SILVER

INSTRUCTIONS FOR

MODEL 904 CAPACITANCE-RESISTANCE BRIDGE

GENERAL: Model 904 is a wide-range precision measuring instrument. Deriving all operating power from any 105/125 volts, 50/60 cycle a.c. mains outlet, it permits the accurate determination of capacitance and power factor of condensers and values of resistors over wide ranges. The measuring circuit is basically a Carey-Foster type of Wheatstone Bridge in which both ratio arms (P1) are simultaneously and oppositely varied to give a logarithmic scale calibration covering two decades (100:1 range) for each of eight ranges. The condenser being measured is compared against built-in standard capacitors upon any one of four ranges. An unknown resistor is similarly compared against built-in standard resistors. Four capacitance ranges (MFD.-RANGE) are:

.001	-- 10 through 1000 mmfd.	(multiply outer dial reading by .0001)
.1	-- .001 through .1 mfd.	(" " " " " .01)
10	-- .1 through 10 mfd.	(" " " " " 1)
1 K	-- 10 through 1000 mfd.	(read inner dial directly)

Four resistance ranges (RANGE-Ω) are:

1 K	-- 10 through 1000 ohms	(multiply outer dial reading by 100)
.1 M	-- 1000 through 100,000 ohms	(" " " " " 10,000)
10 M	-- .1 through 10 megohms	(read outer dial directly in meoghms)
1 KM	-- 10 through 1000 megohms	(read inner dial directly in megohms)

Accuracy is nominally ±3%, diminishing somewhat in range of 100 to 1000 mfd./megohms

POWER FACTOR knob is graduated 0 through 50%, and is operative for power factor measurement of capacitors on all except the lowest capacitance range. Built in D.C. POLARIZING VOLTAGE knob is calibrated 0 through 500 volts (open circuit voltage). Pressing the PUSH TO POLARIZE button applies a selected d.c. voltage to the condenser or resistor under test. Such voltage may be applied during capacitance or resistance measurements.

BRIDGE SENSITIVITY knob controls the 6SN7GT amplifier located between the bridge circuit and the 6E5 electron-ray indicator tube. With it the degree of 6E5 shadow closure may be adjusted for optimum readability on different bridge ranges. When lever switch is in BRIDGE position the 6E5 indicates bridge balance when its shadow shows widest "V".

When lever switch is in 10 MA. LEAKAGE position the 6E5 tube is transformed into a 0-10 MA. milliammeter and is placed in series with the D.C. POLARIZING VOLTAGE source to indicate leakage current and for simultaneous breakdown test of the condenser being tested, with d.c. voltage applied by depressing the PUSH TO POLARIZE button. With lever switch to right (in LEAKAGE 100 MA. position) the 6E5 is converted into a 0-100 ma. milliammeter to indicate high leakage currents, as for large electrolytic condensers.

Minimum calibrated range is 10 mmfd. and 10 ohms. This may be brought down to ¼ mmfd. by connecting a small fixed condenser of about 10 mmfd. across the red and black panel jacks noting its dial reading, then adding the unknown specimen across this fixed condenser and

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observing the increase in dial reading. The capacitance of the unknown is then the difference between the two readings (the capacitance it adds to the small condenser connected across the bridge jacks). A resistor of about 10 ohms shunted across the bridge jacks will similarly allow measurement of an unknown resistor down to $\frac{1}{4}$ ohm in terms of the increment in resistance the unknown adds to the value indicated for the shunt unit alone.

PRECAUTIONS: In measuring low capacitances and low resistances, connect the unknown specimens directly by their leads to the 904 panel jacks to avoid errors due to long connecting leads.

In measuring electrolytic or other polarized condensers, be sure to observe polarity markings of panel jacks.

When measuring a condenser mounted in an equipment without removal of the specimen therefrom, always disconnect the positive (+) terminal of the condenser to be measured and connect it to the + jack of the 904 Bridge. The black (-) jack of the bridge may be connected to a grounded (or already circuit-connected) negative lead of the test specimen. The red jack must always connect only to a lead of the test specimen not connected to any other circuit.

OPERATION: Examine 904 Bridge to make sure tubes are in proper sockets, that no damage has been suffered in shipment. Insert plug into 105/125 volt, 50/60 cycle a.c. mains outlet only. Turn D.C. POLARIZING VOLTAGE knob just far enough to right for its switch "click" to be heard. Allow time for tubes to warm up and visible end of 6E5 to exhibit characteristic green glow.

Connect test specimen to be measured to panel jacks by means of red and black test leads (directly to panel jacks by specimen's own leads if value is below 100 mmfd. or 10 ohms). Set range switch to appropriate position, lever switch to BRIDGE. Set BRIDGE SENSITIVITY to about mid-scale. Adjust main dial for maximum opening of 6E5 tube shadow. Adjust BRIDGE SENSITIVITY to prevent 6E5 shadow angle from opening or closing excessively as main dial is balanced -- so that balance or null adjustment is clearly defined. Read capacitance or resistance from main dial in accordance with range and multiplying figures listed on page one. RANGE knob figures indicate maximum capacity (dial turned counter-clockwise) of each of the eight ranges.

After balancing bridge for maximum 6E5 shadow opening for a test capacitor, adjust POWER FACTOR knob only to increase 6E5 shadow opening. That setting of POWER FACTOR knob which yields maximum 6E5 shadow opening then indicates the power factor of the capacitor being measured. This knob is inoperative upon resistance ranges.

To test electrolytic condensers for leakage and other condensers or resistors for departure from rated values when d.c. voltage is applied to them, make measurement for value as above. Then press PUSH TO POLARIZE button and progressively advance D.C. POLARIZING VOLTAGE knob up to voltage rating of the test specimen. If the specimen is good, no adjustment of the main dial should be necessary to keep the bridge balanced for minimum 6E5 closure.

Now throw the lever switch to 10 MA. LEAKAGE position, press PUSH TO POLARIZE button, advance D.C. POLARIZING VOLTAGE knob progressively up to voltage rating of the test specimen, and estimate d.c. leakage current. If 6E5 shadow over-closes, shift lever to LEAKAGE 100 MA. position. Estimate leakage current by the degree of 6E5 shadow closure. Zero leakage current is evidenced by no closure of its shadow. Progressive closure is a linear measure of leakage current up to full closure, which indicates either 10 ma. or 100 ma. current depending upon setting of lever switch.

POLARIZING CURRENT AVAILABLE: The D. C. POLARIZING VOLTAGE knob scale is calibrated in open circuit voltage -- the voltage available for application to a test specimen drawing no current. This is because 5000 ohm resistor R5 and 36,000 ohm

resistor R9 are wired in series with the arm of P3 and the test specimen to prevent burn-out of the costly 100,000 ohm wire-wound potentiometer P3 in event of excess current being drawn through it. Simple ohms law will show that were a milliammeter to be connected directly to panel jacks and D.C. POLARIZING VOLTAGE knob advanced to 500, only 12½ ma. could flow through the combination of R5, R9, and then at practically zero voltage. It is thus seen that R5, R9 constitute a current-limiting combination protecting P3 from damage, but at the expense of voltage applicable to a leaky capacitor being tested. The user may short-circuit 36,000 ohm R9 if desired, and so have available a voltage under load closely approximating the panel calibration of the D.C. POLARIZING VOLTAGE knob scale for application to capacitor specimens drawing significant current. If this is done it is ESSENTIAL THAT LEAKAGE CURRENT DRAWN FROM 904 BRIDGE NEVER BE ALLOWED TO EXCEED 10 MA. The drawing of higher currents through P3 will result in its burn-out.

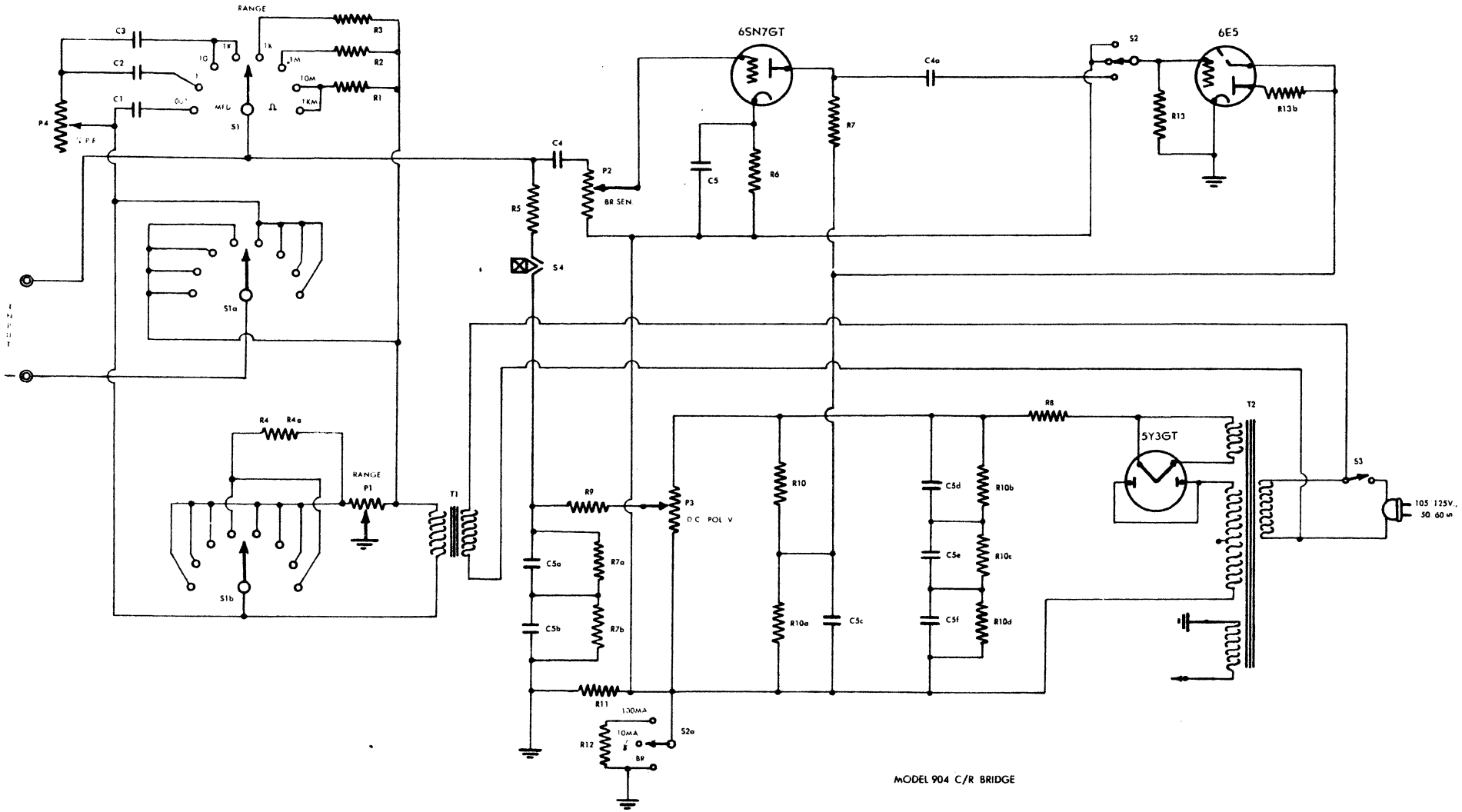
LEAKAGE CURRENT INDICATOR: Two lever switch positions, as previously stated, turn the 6E5 tube into a two-range milliammeter requiring 10 and 100 ma., respectively, for full shadow closure. No more than 10 ma. should be drawn from the bridge, except for intervals of 2 seconds or less, to avoid damage to costly P3. This can be done in practice only if R9 has been short-circuited as suggested above, when currents so high as to damage P3 if allowed to flow through it for more than 2 seconds are available. For approximate estimation of leakage currents drawn by leaky capacitors the 6E5 shadow closure is quite adequate. For accurate current measurement a suitable milliammeter may be connected between test capacitor and black panel jack. Such a meter should be a multi-range instrument such as "VOMAX" in order that the operator may start with a high current range to protect the meter in event of an excessively leaky or short-circuited capacitor, then progressively cut meter current range down to a final easily read range. Such a meter may be left connected in series with the capacitor being tested while its capacitance is being measured only if it may be set to a range of 100 ma. or higher. (Meter resistance could be high enough at lower-current range to impair accuracy of capacitance measurement.)

50 CYCLE OPERATION: When operating upon 50 cycles instead of 60 cycles mains frequency for which the POWER FACTOR dial is calibrated it is necessary to apply a multiplying factor to the POWER FACTOR reading to obtain correct result. POWER FACTOR readings must be multiplied by .865 to obtain actual power factor percentage when Model 904 Bridge is used on 50 cycle mains.

INSULATION RESISTANCE: Resistance of unknown specimens of insulating material may be directly measured by Model 904 Bridge if they lie below 1000 megohms. Place the test specimen between suitable electrodes connected to the panel jacks and measure exactly as in the case of a resistor. Apply any selected voltage up to 500 volts d.c. to test specimen during measurement by pressing PUSH TC POLARIZE button and adjustment of D.C. POLARIZING VOLTAGE knob to apply desired test voltage.

TUBE ALTERNATE: Should type 6E5 tube be unprocurable for replacement needs, type 6U5 may be substituted. No change in Bridge operation will occur using 6U5 electron ray tube, except that 10 MA.-LEAKAGE - 100 MA. ranges will require approximately double these currents to produce complete eye shadow closure; LEAKAGE MA. ranges thus doubling to 20 and 200 MA., respectively, when 6U5 is used in place of type 6E5 tube.

MEASURING SMALL CAPACITANCES: As in any capacitance bridge, Model 904 has within itself a small initial minimum capacitance which varies slightly from bridge to bridge. If RANGE knob is set to .001 - MFD. the lowest scale graduation of the main dial is .05, which equals 5 mmfd. With nothing connected to panel jacks it will be possible to balance the bridge on this range (maximum 6E5 shadow opening) at some dial setting between .05 and .15, or in the range of 5 to 15 mmfd. Whatever the main dial setting for such balance is indicates directly the inescapably small minimum capacitance of the bridge itself. When accurately measuring capacitances below 100 to 200 mmfd. this residual minimum capacity should be allowed for by subtracting it from the indicated value of the specimen being measured. On all except this lowest capacitance range the residual



MODEL 904 C/R BRIDGE

bridge capacitance is so low as to introduce negligable error, and for capacitors of over a few hundred micromicrofarads may be neglected as inconsequential in most cases.

LOOSENED DIAL: Do not loosen the dial knob set-screw from its shaft. The position of the dial upon the shaft of P1 determines the accuracy of calibration of Model 904 Bridge. Should it ever become loose the bridge must be recalibrated. This may be done by connecting a 1% precision resistor known to be accurate to the panel jacks and resetting the dial upon its shaft. The resistor may be of 100, 10,000 or 1 megohm exact resistance. With RANGE knob set to 1K for a 100 ohm resistor, to .1M for a 10,000 ohm resistor or to 10M for a 1 megohm resistor, the bridge should be accurately balanced and the dial refastened to its shaft so that it reads exactly 1.0 (midscale).

PARTS LIST

P1 5,000 ohm potentiometer ± 2%
P2 500,000 ohm potentiometer
P3 100,000 ohm potentiometer with switch S3
P4 1600 ohm potentiometer ± 5%
R4, 4a 3,000 ohm potentiometer and 47,000 ohm ± 1% series resistor pair
R1 100 ohm ± 1% series resistor pair
R2 10,000 ± 1% series resistor pair
R3 1 megohm ± 1% series resistor pair
R5 5,100 ohm 1/2 watt resistor
R6 1,500 ohm 1/2 watt resistor
R7, 7a, 7b 270,000 ohm 1/2 watt resistor
R8 2,000 ohm 2 watt resistor
R9 36,000 ohm 2 watt resistor
R10, 10a, 10b, 10c, 10d 100,000 ohm 1/2 watt resistor
R11 550 ohm ± 1% series resistor pair
R12 55 ohm ± 1% series resistor pair
R13, 13 b 2 megohm 1/2 watt resistor
C1 .0001 mfd. ± 2% mica capacitor
C2 .01 mfd. ± 2% parallel 600 volt capacitor pair
C3 1 mfd. ± 2% parallel 600 volt capacitor pair
C4, 4a .1 mfd. 400 volt capacitor
C5, 5a, 5b, 5c, 5d, 5e, 5f 8 mfd. 350 w.v. electrolytic capacitors
T1 #13254 bridge transformer
T2 #E1812 power transformer