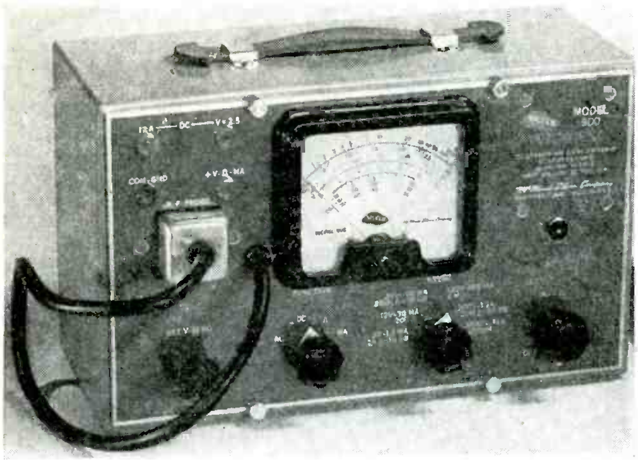
POSTWAR V-T-V-M



An analysis of the Vomax, with practical operation and maintenance data based on twelve months of field experience.

Fig. 1. Control panel of the vacuum-tube voltmeter which measures resistance, d-c, db, d-c and a-c volts from 20 cycles to over 100 mc.

by M. E. LEWIS

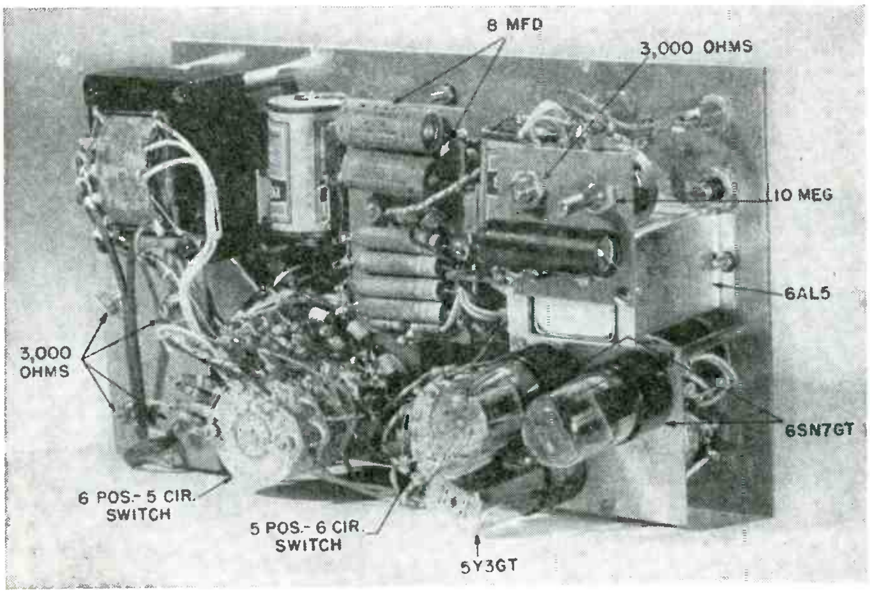
In locating and correcting troubles in receivers, accurate measurements must be used. It is impossible, for instance, to check operating potentials of the many vacuum tube circuits in the modern receiver without measurement equipment. Measurements are the basic, fundamental yardstick by which proper or faulty operation must be diagnosed.

Before the war voltage measurements, due to limitations of then available meters, were pretty much restricted to measurement of voltages present in power circuits of receivers—circuits in which voltages to be measured would not be disastrously dropped by application of low-resistance, power-consuming meters. Then usual voltmeters could not be used to measure actual operating voltages upon avc-controlled grids, series-resistance-isolated plates and screens, high-resistance avc lines, or at resistance-coupled amplifier grids and plates. The possibility of really time-saving measurement of a-f, i-f and r-f *signal voltages* lay in the distant future. This was because the usual 1000 ohm-per-volt d-c meter required significant *power* to function, power not available in such circuits. In a-c circuits the situation was even worse. Copper-oxide rectifiers, used to convert a-c voltages into current required to actuate the d-c meters, not only showed very low input resistance, but exhibited errors seriously increasing with frequency even in the low a-f range.

The need to measure voltages, present in circuits of such high resistance that they could not possibly supply the current required to actuate simple volt-ohm-milliammeters resulted in the development of vacuum-tube voltmeters. In their prewar forms v-t-v-m units were afflicted with errors due to variations in operating potentials of their own vacuum tubes, errors due to changes in characteristics of ageing tubes, and false readings due to small but real residual gas and ion current in these tubes. Nevertheless the v-t-v-m was a great step forward. Their general usage only awaited further development of the art. That development has been achieved, prewar deficiencies have been overcome and the v-t-v-m has become a *must tool* of every Service Man.

In developing a postwar v-t-v-m, one designer[1] has produced a combination unit, a vacuum-tube-volt-ohm-db-ma meter. This instrument, the Vomax, shown in Fig. 1, features a removable r-f probe for direct contact to r-f and i-f circuits.

Fig. 2. Interior view of v-t-v-m.



V-T-V-M Operation

In placing the unit in operation, the r-f probe must be fully inserted into its panel receptacle, with black (negative) and red (positive) test prod tips *not* inserted in panel jacks. The a-c plug is then inserted in line, *Adj.Ω* knob is turned so that *on-off* switch clicks on and pilot bezel illuminates. While allowing 30 to 60 seconds for tube warm-up, *Function* knob is set to *D.C.+* and *Range* knob to 3 V. Then meter pointer is set to zero on meter scale by adjusting *Set V. Zero* knob.

As tubes warm up meter pointer may move up or down scale, possibly even off scale. Incidentally, the meter cannot be injured by over-scale deflection. It can be injured only by overload in direct-current measurement, but is protected against burnout in all voltage, resistance and db operations. If this meter deflection isn't desired during tube warm-up, *Function* knob may be set to *ma* position for initial 30 to 60 second warm-up period.

With these initial adjustments completed, several interesting instrument-characteristic tests may be conducted. It is possible, for instance, to see to what extent errors due to grid and gas current have been eliminated by moving the *Range* knob from 3 V progressively through all six positions to 1200 V.

Meter zero will not shift more than 1% to at most 2% of full scale as *Range* switch is rotated. In rotating this switch the value of grid resistance (meter's d-c input resistance) of the upper section of the center 6SN7GT is changed from 50

[1]McMurdo Silver.

With Ohm-Db-Ma Measurement Features

megohms progressively down to 125,000 ohms, a range of variation sufficient to reveal the slightest trace of grid or gas current.

Shifting *Function* knob from *D.C.* — to *D.C.* + reverses polarity of d-c input, making it possible to keep meter cabinet and receiver chassis under test at the same potential while d-c voltages positive-to-chassis are measured with red test-prod *plus*. Voltages negative-to-chassis can also be measured with meter and red prod polarity reversed by a flip of *Function* knob.

Six basic ranges of 0-3, 0-12, 0-30, 0-120, 0-300 and 0-1200 volts, available with the *Range* knob, are graduated upon the meter scale. Six identical ranges, but in reverse polarity are provided by shifting *Function* knob from *D.C.*+ to *D.C.*—. Six more d-c voltage ranges can be added positive, and six more identical ranges negative, if red test wire tip is shifted from the *+V—ΩMA* jack to the *V x 2.5* jack. Each of these new ranges is 2½ times greater in full-scale voltage value than indicated by each *Range* knob setting. Thus, using the *V x 2.5* jack, d-c voltage ranges of 0-7.5, 0-30, 0-75, 0-300, 0-750 and 0-3000 volts are available at 126 megohms meter resistance, all read by mentally multiplying meter scale readings by 2.5.

Dual-Function Test Prod

Another interesting instrument feature is the *dual-purpose* red test prod which has a 1-megohm resistor built in to isolate instrument capacity from r-f, i-f and a-f grids and plates when measuring their d-c operating voltages dynamically during receiver operation. For all measurements *except* d-c voltage tip is screwed into the end of red prod from which flexible cord emerges. For d-c voltage measurements the tip must be screwed into the far end of the red prod to include the 1-megohm resistor in circircuits.

Ohmmeter

Having established meter zero by adjustment of the *Set V. Zero* knob while *Function* knob was set to *D.C.*+ and *Range* knob to 3 V, *Function* knob can be shifted to Ω position to check the ohmmeter. Meter pointer will now move up scale. It is set to exact full-scale reading by the *Adj. Ω* knob, and resistances between .2 ohm and 2,000 megohms can be measured. The upper meter scale is graduated 0 through 2K (2 kilohms, or 2,000 ohms). To use, the black prod wire tip is inserted into *Com. Gnd. jack*, red prod wire tip into *+V—Ω—MA* jack, and the two prod tips are connected to a resistor to be measured. In reading values a multiple of the *Range* knob pointer to the actual meter reading is used. Thus 10 at meter mid-scale is read as 10 ohms for 2KΩ position of *Range* knob, increasing in multiples of 10 for each advance of the *Range* knob. The center-scale figure (5th or 2MΩ) would yield 100,000-ohm reading. The 6th, or 2,000-MΩ position, involves a further multiplier of 100 times, center-scale 10 indicating 10 megohms.

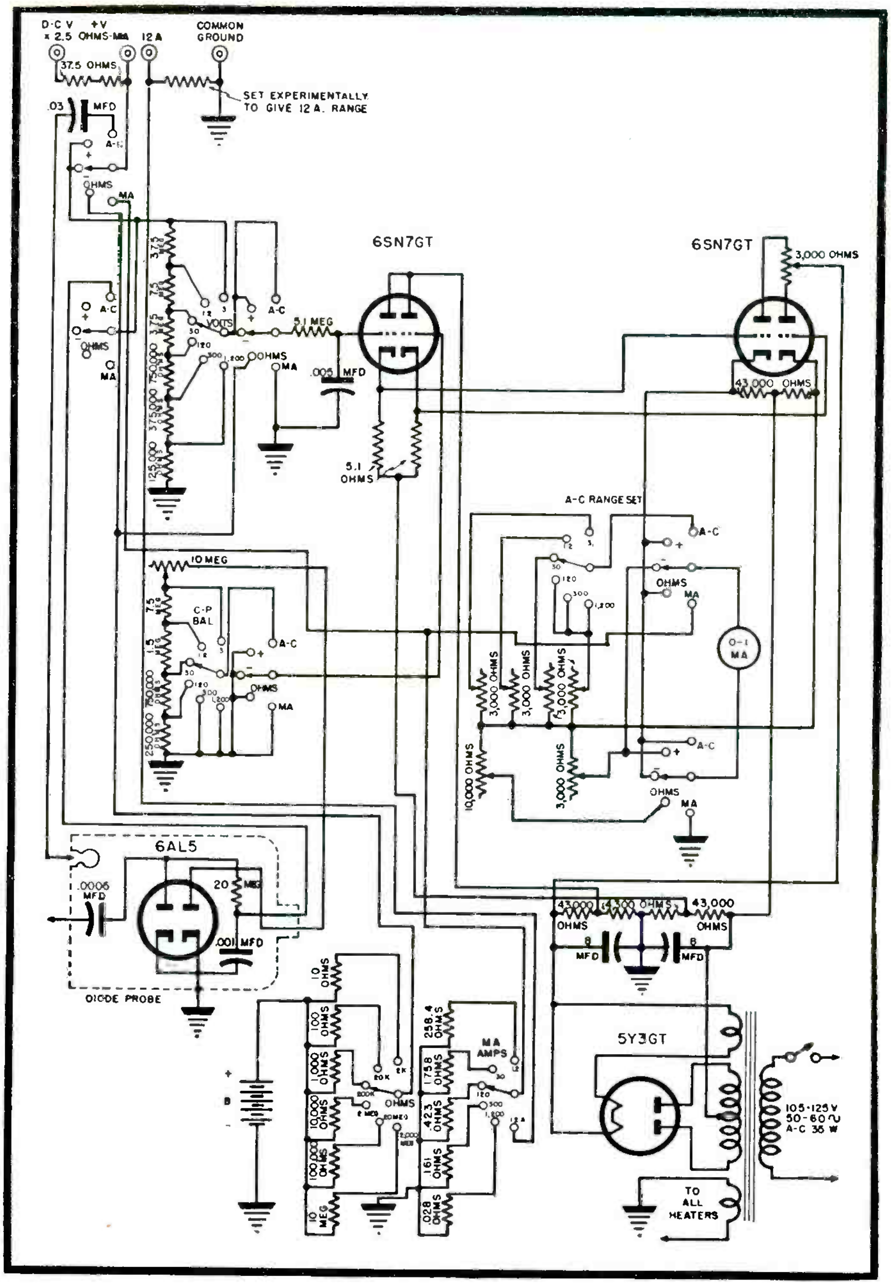


Fig. 3. Circuit diagram of vacuum-tube voltmeter described in this paper.

The Milliammeter

The milliammeter uses different internal current-shunt resistors to provide six-current ranges selected by *Range* knob. Meter accuracy can be checked by measuring known direct currents. To check *Range* knob should be set to 12 amperes position. The high range is used so as not to burn the meter out by applying excessive current to a low-current range. *Range* knob is moved to left until the current flowing through the meter yields an easily read value upon the upper or lower center meter scale. All ranges starting with figure 3 about the *Range* knob are read on the upper center scale. All ranges beginning with figure 12 are read upon the lower center scale marked 12 at the right end. For 3 and 12-volt ranges appropriate scales are read directly. For higher ranges zeroes are added to observed readings.

Checking A-C Operation

With both test lead tips *removed* from panel jacks, with meter set to read zero

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by *Set V. Zero* knob with *Function* knob set to *D.C.+* and *Range* knob set to 3 V, *Function* knob is shifted to a-c position. Meter zero will not change more than 1% to 2%. If zero *does shift* an old, unsheathed, or poorly grounded a-c power line will usually be the cause. The remedy is simple. If reversing the a-c plug in the a-c power outlet does not make a-c meter zero coincident with *D.C.+* zero, a lead from a good ground should be clipped onto one of the four panel screws of the instrument.

The unit also permits the measurement of the actual magnitude of a-c voltage radiated by the local power line, electrical appliances and all similar sources of such undesired radiation. For this measurement the red test lead tip is inserted in the *+V—Ω—MA* jack, allowing it to act as an antenna. The meter reading may be anything from a fraction of one volt up to 30 volts or more. This is actually a-c energy being picked up by the unterminated red test lead acting as an antenna. This can be proved by handling this lead, moving it about, touching its metal tip, and noting the increase in voltage registered, which our body adds, when a finger touches the red prod tip. The long time-constant of the diode input circuit can also be checked during these tests by touching the red prod tip to a panel thumb-screw. Meter reading will take several seconds to fall to zero, due to desirably slow leaking off of charge built up on .03-mfd capacitor by local a-c fields discharging through a 20-megohm resistor and 37.5 megohm through 125,000-ohm resistors in series.

If the black test lead tip is inserted into the *Com. Gnd.* jack and both red and black prod tips are contacted to a source of a-c voltage, the *false* but quite real voltage registered by the meter due to the antenna effect of the lead when unterminated and exposed to locally radiated a-c fields will disappear, and the correct voltage of the source being measured will be indicated.

By providing an unshielded red test lead input capacity of the instrument has been kept low and the instrument can be used to measure a-c voltages beyond 100 kc. Where the user is more concerned with a-c voltage measurements at a-c power-line frequency, the antenna effect of the intentionally unshielded red test lead may be eliminated by using a shielded test lead consisting of an ordinary test prod terminating the inner conductor of a length of one-wire shielded microphone cable. The far end of this test lead would plug into the + V — Ω — *MA* jack, the shield braid of which would terminate at meter end either at the *Com. Gnd.* jack or through a spring clip to a panel thumb-nut.

The R-F Probe

To study operation of the probe, it should be withdrawn from its shell from the panel receptacle. No change in meter zero will be observed. If a finger is now applied to the *live* tip of the r-f probe, the meter will register locally present a-c voltage fields, since the body is now acting as an antenna to pick them up. Touching the probe tip to a panel thumb-

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nut will cause the meter reading to fall to zero, since the meter input is short-circuited, and cannot pick up voltage radiated from the power line, etc.

We can now check a-c meter accuracy together with r-f probe operation. The *Range* knob is set to 120 volts, *Function* knob to *A.C.*, and the probe is inserted in its panel receptacle. Red and black test prods are connected to the a-c line. Meter should read the voltage of same accurately to within ±5%. Now the r-f probe should be withdrawn and its tip contacted to one side of the a-c line, the shell (or tip of the black prod) being connected to the other side of the line. The meter will read only about 80-odd volts. This is quite proper. When we measure voltages using the r-f probe directly, we have substituted a .0005-mfd capacitor for .03-mfd capacitor in the diode rectifier input circuit. The .0005-mfd unit is suitable for a-c voltage measurement in the 15,000 cycle up to over 100 megacycles range. Its reactance is too high for accurate low-frequency measurement. That's why the instrument automatically replaces the .0005 with a .03 when the r-f probe is plugged into panel, to make low-frequency (down to 20 cycles) measurements possible through the panel jacks which include the .03-mfd capacitor in their circuit.

[*To be continued*]

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WIRE RECORDER PREVIEW

Webster-Chicago wire-recorder preview test at plant at 5610 Bloomingdale Avenue, Chicago.

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TRAILER P-A

A p-a system recently installed in a trailer by Broadcast Recorders, Inc., 1538 N. Cahuenga Blvd., Hollywood, Calif. Unit included a 5-channel mixer, recording amplifiers and two recorders.

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ACKNOWLEDGMENT

The November issue carried schematic diagrams on Learadio models 561-562-563 and also the Philco model 43-200 series. These were reproduced without required permission from Howard W. Sams Photofact Folios. We are deeply regretful that this occurred.

Operating The Vomax

by M. E. LEWIS

Part II of an analysis with practical operation and maintenance data based on twelve months of field experience.

Continuing our discussion on the use of the Vomax, let us now study r-f and i-f measurement applications.

It must be remembered that to measure any voltage, two connections must be made to its source. These are made in all except r-f and i-f measurements by the red and black test leads on the instrument. In r-f and i-f measurements these two connections are made to the circuit to be measured, one by the tip of the r-f probe to the *high* side of the circuit, the other by the metal r-f probe shell contacting the *low* (usually chassis) side of the circuit. The r-f probe houses the diode rectifier and the required resistors and capacitors. At usual broadcast band and i-f amplifier frequencies, the *return circuit* need not be through the r-f probe shell, but may be through the black test lead connecting *COM.GND.* jack to receiver chassis. Above 20 mc the return circuit *must be directly to the probe shell* without long intervening connecting lead if accuracy is to be maintained.

Allowing for Input Capacity in R-F

With any voltmeter capable of measuring r-f voltages some input capaci-

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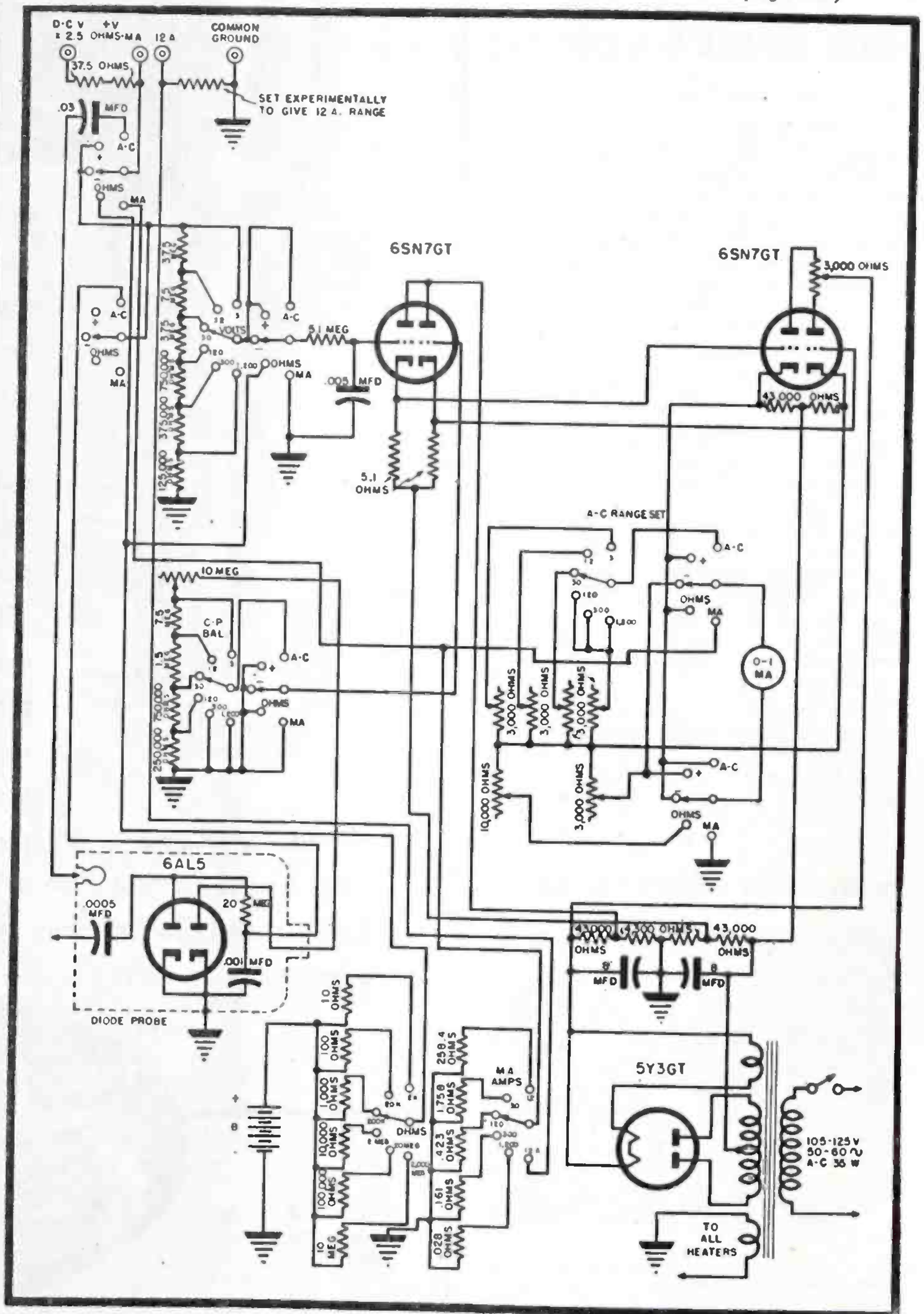

Fig. 1. Circuit diagram of the Vomax.

(*Continued from page* 36)

tance is inescapably associated. By careful design this may be held down close to the actual plate-to-cathode capacity of the diode used as the a-c rectifier. In a precision meter the d-c input capacity can be reduced to a fraction of a micromicrofarad by the simple device of a series resistance in the test prod, a resistance which isolates the meter capacity from the circuit being measured quite effectively. In a signal tracer, for example, this device may also be used, for in it we are not concerned with reading accuracy to a very few per cent. Such a capacity-isolating resistor may not be used in series with the input of an a-c voltmeter rectifier for the power (as contrasted to voltage alone) required, even though it be very small, will result in large errors in meter reading. Such errors are a function of the source resistance. A given a-c voltage measured across a low-resistance power-transformer winding, for example, would give a totally different meter reading from the same voltage when present in a high-resistance grid circuit.

Input capacitance of the v-t diode may be reduced to about 8 mmfd with a standard tube of adequate cathode emission and insulation resistance to stand usefully high applied voltages. In the Vomax the input resistance is made to *look* like 6.6 megohms, but we are left with its inescapable shunt capacity. This is of no consequence until we attempt to measure r-f voltages present across tuned circuits. Fortunately the solution is simple. Suppose we want to measure the grid voltage present across an r-f transformer tuned secondary. The r-f probe tip and shell is contacted to the circuit (tip to grid, shell to chassis) and the receiver r-f (or i-f) circuit trimmer capacitor is readjusted to enough less capacity to allow for the 8 mmfd the r-f probe has added. Then it is necessary to determine the amount of trimmer capacitor readjustment necessary to allow for r-f probe capacity added, while the probe is so contacted to the circuit. This is done by adjusting the trimmer to yield the same signal strength from the speaker with the r-f probe added as before the circuit contact was made.

Decibel Meter

A power-output meter for measuring power output of audio amplifiers, used as an output indicator in receiver-circuit alignment, is actually an a-c voltmeter provided with meter scales automatically translating a-c voltage across a known resistive load into decibel figures; there are three such scales, −10 to +50 db, on the Vomax. These scales are accurate upon the basis of usual rating of 0 db equalling 1 milliwatt in 600 ohms.

Maintenance

With over a year's experience it has become possible to plot a *trouble pattern* for Vomax.

As might be expected, tube failure is first in frequency of physical troubles. Fortunately new tubes can be installed in place of originals that have failed without upsetting calibration more than a per cent or two. This is because degeneration in the tube circuits of the instrument is so great as to divorce variations almost completely in tube characteristics from affecting meter accuracy. The predominant feature of tube failures, very small indeed in total, is the development of heater-to-cathode leakage in the two 6SN7GT tubes used in the d-c voltmeter circuit. This shows up as slow drift of initially properly set meter zero on *D.C.+* or *D.C.−* functions. The remedy is replacement of one or both tubes as required. A second remedy, now permitted by the tube makers, is reduction of heater voltage. This is accomplished by inserting a .9-ohm resistor between the originally grounded 6.3-volt lug of the power transformer and ground. In recent models this resistor has been incorporated. Actually 6SN7GT tubes exhibiting heater-cathode leakage too high to allow use without slow meter zero drift are usually satisfactory for amplifiers, etc., and so should not be discarded after replacement.

Ageing 6SN7GT tubes can be troublesome too, making it impossible to establish meter zero with the *SET V. ZERO* knob, even to the point of meter going off scale first in one direction, then in the other, as *FUNCTION* knob is shifted from *D.C.+* to *D.C.−* positions. The remedy is replacement of one of both 6SN7GT tubes. Development of a poor ground to panel from the 125,000-ohm resistor (*RANGE* switch mounting nut loosened) can account for slow d-c zero drift.

Allowing ohmmeter batteries to run down, to be jarred out of their mounting clips and short-circuit internally, can cause trouble. If run down so that *ADJ.Ω* knob will not bring meter pointer up to full scale these batteries should be replaced. If they are allowed to deteriorate to the point of oozing electrolyte, this electrolyte can damage the wiring cable, *RANGE* and *FUNCTION* switches.

Failure of power transformers is one of the standard headaches. Despite conservative design and operation it just will happen occasionally. In Vomax a warning occurs before this rare type of failure. Since power transformer failures almost always start as short-circuits between turns of the fine-wire-wound high-voltage secondaries, this will cause significant variation of a-c voltage measured, at the separate 5Y3GT rectifier tube plates (tube out of socket). This in turn will cause slow drift of d-c volts meter zero. Replacement of power transformer is indicated if high-voltage secondary shows a difference in voltage between halves of over ±10%. The 8-mfd filters will, like all electrolytics, sometimes give trouble after extensive use. Remedy is replacement should they test *short* or show excessive leakage.

Effects of High Humidity

In extremes of humidity, or when the unit has not been operated for some time, accumulation of atmospheric moisture on its high resistance circuits can cause the d-c volts meter zero not to be identical (out more than 2%) for different settings of the *RANGE* switch. A 30-minute warm-up will evaporate moisture from the 50-megohm d-c voltage divider circuits in most cases. Where this does not help, or to avoid loss of time, the remedy is to make sure certain internal connections are *in the clear*; do not touch metal parts or other connecting wires. The lead from the *+ V-Ω-Ma* jack to the switch should be cleared from contact with other parts. Leads from the 37.5-megohm resistor to the *A.C. + D.C. - Ω/MA* switch should be checked carefully too. The 5.1-megohm resistors going to the grids of the right hand of the 6SN7GT should also be checked, to see that these wires contact only the terminals to which they are soldered. The .005-mfd capacitor should be checked for absence of leakage.

A-C Meter Zero Setting

If a-c meter zero does not coincide with *D.C.+* zero, it can be due to ageing of the 6AL5 dual u-h-f rectifier in the r-f probe (if known not to be due to red test lead tip inserted in *+ V-Ω-MA* jack contrary to instructions in checking zero coincidence). The trouble can be due to use of a *floating* (unsheathed, poorly grounded) a-c power line. Grounding case through a panel thumb nut will cure this. If not the chassis should be removed from its case, *D.C+* meter zero set with *SET V. ZERO* knob, panel grounded to a known good ground, and after shifting *FUNCTION* knob to a-c while leaving *SET V. ZERO* knob set to yield correct zero on *D.C.+*, the 10-megohm pot should be adjusted to establish correct a-c zero. If through adjustment of the pot for the one setting of *SET V. ZERO* knob establishing correct *D.C.+* meter zero, meter pointer on a-c cannot be brought *up* to zero, then a resistor of between 2 and 10 megohms connected from *COM. GND.* jack to the outer lug of the pot to which a circuit connection is soldered, will solve the problem. If meter pointer cannot be brought *down* to zero by adjustment of the pot (panel grounded during adjustment) then one of two remedies exist. The first, least desirable, is installation of a new 6AL5 tube in the r-f probe which will let a-c zero properly. The more economical method is to reverse the original r-f probe circuit wiring so that connections originally made to socket lug *2* are transferred over to lug *7*, and vice versa.

Should the r-f probe appear to be insensitive, it can be due to development of leakage in the .001-mfd mica and should be replaced. This condition can be checked by removing the r-f probe, connecting its shell to one side of a known 50- or 60-cycle a-c voltage, the other side to a .25-mfd capacitor and the free lead of the capacitor (temporarily replacing the .03-mfd tubular oil) to the spring contact found on the inside surface of the steatite r-f probe head. If the .001 is leaky, the meter will read significantly low, using its 120-volt a-c range to measure the power line.

It should be mentioned that a draftsman's error occurred in the first *Instruction Book* circuit diagram. The connection from the top contact of the *A.C.+D.C.-/ΩMA* switch labeled A.C., was inadvertently drawn to the top of the 20-megohm resistor. It should go, as in Fig. 1, to the point of the 20-megohm resistor and the .001-mfd mica, and has always done so in factory production.

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LESTER AND LEHMAN VISIT HALLICRAFTERS

Frank Lester, left, and Ben Lehman of Lafayette Radio, New York, during a recent visit to Hallicrafters, Chicago.