 5-4. Rear-panel mechanical parts.

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