The Hickok Electrical Instrument Co.

CLEVELAND :: OHIO

BULLETIN NUMBER TWENTY-TWO

RADIO TUBE TESTER

MODEL B-47

DESCRIPTION AND PRICES

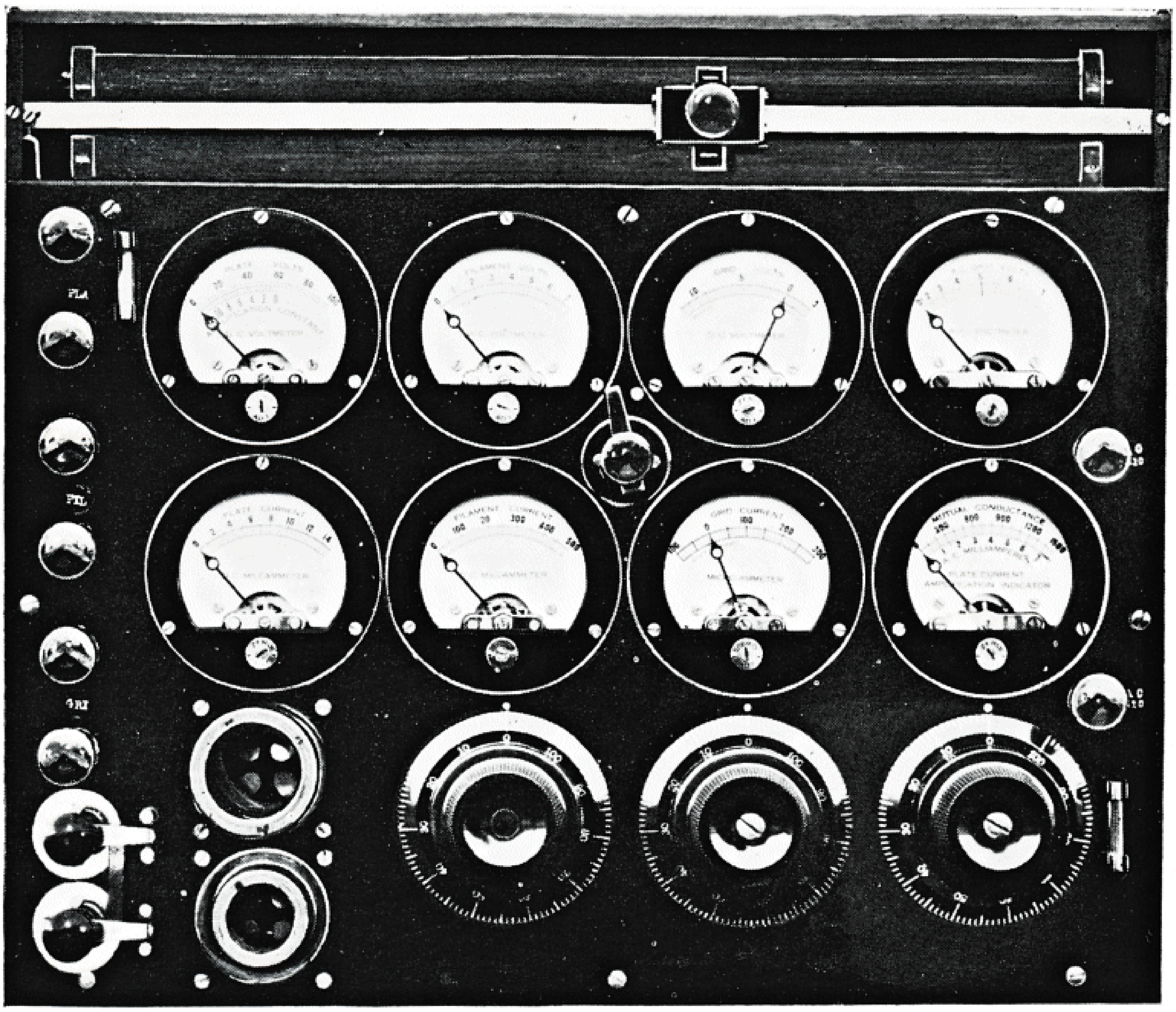

Fig. 1

MODEL B-47
Radio Tube Tester

Dimensions—

Length	16½″
Width	14 ″
Depth	4 ″
Weight	15 lb.

Finish—

Polished Bakelite.

Price—

Standard Model	$350.00
Laboratory Model	$400.00

Note: The Laboratory model is provided with plate voltmeter switch for connecting the grid and plate together. A double scale range and switch for the plate milliammeter for changing the scale range from 15 to 150 milliamperes full scale value. A special switch for changing the scale range of the filament ammeter from 500 milliamperes to 5 amperes full scale value.

The Hickok Radio Tube Tester

The term "Radio Tube Tester" has been applied indiscriminately to a considerable number of devices, many of them giving very limited performance. Some of these so called testers do no more than measure the plate current of the tube. The intelligent use and manufacture of radio tubes, however, requires the measurement and determination of so many of their constants and characteristics, that this can be done only with a very complete precision instrument.

The Hickok Model B-47 Radio Tube Tester is an instrument of this kind. It is a complete radio tube laboratory packed into a single portable case. It provides a D. C. Ammeter and Voltmeter, and also a potentiometer or rheostat in each one of the three circuits of the radio tube, namely the filament circuit, grid circuit, and plate circuit. With these instruments all the usual D. C. or static constants can be measured and characteristic curves plotted, and some of the constants can be read directly, without calculation. In addition the tester is provided with a transformer whose secondary is in series with the grid circuit, a suitable rheostat in the primary of the transformer whereby precisely 5 volts A. C. may be applied to the grid super-imposed upon any desired D. C. This causes an alternating current to flow in plate circuit super-imposed upon the direct current normally flowing. This A. C. component is indicated by an A. C. Milliammeter or current amplification indicator placed in the plate circuit. By this means the dynamic mutual conductance and other important characteristics may be measured directly on the A. C. or dynamic basis. When a three electrode tube is used in a radio set it receives and operates on signals which are alternating current. Tube measurements made with direct current, that is on the static basis are only indicative of how they will perform on alternating current or the dynamic basis. In the Hickok B-47 Tester tubes are tested in the same manner in which they function in a set which is on the A. C. or dynamic basis. Allowances, corrections and calculations are, therefore, unnecessary.

The manufacture of tubes is no longer in the "wildcat" stage. The knowledge of tube performance and tube requirements has become sufficiently general so that tubes can only be sold on measurable performance, and not on unbased claims. The manufacturer must know the quality of his output and the dealer must know the quality of the tubes he is buying. The ideal instrument for obtaining this knowledge is the Hickok Model B-47 Tester. It is so complete that it meets the demands of the radio engineer; yet it is so simple in operation that it can be used as a production tool by the manufacturer, and as a means of inspection by the dealer.

The following is a list of the more important tube characteristics that can be measured with the Model B-47 Tester:

Amplification Constant—Static, direct reading.
Plate Resistance—Static.
Mutual Conductance—Static.
Mutual Conductance—Dynamic, direct reading.
Alternating Current output—direct reading.
Degree of vacuum and ionization current—direct reading.

Total emission from filament.*
Filament voltage—filament current curve.
Filament voltage—plate current curve.
Plate voltage—plate current curve.
Grid potential—plate current curve.
Grid potential—grid current curve.
Numerous combinations of the above.
*This measurement can be made only on the Laboratory model.

Static and Dynamic Measurements of Tube Constants

In the methods heretofore commonly used for determining the various characteristics of a radio tube, such as plate impedance and mutual conductance direct current or static measurements have been made. But when a tube is used in a radio set its function is to receive a signal of alternating current on the grid, and to reproduce and amplify this signal as a similar alternating current of increased power in the plate circuit. But the performance of a tube on alternating current can be inferred only indirectly and with no great accuracy from its direct current or static measurements. In the Hickok B-47 Tester measurements can be made both with direct and with alternating current. The results obtained with alternating current can be read directly from a meter without calculation, and they represent exactly the conditions under which the tube operates in practice. The constants to which this applies particularly are the alternating current output and the mutual conductance. Both of these can be read directly from the instrument marked "Alternating Current Milliammeter." The method by which this is brought about will now be shown.

Referring to Fig. 3, the circuit diagram of the tester, it will be noted that connected in the grid circuit there is the secondary of a potential transformer which impresses 5 volts A. C. on the grid. This voltage is indicated on an A. C. voltmeter, and is regulated by a rheostat. Through the amplifier and relay action of the tube, this A. C. potential on the grid causes an alternating current to flow in the plate circuit. The plate circuit contains besides the D. C. milliammeter also an A. C. milliammeter. This is so constructed that it is unaffected by D. C. and indicates only the alternating current portion or component. When the A. C. grid voltage is adjusted to 5, the D. C. plate voltage to some standard value (usually 90) and the filament is operated at its rated voltage, then the A. C. milliammeter indicates the A. C. output of the tube for these standard conditions.

In the usual radio set giving good loud speaker reception the magnitude of the alternating current voltage received on the grid of the last audio-amplifying tube is on the order of 5 volts. Consequently the A. C. output as measured shows the amount of alternating or voice frequency current that the tube under test could actually deliver for operating a loud speaker. It is at once apparent that the A. C. output is a direct measure of the excellence of the tube, and particularly of its practical performance, and that different tubes may be directly compared by their A. C. outputs. While the measurement is made at 60 cycles it is independent of frequencies up to the order of 100,000 cycles at which point the capacity between the elements of the tube may become noticeable.

While the A. C. output is somewhat in the nature of an empyrical constant, it will now be shown that it is also a direct measurement of the dynamic mutual conductance, which is the most important single constant of a radio tube. Mutual conductance is a measure of the effect of grid voltage upon the plate current, and specifically it is the slope of the grid voltage-plate current curve. Writing this relation as a formula it becomes—

$$\text{Mutual Conductance} = \frac{\text{Change in Plate Current}}{\text{Change in Grid Volts}} \qquad (1)$$

Many are accustomed to considering mutual conductance as the ratio of amplification constant to plate resistance, or as a formula

$$\text{Mutual Conductance} = \frac{\text{Amplification Constant}}{\text{Resistance of Plate}} \qquad (2)$$

The equivalence of equations (1) and (2) can readily be shown as follows.

By definition—

$$\text{Amplification Constant} = \frac{\text{Change in Plate volts}}{\text{Change in Grid Volts}} \qquad (3)$$

Also by definition—

$$\text{Resistance of plate} = \frac{\text{Change in Plate Volts}}{\text{Change in Plate Current}} \qquad (4)$$

Substituting (3) and (4) in (2) we get

$$\text{Mutual Conductance} = \frac{\dfrac{\text{Change in Plate Volts}}{\text{Change in Grid Volts}}}{\dfrac{\text{Change in Plate Volts}}{\text{Change in Plate Current}}} \qquad (5)$$

Cancelling and completing the division we get

$$\text{Mutual Conductance} = \frac{\text{Change in Plate Current}}{\text{Change in Grid Volts}} \qquad (1)$$

This is the same as equation (1) which is what we sought to show.

Going back now to the measurement of A. C. output of a tube, let us assume that a tube gives an output of 4 A. C. milliamperes under the standard conditions given above (rated voltage on filament, 90 volts on the plate, 5 volts A. C. and 0 volts D. C. on grid). When five volts A. C. is connected to the grid there is a change of five volts (effective value) in the grid voltage. The application of this A. C. voltage to the grid causes a flow of 4 milliamperes A. C. in the plate circuit, while prior to the application of an A. C. voltage to the grid there was no alternating current in the plate circuit. Consequently the change in plate current is

.004 amperes (effective value). By formula (1) therefore, the mutual conductance is

$$\text{Mutual Conductance} = \frac{\text{Change in Plate Current}}{\text{Change in Grid Voltage}} = \frac{.004}{5} \qquad (6)$$

Amperes divided by volts gives the reciprocal of ohms or mhos, the mho being the unit of conductance. As tube conductances are very small they are usually given in micro-mhos so that we must multiply by 1,000,000 to obtain micro-mhos. In this case the mutual conductance therefore becomes

$$\frac{.004 \times 1{,}000{,}000}{5} = 800 \text{ micro-mhos.}$$

And in all cases with 5 volts A. C. on the grid

$$\text{Mutual Conductance} = \begin{cases} \dfrac{\text{A. C. Output (amperes)} \times 1{,}000{,}000}{5} & (7) \\[2ex] \dfrac{\text{A. C. Output (Milliamperes)} \times 1000}{5} & (8) \\[2ex] \text{A. C. Output (in Milliamperes)} \times 200 & (9) \end{cases}$$

Consequently the same meter which measures A. C. output also measures dynamic mutual conductance. When a fixed A. C. voltage of five is used on the grid, and when the A. C. output is indicated in milliamperes then the mutual conductance is 200 times the A. C. output in milliamperes and the A. C. milliammeter on the B-47 tester is calibrated in this manner.

The measurement of dynamic mutual conductance and A. C. output need not be confined to the standard conditions previously mentioned, these being given merely to afford a basis of comparison between tests. The indication of the A. C. milliammeter which also indicates directly the dynamic mutual conductance is correct for any D. C. grid, D. C. plate or filament voltage which the user may desire to employ. While the A. C. output and mutual conductance are being indicated, the filament voltage may be changed and the motion of the A. C. milliammeter needle gives a visual indication of the effect of filament voltage on performance. Likewise the plate voltage may be varied during the measurement by operating the plate voltage potentiometer. This shows visually the effect of plate voltage on performance and it is possible to determine directly the plate voltage necessary to produce a predetermined A. C. output. The D. C. grid potential may also be varied during a measurement, again showing visually the effect of grid bias for maximum output, and so indicating the best voltage of the "C" battery to be employed with the tube.

The dynamic mutual conductance of a tube is the best single indication of the performance and quality of the tube, because it measures the very thing that a tube must do in practice, namely transform A. C. grid voltage to the maximum amount of A. C. plate current. It may be called the tubes "batting average." The Hickok B-47 Tester measures this important quantity directly, indicating on the scale the dynamic micro-mhos together with the actual A. C. output of the tube in milliamperes. At the same time it also gives a visual demonstration of the effect of filament voltage, plate voltage, and grid voltage on performance and shows the proper voltage of "C" battery to employ.

The Difference Between Static and Dynamic Methods of Measuring Mutual Conductance

As has been previously stated, the mutual conductance is the slope of the plate current-grid voltage curve or what is the same thing the change in plate current divided by the change in grid voltage which produces it. In Fig. 2, curve A, is a characteristic plate current-grid voltage curve for a type 201-A tube. An inspection of this curve shows that it departs considerably from a straight line, and consequently the slope is different at different points along the curve. This means that the mutual conductance is different at different grid voltages. Thus when the grid voltage changes from minus 2 to plus 3, a net change of 5 volts, the plate current changes from 4.2 milliamperes to 9.2 milliamperes, a net change of 5 milliamperes or .005 amperes. The static mutual conductance in micro-mhos is therefore

$$\frac{.005}{5} \text{ x } 1000 = 1000 \text{ micro-mhos}$$

But when the grid voltage changes from minus 7 to minus 2, also a net change of 5 volts, the plate current changes from 1.2 milliamperes to 4.2 milliamperes, a net change of only 3 milliamperes or .003 amperes. Now the static mutual conductance in micro-mhos is

$$\frac{.003}{5} \text{ x } 1000\text{, or } 600 \text{ micro-mhos.}$$

It is therefore apparent that the mutual conductance is different at different grid voltages, and the question arises: "Which is the proper value of mutual conductance to use for ordinary applications of the tube to alternating current?"

We can answer this by considering the application of an alternating current to the grid. Suppose that we connect the grid to a D. C. voltage of minus 2 volts, to a 2 volts "C" battery for instance. And suppose that we now apply to the grid an A. C. voltage having a maximum value of 5 volts. Then on the positive half of the A. C. cycle the grid voltage will rise to plus 3 and the plate current will increase by 5 milliamperes from its starting value. On the negative half of the cycle the grid voltage will go to minus 7 and the plate current will decrease by 3 milliamperes from its starting value. If the plate circuit contains an ammeter which responds only to A. C., two pulsations of current will pass thru the meter, one reading a maximum of 5 milliamperes and the other reading a maximum of 3 milliamperes in the reverse direction. Under these conditions the meter will register the "effective" milliamperes, that is the D. C. milliamperes to which this A. C. current is equivalent. It is now apparent that if we take this value of current and divide it by the applied voltage then we will get the true value of mutual conductance applicable to this alternating current, that is the dynamic mutual conductance. A little consideration will show that this dynamic value will be less than 1000 micro-mhos, as calculated in the previous paragraph by the static method for the positive half cycle; but that it will be greater than 600 micro-mhos as calculated for the negative half cycle. While the D. C. or static method of measurement therefore, gives a different value of mutual conductance for each different value of grid potential, the A. C. or dynamic method of measurement gives a single value of mutual conductance which is the integrated or effective value of all the different D. C. values; and which is the true value to use for an alternating current of the voltage used in making the measurement.

It is apparent that if the plate current-grid potential curve were a straight line then the static values of mutual conductance would all be the same and would be equal to the dynamic value. It is also clear that as the A. C. voltage on the grid is made smaller and smaller, the value of mutual conductance obtained approaches more nearly the D. C. or static value at this same grid potential. Consequently the value of mutual conductance obtained on the A. C. or dynamic basis depends somewhat on the magnitude of the A. C. voltage applied to the grid. In the Hickok B-47 tester the effective A. C. grid voltage applied is 5.

When the dynamic mutual conductance is measured, as in the B-47 Tester, the ohmic resistance of the A. C. milliammeter, which is approximately 500 ohms, has the effect of slightly reducing the mutual conductance values, this effect, however, duplicates the condition under which the tube actually operates in an audio position in a receiving set, as the average resistance of the primary coils of the ordinary audio transformer is on the order of 500 ohms. Owing to the fact that a three electrode tube is always operated with either considerable ohmic resistance or inductance or both in the plate circuit the static values of mutual conductance are always higher than under actual operating conditions while the dynamic values as indicated by the B-47 Tester more nearly duplicate actual receiving conditions and are, therefore, a better indication of the excellence of the tube under test.

Zero Grid Volts

The term zero grid volts or grid potential is very confusing because it is given different meanings by various radio engineers and makers of tube testing equipment. Theoretically and practically it is not possible for the grid to be at zero potential with reference to the entire filament as there is always a difference of potential along the filament when D. C. is used for heating the filament. From what has gone before it is apparent that tube measurements depend on the potential or voltage between the grid and filament, and if the grid is spoken of as having zero potential or zero grid volts it is when it is the same potential as the filament. But the filament itself is not at constant potential when a direct current is flowing thru it, as occurs in practice. In a 201-A tube for instance, when the filament is operating at 5 volts there is a voltage or potential difference of 5 volts between the negative and positive terminals of the filament. Hence, if the grid is to be at the same potential as the filament we must state whether it is connected to the negative end, or the positive end or an intermediate point of the filament.

In the Hickok B-47 Tester the grid is connected to the negative end of the filament as may be seen in the circuit diagram, Fig. 4. Hence, zero grid voltage on the B-47 Tester means the same voltage as the negative end of the filament. But this does not limit measurements to this grid potential. By means of the grid potentiometer the grid can be given any voltage, positive or negative, which will be indicated on the grid voltmeter, and measurements can be made to comply with any definition of zero grid volts.

Note: Machines having serial numbers below 1000 have the grid return connected to the positive end of the filament, in these machines zero grid voltage is the voltage of the positive terminal of the filament.

General Directions

The tester must be used only in a horizontal position.

The binding posts on the right marked A. C. must be connected to a source of alternating current of approximately 110 volts. The wave shape furnished by any good commercial machine, at any commercial frequency (25 to 125 cycles) is satisfactory. The usual 110 volt, 60 cycle lighting supply is recommended.

The binding posts marked "FIL" should be connected to a steady source of direct current, preferably a 6 volt storage battery. This will serve for most tests on 201-A tubes. A 4 volt tap should also be brought out for use with type 199 tubes. A double throw switch for changing from 6 volts to 4 volts is very convenient for rapid testing of both kinds of tubes. The "A" battery binding posts and also the "B" and "C" posts are plainly marked as to polarity.

The posts marked "Plate" should be connected to a steady source of direct current of suitable voltage for the plate circuit. The commercial dry "B" battery is suitable for many purposes, but for routine testing of many tubes a storage "B" battery is best. The plate circuit potentiometer enables the operator to obtain any plate potential within the range of the "B" battery voltage. But the best results will be obtained if the "B" battery voltage is so chosen that it is just a little above the testing voltage. When this is the case the instrument will operate with the potentiometer slide at the extreme right, that is, with the potentiometer resistance almost completely out of the circuit. Under this condition variations in plate current will not greatly affect the plate voltage, and consequently less manipulation will be required. Most of the tube measurements can be made with plate potentials of 60 or 90 volts. Consequently the "B" battery should have two taps, one about 66 volts and one about 96 volts.

The terminals marked "Gri." should be connected to a steady source of direct current to serve as a "C" battery. The circuit fed by this battery contains a potentiometer of comparatively low resistance for varying the grid potential. Consequently this battery should leave a considerable current capacity. A large size dry "B" battery of not over 22½ volts will serve for many purposes, but a storage "B" battery of about 16 volts is most satisfactory for routine testing. The circuit contains a reversing switch for reversing the polarity.

Directions for Making Measurements

Amplification Constant

If the grid voltage of a tube is changed there will be a resulting change in the plate current. This change in the plate current may be overcome by a corresponding decrease or increase in the plate voltage. The ratio of the change in plate voltage to the change in grid voltage is the amplification constant. Stated as a formula this is

Formula:

$$\text{Amplification Constant} = \frac{\text{Change in Plate Voltage}}{\text{Change in Grid Voltage}} \quad (3)$$

The amplification constant depends only on the construction of the tube, and is practically independent of the way it is measured. To read it directly proceed as follows:

1. Operate the filament at rated voltage.
2. Set the D.C. grid voltage at minus 5.
3. Set the plate voltage at 90.
4. Read the plate current.
5. Set the D.C. grid voltage at 0.
6. Slide the plate potentiometer to the left until the plate current comes back to the value observed at operation 4.
7. Read off the amplification constant on the lower scale of the plate voltmeter.

This method gives the amplification constant over a change of 5 volts on the grid measured from zero grid volts (negative terminal of the filament) to 5 volts negative.

Measurement of Plate Resistance

Formula:

$$\text{Resistance of the plate} = \frac{\text{Change in plate volts}}{\text{Change in plate current}} \qquad (4)$$

The resistance of the plate circuit may be determined by formula (4) for any condition of plate or grid voltage but for determining the static mutual conductance using instructions given under formula (2) proceed as follows:

1. Operate the filament at rated voltage.
2. Set the D.C. Grid voltage at zero.
3. Set the Plate voltage at 90.
4. Read the plate current.
5. Set the D.C. grid voltage at negative 5 volts (maintaining the plate voltage at 90).
6. Read the plate current.
7. Subtract the plate current value observed in operation 4 and 6 which will give the change in plate current.
8. Restore the grid voltage to zero and reduce the plate voltage by means of the plate potentiometer until the plate current falls to the same value as observed in operation 6.
9. Read the plate voltage now observed and subtract it from the original value of 90 which will give the change in plate volts.
10. Divide the change in plate volts as found in operation 9 by the change in plate current as found in operation 7, which will give the resistance of the plate.

Measurement of Static Mutual Conductance

$$\text{Formula: Mutual Conductance} = \frac{\text{Change in Plate Current}}{\text{Change in Grid Volts}} \qquad (1)$$

The static mutual conductance may be found from formula 1 or 2, the results will be the same if either formula is employed. As formula (1) is the simplest to compute its use is advised. The procedure for determining the Static Mutual Conductance by formula (1) is as follows:

1. Operate the filament at rated voltage.
2. Set the plate voltage at 90.
3. Set the D.C. grid voltage at zero.
4. Read the plate current at the above settings.
5. Set the D.C. grid voltage at negative 5 (maintaining the plate voltage at 90).
6. Read the plate current at setting 5 and subtract from reading observed in operation 4, which will give the change in plate current.

7. Divide this change in plate current by the change in grid volts, which is 5, and multiply by 1,000,000, which will give the static mutual conductance in micro-mhos.

The above operations will give the static mutual conductance at a plate voltage of 90 and between grid voltage of zero and negative 5. The static mutual conductance may be found at any other plate voltage desired by substituting any other value desired for 90. The static mutual conductance may also be found at any other portion of the grid voltage-plate current curve such as from zero to 5 volts positive or from 5 negative to 10 negative by substituting the grid values desired.

$$\text{Formula: Mutual Conductance} = \frac{\text{Amplification Constant}}{\text{Resistance of Plate}} \qquad (2)$$

The static mutual conductance by employing formula (2) may be found as follows:

1. Find the amplification constant as given under instructions for finding this constant.
2. Calculate the resistance of the plate as given under the instructions for finding this value.
3. Divide the amplification constant by the resistance of the plate and multiply by 1,000,000 which will give the static mutual conductance of the tube in micro-mhos.

Mutual Conductance, Dynamic—

$$\text{Formula: } \begin{array}{l}\text{Dynamic}\\ \text{Mutual Conductance}\end{array} = \frac{\text{Change in A.C. Plate Current}}{\text{Change in A.C. Grid Volts}} \qquad (10)$$

In the above formula for dynamic mutual conductance it will be noted that this is the same as formula (1) for finding the static mutual conductance with the exception that A.C. units are employed. Referring to page 5 it will be seen that the B-47 instrument measures and indicates directly the three quantities of formula (10) which are the A.C. grid volts, the A.C. plate current and the dynamic or A.C. mutual conductance. The A.C. grid volts are always a fixed quantity of 5 but the D.C. grid volts may be set to any desired value, also the D.C. plate volts. For standardization and comparative results it is recommended that the following settings be used:

1. Operate the filament at rated voltage.
2. Set the D.C. Grid Voltmeter at zero.
3. Set the A.C. Grid Voltmeter at 5.
4. Set the Plate Voltmeter at 90.
5. The dynamic mutual conductance will now be indicated directly on the plate current amplification indicator.

In the following tables are given the average dynamic mutual conductance values for several of the most commonly used radio tubes:

Tube Type	Plate Volts	Fil. Volts	D.C. Grid Volts	Minimum Dynamic Mutual Conductance

Alternating Current Output

The alternating current output of a three electrode tube is the A.C. current present in the plate circuit caused by the application of A.C. volts to the grid. In the B-47 instrument this output can be read directly on the A.C. Milliammeter and as explained on page 5, the A.C. output in milliamperes is always 1/200 of the dynamic mutual conductance in micro-mhos.

Degree of Vacuum-Ionization Current

It has been established by tests that when a tube is operated with a negative voltage on the grid and the usual D.C. voltage on the plate that if the tube is soft an ionization or inversed current will flow in the grid circuit and will be indicated by a deflection of the Grid Micro-ammeter toward the left. To determine the existence of the ionization proceed as follows:

1. Set the grid voltmeter switch on the right-hand button (this switch should be on the left button for all other tests).
2. Set the A.C. grid voltmeter at zero.
3. Operate the filament at rated voltage.
4. Set the plate voltmeter at 90 volts (not critical).
5. Set the D.C. grid voltmeter at negative 2 volts (not critical).
6. The degree of ionization, if any, can now be read directly on the grid micro-ammeter. If ionization is present the meter will indicate to the left, if ionization is not present the meter will indicate zero. The amount of deflection permissible of the micro-ammeter for hard tubes such as the 201-A or 199 type is ¼ to ½ division or 2.5 to 5 micro-amperes for the above grid and plate voltage settings. A soft or detector tube such as the UV 200 will indicate 50 to 100 micro-amperes inverse or ionization current.

Total Emission from the Filament

This can only be read on the Laboratory model. The maximum emission of the filament for any desired plate voltage will be obtained when the grid of the tube is operated at the same positive voltage as the plate. In the Laboratory model a special switch is provided which disconnects the grid from the grid potentiometer and connects it directly to the plate. A double scale is also provided for the plate milliammeter to take care of the high plate current, this high scale has a full scale value of 150 milliamperes. To find the total emission of the filament for a standard voltage proceed as follows:

1. Operate the filament at rated voltage.
2. Set the plate voltmeter switch on the right-hand button (this should be set on the left button for all other tests).
3. Set the plate milliammeter switch on the right-hand button which will change the plate milliammeter to the high scale (this also automatically removes the A.C. milliammeter from the plate circuit).
4. Set the plate voltmeter at 60 volts.
5. The total emission of the filament will now be indicated directly on the high scale of the plate milliammeter.

Other voltages than 60 may be applied to the plate if desired. The tube should not be left on the test over 30 seconds or it will be injured owing to the high plate current. This test is valuable in determining the activity of the filament emission and the probable life of the tube under normal conditions. Values for this test very greatly for different types of tubes and filaments and are also affected by geometrical dimensions of plate and grid. Additional information regarding this test will be furnished upon request.

Filament Voltage—Filament Current Curve

The current consumed by the filament at varying filament voltages can be plotted as a curve after making this test. The changing resistance of the filament at different temperatures can also be calculated by the following formula:

$$\text{Resistance of the filament} = \frac{\text{Filament volts}}{\text{Filament current}} \qquad (11)$$

To find the filament current at several voltages proceed as follows:

1. Set the plate and grid voltmeters at zero.
2. Set the filament voltmeter at 1 volt.
3. Read the filament current at the above settings.
4. Increase the filament volts by steps of 1 volt and read the filament current at each of the settings. In the case of a 201-A tube readings should be made from 1 to 7 volts. For 199 from 1 to 5 volts. From the filament current values obtained by operations 3 and 4 a curve may be plotted on suitable cross section paper, also the resistance values of the filament can be calculated from formula (11) and also plotted.

Filament Voltage—Plate Current Curve

This curve is of value in finding the minimum voltage values at which the filament can be operated and give the necessary emission and also mutual conductance values. To plot this curve proceed as follows:

1. Set the plate voltmeter at 90 volts. (Other values of plate volts may be used if desired.)
2. Set the D.C. grid voltmeter at zero. (Other values of grid voltage may be used if desired, such as —4.5, which duplicates conditions when a 4.5 volt "C" battery is used.)
3. Set the filament voltmeter at 1 volt and read the plate current at this setting.
4. Increase the filament voltage by steps of 1 volt and read the plate current at each setting. In the case of a 201-A tube readings should be made from 1 to 7 volts. In the case of 199 tubes from 1 to 5 volts.

From the plate current values obtained by operations 3 and 4 the filament voltage-plate current curve can be plotted on suitable cross section paper.

Plate Voltage—Plate Current Curve

This curve gives the different values of plate current obtained by changing the volts applied to the plate when the filament and grid volts constant are held at a constant value. To plot this curve proceed as follows:

1. Operate the filament at rated voltage.
2. Set the D.C. grid voltmeter at zero (other grid voltages may be used if desired, such as —4.5 or any other value at which the tube may be used under actual operating conditions).
3. Set the plate voltmeter at 10 volts and read the plate current.
4. Increase the plate volts by steps of 10 volts and read the plate current at each setting.

From the values obtained by operations 3 and 4 the curve may be plotted on cross section paper.

Grid Potential—Plate Current Curve

This curve may be considered as the most important of all the curves indicating the actual characteristics of three electrode tube as it shows the effect of grid potential upon plate current. From this curve the static mutual conductance can be calculated by formula (1) and the performance of the tube in amplifying the received signal can be determined with a fair degree of accuracy. The static mutual conductance is inferior to the dynamic values of same, but of all the static characteristics this curve is most valuable. To plot this curve proceed as follows:

1. Operate the filament at rated voltage.
2. Set the plate voltage at 90 (other values may be used if desired, such as 40-60-80 or 120).
3. Set the D.C. grid voltage by means of the grid potentiometer at the greatest negative voltage at which there will be a readable quantity of plate current and read the plate current at this point.
4. Change the D.C. grid voltage by steps of 1 volt toward zero and read the plate current at each setting. Continue this operation until positive 5 volts are reached. Lay off the plate current reading on suitable cross section paper which will give the grid voltage-plate current curve as illustrated by Fig. 2.

Grid Potential—Grid Current Curve

This curve is valuable in determining the amount of negative grid potential required to prevent the flow of grid current in operation. It also shows the inverse or ionization grid current present, if any, and indicates whether the tube is hard or soft. To plot this curve proceed as follows:

1. Operate the filament at rated voltage.
2. Set the plate voltmeter at 90.
3. Set the grid micro-ammeter switch on the right-hand button.
4. Set the D.C. grid voltmeter at positive 5 volts or the extreme right-hand division of the scale. (The A.C. grid voltmeter must always be set at zero for this and all other static tests.)
5. Read the grid micro-ammeter at setting 4. Change the grid voltage by means of the grid potentiometer by steps of one volt toward negative (toward the left) and read the grid current of each setting. Continue until the grid current falls to zero. In the event that the grid micro-ammeter reverses at zero and indicates to the left of zero the tube is soft, if not, the tube is hard. After reading all the points of operations 4 and 5, plot them as a curve as shown in curve "B," Fig. 2.

Production Tests:

Where a large number of tubes are to be tested by manufacturers in routine testing a test which will give the minimum dynamic mutual conductance and the minimum plate current for standard conditions are recommended. A test to determine if the tube is sufficiently hard is also recommended. These two tests give sufficient indication of the condition of the tube to be used as standard tests. It is recommended, therefore, that the settings as given on Page 11 for dynamic mutual conductance be made as the first test and minimum values established for same.

For the second test showing the degree of vacuum follow instructions as given on Page 12 under the heading of "Degree of Vacuum—Ionization Current."

It is also recommended that the tubes under test be first put through the dynamic mutual conductance test. After they have all passed through this test change the machine to read the degree of vacuum-ionization test as a second operation.

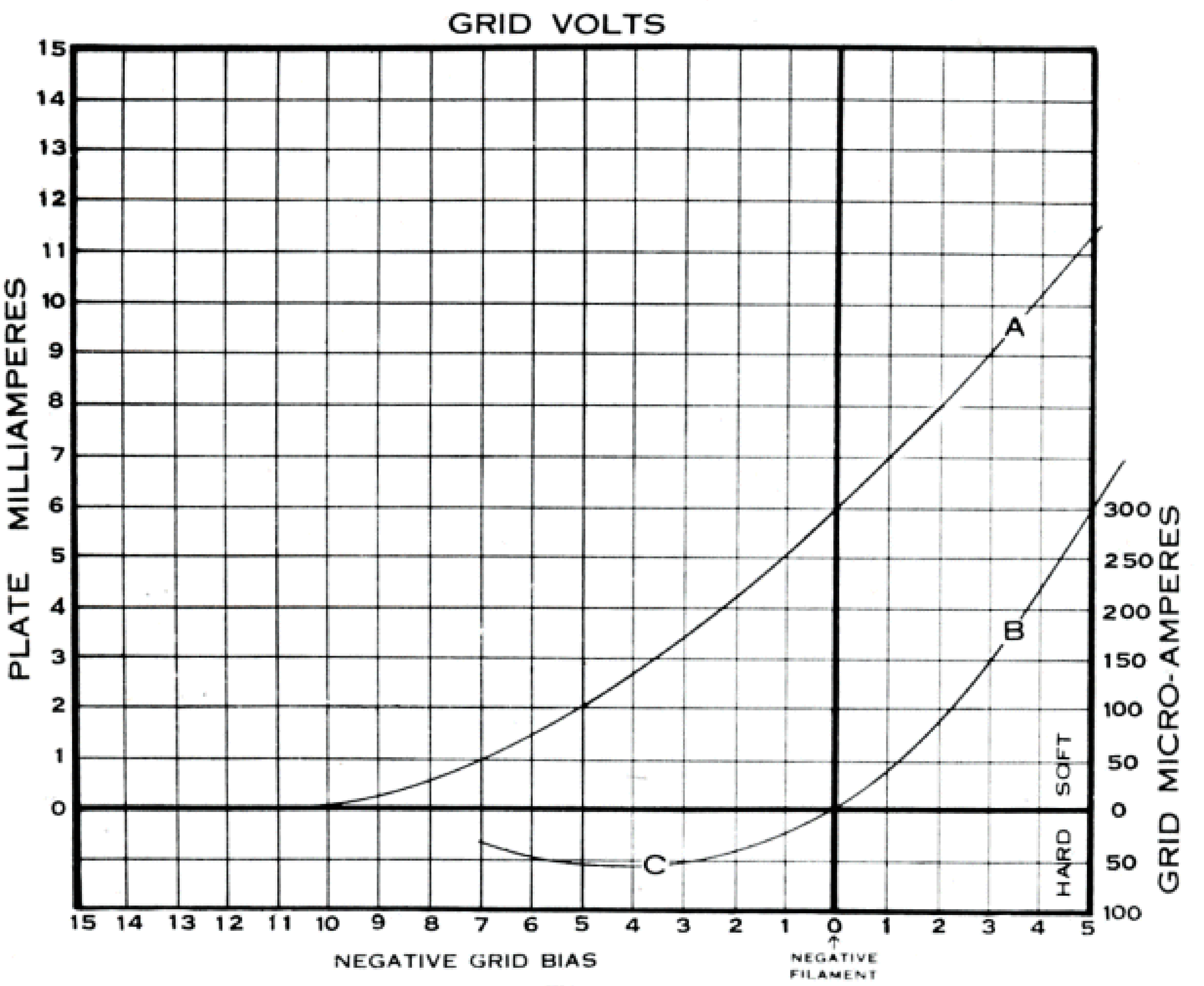

Fig. 2

"A" Characteristic Plate Current Curve of 201-A tube at 90 volts.
"B" Characteristic Grid Current Curve of 201-A tube.
"C" Negative Grid Current in soft tube. The "C" portion will not be found in hard tubes.

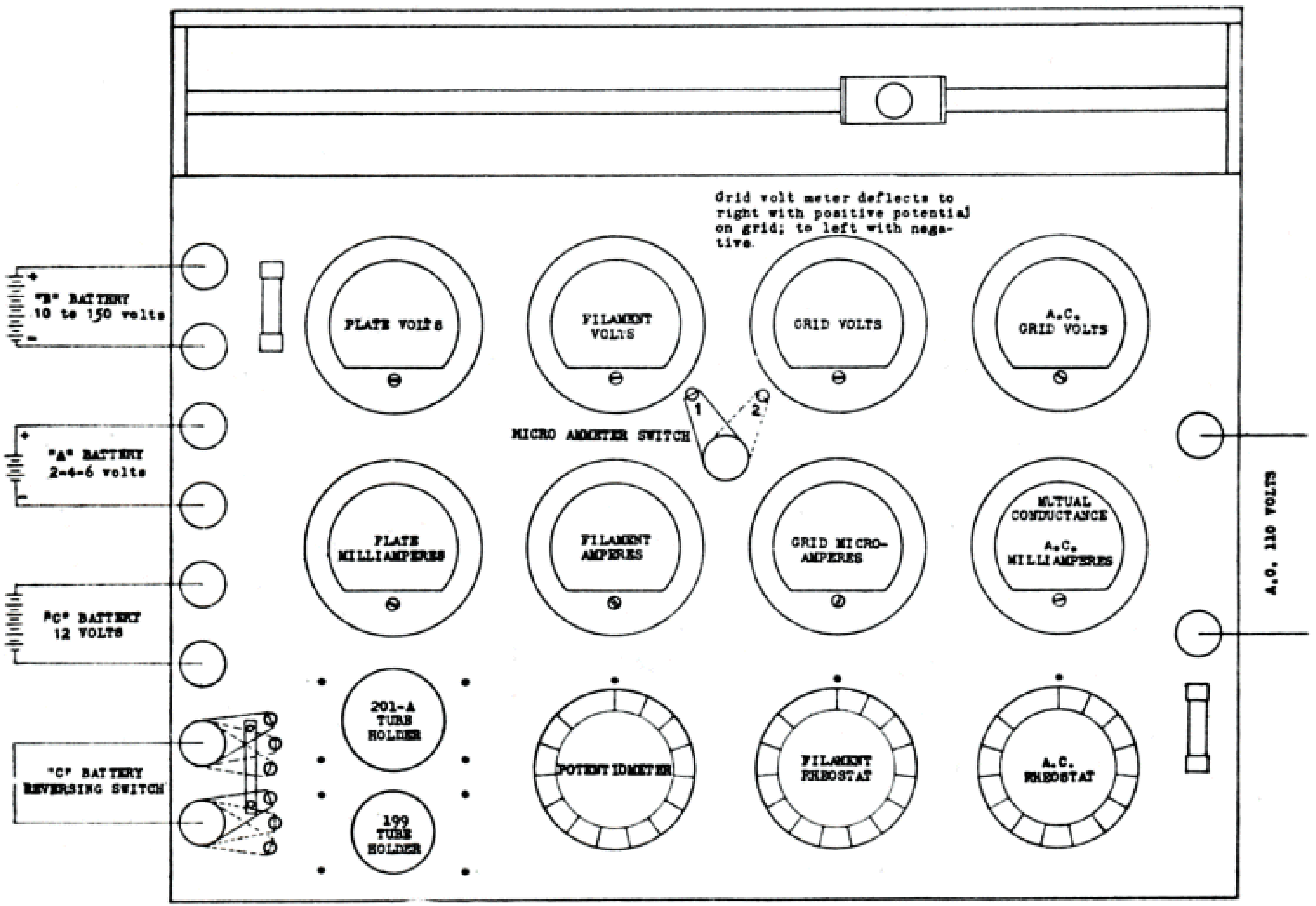
Grid volt meter deflects to right with positive potential on grid; to left with negative.

Fig. 3—Diagram of external connections.

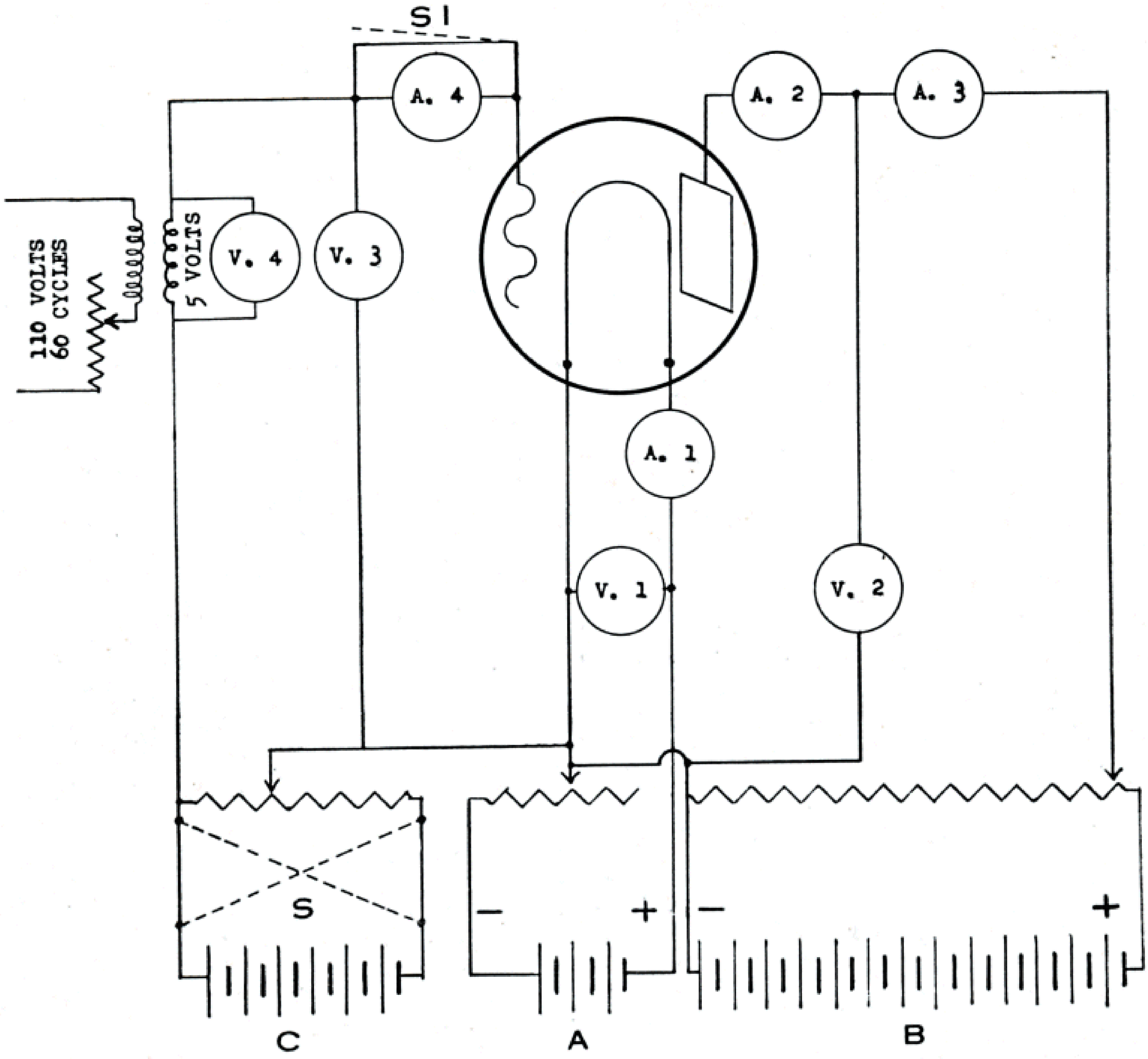

Fig. 4

Diagram of Internal Connections

V. 1 Filament Voltmeter.
V. 2 Plate Voltmeter.
V. 3 D.C. Grid Voltmeter.
V. 4 A.C. Grid Voltmeter
A. 1 Filament Milliammeter.
A. 2 Plate Milliammeter.
A. 3 A.C. Milliammeter.
A. 4 Grid Micro-Ammeter.
S. "C" Battery Reversing Switch.
S. 1 Micro-Ammeter Switch.