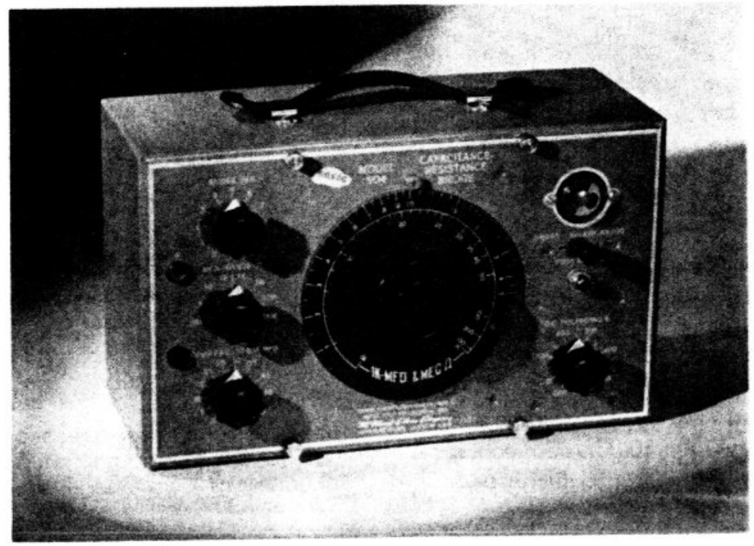
SILVER

MODEL 904 CAPACITOR — RESISTOR TESTER

10 MMFD/OHMS THRU 1000 MFD/MEGOHMS



Accurate measurement of capacitors . . . air, ceramic, mica, paper, oil, electrolytic, etc. . . . and resistors, is a prerequisite to successful design and servicing of radio and electronic apparatus. Created for use in our own and other serious design laboratories as was "VOMAX", the high accuracy, tremendous range and extraordinary flexibility of MODEL 904 place it in the class of costly laboratory equipment heretofore beyond the reach of all but a few.

MODEL 904 is direct reading in capacitance and resistance upon a 5" diameter "logarithmic" dial of substantially constant percentage accuracy. A total of eight 100:1 ranges, four for resistance and four for capacitance, cover 10 ohms through 1000 megohms and 10 mmfd. through 1000 mfd. Capacitances down to ¼ mmfd. and resistances to ¼ ohm are directly and accurately measurable as the increments they add to any convenient small value of C or R simultaneously connected to MODEL 904 Bridge. The open dial scale makes measurement of low values easy and accurate. Accuracy is to ±3% or better up to 100 megohms./mfd., diminishing slightly between 100 and 1000 megohms./mfd. The two high C and R ranges employ special "expanding" circuits to reach 1000 megohms/mfd. accurately. Sensitivity control permits optimum null indication over the great range of MODEL 904.

MODEL 904 enables direct measurement of all types of capacitors with from 0 up to 500 volts internal d.c. potential applied **during** measurement. This same continuously variable built-in d.c. potential is applicable to electrolytic capacitors and to specimens in insulation resistance testing. One terminal of the unit being measured may be grounded . . . capacitors may be measured without removing them from apparatus in most instances.

The power factor control is calibrated directly in % power-factor, 0-50% for .1 through 1000 mfd., and 0-.5% for .001 through .1 mfd. Power factor accuracy is 5%. A 3-position lever switch controls the electron ray tube. Position 1 gives bridge balance indication. Positions No. 2 and No. 3 switch the "electron eye" successively into an 0-10 and 0-100 ma. milliammeter for direct indication of capacitor leakage currents.

Style, size, weight and convenience are identical with "VOMAX". Quality of parts and construction parallel "VOMAX" . . . to bring to the serious technician heretofore unable to afford them the accuracy and range of costly laboratory equipment.

MODEL 904 CR BRIDGE draws 35 watts from any 105/125 volt, 50/60 cycle a.c. line. Complete with 1 — 6SN7GT bridge amplifier, 1 — 6E5 electron ray indicator and 1 — 5Y3GT rectifier tubes. A.C. input cord and plug and one pair of 30" test leads with alligator clips are included. Size and weight identical to "VOMAX". Code CABRI. **NET PRICE $49.90.**

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 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 counterclockwise) 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, <u>except for intervals of 2 seconds or less,</u> 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 <u>only</u> 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 TO POLARIZE button and adjustment of D.C. POLARIZING VOLTAGE knob to apply desired test voltage.

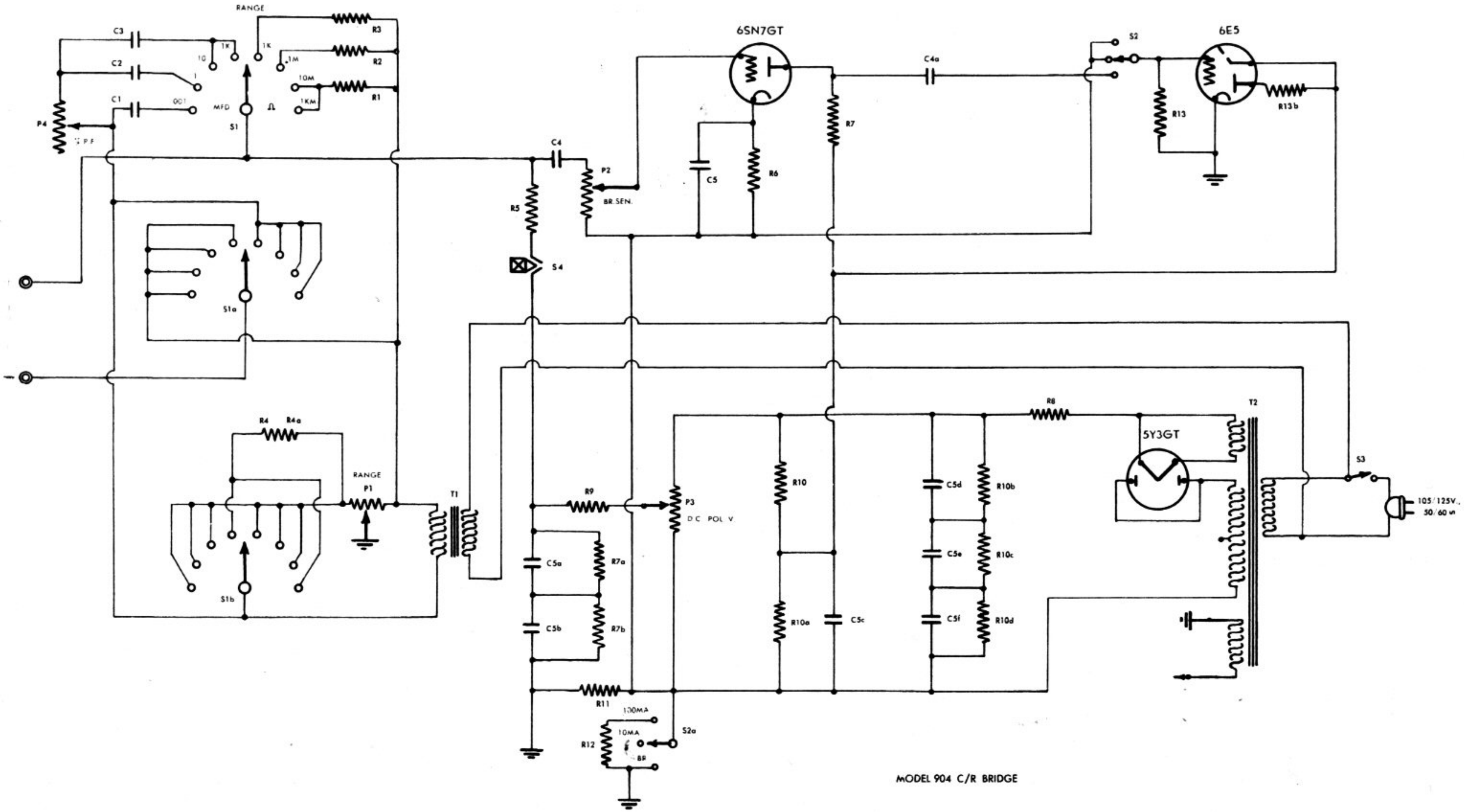
TUBE ALTERNATE: Should type 6E5 tube be unprocurable for replacement needs, type 6U5 may be substituted. No change in Bridge operation will occur using 6U5 electron ray tube, except that 10 MA.-LEAKAGE - 100 MA. ranges will require approximately double these currents to produce complete eye shadow closure;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



MODEL 904 C/R BRIDGE

By McMURDO SILVER *

A PRECISION INSTRUMENT

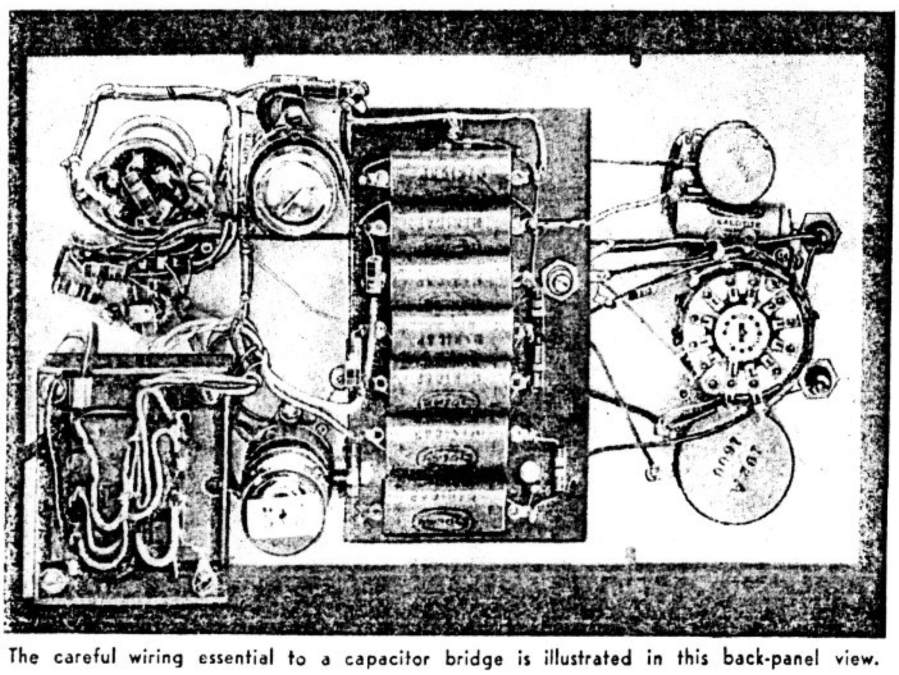
Laboratory Accuracy in a Serviceman's C/R Bridge

IN the early days of one- to five-tube battery receivers with usually but a single function per tube and circuit, location and correction of troubles was simple indeed. The exact reverse is true today, for even the simplest type of five-tube broadcast receiver has several multiple-function tubes, each function having its own separate circuit and set of component parts. Most important is that each one of these circuits—and there can be many indeed in a complex modern receiver—employs a large number of individual capacitors and resistors. Even partial failure or alteration in value of but one of the many unimportant-appearing little capacitors or resistors can—and usually does—cause the poor performance which the technician is employed to correct.

Drawing upon his thirty-five-odd years of experience in the design of high-quality radio receivers as a guide to the precise types and forms of measuring equipment which can most effectively serve the serious maintenance technician, the writer has recently completed a piece of measuring equipment going far beyond the rough approximations heretofore available at low cost. It has been his goal to bring to the maintenance profession those orders of accuracy heretofore available only in laboratory instruments costing several hundred dollars or more, and hence beyond reach of most service organizations.

* 1249 Main Street, Hartford, Connecticut

If, in the design laboratory, it has been necessary to measure resistors and capacitors to an accuracy of a few percent, then it is obviously desirable that the maintenance technician be able to do likewise. Excellent approximations of resistance values may be made by a well designed and built ohmmeter. Capacity may not be so measured accurately, for *two values* enter into capacitance measurements—actual capacitance in microfarads or micromicrofarads, *plus power factor*. Considering only resistance measurements for a start, the good ohmmeter cannot be particularly accurate over much of its range because of the characteristic slope of its meter scale. The usual ohmmeter scale is "open" over its lower half and its accuracy can be excellent over this portion of its scale. Over the upper half, however, the scale graduations become increasingly crowded, since they must reach practically infinity at full-scale. Allowing for the normal and usual ±2 percent accuracy of even the best meters, a glance at the upper half of the ohmmeter scale in terms of graduation crowding versus such meter variation shows why high accuracy cannot be anticipated. It is true that this condition can largely be set at nought by provision of such a multiplicity of resistance ranges that it is seldom necessary to use the crowded high end of the scale in practice. Nevertheless, the really accurate method of measuring resistance is by means of the Wheatstone Bridge—the ohmmeter serves an essential function but for truly accurate measurement the bridge is a "must".



The careful wiring essential to a capacitor bridge is illustrated in this back-panel view.

SUPERIORITY OF THE BRIDGE

It is true that an ordinary a.c. voltmeter or ammeter can be used to measure capacitance in the usual ohmmeter manner, but what actually happens is that the technician measures *capacitative reactance* which is then translated into capacity in terms of that capacitance which exhibits a given capacitative reactance at the particular a.c. frequency of measurement. Such attempts at measurement of capacitance cannot be more than approximately useful, since they ignore power factor. It is possible to find a capacitor apparently quite satisfactory so far as capacitance goes, yet have this capacitor exhibit such a high power factor as to be operatively useless. The fundamental Wheatstone Bridge method permits measurement of both capacitance and power factor, and so is a prime essential to the serious technician. Such a bridge may be so designed that it can provide resistance measurements with accuracy far exceeding the ohmmeter method, hence is most desirable.

One of the disadvantages of bridges so far available to the service technician is not alone that their accuracy left much to be desired because of low-cost components and the cursory test and calibration necessary to yield a low final selling price, but their lack of range as well. The equipment designer and the maintenance technician alike must be able to measure down to a fraction of an ohm, a fraction of a micromicrofarad—as well as up toward 1000 megohms and 1000 microfarads. Small compression mica trimmer capacitors—even air trimmers—of extremely low capacity can be causes of trouble and so must be capable of measurement in any well-equipped shop. Low values of resistance measurement are also necessary when "shooting trouble" in auto radio primary circuits, a.c. receiver heater circuits and the like. High ranges of resistance must be accurately determined in grid leaks and performance-impairing circuit leakage, while high values of capacitance appear in the filter capacitors of battery eliminators for portable battery sets as well as in "a.c., b.c. and d.c." sets themselves.

PRACTICAL PRECISION BRIDGE

The capacitance-resistance bridge illustrated and diagrammed covers the direct range of 10 ohms through 1000 megohms and 10 μμf through 1000 μf. This is not its real range, for in operation it reaches down to ¼ ohm and ¼ micromicrofarad—low enough to cover compression mica trimmers and high-resistance or faulty connections in auto radio heater and vibrator input circuits, where high current requirements necessitate low circuit resistance. Values of unknown capacitances and resistances below 10 μμf and 10 ohms are measured and indicated directly, as the increment such low values add on the bridge dial when they are shunted across some convenient small value of capacitance or resistance first connected to the bridge terminals and measured. With a 10 μμf capacitance (conveniently provided by a pair of wires twisted together just sufficiently to give a 10 μμf indication on the bridge) it becomes possible to measure accurately capacitances as low as ¼ μμf. The same is true for resistance, substituting a 10 ohm resistor for the 10 μμf test capacitor.

Power factor of capacitors in the ranges usually made up of paper, oil and electrolytic structures should be measurable up to 50 percent. Since paper capacitors seldom are made below .001 μf, and as mica, ceramic and air capacitors seldom exhibit poor power factor without complete failure, we may establish power factor measurement as essential in the range of .001 μf up through 1000 μf.

For electrolytic capacitor measurement and reforming after idle periods the ideal bridge must incorporate a source of continuously variable d.c. potential which may be applied to any capacitor under test. Provision must be made for determination of leakage currents through electrolytic capacitors as well.

If we can provide means for measuring condenser capacitance under conditions where actual d.c. operating voltages are applied at the same time that capacity is being measured, we may locate those intermittent condensers which are the bane of the service technician; condensers which test correctly out of circuit but which fail to function when restored to the equipment from which they were disconnected because a d.c. potential not present in outside measurement is reapplied to them.

Fig. 1 and the photos illustrate and diagram a capacitance-resistance bridge satisfying all of the requirements set forth above, a precision measuring instrument yielding an accuracy in measurement of capacitors and resistors of ±3 percent nominally over the range of ¼ μμf or ohm up through 100 μf or megohms; with such laboratory order of accuracy falling off slightly only between 100 and 1000 μf or megohms. Using it, power factor may be accurately determined, polarizing voltages may be applied to any and all types of capacitors during actual capacitance measurement, leakage currents in two ranges of 0-10 and 0-100 ma may be measured—even insulation resistance up to 1000 megohms with 0 to 500 volts d.c. applied may be accurately determined.

Operation is simple as it is accurate. The power cord plug inserted into any 105/125 volt, 50/60 cycle a.c. mains outlet, the bridge is turned on by moving the lower right knob from OFF to ON, and tubes allowed to warm up. Middle right lever switch set to BRIDGE, it is only necessary to connect an unknown resistor or capacitor to the two left panel jacks by means of the clip leads supplied and set RANGE knob to that position which allows the electron-ray tube to open to a maximum for some setting of the 5-inch dial, when the value of the unknown is read directly from the dial setting multiplied by the indicated RANGE knob figure. The upper left knob allows adjustment to the degree of "eye" opening which yields most accurate readability. The lower left knob reads power factor directly in percent at that setting which, after the bridge is balanced, yields greatest farther opening of the "eye." D.c. polarizing voltage is applied in accordance with the rating of the capacitor under test by appropriate setting of the lower right knob and depressing of the button-switch immediately above it. Capacitor leakage current is read on the "eye" as the percentage of closure it exhibits when the lever switch is thrown to the 10 or 100 ma leakage positions with polarizing voltage applied. No eye closure indicates no leakage current; full eye closure indicates 10 or 100 ma leakage current, depending upon lever switch position.

Fig. 1 illustrates circuit-wise how all of these functions are incorporated in an instrument measuring only 12⅜ inches long, 7⅜ inches high and 6 inches deep over knobs, in a weight of but 10 pounds, and all with large and costly laboratory instrument accuracy. The actual bridge measuring circuit itself consists of a 4-arm Wheatstone Bridge circuit in Carey-Foster form. The main

Front view of the Silver Model 904 Capacitance-Resistance Bridge.

dial controls the ±2 percent precision potentiometer P1 which constitutes two simultaneously variable arms of the bridge. A third bridge "arm" is always the unknown, or X, connected to the INPUT terminals. The fourth, or "standard" arm consists of C1, C2 or C3 for three capacitance ranges, or of R1 R2 or R3 for three resistance ranges. To obtain the two special high ranges of 10 to 1000 μf or megohms, special "expanding" resistors R4, R4a are cut into circuit at one or the other end of P1 by the range switch S1, S1a, S1b. Standard resistors are held to ±1 percent accuracy; capacitor standards, of mica and special mineral oil construction, to ±2 percent.

This type of bridge circuit wherein two arms are varied simultaneously and oppositely in value yields the advantage of a 100 to 1 range for each rotation of P1, plus the desirable logarithmic scale calibration wherein accuracy is substantially constant percentage-wise at low, medium or high settings of the dial scale. It also lends it-

(Continued on page 51)

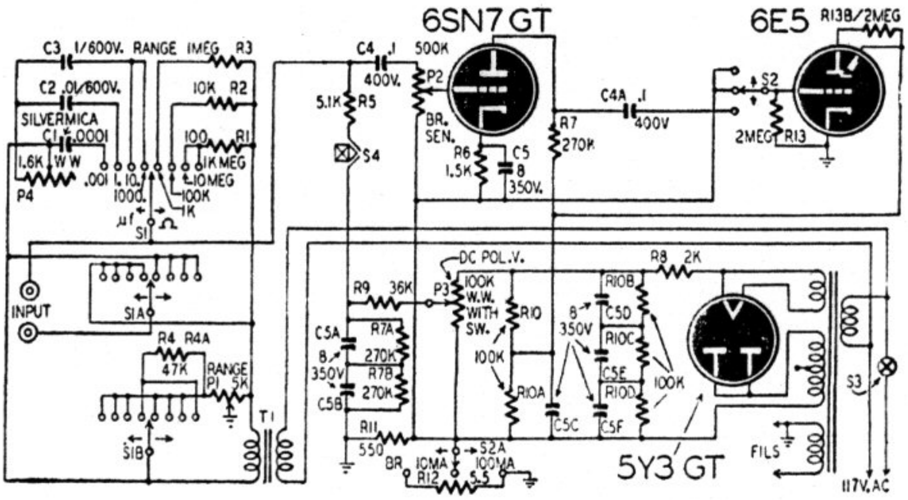


Fig. 1—Complete schematic of the bridge. Measurements are made with three main controls.

self admirably to extension of its range through the "vernier" effect upon P1 of adding R4, R4a into circuit to cover from 10 to 1000 µf or megohms.

Voltage for operation of the bridge itself is supplied through special transformer T1 connected to the horizontal bridge arm junctures. Balance is indicated by the absence of voltage across the vertical bridge arm junctures (ground and arm of S1) indicated by the 6E5 electron-ray tube, with the null voltage amplified by the 6SN7GT triode to its left in Fig. 1. Indicator sensitivity is controlled by potentiometer P2.

The power transformer provides heater voltage to the three tubes, and has its high voltage secondary connected as a whole to the 5Y3GT rectifier tube used as a half-wave rectifier. Filtration is a simple problem in this type of instrument, while such use of an essentially standard power transformer and rectifier tube permits obtaining something over 500 volts d.c. output simply and easily. For operation of the amplifier and indicator tubes this is cut down to 200 volts by the voltage divider R10, R10a. The full 500 volt d.c. output of the power supply appears across extra-heavy potentiometer P3, with any panel-calibrated portion of this voltage from 0 to 500 volts obtainable from its arm for application to the capacitor—or resistor—under test through filter resistor R9, PUSH TO POLARIZE button switch S4, and isolating-current limiting resistor R5. C5 through C5f are all 8 µf, 350 working volt electrolytic capacitors. C5d, C5e and C5f in series are the filter input capacitor of 1050 volts rating for the 500 volt circuit voltage—ample safety indeed against line surges. Voltage distribution across them, as well as across C5a, C5b and C5c is held constant and capacitor life is prolonged by shunt resistors R7a, R7b and R10b, R10c and R10d.

Switches S2, S2a shift the function of the 6E5 indicator tube from that of a bridge balance (null) indicator over into a two-range milliammeter with resistor shunts R11 and R12 yielding 0-10 and 0-100 ma ranges. The 6E5 connected across one or both of these resistors in series with the internal d.c. polarizing voltage source and the specimen under test provides a milliammeter which may not be burned out like the ordinary meter movement if a short-circuited condenser is inadvertently tested.

"Where extremely precise measurement of the leakage current through capacitors under test may be required, a more accurate indicator than the 6E5 is preferred. The milliammeter in any conventional volt-ohm-milliammeter may be employed for such precise measurement. It is merely necessary to connect such milliammeter between the capacitor under test and the black jack of the bridge. The meter should be short circuited for all except leakage current measurements, for its resistance can upset power measurements."