Treatise on Testing Units for Service Men

By

John F. Rider

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for
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IN THE BELIEF THAT THIS BOOKLET WILL BE OF CONSIDERABLE HELP TO THE RADIO SERVICE MAN IN LAYING OUT HIS TEST EQUIPMENT, WE HAVE PURCHASED A NUMBER OF COPIES FOR DISTRIBUTION AMONG OUR SPECIAL FRIENDS.

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TABLE OF CONTENTS

Section 1.

Section 2.

Section 3.

Section 4.

Section 5.

Introduction

The individual who can most effectively and most economically service a faulty radio receiver installation, will fare best in the long run. Economy and rapidity of operation are the two paramount factors in every service business, be it radio or automobiles.

A radio service installation must include certain equipment other than testing units designed solely for direct application to radio receivers. Many of the parts of, or associated with, radio receivers require testing and observation. Knowledge thus gained, is of invaluable aid in the complete routine of radio servicing.

By the same token, the radio service man must have a broad vision. He must be able to adapt one unit to function in many places. Practically every radio service unit possesses the property of versatility. Another lead, another meter, or perhaps another switch and the utility of the testing unit has been greatly increased. The service man must thoroughly understand his testing equipment. He must be fully aware of the function of each unit, each meter. He must know what he should expect, what the meter should indicate. This knowledge more than any other, will expedite radio servicing.

The prime property of a servicing unit, should be rapidity of operation consistent with results. As such, the equipment mentioned in this treatise has been designed to produce information and results with minimum effort on the part of the operator.

Dimensional constructional details have been omitted, since the constructor alone knows his limitations. The equipment described herein can be built in any form; on a baseboard, panel or in a cabinet. Whatever the form of construction, it should be such that it permits rapidity of operation,since the time factor over a period of a year is manifest in dollars.

Section 1. Tube Testing Units

Tube Reactivator

A tube reactivator constructed by the writer is shown in figure 1. As a reactivator, this unit is suitable only for rejuvenating thoriated tungsten filaments. Oxide coated filaments cannot be reactivated. Once the oxide is burned off, the tube is useless. The unit shown is suitable for the reactivation of 199, 120, 200A, 201A, 171, 210, 213 and 216B type tube filaments.

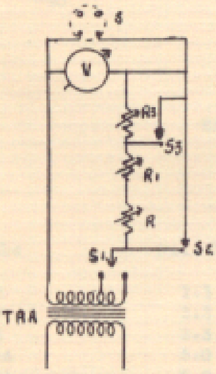

Fig. 1

S is a standard four prong socket. TRA is a toy transformer such as is used for the operation of toy electric trains. The unit selected should provide output voltages from 3 to 18 volts in steps of at least 2 volts. The frequency and input voltage rating of the transformer, is governed by the available line supply. Switch S1 is a part of the transformer. The voltmeter B is a Weston #476, 0 to 25 volts AC. The resistance values are as shown in the illustration and are employed to reduce the transformer output voltage to the "flash" or "cooking" voltage.

The process of reactivation consists of the application of a "flash" voltage, followed by a "cooking" voltage, these values being indicated on the voltmeter V. The resistances employed to reduce the transformer output voltage to the correct tube terminal voltage, are variable (rheostats) and are utilized for the original adjustments after which the proper filament voltage is obtained by setting S1 to the 18 volt tap and operating the push button for the flash voltage and the contact switches for the "cooking" voltage. The effect of the voltmeter resistance upon the transformer output is balanced by means of the associated control resistances which are adjusted to provide the correct filament voltage as indicated upon the voltmeter. This voltmeter is always in the circuit. To "flash" at 18 volts, S1 is set at the 18 volt tap and S2 which is a push button, is closed for an instant or the period of flashing. To "flash" at 12 volts, S1 is set to the 12 volt tap and S2 again closed for the period of flashing. To "cook", S1 is placed on the 18 volt tap and S3, the contact switch is closed when the cooking voltage is more than 4 volts. R1 controls the cooking voltage values above 4 volts. If set at 7 volts, the value of R2 can be made such as to afford a filmament voltage of 4 volts when S3 is open and R2 is in the circuit. During cooking S2 remains open. With S3 closed, R1 provides cooking voltages between 6 and 9 volts. The adjustment of R governs the "flash" voltage.

Reactivating Voltages

Tubes	Flash Voltage	Cooking Voltage
-99	12 for 1 sec.	4 for 15 min.
-20	12 for 1 sec.	4 for 15 min.
-01A	16 for 1 sec.	7 for 15 min.
-00A	16 for 1 sec.	7 for 15 min.
-71	16 for 1 sec.	7 for 15 min.
-10	no flash	9 for 15 min.
-13	no flash	6 for 15 min.
-16B	no flash	9 for 15 min.
-40	16 for 1 sec.	7 for 15 min.

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Electronic Emission Table

Tube	Fil. Voltage	Plate Voltage	Minimum Emission
12	1.1	50	6.0 milamperes
-99	3.3	50	5.5 milamperes
-20	3.3	50	13.0 milamperes
-01A	5.0	50	20.0 milamperes
-00A	5.0	50	14.0 milamperes
-40	5.0	50	14.0 milamperes
-12	5.0	50	45.0 milamperes
-12A	------------------No Emission tests		
-71	5.0	50	40.0 milamperes
-10	6.0	100	85.0 milamperes
-50	6.0	250	505.0 milamperes
-26	1.5	50	35.0 milamperes
-27	2.5	50	35.0 milamperes
-13	4.0	100	40.0 milamperes each
-16B	6.0	125	85.0 milamperes
-80	5.0	80	100.0 milamperes
-81	7.5	150	200.0 milamperes

A Calibrated Vacuum Tube Bridge

The occasion often arises when it is necessary to ascertain some of the major electrical constants of a vacuum tube, for example, electronic emission, "mu" or amplification factor, plate impedance and mutual conductance. To plot curves which will afford this information, is quite a tedious process and involves extensive calculation. Herewith is shown a testing unit suitable for the determination of these values, without recourse to curves or extensive calculations.

With respect to the testing of AC and DC tubes, the same system is applicable to both since only the type of filament potential differs. The fact that AC tubes such as the 226, the 227, the Kellog and the Arcturus utilize AC filament voltages when the tube is applied to a receiver, does not necessarily signify that the electrical constants of the tube must be ascertained with AC filament potential, unless the output ripple is being determined. If such constants as plate current with various plate voltages, amplification factor, plate impedance and mutual conductance, are to be determined, the filament can be operated with DC potentials. Referring to figure 2, this method is applicable for the testing of the conventional type of vacuum tubes.

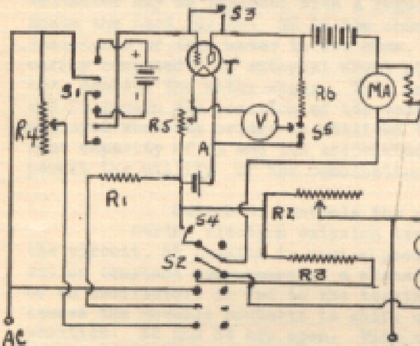


Fig. 2

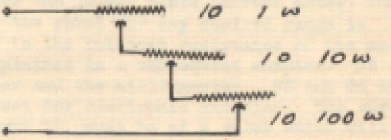


Fig. 2B

Cathode
Connects to
"B" minus

Fig. 2A

This arrangement permits the determination of the electronic emission and the dynamic values of amplification constant or mu, plate impedance and mutual conductance, the latter being obtained by a very simple calculation. This bridge is one of the best available for this work and if instructions are followed, results will be equal to that obtained by the writer. The multiplicity of switches should not confuse the reader. They appear difficult but once the unit has been completed, operation is very simple. Figure 2A shows the change necessary when the cathode type of tube is employed. We refer to the 5 prong tube. The 4 prong cathode tube operated at a filament potential of 15 volts, can be placed into the regular socket. T is the vacuum tube under test. A is the filament battery. This type of filament potential source is satisfactory for the testing of AC and DC tubes. In the case of the 5 prong cathode tube (AC) grid return and plate return leads are connected to the cathode, since the filament is merely a heater and the cathode is the source of electrons. The filament is not a portion of either the grid or plate circuits. PH is a headset. The potential of battery B is governed by the value at which the test is to be made. S1 and S2 are 12 pole anti-capacity cam switches. The switches employed by the writer were of Federal manufacture. Voltmeter V is a Weston 301 0 to 8 volts DC voltmeter. MA is a Weston 301 0 to 10 DC milliammeter. R1 is a 10 ohm fixed resistance (Electrad Truvolt type B). R2 is a variable calibrated 1000 ohm resistance consisting of 10 1 ohm resistances, 10 10 ohm resistances and 9 100 ohm resistances arranged as shown in figure 2B. These resistances are likewise Electrad Truvolt type B. These resistances were employed because accurate adjustment of each resistor is possible by sliding one of the end contacts. The inductance of these resistances is sufficiently low to permit their use at 1000 cycles, the frequency applied to the bridge. The method of determining resistance will be discussed later.

Resistor R3 is a fixed 1000 ohm resistance. R4 is a duplicate of R2. The rheostat R5 is 12 ohms, capable of carrying 2 amperes. In order to control the -99 type of tube requiring 3.3 volts at the filament terminals, the source of filament voltage is reduced to 4 volts. R6 is the multiplier resistance for voltmeter V and is of 14,880 ohms, and increases the range of the voltmeter to 248 volts, multiplying each division 31 times. If desired, this voltmeter may be replaced with a regular double scale instrument which will eliminate the need for R6. R7 is the shunt for the 10 mil plate current meter. The resistance of this meter is 8.5 ohms, and the shunt for any desired range is easily computed. An external shunt equal to the internal resistance of the meter, doubles the meter scale. This is explained in a subsequent chapter. S5 and S6 govern the position of the voltmeter and the milliammeter. S3 and S4 are employed when the bridge is utilized to test for electronic emission. The current capacity of MA and its associated shunt R7, must be of a value which will permit the utility of the combination when testing for electronic emission.

Switch S1 controls the position of the grid bias battery.

During electron emission tests, the C battery and headset are out of the circuit, S2 remains in neutral position, S3 and S4 are closed. For amplification constant measurements, a signal preferably of 1000 cycles from some sort of an oscillator, is fed to the terminals AC and AC 1. S2 key is down which causes the movable contacts to shift upwards. S1 key is likewise in the down position. S3 and S4 are open. With this arrangement R1 and R2 are in the circuit and R2 is varied until the sound in the phones is minimum. The mu of the tube being tested, is now equal to R2/R1, that is, the setting of R2 for minimum sound. Plate impedance is measured by resetting S2 into the "up" position. R2 remains as before. R4 is now varied until the sound in the headset is minimum. The plate impedance is equal to the setting of R4 x 100.

With S1 down, S2 down, S3 open and S4 open, amplification constant is

"mu" = R2/R1. (With S2 up plate impedance is) Rp = R4 x 100

Mutual conductance Gm = mu/Rp

A General Utility Tube Tester

The wiring diagram illustrated in figure 3 is that of a general utility tube tester suitable for all operating tests of all types of tubes including the shield grid and rectifying tubes other than the gaseious rectifier. The design of the illustration is such that the tube test may be made with a local source of filament, plate and grid potential, AC or DC or by means of a plug insert operated in conjunction with a receiver. Under these conditions, the various indicating instruments may be employed to measure receiver voltages. As is evident in the wiring diagram, a B voltage controlled resistance is provided to be used in conjunction with an external B supply, thus making the system portable. The filament supply for portable use is not shown and if desired, may be a filament transformer with the proper taps. For operation with a receiver, the leads from the plug insert are connected to the five bindings posts, G,F,C,F and P. The indicating instruments illustrated, are of Weston manufacture, Ma being a type 301 DC 0 to 20 milliammeter. The AC voltmeter is a model 476 three scale instrument. The DC voltmeter is in reality a 0 to 2 301 DC milliammeter operated in conjunction with series resistances.

The four prong socket is satisfactory for all 4 prong tubes including filament rectifiers. The 5 prong tube socket is utilized for the 5 prong cathode type AC tube. The switch S7 adjusts the system for use with separate filament and plate supply or a plug insert for receiver power supply. Position D is utilized for the former condition and position U for the latter. Assuming separate filament and plate supply, electronic emission is determined by setting S4 to A, S3 open and S9 closed and S5 closed if the plate current is in excess of 20 milliamperes. The position of S4 governs the measurement of electronic emission for filament type full wave rectifiers. With S3 open and S9 closed, alternating the position of S4 between points A and B, connects the plate voltage to either one of the anodes within the tube. The position of S6 governs the connection of the DC voltmeter, position 1 indicating DC filament potential and position 3 plate potential at the element. When testing for electronic emission, S1 and S2 remain open. If AC filament voltage is applied, S8 is set to either A or B to indicate applied AC filament potential.

For all plate current tests S9 is open and S4 set to position A. This arrangement is utilized for all tubes other than the shield grid. S1 remains open and S2 controls the polarity of the C bias applied during the test. This switch is manipulated for the grid swing test. When testing shield grid tubes, S3 is set to position B, the clip connected and the B plus 45 potential is applied. The "D" position of S7 connects the grid return to the B minus. For all external tube tests of 5 prong cathode type tubes, the cathode is connected to B minus.

When testing with a plug insert, in order to utilize a receiver power supply, S7 is set to the "U" position and the B voltage control resistance R is short circuited by manipulating the movable lever. S2 is opened and S1 closed. S3 is set to position A and S4 is likewise set to position A. S9 remains open. When a 5 prong insert is utilized to test 5 prong cathode type tubes, the cathode is disconnected, from the tester B minus by pressing button S10. With S1 open, S2 may be manipulated to show the effect of additional grid bias.

Switch S5 controls the position of R1, the shunt resistance which increases the range of MA to 200 milliamperes. The internal resistance of this meter is 1.5 ohms and the ohmic value of the shunt R1, is .111 ohm. As we mentioned voltmeter V is a milliammeter operated with series resistances. R2 is a resistance (Truvolt) of 250,000 ohms, consisting of two 100,000 ohm resistances and one 25,000 ohm resistance. The meter and this resistance constitute a potential measuring arrangement (DC) with a maximum of 500 volts. Each tenth of 1 milliampere is equal to 25.0 volts. R3 is a Truvolt 5000 ohm resistance type B and when operated in conjunction with the meter permits maximum operating range of 10 volts DC. Resistance R4 is the same. The 3 binding posts are associated with the DC voltmeter and points 2 and 3 of S6. These binding posts permit external use of the voltmeter, Similar binding posts are provided for the milliammeter MA and the AC voltmeter. The resistance R is a 10,000 ohm Truvolt type T100. The condenser C is 1 mfd.

This unit is illustrated in greater detail in the last chapter devoted to a service station test bench. If desired, this unit may be employed to test the amplifying properties of various types of tubes. External filament and plate supply are used. Switch S7 remains open. S1 is open and S2 is arranged for a negative bias. The AC input is connected across terminals G and minus F if it is a 4 prong tube, and across G and C if it is a 5 prong tube. A separate lead is connected between the minus B terminal and minus F or C, depending upon the type of tube under observation. S4 is opened and an output system similar to that shown in figure 13 is connected across points A and X, associated with S4 and the output indication noted for various values of input.

Switch points 2 and 3 of S6 make available voltmeter V for external measurements of voltages between 0 and 10 and 0 and 500. The value of the grid bias is governed by the conditions of test. A potential of 1.5 volts is sufficient for the grid swing test. If desired, this system may be utilized as a qualitative vacuum tube voltmeter when measuring large values of AC voltage, by arranging the system for normal plate current measurement, removing the output indicating system, applying sufficient C bias to reduce the plate current to approximately 0 and operating under conditions similar to the amplifying test.

The wiring diagram of the system is illustrated on the following page.

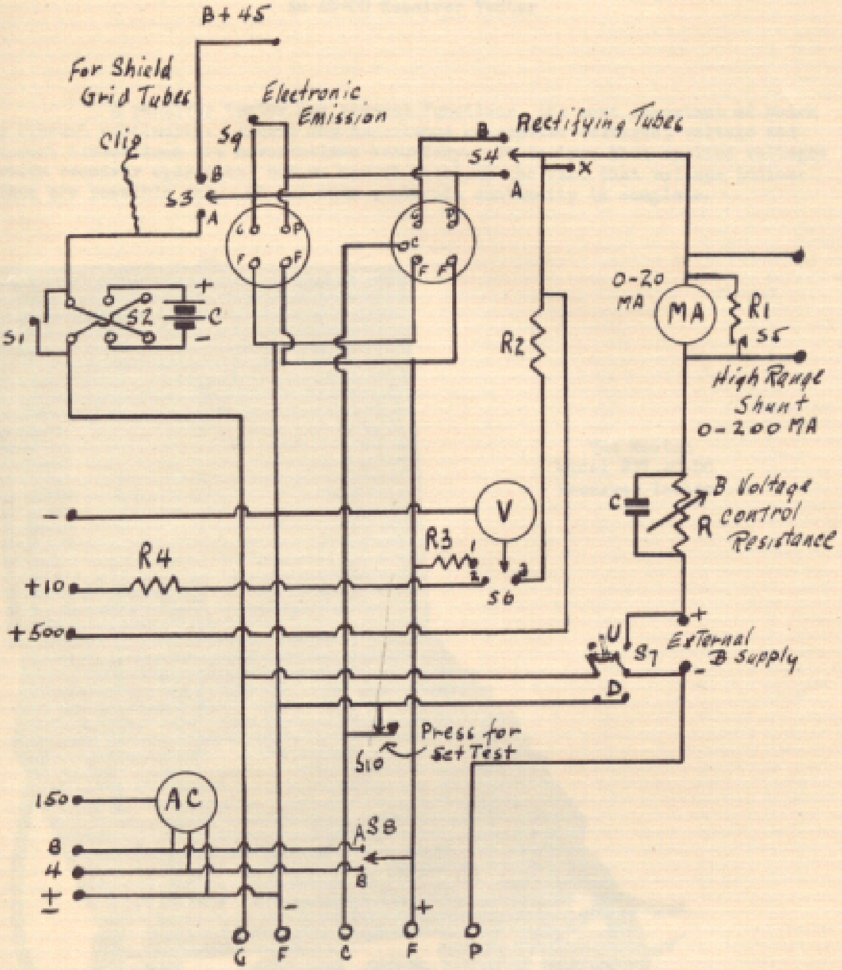


Fig. 3

Wiring diagram of General Utility Tube Tester

An AC-DC Receiver Tester

A receiver tester has several functions, the most important of which is circuit continuity. Albeit the importance of applied voltages, voltage and current indications are nevertheless secondary. It is true that applied voltages govern receiver operation, but we cannot overlook the fact that voltage indications are possible only, if and when , circuit continuity is complete.

The Weston
Model 537 AC-DC
Receiver Tester

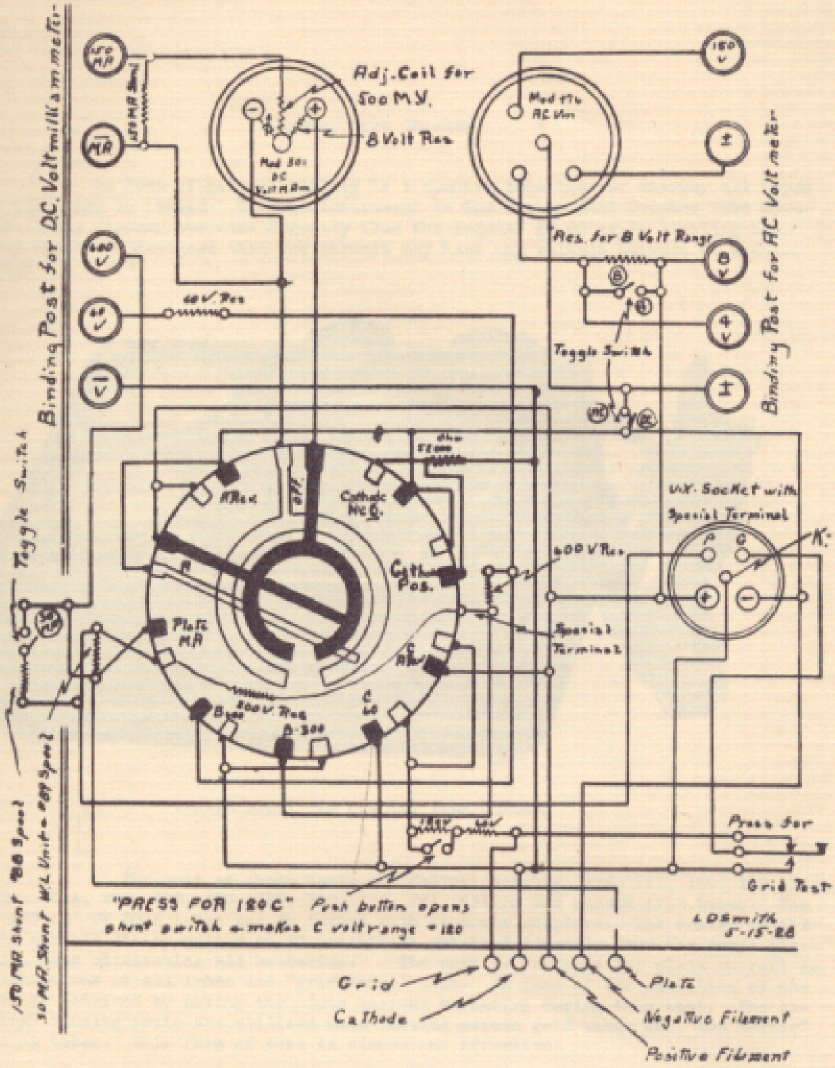
A voltage indication upon any one instrument in a receiver tester, signifies first, circuit continuity, since lack of continuity prohibits voltage indication. The success of a receiver tester is based upon the knowledge possessed by the service man. Correct interpretation of meter readings is possible only under one condition; knowledge of the correct operating characteristics and requirements. This necessitates a thorough comprehension of the components constituting a receiver as indicated upon the receiver wiring diagram. The correct interpration of phenomena associated with the parts of a receiver, is imperative. The service man must needs know that the voltages at the tube elements are less than the voltages at the sources of potential, due to the voltage drops along the circuit. He likewise, must know the possible and the probable causes , depending upon existing conditions, for such phenomena as insufficient plate current, excessive plate current, insufficient plate voltage, excessive plate voltage, insufficient grid voltage, excessive grid voltage and insufficient or excessive filament voltage. It is unfortunate that space does not permit a full discussion of what the service man should know. This data is the subject for another book written by this author and entitled "The Service Man's Manual".

The receiver tester successfully utilized by the writer is a Weston model 537 shown photographically on page 7 and schematically in figure 4 on page 9. Strange to say the writer preferred the purchase of an instrument of this type rather than the construction of a portable device of this kind. The reasons are numerous. First, compactness. Second, ease of operation. Third, efficiency and fourth, economy......One of the requisites of portable equipment is that it be compact and an AC-DC set tester which is also a tube tester, is difficult to construct when space is definitely limited. Conventional resistances available as multiplier resistances or shunt resistances do not lend themselves to the construction of such a device when the space is limited, since the purchaser of these resistances cannot specify the physical dimensions required. He must buy what he can or is available. Since wire wound resistances are preferred, high resistance units for use as multipliers are usually of some size unsuited for such work.

With a definite space limitation, multiplicity of switches is unsatisfactory and a single control affords greater ease of operation. The purchase of special resistances as multipliers or shunts, with respect to physical dimension, in order that the unit fit within a certain space, increases the cost in addition to the actual constructional labor involved, to a figure in excess of the cost of the finished product, hence the finished product is preferable in this instance. The utility of the device shown is not only that of an AC-DC set tester but it is also a tube tester and the equivalent of nine individual meters.

Bearing in mind however, that a home constructed device of this type is satisfactory for the service station, where space is not of such great importance, we show the electrical constants of a similar tester in the chapter devoted to a test bench for the service station.

With respect to the receiver tester illustrated, we can truthfully say that it fulfills every requisite of a set tester. The connections associated with the plug inserts are shown in figure 4A.



Wiring Diagram of Weston 537 AC-DC Receiver Tester

Counter Tube Checker

An item of general utility is a counter tube checker whereby all types of tubes may be tested. Such an instrument is the Weston #533 Counter Tube Checker. This checker operates directly from the regular AC 60 cycle lighting circuit and is so designed that the circuit may have any voltage between 90 and 130 volts.

Weston Model 533 Counter Tube Checker

The unit as shown tests the following tubes, 226, 227, 199, 120, 201A, 112A, 171A, 240, 210, 250, 213, 280, 216, 281, Kellog and screen grid tubes. The UV 199 and UV 201A tubes can be tested with separate adaptors. The design of the unit permits its operation at AC potentials obtained directly from the power circuit, thus eliminating all batteries. The unit is suitable for plate current determinations of all tubes and "grid swing" test. An idea of the condition of the tube is obtained by noting the plate current variation during this test. The external binding posts are utilized when testing screen grid tubes and "top heater" Kellog tubes. This form of test is simple and effective.

Filament and plate voltages are AC, being obtained from the power circuit. A calibrated rheostat and indicating instrument expedite filament voltage adjustment removing all need for calculation. The plate current is indicated on a double range DC 20-80 milliammeter. This indication is procured by means of the rectifying property of the vacuum tube. Plate readings are compared with standard readings furnished on an instruction card.

Eliminator Testers

B eliminators are frequent sources of trouble and require servicing. Unfortunately, however, manufactured B eliminators do not provide easy accessibility, hence the service man is frequently obliged to use his own ingenuity to reach certain parts of the eliminator unit. Since most of the B eliminators utilize gaseous or filament type of rectifier tubes, it will be best if we concern ourselves with testing equipment suitable for these units. The drawing shown below in figure 5 illustrates a system whereby all AC voltages in B eliminators of the above types, may be determined. The tester utilizes two AC voltmeters, one for indicating the applied AC filament voltage (filament type rectifier tube) and the other for indicating the applied AC plate potentials for all types of rectifiers. Jacks are arranged across the various circuits and the voltmeters are plugged in as required.

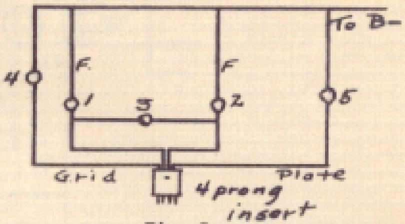


Fig. 5

These voltmeters need not be parts of the tester. Instruments employed with other testers may be connected to plugs and inserted into the jacks provided. The method of testing calls for the insertion of the four prong insert into the B eliminator socket and insertion of the various voltmeters to read available voltages. The eliminator rectifying tube is not utilized, since this tube is tested on some other device. One arrangement employing the filament type of rectifier tube (half wave) cannot be tested with this system and this is the arrangement wherein one end of the plate winding connects to the center tap of the filament winding and the other end of the plate winding is "positive". The same plug insert is suitable for all rectifier tube sockets, that is, for the type used with filament rectifiers and for the type used with gaseous rectifiers such as the Raytheon and QRS. The plug insert is shifted from one socket to the other when testing two tube full wave filament type B eliminators.

Referring to the above illustration, all the jacks are single open circuit and the designations are as follows. 1 and 2 are used to measure the AC plate voltage applied to the anodes of the gaseous rectifier tubes. 3 is used when measuring the filament voltage of filament type rectifiers. 5 is used when measuring the AC plate voltage for half wave rectifiers, such as the 216B and the 281. 4 and 5 are used when measuring the AC voltages applied to the anodes of a single tube full wave rectifier such as the 280 or the 213.

The B minus lead shown in the drawing should be connected to the B minus terminal of the eliminator. If however, the eliminator is equipped to furnish C bias voltages, this B minus connection should be made to the most negative C bias terminal.

The high range AC voltmeter should be capable of indicating a potential of at least 750 volts and the jacks and plugs employed should be capable of withstanding this potential. The eliminator input potential should be"off" when voltmeter plug is inserted.

A Signal Generator for Receiver Testing

Interest has been displayed in a signal generator suitable for receiver testing, wherein a variable audio frequency is employed to modulate a locally generated radio frequency carrier, the modulated carrier being then fed into the receiver via a dummy or phantom antenna. The frequency spectrum of the radio frequency generator is variable. See figure 6.

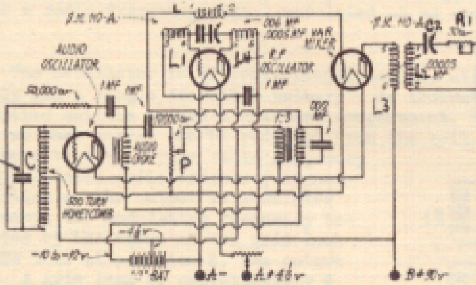


Fig. 6

The electrical constants are shown in the illustration. The wave form of the audio output is governed by the setting of R and its adjustment should be such that the tube is just beyond the oscillation point. The audio output is governed by the setting of the potentiometer P. This adjustment in conjunction with the coupling between L and L1 will govern modulation, and the coupling between L and L1 will likewise govern the intensity of the modulated output from the mixer tube. The audio frequency value is governed by the capacity C and the radio frequency by the L1 C1 circuit.

The dummy antenna shown consists of an inductance L2, a variable capacity C2 and a 50 ohm rheostat R1. The inductance combination, L, L1 and L4 is a Silver Marshall type 110A with L as the adjustable rotor. L2 and L3 are the coils in a similar unit, with L2 the adjustable rotor. The value of C2 and R1 is adjusted to simulate the approximate constants of an antenna system. The writer suggests, if a permanent installation is made, that the filament and plate circuits should be equipped with meters and a meter inserted into the grid circuit to indicate operation of the oscillator (radio frequency). The insertion of this meter makes possible the use of this oscillator as a tube tester to determine ease of oscillation.

This signal generating circuit was originally shown in the January, 1928 issue of Radio. The 50,000 ohm resistance and the 10,000 ohm potentiometer employed by the writer, were Truvolts, type B500 and T500 respectively. The filament and plate voltmeter should be a double range, 0 to 8-250 volts DC instrument and the radio frequency meter, a thermo couple 100 milliampere galvanometer.

Section 3. Oscillators

Radio frequency and audio frequency oscillators utilized as local sources of signals necessary when testing radio receivers, constitute essential servicing equipment. In figure 7 is illustrated a self modulating radio frequency oscillator suitable for stationary and portable work wherever a radio frequency signal or a radio frequency signal modulated at an audio frequency, is necessary.

The oscillator is of conventional design, utilizing a 199 tube dry cell A supply and a single 45 volt B battery . As indicated in the wiring diagram, the entire unit is within a shielded compartment, the shield being open at the coil so that energy can be radiated from the coil. The switch SW 1 controls the generation of a pure radio frequency signal or a modulated radio frequency signal. When in position A, the output is modulated radio frequency, the modulating frequency being controlled by the value of the grid leak G L. When SW 1 is at position B, the output is pure RF. A grid leak of approximately 5 megohms will produce a modulated frequency of approximately 800 cycles, this frequency being quite satisfactory for conventional testing work and particularly when the oscillator is used as a local source of signals during the process of adjusting the neutralizing condensers in a receiver. The frequency is controlled by means of the L C circuit. For the broadcast band L is an inductance of approximately 175 microhenrys and C is a variable capacity of .0005 mfd. L 1 is the tickler coil. L 1 and L 2 are wound on the same form with 1/8" separation. L is 50 turns of #22 D.S.C. wire and L 1 is 36 turns of #22 D.S.C. wire wound on a form 3" in diameter. C 1 is a .00025 mfd condenser. SW 2 is a conventional filament battery switch. C 2 is a 1 mfd condenser rated at 200 volts DC.

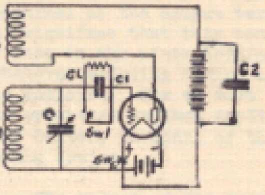


Fig. 7

*See page 33.

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Beat Note Audio Oscillator

A beat note audio oscillator is shown in figure 8 . This system is adaptable to the generation of AF and RF signals; the principle of operation being the production of a beat signal between two radio frequency oscillators, one being variable and the other constant at a predetermined frequency. Two separate radio frequency oscillators are employed and by means of inductive coupling between the detector tubes and the oscillator tubes, the tendency to pull together at the lower audio frequencies, is greatly minimized. By further utilizing loose coupling between the coupled circuits, a fairly constant output independent of frequency is assured. While this system is suitable for the generation of radio frequency signals, it functions best as a generator of audio frequency signals. When so used, the constant oscillator is tuned to 200,000 cycles and the variable oscillator is tuned to frequencies between 190,000 and 200,000 cycles, thus producing a beat from 0 to 10,000 cycles.

The practical operating band does not actually extend to the zero beat but is limited to approximately 40 cycles which value is sufficiently low for every day work. Experiments have shown a sign wave output for all frequencies above 60 cycles and a small harmonic component between 30 and 60 cycles. This oscillator is satisfactory for use wherever an audio oscillator is required and as a matter of fact, satisfactory results have been obtained when the frequency difference was as high as 50,000 cycles. The calibration of this oscillator will be discussed later in the text. Filament and B potentials should be maintained constant during operation and the same is true if constant calibration is desired. Reference to the B plus 45 terminal as the output terminal, signifies that this connection goes to the plate terminal of whatever coupling device is being employed. The 45 volt plate potential is then applied to the battery terminal of this coupling device.

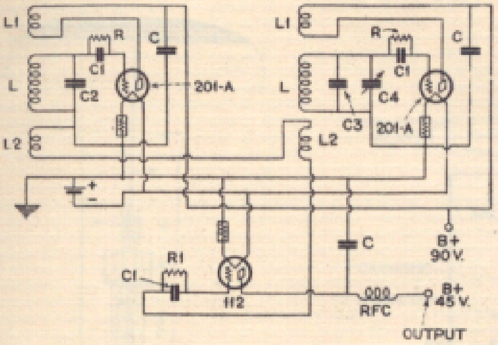

Fig. 8

The values of the components shown are as follows; L 60 turns #24 D.C.C. wire on 3" form. L 1 - 48 turns of #24 DCC wire on same form adjacent to L with 1/8" separation with L 1 at grid end of L. L2 8 turns of #26 DCC wire on same form near filament end of L with 1/4" separation. C 1 .00025 mfd grid condenser. R 2 meg grid leak. R 1 5 meg grid leak. C .001 mfd fixed condenser. C 2 .0025 mfd fixed condenser. C 3 .0025 mfd fixed condenser. C 4 .001 mfd variable condenser with fine vernier adjustment. This condenser may be shunted with a . .000025 mfd vernier condenser. R F C 85 milhenry choke. Automatic filament control devices are utilized.

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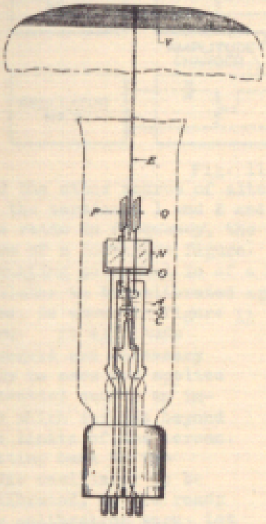
The Cathode Ray Oscillograph Tube

There is available for the scientific service station a piece of laboratory equipment which in its scope of operation and field of utility is without a peer. This unit is the cathode ray oscillograph tube, #224A, a by product of the Bell Telephone Laboratories of the Western Electric Co. The following is an excerpt from a description of this tube and its operation by the writer in Radio Engineering, October, 1927 issue.

Before we enter into the field of operation of this marvelous laboratory unit, let us devote a few minutes to the tube itself, to its constructional details. The cathode ray oscillograph tube, as shown in figure 9 is a pear shaped bulb, with the active metal elements contained in the narrow neck of the bulb and the fluorescent screen is located on the wide part of the bulb. This fluorescent screen is spread over the inner surface of the bulb. The active elements within the tube consist of a filament, the source of the electronic beam, a metal shield, a platinum sleeve, two sets of non-magnetic deflecting plates, a small amount of argon gas and the fluorescent screen. The cathode or filament and the shield are located in a small bottle shaped glass tube, fitted in the neck of which is the platinum tube, functioning as the anode, and through which the electronic stream is projected so as to pass between the deflecting plates.



A phantographic view of the Cathode Ray Oscillograph Tube. V is the viewing screen; P-Q and N-O the deflecting plates; E, the cathode ray; A, the anode; S, the screen and C, the cathode.

Fig. 9

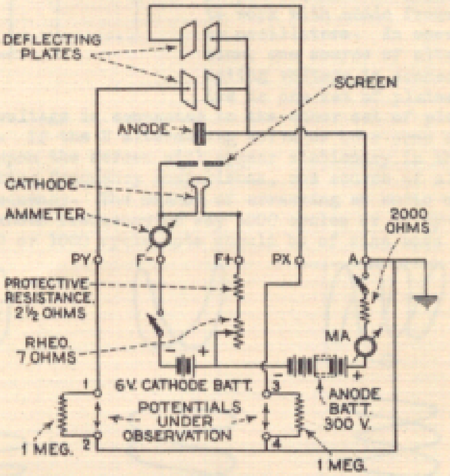


Fig. 10

After leaving the cathode or filament and passing through the tubular anode, the electronic stream passes between two pairs of non-magnetic deflector plates. These plates are rigidly fixed to the inner glass tube and are arranged in parallel pairs, the two pairs being at right angles to each other. See figure 9 . One plate of each pair is connected to the anode, and is therefore maintained at a potential governed by the potential of the anode. The other plate of each pair is arranged for connection to one of the potentials to be observed.

The function of the argon gas within the tube is to focus the electronic stream. Without this gas the beam would spread out and be useless for observation work. In addition, it increases the sensitivity of the tube, by obviating the use of a very high potential, otherwise necessary for the focusing of the beam. With the high potential the tube loses sensitivity.

The wiring diagram of the tube and its associated operating equipment is shown in figure 10 . The ammeter is a Weston 301A 0 to 2 DC and the meter MA is a Weston 301 DC 0 to 5 milliammeter. The 2000 ohm resistance in the anode circuit is a B 20Truvolt . The application of the tube for frequency comparisons is shown in figure 11 oscillator #1 being the oscillator to be calibrated and oscillator #2, any other audio oscillator with a known frequency. The amplitude changers are simply capacity-potentiometer output systems.

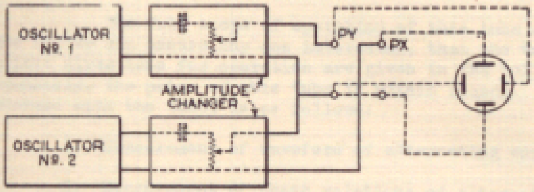


Fig. 11

Very accurate frequency comparisons may be made with the cathode ray oscillograph tube. This should be of interest to people who have occasion to work with audio frequency oscillators. In operation, one source of alternating voltage is connected to one set of plates and the other source of alternating voltage is connected to the other set of plates, to the terminals 1 and 2 and 3 and 4. If the 2 alternating voltages bear some simple ratio in frequency, the pattern upon the screen will appear stationary in the form of a Lissajous figure. When making frequency comparisons, one source of alternating potential is of a known frequency. The method of arranging an audio oscillator to be calibrated against a known frequency of say 1000 cycles or 60 cycles, is shown in figure 11 . The 60 or 1000 cycle note should be of sine wave form. The amplitude changers are necessary only in case the applied potential causes an image which spreads beyond the limits of the screen. Getting back to the audio oscillator to be calibrated, we are ready for calibration work. Let us assume that a known frequency of 1000 cycles from a separate hummer type of oscillator, is applied to one set of plates. An oscillator of this type should be found in every service laboratory. An approximate setting of the unknown oscillator is made at 200 cycles and close adjustment is carried on until a stationary image similar to that of figure 12 A or B is observed. The ratio of the two frequencies can be determined when the pattern is stationary by drawing two straight lines tangent to two adjoining sides of the figure as in figure 12 C. The ratio of the number of points at which these lines are tangent to the peaks of the loops on the two sides, is the frequency ratio of the two voltages.

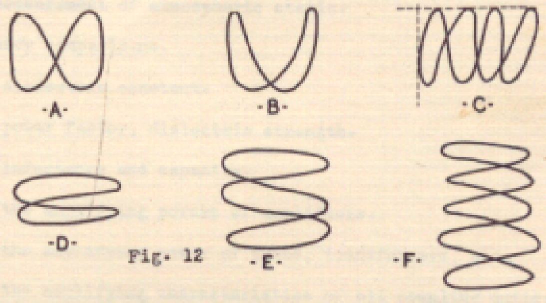


Fig. 12

Apparently figures 12 A and B denote a 2 to 1 ratio and the setting of the oscillator (unknown) is such as to produce a 2000 cycle note. In such calibration work, it is necessary to know the direction of the beam as viewed upon the screen for individual potentials applied to the two sets of plates. Figure 12 C denotes a 1 to 4 or a 4 to 1 ratio, depending upon the position of the respective potentials upon the viewing screen. If figure 12 A indicates a 2 to 1 ratio, figure D would be a 1 to 2 ratio where the frequency of the unknown source is one-half the frequency of the known source. This condition is obtained by adjusting the unknown oscillator to produce a frequency less than that of the known. By the same token, figures E and F indicate a 1 to 3 or 3 to 1 and a 1 to 5 or a 5 to 1 ratio respectively.

The full scope of operation of this tube cannot be described in these pages but we can assure any one interested, that the tube will soon earn its cost. Explicit directions for operation are given in the bulletin accompanying each tube. Fortunately, the price of this tube is within reason. An idea of what work may be performed with the tube, is as follows:

1. Measurement of waveform of alternating currents.
2. Measurement of phase relations of alternating currents.
3. Study of current to voltage relations in electrical apparatus.
4. Characteristics and properties of electrical oscillation generators. (vacuum tubes).
5. Measurement of corona effects along electrical lines.
6. Detection and measurement of atmospheric static.
7. Accurate frequency comparisons.
8. Measurement of dielectric constant.
9. Measurement of power factor, dielectric strength.
10. Measurement of inductance and capacity.
11. Measurement of the amplifying powers of amplifiers.
12. Measurement of the amplifying power of tubes, transformers, etc.
13. Measurement of the amplifying characteristics of all coupling units.

Section 4. Indicating Systems

Judging the signal output of a receiver under test by listening to the signal is very unreliable because of the gradual diminuation of aural sensitivity after a certain period of strain. Furthermore, the responsivity of the ear varies with frequency. Consequently, definite indicating instruments must be used. A simple arrangement suitable for indicating receiver signal output is shown in figure 13 . The transformer shown is coupled to the output of the receiver, the crystal, carborundum, rectifies the signal in the transformer secondary so that the current flow through the meter MA is uni-directional and consequently will produce a deflection upon the meter. The milliammeter has a range of from 0 to 5 milliamperes. Its range can be increased in the event that the signal deflection extends beyond the scale. The means employed to extend the operating scale and ranges of meters, will be discussed in a subsequent section.

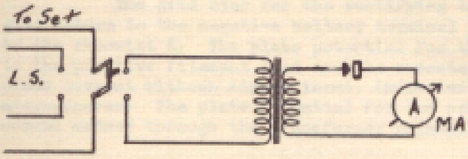


Fig. 13

Since it is customary to test receivers with a constant unfluctuating signal with one modulating frequency, the indication on MA will be steady while the signal is being fed into the receiver.

A system of determining relative degrees of efficiency of the entire system preceding the audio amplifier,* is shown below. The diagram below illustrates a double rectifying system. One tube functions as the second detector in the superheterodyne. This is the regular second detector with one change in its plate circuit. Whereas its plate is normally connected to the plate terminal of the first audio coupling unit, this system provides for the incorporation of an intermediate frequency transformer in series with the plate of the detector tube and the plate terminal of the first audio coupling unit. The peak frequency of this intermediate transformer should be variable in order to permit its application to all superheterodynes. The other rectifying tube is utilized as a vacuum tube voltmeter to indicate the intensity of the radio frequency component in the plate circuit of the detector tube.

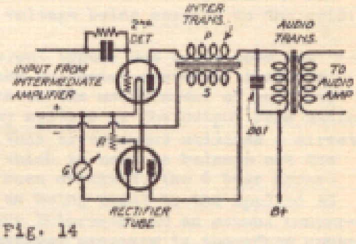


Fig. 14

The RF component passes through the primary of the intermediate transformer and is bypassed across the audio frequency transformer primary. An RF voltage is therefore induced in the secondary of the intermediate and the voltage available is impressed across the grid filament circuit of the rectifier. This voltage actuates the galvanometer in the plate circuit of the rectifying tube. Since the RF component is usually steady, the modulating component present in the plate circuit of the second detector tube, does not effect the rectifier tube plate circuit.

* This system pertains to superheterodynes.

The galvanometer in the plate circuit indicates a small value of DC plate current without a signal input, and the deflection on the meter increases when a signal is applied. The greater the magnitude of the signal applied to the second detector, the greater the magnitude of the RF component passing through the intermediate transformer primary in the plate circuit of the second detector tube and the greater the voltage across the grid filament circuit of the rectifier tube voltmeter. This in turn, increases the deflection on the galvanometer. The constants shown in the system are employed by the writer and galvanometer G is a Weston model 1 0 to 1 milliampere, portable DC instrument with an internal resistance of 210 ohms.

The grid bias for the rectifying tube is obtained by connecting the grid return to the negative battery terminal or filament lead and by adjustment of the rheostat R. The plate potential for the tube is obtained by connecting to the positive filament lead and the rheostat R is adjusted until the normal plate current without signal input, indicated on G, is approximately 10 or 20 microamperes. The plate potential for the second detector, is applied in the normal manner through the transformer primaries.

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Tube Voltmeters

The vacuum tube voltmeter because of its versatility, finds extensive utility in the service man's workshop. In direct contrast to the crystal-milliammeter indicating system shown earlier in this section, the vacuum tube voltmeter finds application as a signal indicating medium or measuring device in all parts of the receiver. The tube voltmeter does just what its name implies. It employs a vacuum tube to measure voltage by utilizing the tube as a detector and the increase in plate current as an indication of the voltage being applied to the grid.

Vacuum tube voltmeters are of different types, but space does not permit a detailed discussion of all available tube voltmeter systems. A simple tube voltmeter suitable for qualitative work such as the measurement of moderate values of AC voltage available in audio frequency systems or the output from audio frequency oscillators, is shown in figure 15 . This arrangement utilizes a direct comparison potential in the form of a C battery which is used to balance out the effect of the applied AC. When the balance has been obtained, the C bias necessary to arrive at this state, can be considered as being equal to the applied AC potential. The average service laboratory is more interested in an actual comparison rather than quantitative measurements and extreme accuracy is therefore unnecessary. The operation of the tube voltmeter shown, is based upon the following principle.

Operation at the lower end of the grid voltage plate current characteristic of a three element vacuum tube makes the tube function as a rectifier, wherein the negative half of the applied AC cycle has negligible effect upon the plate current, but the positive half of this cycle causes a definite increase. By proper calibration, plate current increase can be interpreted in applied AC input potential. Furthermore, an additional negative bias when applied, can be utilized to balance out the effect of the positive half of the incoming AC cycle. With a reasonable degree of accuracy, the value of this additional bias is equal to the applied AC potential. This type of tube voltmeter is shown below in figure 15 and is applicable wherever a continuous circuit such as a choke or resistance can be connected across the input of the tube voltmeter, providing a path for the C bias. In other words, this type of tube voltmeter is utilized to measure voltage across a structure which will pass direct current.

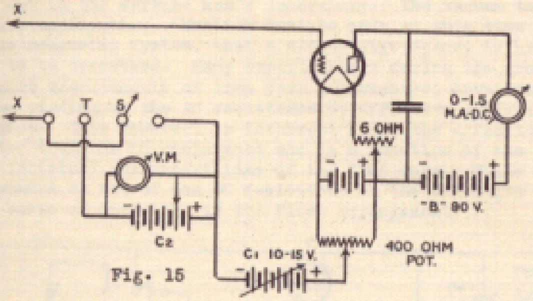

Fig. 15

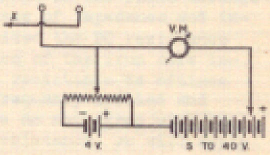

Fig. 16

The above instrument has been utilized by the writer for the measurement of amplifier power output and checking with precision instruments proved the utility of the voltmeter for the measurement of input peak voltages between 4 and 90 volts. The plate current meter is a Weston 301 0 to 1.5 DC milliammeter and the grid bias voltmeter was a Weston model 45 double range 0 to 15-to 150 volts DC.

Referring to the above illustration, we adjust the plate current with terminals XX connected to whatever source is to be measured, without signal input however, by connecting S and S1 and adjusting C1 and the potentiometer. The current indication on the plate meter should be preferably a few microamperes, say 5. The signal is then applied, S is changed to T and C2 adjusted until the increased deflection on the plate meter is again reduced to its original setting. The voltage indicated on VM can be considered as being equal to the applied AC. A finer degree of grid bias control than that available in figure 15 is shown in figure 16 by the addition of a separate 4 volt battery shunted by a potentiometer. The C battery bank in this illustration replaces C2. C1 remains intact.

The Measurement of Inductance and Impedance

The measurement of inductance and impedance is a rare occurence in the life of the service man but the occasion arises when such work must be carried out in the service man's laboratory. The vacuum tube voltmeter finds extensive application. Mention must be made at this time prior to the description of the measuring system, that a slight discrepancy is present in the first arrangement to be described. Many experimenters during the process of impedance and inductance measurements of iron core inductances, have utilized the DC resistance of the winding as the AC resistance or effective resistance of the iron core inductance. This however, is incorrect since the effective resistance is oftimes greater than the DC resistance and is a function of the frequency applied and the electrical characteristics of the iron core. While we do not agree with the acceptance or use of the DC resistance as the effective resistance, we will apply this basis of operation in the first arrangement.

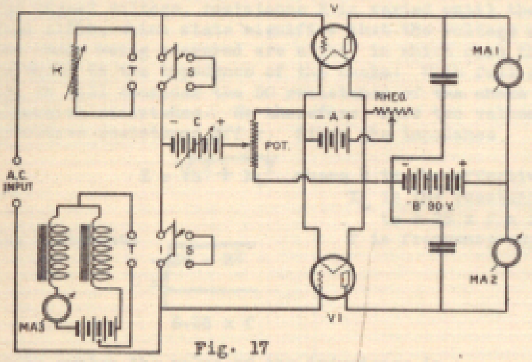

Fig. 17

The first arrangement for impedance measurement of iron core chokes shown in figure 17 utilizes two vacuum tube voltmeters. The function of these tubes after calibration is to indicate balance rather than voltage applied, although the balance condition is indicative of equal values of applied input potential. These two voltmeters contained in one housing, operate on the principle previously described.

An idea of the equipment necessary can be gleaned from the wiring diagram shown and if it will be of aid, the writer will mention the units employed in his own device. V and V1 are standard 01A tubes. The rheostat is a 10 ohm unit. The bypass condensers are of 1 mfd. each. MA1 and MA2 are Weston 301 0 to 1.5 DC milliammeters. MA3 is a Weston 301 0 to 150 DC milliammeter. The potentiometer is a 400 ohm unit. The variable resistance associated with the terminal T of the upper D P D T switch, is a calibrated resistance box with a maximum resistance of 100,000 ohms. If possible, this should be a decade box. If constructed by the reader, it should be variable in steps of 10 ohms and the resistances employed should be non-inductive.

Since the impedance of iron core chokes is usually required at some low value of frequency, say 50 or 60 cycles, the AC input should be 60 cycles. The operation of the complete unit, however, is not limited to 60 cycles but the comparatively low value of the balancing resistance R limits the use of the bridge when the frequency is greater than 60 cycles for the measurement of inductances of such value that the impedance of the inductance is not greater than 100,000 ohms. With switches I and I in the S position, the potentiometer and C bias voltages are adjusted so that MA1 and MA2 read alike and the deflections on these meters are approximately 5 or 10 microamperes. If V and V1 are alike, this balance will be easily attained. The C bias should be sufficient to reduce the normal plate current to the value mentioned. Precautionary measures must be taken, by applying a certain value of C bias before balancing in order to prevent burnout of the two plate current meters since the normal plate current without C bias is greater than the range of the instrument.

Neglecting for a moment the two chokes illustrated in the drawing, let us imagine that only one is present, thus excluding the other choke, MA3 and the associated battery. The two D P D T switches are set to the T position and the signal voltage applied. Since the characteristics of iron core inductances vary with the current through them, it is necessary that all measurements be made with equal applied voltage. A voltage of 1 volt across the inductance is customary. We therefore, suggest that the voltage from the AC source applied across the voltmeter be the minimum value necessary for operation of the system.

Assuming correct position of the two switches and the application of the signal voltage, resistance R is varied until the two plate current meters read alike, which state signifies that the voltage across the setting of R and the choke being measured are alike, in which case the resistance setting of R is equal to the impedance of the choke. With full recognition of the discrepancy, we will consider the DC resistance of the choke as being equivalent to its effective resistance. We therefore, know two values, the impedance Z and the effective resistance Eff r. Since the impedance

$Z = \sqrt{R^2 + X_L^2}$ where R is the effective resistance
X_L is the reactance, which in turn is equal to 6.28 x f x L
f is frequency applied

the inductance

$$L = \frac{\sqrt{Z^2 - R^2}}{6.28 \times f}$$

at 60 cycles the value of the inductance is

$$L = \frac{\sqrt{Z^2 - R^2}}{377}$$

If one is not interested in the effective resistance, the above arrangement is quite satisfactory, but if the above value is of interest and also the phase angle, the system which will be described is preferred. As an example of the misleading information obtainable when the DC resistance is considered as the effective resistance, is the following. A plate coupling choke of 204 henrys inductance measured at 60 cycles had an impedance of 83,300 ohms and a DC resistance of approximately 3098 ohms, but its effective resistance was 31,300 ohms. Since the phase angle, indicative of efficiency of design, is a function of the effective resistance and impedance, it is evident that the accepted method of measurement is erroneous and misleading.

Accepting the arrangement shown, we will apply the combination tube voltmeter to the measurement of iron core inductances with DC in the winding. The method of measurement is the same as described in the preceding paragraph. It is however, necessary to utilize two identical chokes when the impedance of one with DC through the winding is to be determined. The two chokes are connected in parallel as shown and the battery tapped in the center supplies the DC for the chokes. The meter indicates the current flow. By splitting the battery as shown, DC voltage is not applied to the grid of the tube voltmeter. It is imperative that the DC in the chokes be perfectly balanced in order to preclude any effect therefrom upon V1. When balance of the entire unit is obtained, the resistance setting of R is equal to one-half the impedance of the choke being measured.

Another method of inductance measurement, applicable to iron core chokes and incidentally preferred by the writer, is shown below in figure 18. This system utilizes the resonance principle and makes use of the voltmeter for the determination of resonance and also for the measurement of voltages which will provide the effective resistance value of the choke in question.

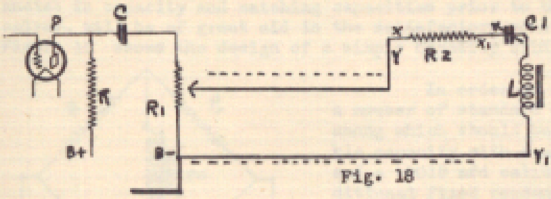

Fig. 18

P is the plate of the output tube of an amplifier connected to an audio oscillator or to a source of audio frequency. R is the plate coupling resistance for this output tube and replaces the normal choke employed. C is the coupling capacity and is of 20 or 30 mfds. R1 is a potentiometer with a resistance value of approximately 4000 ohms when the output tube is a 250. The oscillator and amplifier must be so arranged and operated that the signal across R1 is of sine wave form or with minimum harmonics. The choke to be measured is inserted into the circuit as shown. C1 is a decade condenser box with a capacity range from .0005 mfd to 2 mfd. R2 is a fixed non-inductive resistance of 2000 ohms. A tube voltmeter is connected across points X and X1 and with a signal input into the test circuit, C1 is varied until the C1 L circuit is in resonance with the applied frequency, in which case the tube voltmeter would indicate maximum voltage. The setting of R1 should be such that the applied voltage is the minimum necessary to give a readable deflection on the tube voltmeter. Since the value of capacity at resonance is known, the inductance of the choke L is

$$= \frac{25,281}{f^2 \times C}$$

where f is the frequency of the applied signal and C is the capacity setting of C1 at resonance.

If the applied frequency is 60 cycles, the reactance X_L of the choke is 6.28 x 60 x L. The voltage across R2 is now measured with the tube voltmeter and then the tube voltmeter connections are placed across points Y and Y1 and the voltage again measured without disturbing the input or the resonance condition. With a known voltage across X and X1 and a known resistance, it is easy to calculate the current in the circuit or through the resistance. Since the current in a series circuit is the same in all parts of the circuit, the current through the resistance determined by dividing the measured voltage by the known resistance of R2, is the current in all parts of the circuit. At resonance, reactance of the choke is balanced by the reactance of the condenser . Knowing the applied voltage as measured across Y and Y1 and knowing the current through the circuit, the applied voltage divided by the current gives the total resistance, since reactance is absent at resonance. The total resistance minus that of R2 gives the effective resistance of L, because the effective resistance of C1 is negligible.

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Measuring Capacity

A unit for testing relatively small values of capacity such as small bypass condensers and the sections of gang condensers is an important item in every service station. This is particularly true when custom set building lies within the scope of the establishment. A unit suitable for determining discrepancies in capacity and matching capacities prior to their installation in a receiver, will be of great aid in the satisfactory construction of that receiver. Figure 19 shows the design of a simple capacity bridge.

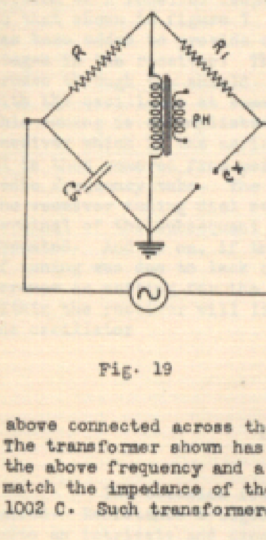


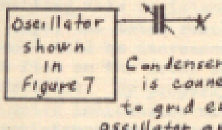
Fig. 19

In order to carry out this type of work, a number of standard capacities must be at hand, among which should be a calibrated vernier variable capacity with a maximum of 20 micromicrofarads and a .0015 mfd calibrated variable condenser. Additional fixed condensers of known capacity should also be available. A decade capacity box with a range of from .001 mfd to 1 mfd will be found very handy. Referring to the illustration R and R1 are accurate 5000 ohm non-inductive resistances. The AC supply is an oscillator generating an audio frequency, preferably a 1000 cycle note. To check an unknown capacity, the standard Cs is balanced against the unknown condenser CX, until the sound in the headset is minimum, at which time the capacity of the unknown is equal to the capacity setting of the standard.

A small vernier of the value mentioned above connected across the standard condenser, will greatly facilitate balancing. The transformer shown has a primary impedance of approximately 200,000 ohms at the above frequency and a secondary impedance of approximately 20,000 ohms to match the impedance of the headset, which incidentally is a Western Electric type 1002 C. Such transformers are available .

A Resonance Indicator

A method of determining discrepancies in resonance settings of multistage tuned radio frequency receivers is doubtless of importance to the service man. A simple modulated radio frequency oscillator, judiciously employed, will function excellently in this respect.



Condenser is connected to grid end of oscillator grid inductance

Fig. 20

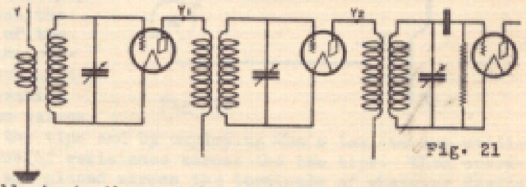


Fig. 21

Figures 20 and 21 illustrate the oscillator and the radio frequency portion of a receiver respectively. The oscillator is identical to that shown in figure 7 with the exception of a small coupling capacity which has been added to provide coupling between the oscillator and the various tuned stages in the receiver. The oscillator is shielded and the flexible lead X protrudes through the shield. The receiver to be tested is adjusted for resonance with the oscillator at some wave length free from external station interference. This tuning is accomplished by connecting X of the oscillator to point Y of the receiver which is the aerial terminal. The lead X from the vernier condenser C1 is then removed from point Y and shifted to the plate connection of the first radio frequency tube. The receiver is again retuned to maximum resonance and the receiver tuning dial setting noted. Then the lead X is shifted to the plate terminal of the subsequent radio frequency amplifying tube Y2 and the procedure repeated. And so on, if there are more stages of RF. If the original broadness of tuning was due to lack of resonance, one of the stages will show a marked difference in setting for the same input frequency. A defect in coil construction within the receiver will likewise show broad tuning, when tuned to resonance with the oscillator

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DC Resistance Measurement

The occasion frequently arises when the DC resistance of a unit is required. Resistance bridges find extensive application but their construction is quite an intricate and expensive problem. This is so because of the difficulty encountered when endeavoring to purchase upon the open market, the required number of highly accurate non-inductive, calibrated resistance units. The writer has in his laboratory an expensive DC resistance bridge in addition to an improvised Ohmmeter of great utility.

This Ohmmeter when calibrated will be found to be of great advantage out in the field for the testing of units and for the determination of their resistance. A small switchboard type of meter may be employed for the portable unit, and a large portable type of instrument for the stationary unit in the service station. The Ohmmeter shown below consists of a portable milliammeter operated in conjunction with a 22.5 volt B battery block and an accurate 22,500 ohm resistance connected as indicated. The connecting leads X and X1 are two rigid prongs with metal tips. The handles are of bakelite and the connecting wires terminating in the two tips, pass through a hole in the bakelite handle. When the two tips are shorted, the meter indicates a current of 1 milliampere in the circuit. If we add a resistance, by connecting this resistance across the two tips, the total resistance of the circuit will be increased and the current flow on the meter will consequently decrease. By properly calibrating the meter indications with known values of resistance connected across the tips and by employing Ohm's law, we can utilizw the meter deflection as the value of resistance across the two tips. When operating this device, the two tips are placed across the terminals of whatever device is being tested. The meter employed by the writer is a Weston 301 0 to 1 DC milliammeter and the calibrated resistance R is a Truvolt type B. The original resistance was of 25,000 ohms. One of the end terminals was shifted until the required resistance was obtained.

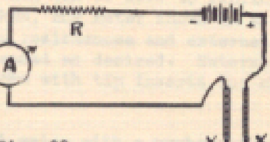


Fig. 22

The utility of this device is such that an approximate value of the resistance being measured, is satisfactory, hence the gradual decrease of the voltage rating does not greatly influence results, until the available voltage has decreased approximately 2 volts, at which time replacement is necessary. The drain however, is very small and a long period will elapse before the battery voltage will decrease the above amount. The meter-battery combination mentioned above is suitable for the determination of resistance values as high as 4 megohm. If calibration is impossible, a minute of calculation will result in the DC resistance of the unit being measured. Let us assume that the two tips have been connected across a device and the meter indicates .1 milliampere or .0001 ampere. What is the resistance of the unit being tested. According to Ohm's law

$$R = E/I \text{ and substituting in the formula } R = 22.5/.0001$$

The total resistance in the circuit is therefore 225,000 ohms. From this we subtract the original resistance of 22,500 ohms and the resistance of the unknown is 202,500 ohms. Suppose another item is tested and the meter indicates a current flow of .00095 ampere or .95 milliampere. What is the resistance of the unknown? The total resistance is 23,684 ohms. The unknown resistance is therefore 1,184 ohms. Another resistance is measured and the current indication is 22 microamperes. The total resistance is 1,022,500 ohms. The unknown resistance is then equal to 1,000,000 ohms.

The unit shown above functions excellently as a contimuity tester, when applied to the testing of receivers in conjunction with the regular receiver tester. The receiver tester is applied first, followed by the above when special continuity testing is desired.

Section 5 . Multirange Meters

The remainder of this treatise will deal with multirange meters, that is with meters equipped with external resistances to increase the voltage scale and with external shunts to increase the current range. The reader should remember that any one of the meters described in this section can be used to replace any meters shown in wiring diagrams. By the same token, any meter shown in a wiring diagram can be equipped with the external series resistances and external shunts as described herein, and the operating range extended as desired. External shunt and series resistances may be connected to tipjacks with tip inserts for changing operating ranges.

While it is possible to equip one current meter with a number of series resistances and external shunts, we do not believe that it is the best system, since the meter is still limited to one use at one time; consequently the resistances and shunts do not find practical use. We prefer to equip a milliammeter with a number of series resistances so as to give it a number of operating ranges as a voltmeter. Increased use as an ammeter is another item, and we prefer to use another milliammeter equipped with e number of shunts. The situation frequently arises when both high reading milliammeters and high reading voltmeters are required.....Separate instruments are preferable, since they expedite testing in every way.

Let us first consider the conventional high resistance voltmeter. The operating range of a voltmeter can be increased by the use of an external. If the external resistor is equal to the internal resistance of the voltmeter, the operating scale of the meter is doubled. If the external resistance is equal to three times the internal resistance of the voltmeter, the scale is multiplied four times. The value of this external resistor is governed by the increased range desired and by the ohms per volt value of the voltmeter and the total resistance of the instrument. The former or the latter values are usually quoted in the meter manufacturers' literature. If the ohms per volt value is quoted, the total internal resistance is equal to

Rpv x maximum voltage deflection.

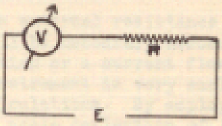


Fig. 23

For example, a meter rated at 1000 ohms per volt, has a maximum range of 250 volts. The total internal resistance is therefore 1000 x 250 or 250,000 ohms. To increase the meter range to 500 volts, it is necessary to add an external resistor of 250,000 ohms. The application of this arrangement is shown in figure 23 .

If the ohms per volt value is unknown, it can be determined by means of the arrangement shown in figure 24 . The voltmeter in series with a milliammeter is connected across a source of potential. Note the voltage indication and the current drain. Divide the indicated voltage by the indicated current and the result can be considered as the internal resistance of the voltmeter. The milliammeter MA should have a range of from 0 to 20 mils DC when testing the average DC voltmeter. It is not necessary that the voltmeter deflection be full scale. A meter with a range of from 0 to 5 mils is satisfactory for testing voltmeters rated at more than 200 ohms per volt.

This arrangement is illustrated in figure 24 . The internal resistance of the battery and the internal resistance of the milliammeter are sufficiently low to be classed as negligible.

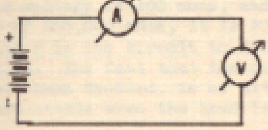


Fig. 24

If one is in a position where he can secure accurate resistances capable of dissipating 1 watt, he can satisfactorily improvise a high resistance DC voltmeter by employing a 0 to 1 DC milliammeter in conjunction with a number of series resistances. The principle governing the arrangement shown in figure 25 is that a certain voltage is required to cause a certain current flow through a certain resistance. Every current indicating meter possesses a certain amount of resistance and a certain potential is necessary to cause the maximum current flow indicated upon the meter scale to flow through the internal resistance of the instrument. The writer has had occasion to construct several such units and one will be considered as a concrete illustration. A Weston model 301 0 to 1 DC milliammeter with an internal resistance of 27 ohms, requires a potential equal to .001 x 27 or .027 volts for full scale deflection. In other words, a DC voltage of .027 volts when applied to the meter, will cause full scale deflection of .001 ampere.

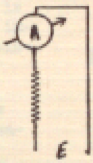


Fig. 25

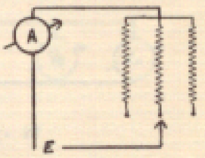


Fig. 26

If we now place in series with this meter an external resistance of finite value, it is logical that a greater potential will be necessary across the meter-resistance combination to cause full scale deflection or a current flow of .001 ampere. Inasmuch as the voltage drop across the instrument is very small, we can consider it entirely negligible in all future calculations. By employing Ohm's law and bearing in mind that the meter has a full scale deflection of 1 milampere, we can calculate the value of the external resistance to permit the application of any value of potential. This formula is

$$R = E/I \text{ where}$$

R is the external series resistance, E is the potential to be applied or the maximum potential and I is the full scale deflection of the meter. Utilizing the meter mentioned and applying the formula , we find that an external resistance of 500,000 ohms will permit the application of 500 volts and will cause full scale deflection. By the same token, an external series resistance of 1 million ohms will permit a maximum potential of 1000 volts. When selecting the resistance, it is essential that its resistance remain constant when carrying the full load of 1 milliampere and that the resistance be accurate if the voltages are to be simple multiples of 1. The writer has found wire wound resistances most suitable for this work and in this direction made use of Electrad Truvolt wire wound resistances. These units because of their construction, permitted accurate adjustment of the external resistance so that the applied voltages were even multiples of 1 and interpretable directly in meter deflections.

For example in figure 26 we show a multirange improvised high resistance voltmeter operated in conjunction with three resistances R, R1 and R2 and a shunt resistance R3. This shunt is equal to the internal resistance of the meter thereby doubling its current scale, making it a 2 mil meter and at the same time, doubling the permissible voltage with each series resistance. In other words, if with R3 open and R1 equal to 100,000 ohms, the maximum permissible voltage is 100 ohms, and with R1 of 250,000 ohms, it is 250 volts and with R2 of 500,000 ohms, it is 500 volts, closing R3 raises the permissible voltage with R in the circuit to 200 volts, with R1 to 500 volts and with R2 to 1000 volts. The fact that the drain has been increased to 2 mils when the voltages have been doubled, is of little consequence since eliminator output will vary very little when the load is increased 1 mil.

While upon the subject of current meters, we might add that DC ammeters rated at from 5 to 100 amperes, can be made into millivoltmeters by removing the shunts. The millivolt value of such instruments is usually obtainable from the manufacturer. Millivoltmeters can be improvised in the manner illustrated for high resistance voltmeters. A multivoltmeter of the type mentioned can be calibrated with a standard in the manner shown in figure 27. The standard voltmeter is connected across a source of potential. The improvised multivoltmeter with its external resistances is then connected across the standard and the deflections compared. If desired, a calibration curve similar to that shown below in figure 28 can be made. Emperical determinations have proved to the writer that with a reliable meter and accurate resistances, calibration with a standard is not necessary. If, however, one doubts the exactness of the resistance value of the resistor, a comparison with the standard should be made. Comparison against a standard is recommended.

Fig. 27

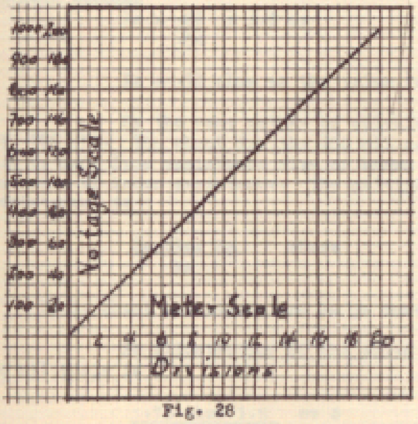


Fig. 28

The ordinate of the graph is designated in the voltage scale and the abscissa carries the meter scale reading since the meter used, possessed 20 scale divisions, each division was equal to 10 volts on the 200 volt scale, 5 volts on the 100 volt scale, 20 volts on the 400 volt scale, 25 volts on the 500 volt scale and 50 volts on the 1000 volt scale.

The calibration curve shown herewith should not be considered as standard and individual calibration is recommended. The shunt utilized with the above meter must be absolutely accurate in order that the voltage readings be correct. If the resistances are not accurate, the voltage scale depends upon the value of the external resistance divided by 1000. In other words, if the resistance is equal to 290,000 ohms, the maximum permissible voltage is 290 volts.

The current scale of a milliammeter or an ammeter is increased by shunting the meter with an external resistance as in figure 29 . In order to select the correct shunting resistances, it is essential that the internal resistance of the current indicating device be known and also the maximum current requirement. Fortunately, meter manufacturers invariably mention the internal resistance of their instruments, and when this information is available, selection of the shunt resistance or resistances is simply the application of the following formula

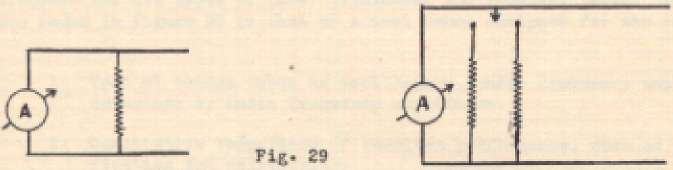


Fig. 29

$$Rx = \frac{Ia}{Is} \times Ra \text{ where}$$

Rx = unknown shunt resistance, Ia is meter current scale, Is is current through shunt which in turn is equal to the total current flow minus the current flow through the meter and Ra is the resistance of the instrument. For example, let us consider the multirange milliammeter employed by the writer. The meter is a Weston 301 model 0 to 20 DC milliammeter with an internal resistance of 1.5 ohms. Let us assume that we wish to increase this range to 60 mils, 100 mils and 200 mils. We will therefore require three shunt resistances as shown above. For the first case applying the formula, we find that Is is .04 ampere and the formula becomes

$$Rs = \frac{.02}{.04} \times 1.5 \text{ or}$$

Rs = .75 ohms as the value for the 60 mil range shunt.

By the same method of calculation, the shunt for the 100 mil range is .375 ohm. The shunt for the 200 mil scale is .111 ohm. The shunt resistances can be made from resistance wire of known ohmic value per foot or inch or of copper wire of known resistance. The multiplying factor with any one value of shunt resistance, is

$$\frac{Rs \text{ plus } Ra}{Rs} \quad \text{where}$$

Rs is shunt resistance and Ra is instrument resistance.

An illustration of the above in the multirange milliammeter for the 60 mil scale is

$$\frac{.75 \text{ plus } 1.5}{.75} \text{ or } 3$$

Service Station Test Bench

The modern radio service station is equipped with a complete test bench equipped with sufficient meters to permit all possible measurements upon radio receivers and all types of tube, eliminator and receiver tests. The illustration shown in figure 30 is that of a test bench equipped for the following.

1. Test of vacuum tubes as oscillators, radio frequency amplifiers, detectors or audio frequency amplifiers.
2. Qualitative comparison of receiver performance, such as amplification and selectivity.
3. Measurement of AC voltages applied to filaments and plates of rectifiers.
4. Voltage regulation curve of B eliminators.
5. Voltage regulation curve of A eliminators.
6. Continuity testing
7. Measurement of AC line voltage input into receiver.
8. Measurement of charging current of DC charges.
9. Tests of dry cells.
10. Measuring AC current consumed by receiver.
11. Measurement of filament current of AC and DC tubes.
12. Generation of local signal for receiver neutralization.
13. Measurement of filament transformer output voltage and voltage regulation.
14. Electronic emission of vacuum tubes including filament type rectifiers.
15. Test of screen grid tube
16. General test of all types of tubes. (AC and DC) with local power.
17. Conventional receiver test including continuity, applied voltages including cathode and all tubes including the 250.
18. Sensitivity test of receiver.
19. Affords utility of thermo-galvanometer, AC voltmeter, 0 - 4 - 8

- 150 volts and AC voltmeter 0 - 500 - 1000 volts; DC ammeter 0 - 3 amperes and DC ammeter 0 - 50 amperes; AC ammeter 0 - 3 amperes; DC milliammeter 0 - 1 milliampere and DC milliammeter 0 - 20 - 200 milliamperes; DC voltmeter 0 - 50 - 500 volts.

All of the above instruments are parts of the test bench and are utilized in the testing equipment, but binding posts are provided to permit external use of each instrument . The test bench is segregated into four parts and the wiring diagrams in figures 31, 32, 33 and 34 illustrate the system of wiring. Dividing the wiring diagrams into four units does not mean that the test bench should be divided in similar manner. The individual wiring diagrams are furnished to facilitate comprehension. The legend of parts illustrated upon the test bench panel are indicated upon the individual wiring diagrams but to simplify matters will be separately quoted at this time. The various resistances employed in the systems are not shown upon the panel but are mentioned in the wiring diagram. With respect to the designations upon the panel, the following are the explanations.

TG, thermo-galvanometer; oscillator, oscillator tuning condenser dial; dummy ant, dummy antenna condenser dial; FR, oscillator filament rheostat; DAR, dummy antenna resistance; C, coupling control for varying coupling between oscillator and dummy antenna; DPST, double point single throw switch; 1, 2, 3, 4, 5, 6, 7, 9, 10, and 13, toggle switches; 14, a double pole double throw switch; 11 and 12, single pole 2 point switch as shown; AC 1, 0 - 500 - 1000 volts AC voltmeter; AC 2, AC 4, 0 - 4 - 8 - 150 volts AC voltmeter; AC 3, 0 - 3 AC ammeter; DC1,0 - 3 DC ammeter; DC 2, 0 - 50 DC ammeter; DC 3, 0 - 1 DC milliammeter; DC 4, 0 - 20 - 200 DC milliammeter; DC 5, 0 - 50 - 500 DC voltmeter; LP, line plug socket; IN, input to receiver from dummy antenna; OUT, output from receiver to indicating system; 8, double point double throw switch; B - G F F P, binding posts for B eliminator tester providing connection for plug insert; G F C F-P, binding posts for tube and set tester permitting application of external power supply or 4 or 5 prong plug insert for set testing. The circles associated with the meters are the binding posts for external connection. The two plugs associated with AC 1 and AC 4 permit connection of the proper voltage scale. "B" R is the load resistance utilized when determining voltage regulation of B eliminators. The sockets shown are 4 and 5 prong respectively. Explanation of the function of each unit indicator on the panel will be described when the wiring diagrams are discussed. BPS is the bi-polar switch whereby the instruments utilized in the tube and set tester are connected into the circuit.

The field of utility of this test panel was not fully enumerated. Many other tests may be carried out by inter-connection of the various meters, via the external binding posts and since these will undoubtedly present themselves when the test panel is being operated, detailed discussion is unnecessary. We will however, illustrate a few examples later in the text.

The first part of the test panel consists of the signal generator and dummy antenna. This generator is quite simple and not as elaborate as that shown in figure 6. As a matter of fact, the system utilized is identical to that illustrated in figure 7. Plate voltage connections do not terminate upon the panel, but filament control of the oscillator tube is obtained by means of the toggle switch 13 and the filament rheostat. The electrical constants of the various units employed in the signal generator are given in the description of the system.

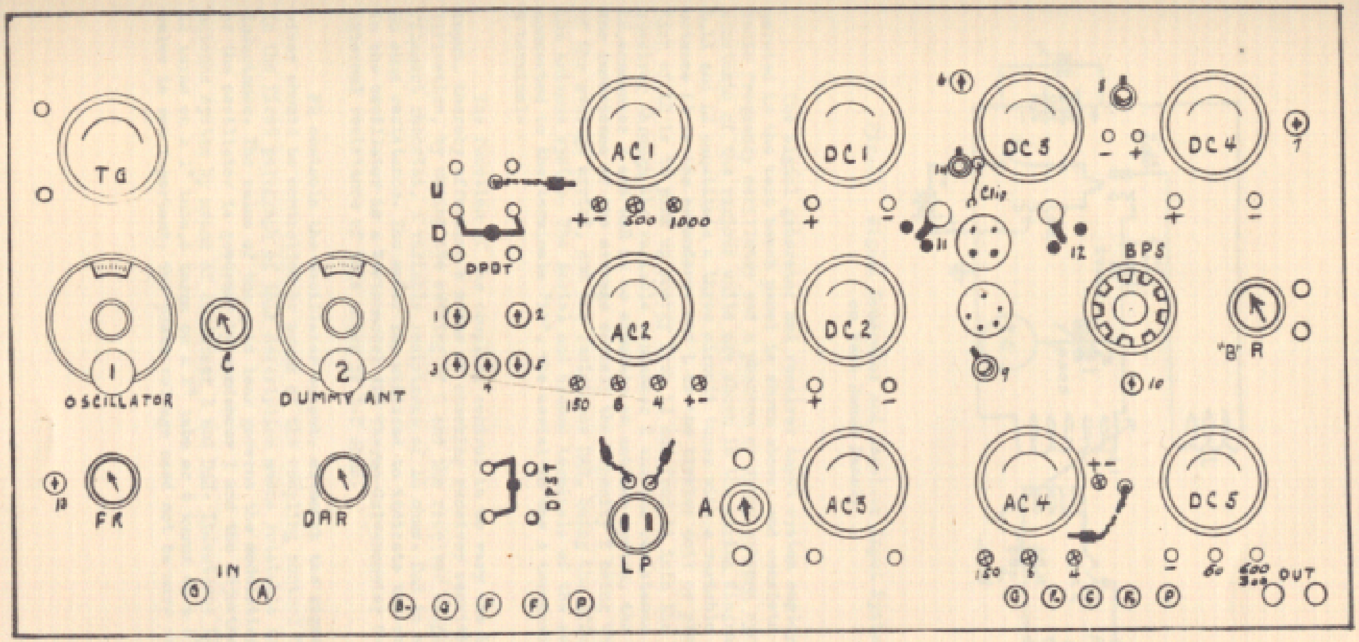


Fig 50. Test Bench Panel

Terminals ● are pin jacks

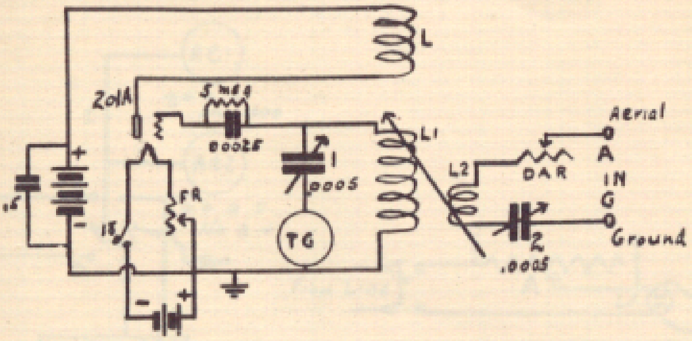


Fig.31 Signal Generator and Receiver Input System Employed on Test Bench Panel.

The signal generator and receiver input system employed or rather incorporated in the test bench panel is shown above, and consists of a self modulating radio frequency oscillator and a phantom or dummy antenna system. The electrical constants of the various units are shown in the wiring diagram. The inductances L,L1 and L2 constitute a three circuit tuner with a variable primary L2. The inductance L1 is the secondary, and L is the tickler coil or plate winding. The function of L2 is to pick up energy from L1 and feed it into the aerial coil in the receiver through the variable condenser 2 and the resistance DAR. The purpose of L2,condenser 2 and DAR is to simulate an antenna system, the inductance L2 being the inductance of the average aerial; the capacity 2 being the distributed capacity of the average aerial, and the resistance DAR, being the effective resistance of the antenna system. The Aerial and Ground terminals of the receiver under test are connected to the terminals "IN", the aerial to the A terminal and the ground to the G terminal.

The function of the coupling control is to vary the intensity of the signal input, thereby affording a means of checking receiver sensitivity and overall amplification, by noting the setting of C and the receiver output. FR is the oscillator filament rheostat, a variable resistance of 15 ohms. DAR is an ordinary rheostat of 50 ohms resistance. The meter TG, utilized to indicate the radio frequency current in the oscillator is a Westonmodel 425 Thermo-Galvanometer 0-115 milliamperes. The internal resistance of this meter is 5.3 ohms.

FR controls the oscillator output, although the signal input into the receiver should be controlled by means of the coupling control C. The term 'variable' in the first paragraph of this description means rotatable rather than variable in inductance. The value of the grid leak governs the modulating frequency. The tuning of the oscillator is governed by condenser 1 and the adjustment of the ficticious antenna system by means of condenser 2 and DAR. Inductance L2 need not be more than 12 turns on a 1" tube,8 turns on a 2" tube or 6 turns on a 3" tube. Its inductance value is not important. The plate voltage need not be more than 45 volts.

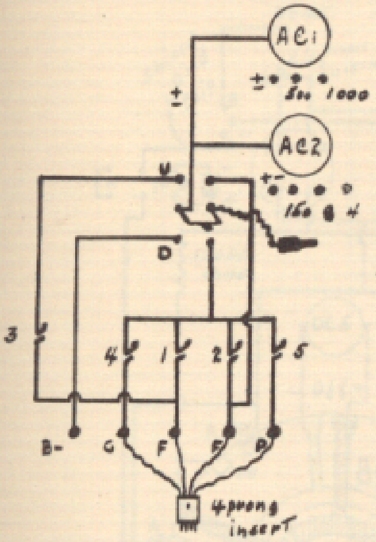


Fig. 32

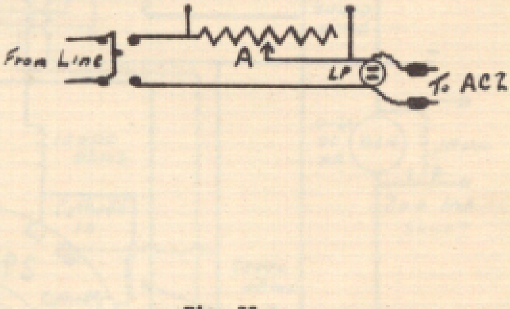


Fig. 33

The second part of the test bench panel consists of the unit utilized to measure the AC voltages applied to B battery eliminators, a manually operated line voltage control resistance whereby the input voltage to power devices may be determined, equipment for voltage output curves of filament transformers and a variable resistance utilized when determining voltage output curves of A eliminators.

The B eliminator tester is shown in figure 32 and the various AC voltages applied to the rectifier tubes are determined by utilizing the voltmeters AC 1 and 2, the DPDT switch and the small contact switches 1 to 5 inclusive. The principle governing the use of this arrangement is described on page 10. In this case, however, we utilize switches rather than the plug mentioned on page 10. The U position of the DPDT switch is used when measuring filament voltage applied to rectifier tubes or any other AC voltages between 0 and 150 volts, the plug being inserted into the proper voltmeter pinjack. Contact switch 3 controls this circuit.

To test a B eliminator, that is, the AC voltages applied to the rectifier tube or tubes, the rectifier tube is removed from the socket and the 4 prong insert plugged into the rectifier tube socket. The B minus terminal connects to the B minus of the eliminator or to the maximum C negative if grid bias voltage is also available from the eliminator. For voltages above 150 volts AC, the switch is set to D and the voltmeter plug inserted into the 500 volt or 1000 volt jack. The correct contact switch is then manipulated. The circuits mentioned on page 10 are controlled by the similar numbered switches, Reference to page 10 will explain the function of this system.

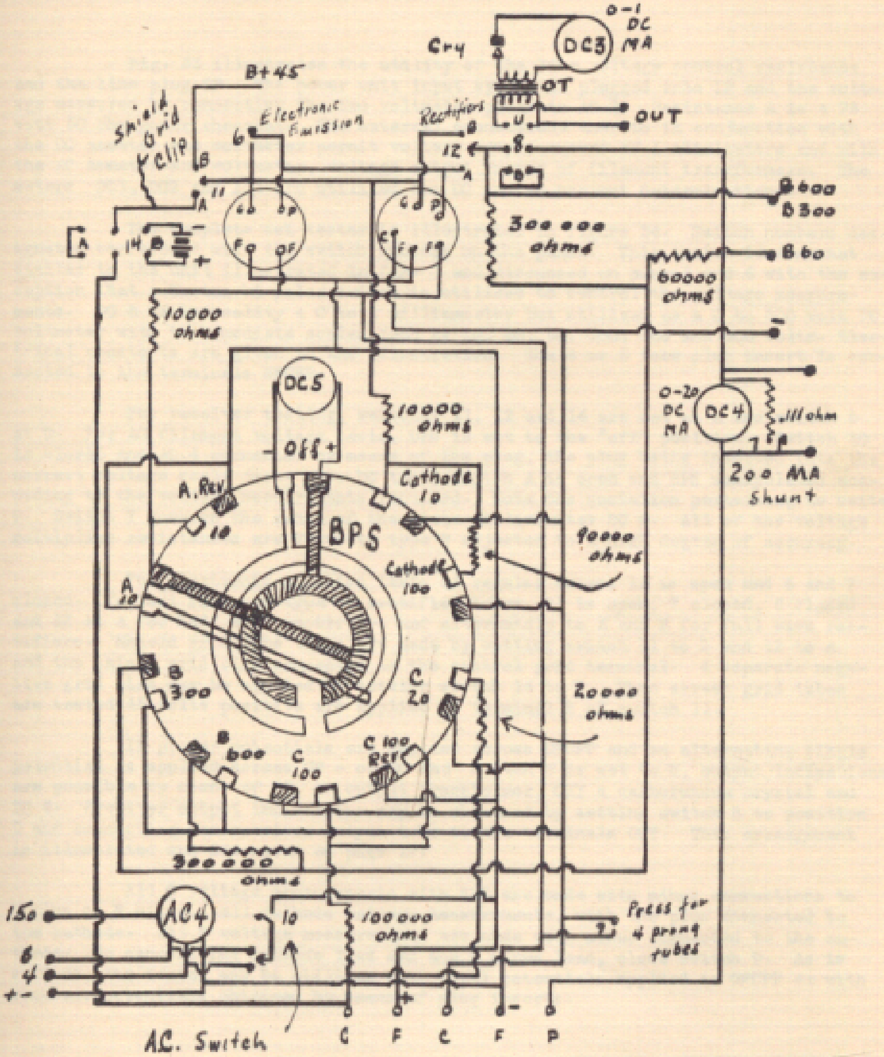


Fig. 34

Wiring diagram of panel bench set tester and tube tester.

Fig. 33 illustrates the utility of the line voltage control resistance and the line plug LP. The power unit input system is plugged into LP and the voltage measured by connecting the two voltmeter plugs to AC 2. Resistance A is a 75 watt 50 ohm power rheostat. The external connections thereto in conjunction with the DC ammeter and voltmeter permit voltage output curves of A eliminators and with the AC ammeter and voltmeter, voltage output curves of filament transformers. The meters DC1, DC2 and AC3 are utilized for DC and AC current determinations.

The complete set tester is illustrated in figure 34. Switch numbers designated correspond with the switch numbers on the panel. This tester is somewhat similar to the unit illustrated in fig. 3 and discussed on pages 5 and 6 with the exception that a Weston bi-polar switch is utilized to control the voltage measurements. DC 5 is in reality a 0 to 1 milliammeter but utilized as a 0 to 600 volt DC voltmeter with intermediate scales such as 10, 20, 60, 100, 300 and 600 volts. Electrical constants are given in the illustration. The 4 or 5 tube plug insert is connected to the terminals GFCFP.

For receiver testing, switches 11, 12 and 14 are set at A and switch 8 at D. For AC filament voltage tests, BPS is set to the "off" position. Switch 10 is closed and AC 4 connected by means of the plug, the plug being inserted into the correct voltage scale jack. For DC test, switch A is open and BPS manipulated according to the voltage measurements required. Note the quotation pertaining to switch 9. Switch 7 governs the range of the plate milliammeter DC 4. All of the voltage multiplier resistances are Truvolts type B adjusted to a high degree of accuracy.

For electronic emission tests of regular tubes, 11 is open and 6 and 7 closed. To test filament type of rectifier tubes, 11 is open, 7 closed, 6 closed and 12 at A for half wave rectifiers and alternately to A and B for full wave rectifiers. Shield grid tube tests are made by setting switch 11 to B and 12 to A and the shield grid clip connected to the control grid terminal. A separate negative grid bias may be applied by setting switch 14 to B. When screen grid tubes are tested 45 volts positive are applied to terminal B of switch 11.

If proper potentials are applied across GFCFP and an alternating single potential is applied across GF - or GC and switch 8 is set to U, output indications are possible by means of OT, an output transformer, CRY a carborundum crystal and DC 3. Receiver output indications may be obtained by setting switch 8 to position D and connecting the receiver output tube to the terminals OUT. This arrangement is illustrated and discussed on page 17.

All C voltage measurements with BPS are made with minus connections to F plus or F minus, all cathode voltage measurements, with the plus connected to the cathode. All B voltage measurements are made with minus connected to the cathode. To connect the cathode lead and the F minus lead, close switch 9. As is evident, the tester may be utilized with local potentials applied to GFCFP or with receiver potentials obtained by means of plug inserts.

Appendix

Electrical measuring instruments are indispensable to every individual who has occasion to come in contact with electrical devices, and among this classification are radio service men, custom set builders, non-professional set builders and every radio receiver owner. Electricity in general, to the multitude in general is a mysterious agent. We at the present time are concerned with radio, consequently will devote our discussion to that phase of the electrical industry.

Every part of a radio receiver is a vulnerable item. The electrical forces acting within these units, curbed by the knowledge of man, are constantly seeking an exit. The slightest slip, the slightest error and some unit or perhaps a complete device must be replaced. Electrical measuring devices are therefore, essentials wherever electricity is the actuating power. Comprehension of existing electrical conditions is possible by means of only one channel, electrical measuring devices or instruments. The service man who is called upon to isolate a fault, or to discover an error or to repair a defect can do so only if he has the proper electrical measuring instruments whereby he can determine existing incorrect or correct conditions. Radio receiver servicing, in fact the servicing of any electrical device, is impossible unless electrical measuring devices are utilized.

Receiver diagnoses to locate trouble cannot be accomplished by aural observation. Electricity, the mysterious agent, is invisible to the naked eye but clearly visible to the same eye when its reactions are noted upon electrical indicating or measuring instruments. Correct operating conditions in a radio receiver cannot be determined unless electrical meters are employed to indicate the current and potential at various points.

The radio service man in particular must be a prolific user of electrical meters since they afford rapid, economical and accurate servicing. The radio service man cannot operate without meters. He requires potential indicating devices to determine plate voltage, filament voltage, line voltage, grid voltage, eliminator voltage and many others. He requires current indicating devices to determine plate current, filament current, grid current and many others. Every one of these indications gives him information relative to the operation of the receiver. These indications alone, permit the isolation of the source of trouble, since he is visually advised of incorrect operating conditions. Every form of trouble becomes evident when electrical measuring devices are employed.

It is true that correct interpretation of the meter indications is imperative but neither diagnoses or interpretation are possible if existing conditions are unknown. The abundent use of electrical meters is the basis for successful and profitable radio receiver servicing.

The custom set builder is in like position. He, cannot determine the efficacy of the various components which he contemplates utilizing and incorporating in the tailored receiver. His product must be the acme of coordination and this is impossible unless he is aware of the electrical characteristics of every one of the units employed in the receiver. To determine these electrical characteristics you must employ indicating devices. Hence electrical meters are the basis for successful custom receiver building.

The radio receiver owner likewise requires electrical meters in order to protect his receiver investment. This is particularly true since the advent of electric receivers and power sources for filament, grid and plate potentials. The operating life of many units employed in the receiver, is governed by the potentials applied and unless one knows accurately, the existing electrical conditions, it is impossible to operate in a satisfactory manner. Electrical meters are visual guides and their use is justified in every instance. The lack of an electrical meter is daily costing thousands of dollars to radio receiver owners in this country and it is the duty of the service man or the custom set builder to advise the use of electrical indicating instruments or to incorporate such devices when a receiver is sold.

Believing that the custom set builder and the service man should have a knowledge of electrical indicating instruments, we present the following, an excerpt from a monograph published by the Weston Electrical Instrument Co. and entitled "Principles of Permanent Magnet Movable Coil and Movable Iron Types of Instruments." Electrical meters available today are of various types and thorough comprehension of these types will prove of inestimable value.

Direct Current Permanent Magnet Pivoted Movable Coil Type of Instrument.

Examine the assembled internal construction (Fig. I) of a direct current permanent magnet, pivoted, movable coil type of instrument. Then we shall dissect it so that its parts may be considered in detail.

You will note that the most prominent visible parts depicted in Fig. I are a magnet and a movable coil. The latter is made of several turns of wire carefully insulated and wound upon a rectangular aluminum frame. This coil is pivoted in sapphire bearings and arranged so that a current may flow through its windings. By virtue of its mounting, rotary motion only is possible. This motion is opposed by means of two springs which also serve as conductors to carry the current into and from the movable coil winding.

It should be remembered that this movable coil, although containing no iron, has all the properties of a magnet when a current is sent through it; and therefore, it will have polarity. Since it lies in an intense magnetic field it will tend to move -- due to the action between the electro magnetic effect created by the current carried in the winding of the coil and the magnetic field of the permanent magnet causing these two magnetic fields to establish a certain relation of their respective lines of magnetic force.

Hence, when current is sent through the movable coil which also carries a permanently affixed pointer (see Fig. V) a deflection will be obtained corresponding to the strength of that current. The pointer moves over a precisely calibrated scale and indicates the value of the current being measured.

Ampere's law which shows the attraction of a magnet to a movable circuit carrying a current, serves very nicely to demonstrate the fundamental principle of the instrument, but in applying this principle to an instrument of precision each operative part must be so nicely designed and proportioned that the apparatus as a whole will give uniformly dependable results.

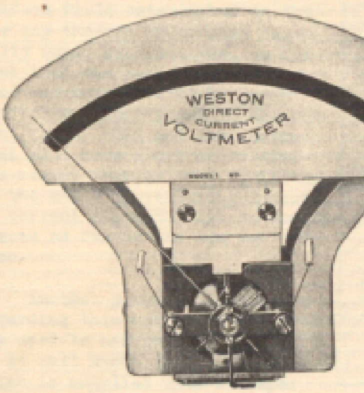


Fig. I

Direct Current Movable Coil System

We should now consider the permanent magnet, or rather the field pattern of the magnet made visible by iron filings (Fig. II)

As you see, the effects of the magnetic lines of force are made visible in every direction. Only those passing directly between the poles are of service in the operation of the instrument. These useful lines of force that form the field in the space where the movable coil rotates normally, consist of nearly straight lines between the poles of the magnet. However, such a distribution of the lines of force does not serve our purpose as will be seen later.

The next step in the construction of the magnetic system is the addition of pole pieces attached to the ends or poles of the magnet.

The addition of these pole pieces has the effect of concentrating the magnetic lines that we wish to use, and that they form a ring on the faces of the pole pieces. Yet there are some lines in the center which are still parallel and have not taken a uniformly radial position such as is desired.

The radial position of these lines is the ideal that is sought since it gives us a concentrated and uniform field throughout the path of rotation of the moving coil. To obtain this uniform or radial field, a cylindrical core of soft iron is inserted.

In Fig. III it can be readily seen that we now have obtained a uniform radial field.

To permit freedom of rotation of the movable coil within this radial magnetic field, the

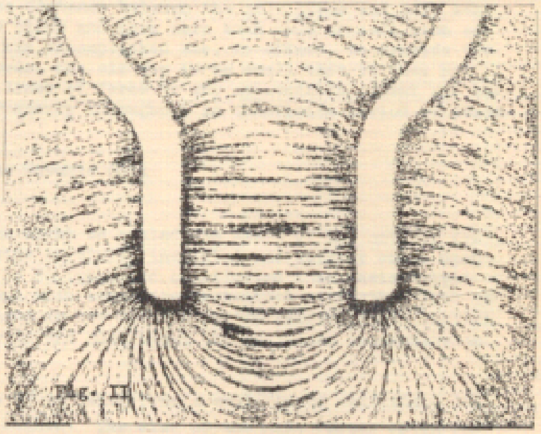
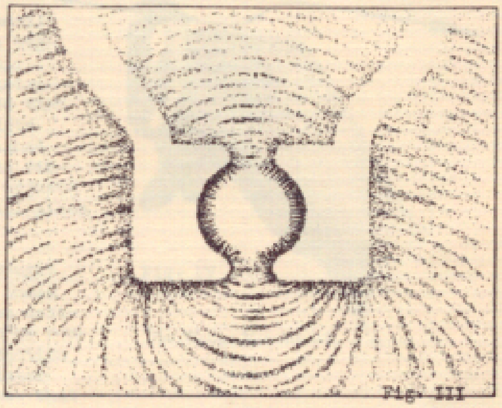


Fig. II

Lines of Force of a Weston Permanent Magnet.

air gap between the core and pole pieces must be accurately established. This is made possible through precise mechanical manufacturing operation. The air gap, for an average instrument, is made 0.05 inch in width, i e, the annular space between the pole piece and core through which the moving coil travels is 0.05 inch wide.



Lines of Force of a Weston Permanent Magnet with Pole Pieces and Core.

Since there is practically a uniform field established in the air gap through which this carefully wound coil rotates, it follows that the deflection of the coil and pointer will be correspondingly proportional to the current in the coil and the instrument will have a uniformly divided scale, that is, the divisions on the scale representing increase in current strength will be evenly spaced as far as the eye can discern.

Another point of importance regarding this magnet is the methods used to assure its permanency. It is well known that a magnet which is supplied with a keeper or piece of soft iron will retain its magnetism longer than with no keeper, and when this keeper is properly designed, the magnetism will be retained unimpaired indefinitely, as it provides a path of low reluctance for the lines of force.

You will recall that the distance between the pole piece and core was made very minute and that the pole piece and core were each made of soft iron so you can readily see what actually was accomplished was, in effect, to provide the magnet with a keeper. In other words, the air gap is so small that it does not disrupt or impede the path of the lines of force to any appreciable extent and enables the magnet to retain its permanency throughout an indefinite period of years.

The Movable Coil

The Movable Coil, which might be called the heart of the movable system, is made of several turns of wire carefully insulated and usually wound upon an aluminum frame. Its parts are so designed and constructed that their weight is reduced to the minimum consistent with requisite mechanical strength. This is very important since excessive weight in the movable system causes pivot friction and a rapid wearing out of the pivots and also makes the coil less responsive to small changes in current.

The coil shown in Fig. IV is taken from a switchboard voltmeter, its dimensions are roughly 1 by 1-3/8 inches. The size of the many Weston coils depends upon the type of instrument in which they may be used.

In the popular miniature precision instrument known as the Weston Model 280, the movable system weighs less than 0.2 gram, although consisting of sixteen parts.

Some of these parts are so small that they must be examined under a magnifying lens in order to learn their exact form. Yet, their mass is distributed with such care and exactitude that the center of gravity of the complete movable coil is almost exactly aligned with the pivots. This alignment is finally perfected by means of minute adjustable nuts on the cross arms and tail piece of the pointer.

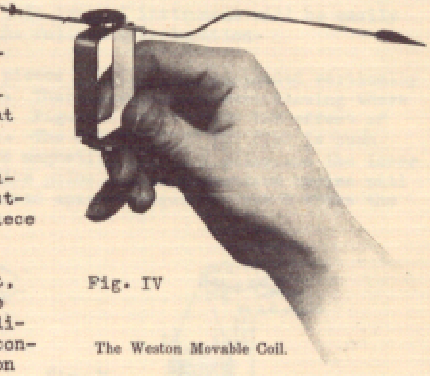


Fig. IV

The Weston Movable Coil.

The student may, at first thought, conclude, due to the smallness of these parts, that the instruments are too delicate for commercial work, but when he considers that the only mechanical function of these parts is to carry the pointer across the scale, he can readily see that the parts are more than adequate in size and strength for the work for which they are intended, even when consideration is given to incidental overloads and shocks of an ordinary character.

In conclusion, we might add that the design of these instruments has been so perfected and the various parts so carefully coordinated in regard to the functions they severally perform, that this corporation is enabled to supply an instrument of quality for any field of service known at the present time.

Another point to be noted in reference to the action of this moving coil is the manner in which it is "damped". That is, the way in which its motion is slowed down to prevent excessive overswing and oscillation before settling to rest at its final position.

You will remember that the coil is wound on an aluminum frame. Thus when it rotates through the magnetic field of the magnet, currents are induced in it. These currents are known as eddy or Foucault currents and since they are produced by the oscillation of the coil, they absorb energy from the movable system and greatly diminish the amplitude of the swing, quickly bringing it to rest.

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Movable Iron or Electromagnetic Instruments

The movable iron or electromagnetic type of instrument finds wide application as a commercial AC instrument for current and voltage measurements.

The principle of operation of this type of instrument will be easily understood by referring to figure V and the following explanation.

In Figure V sub 1 we have two pieces of soft iron suspended vertically in a coil or solenoid by means of threads. There being no current flowing there will be no action between the iron pieces. Figure V sub 2 shows the effect of passing a direct current through the coil. The direction of the flow is such that the upper ends of the iron pieces are magnetized to be N poles and the lower ends of the iron pieces S poles. Since like poles of two magnetized bodies will repel one another, the iron pieces are forced apart. Figure V sub 3 shows the same action but with the current reversed. If this reverse is sufficiently rapid the iron pieces will remain apart until the current flow is stopped. Fig. V sub 4 illustrates the coil horizontally placed with one iron piece fastened so that it cannot move while the other piece is free to move. Figure V sub 5 shows the effect on this arrangement when current flows. In Figure V sub 6 the movable iron piece is attached so that it can only move by rotation. Thus when current is passed through the coil the movable piece will rotate on its staff and the pointer attached to it, will move over the scale. This is virtually the manner in which the movable iron repulsion principle is applied in the Weston instruments.

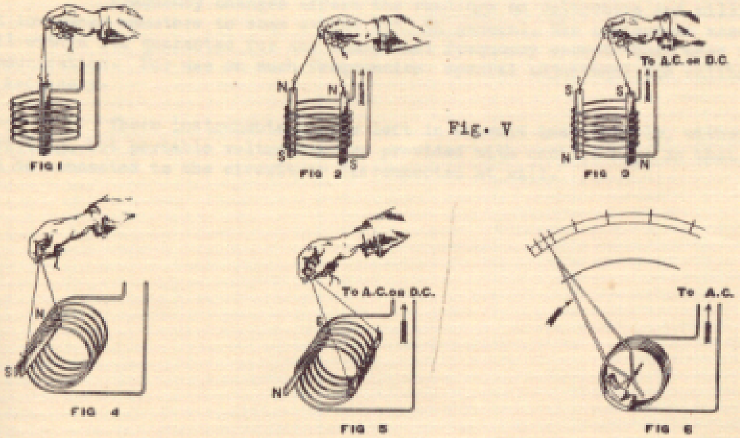

FIG 1 FIG 2 FIG 3

Fig. V

FIG 4 FIG 5 FIG 6

Rotation of the movable iron piece is opposed by a spiral spring. The force causing rotation depends on the strength of the magnetic field set up by the coil or solenoid. The field strength depends on the current flowing. Thus when current flows through the coil, the movable iron piece will rotate to such a position where the rotational force and spring force become equal. Motion then stops and the pointer position shows the scale value for the current flowing.

In an ammeter the current passes through a relatively heavy conductor in the form of a coil. The size of this conductor and the number of turns in the coil depend on the current range of the instrument. In a voltmeter, a large number of turns of comparatively small wire makes up the coil. In order that the low resistance of the coil might not permit an excessive current to flow when the instrument is connected to the circuit, a resistance is placed in series with the coil so that the current flowing through it is reduced to the required value.

This type of instrument will operate on either direct or alternating current, but it is more accurate on alternating current.

Frequency changes affect the readings on voltmeters and milliammeters and low range ammeters to some extent but, in general, the instrument accuracy is well within its guarantee for any commercial frequency except those used in radio communication. For use on such frequencies, special adjustment and calibration is necessary.

These instruments may be left in circuit indefinitely, without error resulting, but portable voltmeters are provided with contact keys so that they can be connected to the circuit or disconnected at will.