TREASURE-SEEKING CIRCUITS

AN ELEVEN-PAGE ARTICLE BY J. E. ANDERSON

RADIO WORLD

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A Simple Transmitter for Beginners

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6L6 Transformerless Push-Pull

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Commercial Capacity Meters

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SEPTEMBER

1936

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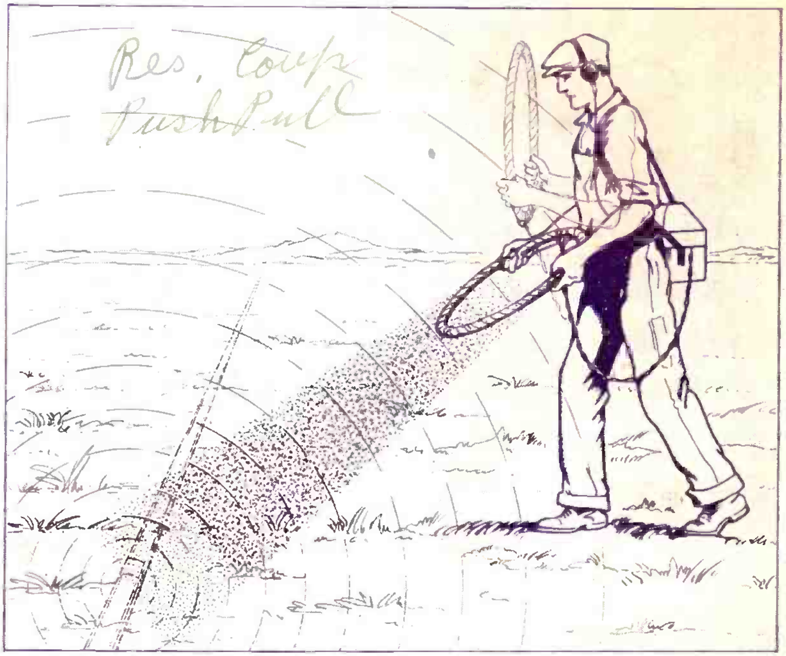

An electromagnetic method of locating cable, by producing a wave that does not interfere with the cable current, has been developed by Bell Telephone Laboratories. See page 18.

SIMPLE TUBE VOLTMETERS

A THIRTEEN-PAGE ARTICLE BY HERMAN BERNARD

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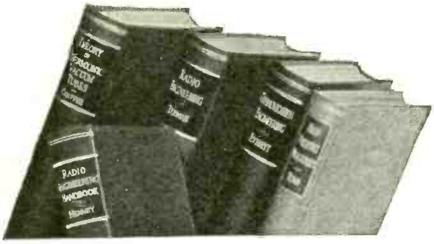

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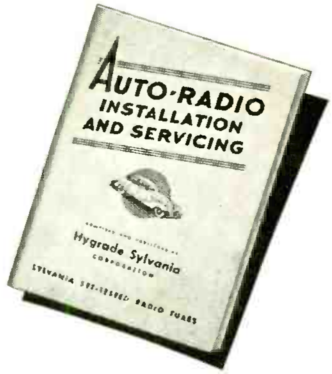

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Treasure-Seeking Circuits

Methods of Wresting Secrets from the Earth That May Lead to Fabulous Riches

By J. E. Anderson

HIDDEN treasure has always commanded interest and always will. The hope of sudden acquisition of immense riches is exciting and fascinating and often leads to rash expeditions and undertakings. Often the cost of the search is vastly greater than value of the treasure when and if found.

By hidden treasure is not meant alone the hoards of gold and silver and precious stones buried by pirates of old on tropic isles, but includes sunken ships, usually with gold cargo, flowing water veins in dry regions, oil, gas, salt of various kinds, ores yielding gold and silver and other valuable metals, and coal. All these, in most instances, are hidden, either by men or by nature.

WHERE SCIENCE STANDS OUT

To reduce the cost of exploring for hidden treasures and to increase the chances of finding them, countless devices have been invented in this and other countries for finding them. Thousands of patents have been granted. How many of these are experimentally valid is hard to say. Some of the devices are arrangements based on no theory and very likely on no practice, and the inventors leave the impression they do not know what it is all about. These so-called inventors disclose, not a new device or method, but only their own ignorance. Any one who reads these patents critically is left with a feeling of profound disappointment.

Of course, there are a few patents based on scientific principles, made by inventors who had a thorough grasp of the subject. The disclosures of the means and methods are lucid, logical, and understandable. Whether or not these devices function well is another matter. The observations with the devices must be taken skillfully and precisely to have any definite meaning, and the data collected must be interpreted expertly.

All devices for locating underground treasures are based on the supposition that the presence of an orebody or other valuable mineral deposit makes the earth under the surface nonhomogeneous. The valuable deposit may be more dense or less dense than the surrounding earth. It may have greater or less electrical conductivity, or greater or less specific electric conductivity, or greater or less mechanical elasticity, or it may have greater or less magnetic permeability.

Means, methods and devices for locating hidden treasures may be divided into several groups, depending on the physical property of the soil. Thus the methods may be divided into (a) gravitational, (b) magnetic, (c) seismic, (d) electrical, (e) geothermal, and (f) radioactive.

THE METHODS EXPLAINED

The gravitational methods depend on the nonhomogeneity of the density of the earth, and pendulums, either ordinary or torsional, are used for detecting the presence of a disturbing element, such as a pool of oil. Pendulums are

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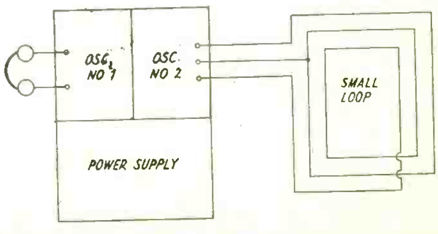

FIG. 1
Required components of a simple heterodyne treasure finder. A loop and two oscillators are used.

Author's Report Based On Exhaustive Research

The data contained in J. E. Anderson's article on treasure-seeking circuits were obtained from original sources during an investigation lasting several weeks and are authoritative. Greatest stress has been laid by the author, who is himself a physicist as well as radio engineer, on those methods and circuits well grounded on scientific principles. It must be borne in mind, however, that neither the author nor the editors and publisher of RADIO WORLD devised these methods, and that responsibility for the accuracy and practicality rests with the originators of the devices.—EDITOR.

(*Continued from preceding page*)
used for "weighing the earth," or for determining the gravitational attraction. This attraction is greater the more dense the earth is in the immediate vicinity of the pendulum. By weighing the earth systematically at many points in the region to be explored for minerals, an idea can be obtained as to the nature of the soil deep under the surface.

The magnetic methods depend on the distortion of the earth's magnetic field by the presence in the ground of paramagnetic substances, such as iron, nickel, cobalt and certain compounds of these. Such magnetic substances would carry the magnetic flux more easily than the surrounding substances, and the lines of force would point in the direction of the ore-bodies, or would deviate somewhat toward them. Both the horizontal and the vertical components would be affected and observations could be made on either. Apparently, most

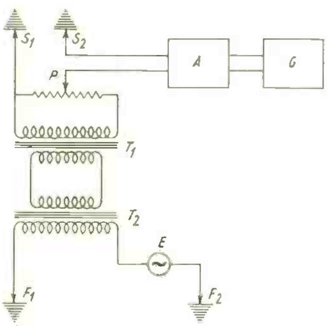

FIG. 2
Ambronn's arrangement for exploring the sub-soil for conductive ores and minerals.

observations are made on the vertical component, and the simplest instrument is a magnetic needle capable of turning freely on a horizontal axis, that is, a dip needle.

The seismic methods depend on elastic properties of the earth. A seismic disturbance is started at some point in the region to be explored, and then the manner of propagation of this disturbance in the surrounding territory is determined by measurements at selected receiving points. At these places the time of arrival, the direction of arrival, and the intensity of the disturbance are measured. The disturbance, usually, is the detonation of a charge of explosive at some distance below the surface, but other methods of setting up strong seismic waves may be employed.

SEARCH FOR NONHOMOGENEOUS

If the earth possesses horizontal homogeneity the field pattern, or graph, of any one of the measured quantities will be quite regular. But, on the other hand, if there is lack of homogeneity in the elastic constants of the earth, the field pattern will be considerably distorted. An inelastic body, such as lead for example, would absorb the seismic wave energy, and such a body would throw a shadow in one direction. That is, it would make the intensity of the received waves zero or weak. It would also change the direction of the waves.

Another body may be highly elastic. This would absorb little energy, the waves would travel faster, and they would be stronger on arrival at any of the receiving points influenced by that body. Again, there might be reflections of waves, which would occur whenever the wave front hit a boundary between two layers of different density.

The devices used for detecting seismic waves set up artificially are based on the same principles as those that are used for detecting and measuring earth tremors. That is, they are seismographs or seismometers. Naturally, they have to be portable.

The electrical method depends on the electrical properties of the various substances in the earth. Some employ direct current and others alternating. Of the alternating some employ sub-audible frequencies, some audible, some super-audible, some low radio frequencies, and some ultra-high radio frequencies. The properties employed are the resistivity, the specific inductive capacity, and to some extent the permeability.

MUCH ATTENTION ON INDUCTION

Induced currents in subterranean conductive masses form an important element in the theory of many instruments. If an alternating current is started between two separated points, the resulting varying magnetic force will induce currents in any conducting bodies that may be below the surface. These currents in turn will set up a secondary varying magnetic field. Both the primary and the secondary fields will affect the receiving instrument. The secondary field will arrive at the receiving point out of time phase with the primary. The resultant field, therefore, will be elliptically polarized.

The presence of elliptical polarization in the magnetic field is a definite indication that there is a conductor in the vicinity of the apparatus.

There are two classes of apparatus based on this principle, one making use of the magnetic component and the other of the electric component of the electromagnetic field.

The geothermal methods depend on the measurement of the earth temperatures by lowering the instruments into boreholes. The vertical temperature gradient, or the change of temperature with depth, in the different strata gives an idea of the nature of the earth surrounding the boreholes.

The location and extent of certain mineral deposits can be determined by detecting and measuring the emanations from them due to their radio-active properties.

THE DIVINING ROD

The oldest and best-known of all the instruments for subterranean prospecting is the divining rod. Searching with a divining rod for hidden material is called dowsing. The rod's

Dowsing, or searching with a divining rod for some hidden material, is an art of great antiquity. The "virgula divina" was described by Cicero and Tacitus. The illustration below shows the "virgula furcata" (forked twig) used in prospecting for metals. This illustration was reproduced, through the courtesy of the New York Public Library, from Agricola's famous "De Re Metallica," printed in 1556.

The modern professional dowser is a water-finder. He walks about holding a forked twig of hazel or willow, until suddenly the twig twitches. "There," says the dowser, "water will be found." Professor Sir William Barrett, who made the classic study of the subject, ascribed the phenomenon to "motor-automatism," an obscure reflex action somewhat similar to the homing instinct of a pigeon. The cable-dowsing method of Bell Telephone Laboratories (see page 18)*, however, depends upon electromagnetism rather than upon motor-automatism.*

origin has been lost in antiquity. Its attempted use is practically universal. Its primary purpose is to predict where underground streams flow, and thus to save the work of digging dry wells. In one of its form it consists of a Y-shaped twig cut from a sour apple tree. If the twig is cut and used in the spring when the sap flows copiously and when the ground is soaked, it may sometimes be effective to disclose the presence of water.

The method of using the divining rod is as follows: The observer grasps one prong of the Y in each hand, between his thumb and index finger, with the stem of the Y pointing upward, and then walks slowly over the terrain to be explored. When he comes to an underground water course the divining rod twists between his fingers until the stem of the Y points downward directly at the water. This method

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works spectacularly if the twig-twister can "allow" skillfully the twig to turn against much ostensible opposition. The scheme might have been abandoned centuries ago if it had not produced some results. It must be admitted that digging a well without the assistance of a divining rod is equally promising of abundant water, provided the well is dug deeply enough.

THE HETERODYNE METHOD

An electrical method which has some scientific basis depends on the beating of two loosely-coupled high-frequency oscillators. The two oscillators may be of any type, and they should preferably be equal except in the type of coil used. Both should be as small as practicable and both must be portable. One of

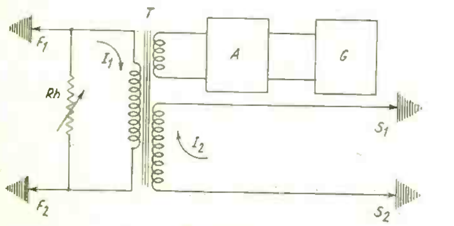

FIG. 3
A modification of the arrangement in Fig. 2 in which the detecting circuit is not included in the earth circuit.

them is carefully shielded from the other and from the observer, and its frequency is fixed, although there may be a provision for changing the frequency for adjustment purposes. The other is also shielded except that the oscillating coil is in the form of a loop. This loop should be attached to a handle of convenient length so that it may be placed flat on the ground or very close to the ground. The leads to the loop should be insulated from the handle and shielded. The handle should be of such length that the observer may put the loop on the ground without stooping. This is for comfort and convenience only.

The two oscillators are adjusted so that when the loop coil is placed on dry ground which contains no conducting bodies, the two frequencies should be equal. That is, the oscillators should be adjusted to zero beat. Now suppose that a conductor of any kind is placed in the field of the loop. The currents induced in the conductor will alter the inductance of the loop and therefore the frequency. This change will appear as a change in the beat frequency.

It is clear that the higher the frequency of the two oscillators the greater will be the sensitivity of the device. Therefore the frequencies used should be rather high radio frequencies, at least above 10 megacycles. The change in the beat frequency will be greater the larger the conducting body, the closer it is to the loop, and also the better the conductivity of the body. Even small metallic objects near the loop will affect the beat frequency appreciably.

The method of observation is as follows: The operator carries the loop in one hand and the shielded oscillator box in the other. He adjusts for zero beat. He then walks slowly over the terrain to be explored. holding the loop close to the ground with its plane horizontal. Whenever the loop comes near a piece of metal, the frequency will change, and the change will be greatest when the object is directly under the center of the loop and the loop is on the ground.

One man who operated a treasure finder of this kind for a short time reported locating a quarter, a few dimes, four nickels, a piece of a horseshoe, one big spike, one little spike, a peck of assorted nails and tacks, and a few trinkets. He also acquired some experience in the behavior of beat frequency oscillators. Fig. 1 gives an outline of what is required for a treasure finder of this simple type.

LOW FREQUENCY METHOD

A low frequency treasure finder due to Richard Ambronn, of Germany, is illustrated in Fig. 2. E is a generator of an alternating voltage of from 0.3 to 10 cycles per second of as little harmonic content as possible. This is connected in series with the primary of a transformer T_2. The circuit is completed through the ground to be explored for minerals, one side of the transformer primary being connected to a grounded electrode F_1 and one side of the generator being connected to another electrode F_2. These two grounded electrodes are at some distance apart, the actual distance depending on the extent of territory to be explored and on the thoroughness with which it must be done. It is clear that an alternating current will flow in the ground between the two electrodes and that this current will spread out, both sidewise and downward. If the earth in the vicinity of the apparatus is homogeneous, or if it is made up of homogeneous horizontal layers, the lines of current flow will be regular, and so, also, will be the equipotential lines on the earth's surface between the two points F_1 and F_2. But if there is a conducting body in the vicinity of the apparatus the field pattern will be distorted. If this distortion could be charted an idea of the size and location of the disturbing body could be obtained.

One way of charting the field is to set up a very sensitive detector of the ground currents. This detector is connected to ground by means of two spaced electrodes S_1 and S_2. A is a high gain amplifier and G is a vibration galvanometer, the moving element of which is tuned to the frequency of the current used. The tuning not only increases the sensitivity manifold but it also eliminates stray earth currents and harmonics of the generator E.

WHEN GALVANOMETER DEFLECTS

If S_1 and S_2 be driven into the ground at random, there will in general be a deflection on the galvanometer. However, for a given position of S_1 there will be an infinite number of points at which S_2 may be placed so there will be no deflection. These points all lie on an equipotential line. When one such line has been obtained, S_1 is moved to another point and the second equipotential line is found by moving S_2 to points where no deflection occurs. Many such lines should be taken. Lines of current flow may be drawn between F_1 and F_2 by tracing them so that they are at right angles to all the equipotential lines. By examining the chart for deviations from regularity in the field pattern, conducting bodies can be located.

It may not always be possible, however, to get a null point by the simple arrangement disclosed above. Then a minimum is first found and the remainder is balanced out. This is done

ment are suggested by the inventors, but none is claimed as exclusively correct. What is claimed is that the arrangement works and that the inventors have located valuable oil and gas deposits by means of their prospecting system.

EARPHONES USED

In Figs. 5 and 6, E is a generator of frequencies (60 cycles up) at a voltage of 110 volts or more. M is an alternating current meter. K is metal stake driven into the ground and is a fixed electrode. P_2 is the other electrode when near K and P_1 the other electrode when far removed from K. For convenience P_1 and P_2 are equal and separate electrodes either of which can be selected by means of switch S. C3, which is picked up when S is

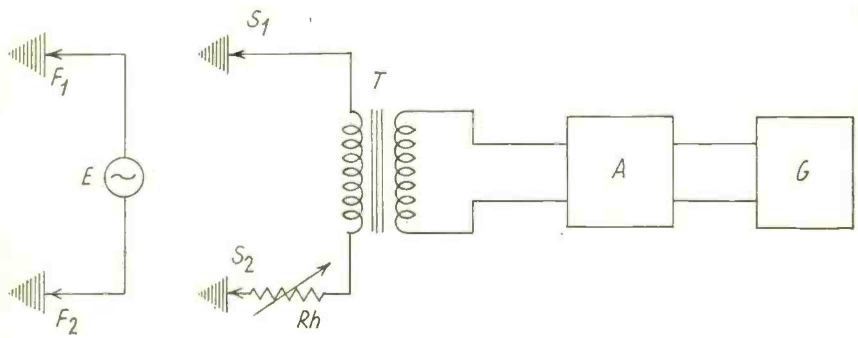

FIG. 4
A third form of Ambronn's arrangement for prospecting for minerals.

by diverting part of the transmitted current to the receiver through transformers T_2 and T_1. By making an adjustment on the potentiometer P a true null point can be found. Figs. 3 and 4 show two modifications of the arrangement in Fig. 2.

AN IMPEDANCE METHOD

In Fig. 5 is illustrated a method due to Billotte and Lipson. The equivalent circuit is shown in Fig. 6. The capacities C_1 and C_2 in Fig. 6 are the capacities of the metal plates P_1 and P_2 with respect to the earth. These plates are separated and insulated from the earth by sheets of bakelite or similar non-conductors.

From Fig. 6 it appears that this method of locating orebodies depends on the measurement of the resistance between two spaced points, which is done by a differential method, or by measuring the impedance between the two points. The arrangement is said to be useful for detecting the presence of deposits of oil and gas because of the fact that the dielectric constants of these substances differ from those of the surrounding rocks. And it is possible to differentiate between the two, because, it is claimed, if the deposit is oil the meter needle is steady, whereas if it is gas the needle fluctuates and behaves erratically.

Several theories of operation of this arrange-

set on point (3), is used for establishing proper zero setting.

Fig. 7 shows more in detail the transmitter E and the receiver-detector M. The generator is an 800-cycle buzzer powered by means of a battery B. A filter consisting of two 1 mfd. condensers and a one henry coil is inserted in the circuit to improve the tone and facilitate oscillation. Earphones are inserted in the circuit for an aural check on oscillation. Two step-up transformers T_1 and T_2 are used to transmit the signal to ground and to the detector. This is a typical vacuum tube voltmeter or biased triode detector circuit with a plate milliammeter to indicate the intensity of the signal applied to the grid. Provision is made for measuring and adjusting element voltages.

ELECTRIC FIELD METHOD

A method of locating underground orebodies based on finding the normal to the plane of the vibration ellipse of an elliptically polarized electric field has been devised and described by Ricker. As in all electrical methods, this one requires the setting up of an electric current between two spaced points in the earth. These points are designated by G_1 and G_2 in Fig. 8. E is an oscillator generating a strong alternating wave of any frequency

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of from a few cycles per second up to 20,000 cycles per second. An ammeter A is connected in the circuit to show how much current is flowing in the ground. Suitable values are 110 volts for the voltage of the generator, 10 amperes for the current, and 500 cycles per second for the frequency of the oscillator. Of course, the voltage required for driving 10 amperes through the circuit will depend on the distance betwen the two grounded electrodes and on the nature of the soil between them.

it and they will result in a secondary electric field. This will be out of time phase with the energizing field and therefore at any point in the area the electric field will be elliptically polarized. The electric vibration will be along an ellipse, as in Fig. 9, instead of along a straight line.

If a metal rod dipole antenna, such as DH in Fig. 10, is placed in the elliptically polarized field, there will in general be a current induced in the rod, and this can be detected by means of a suitable amplifier. However, there is one position in which no current will be induced, and that is when the rod is perpendicular to the plane of the vibration ellipse, that is, when it is parallel with D_1H_1 in Fig. 9, D_1H_1 being at right angles to every line that can be drawn through the center of the ellipse.

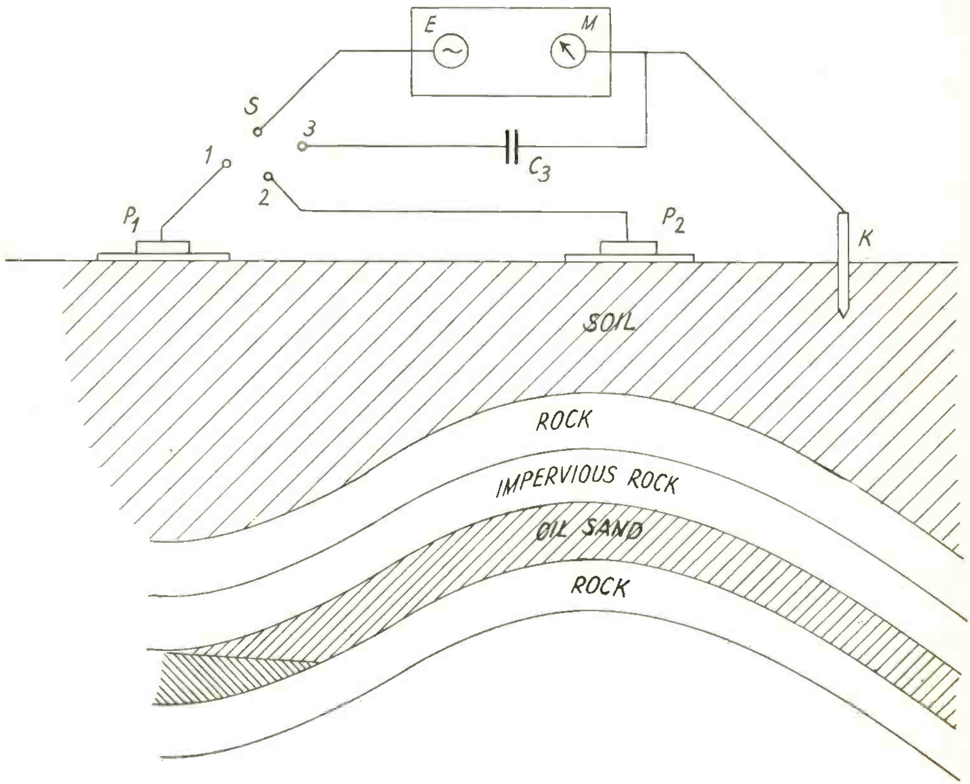

FIG. 5
Cross section of a section of the earth's crust showing a layer of oil bearing sand between rock layers together with a device for locating such a deposit. The arrangement is due to Billotte and Lipson.

If the ground between and about G_1 and G_2 is electrically homogeneous, the electric field both above and below the surface will be regular. This does not require, of course, that the ground be free from different strata. Different rock and soil strata may be present without upsetting the symmetry provided that they be of approximately equal thickness in the vicinity of the test equipment.

FORTUNE IN SECONDARY CURRENTS

If, on the other hand, there is a considerable body of comparatively high conductivity in the ground, secondary currents will be induced in

If the field is undistorted and if the center of the metal rod be placed on the line joining G_1 and G_2, or on that line produced, the line DH will be horizontal when the no-signal adjustment has been effected, and it will be perpendicular to the line G_1 G_2. But if the field is distorted and elliptically poralized, the line DH will be inclined from the horizontal by an amount depending on the polarization, and it will also devitate slightly from perpendicularity with the line G_1 G_2 when the zero signal position has been • found.

OBSERVATIONS FACILITATED

It is not necessary that the center of the metal pick-up rod always be on the line joining G_1 and G_2, but if it is the work of taking measurements is greatly simplified.

In order to facilitate observations, therefore, the metal rod DH is mounted on a portable tripod, provided with leveling screws, in such a manner that it can be turned about both a horizontal and a vertical axis passing through the center of the rod. Each axis of rotation is provided with a graduated scale so that angular displacements in both directions can be read. A peep sight is also provided so that the horizontal axis of the rod can be aligned with G_1 G_2, which is called a survey line.

The region to be explored for minerals is laid out into a large number of lines, all radiating from a common point, as shown in Fig. 11. Along these lines observation points are marked out, separated by equal distances, say 250 feet. It is convenient to number the radial lines by Roman numerals in the clockwise direction and to number the observation points along every radial line consecutively from zero upward. Thus observation point II-4 would be found at the intersection of the fourth circle and the radial line 0-II. As will be noticed, it requires two opposite radial lines to form one survey line.

Now suppose that the field to be explored has been laid out systematically as just described. We are then ready to set up the prospecting equipment. We first select one of the survey lines, say V-O-XI, and place the grounded electrodes G_1 and G_2 at V-2 and XI-2, respectively. (If the distance suggested above is used between the observation points, the distance between the grounded electrodes will be 1,000 feet.)

We next set up the tripod with the receiving equipment at one of the observation points on the selected survey line. The tripod is leveled. By means of the peep sight the horizontal axis

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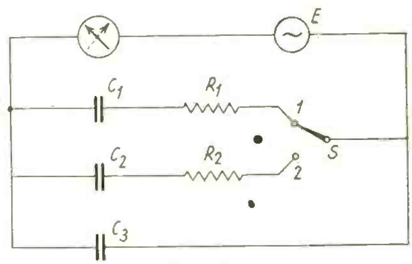


FIG. 6

The electrical circuit in Fig. 5 may be reduced to this simple network.

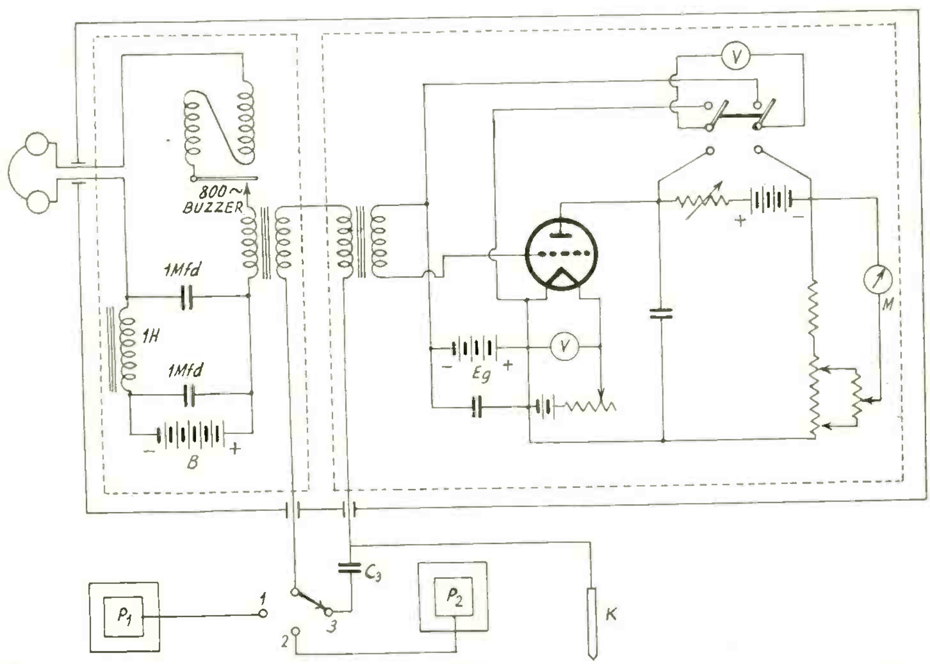


FIG. 7

The complete circuit of Billotte and Lipson, showing a buzzer generator in shielded compartment at left, the receiver in another shielded compartment at right, and the ground energizing circuit below.

(*Continued from preceding page*)

of the metal rod is brought into parallelism with the line G_1 G_2, which for the moment is line V-O-XI. After these preliminary adjustments, the rod is turned until no sound is heard in the phones, when the longitudinal axis of the rod is perpendicular to the plane of the vibration ellipse. In general the rod will make an angle with the horizontal. This should be noted and recorded. Also, the rod will no longer be quite perpendicular to the line G_1 G_2. This deviation should also be noted and recorded.

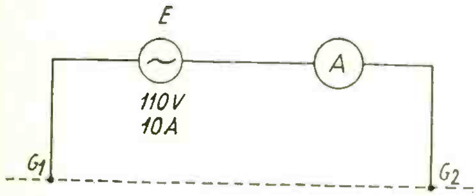


FIG. 8
The ground energizing circuit as used by Ricker.

For both angles the sense of the deviations should be noted.

ARROW LENGTHS SIGNIFICANT

Now the receiving equipment should be moved to each of all the other observation points on the selected survey line, and the data noted and recorded. Then the energizing circuit should be moved to another survey line and the entire process repeated. This should be done for all the survey lines laid out.

When the data have been obtained for every observation point in the field, they should be entered on two sheets of polar co-ordinate paper as indicated in Fig. 12. The length of each arrow indicates the magnitude of the deviation at the point it is placed, and the direction it is drawn indicates the sense. In regards to the sense there is an ambiguity, especially in respect to the deviation of the rod from the horizontal. To remove this ambiguity one end of the rod may be called the positive, and then when this end is elevated above the center of the rod the angle may be called positive. This positive angle may be represented by an arrow

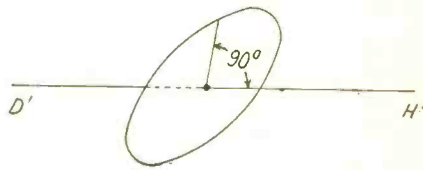


FIG. 9
Illustrating elliptical polarization. The direction of vibration is indicated by the arrows. The vibration ellipse is at right angles to the line D'H'. If there were no elliptical polarization, the ellipse would degenerate into a straight line at right angles to D'H'.

pointing in the clockwise direction. If the positive end of the rod were below the center of the rod, the arrow would have to be drawn in the counter-clockwise direction. The angular deviation of the rod from the horizontal is more important than the deviation of the horizontal axis from the survey line.

MINERAL DISCLOSED

The location and extent of a mineral deposit can be determined by studying and interpret-

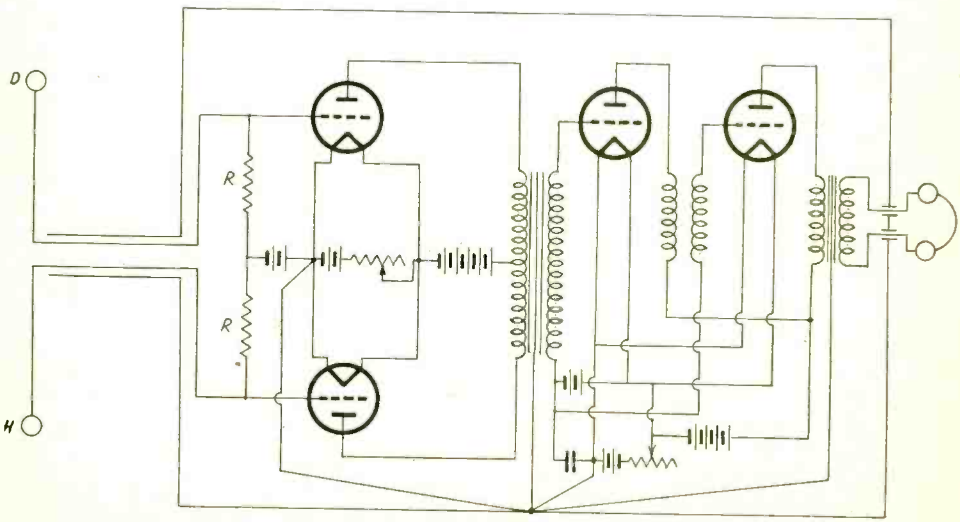


FIG. 10
The circuit of the detector amplifier and pick-up rod used by Ricker in his method of prospecting. When the rod DH is at hight angles to the vibration ellipse, as in Fig. 9, no signal is heard. In any other position of the rod there is a signal.

ing the angular deviations as represented on the two graphs, or on either of them. It should be pointed out that if the conductivity of the ore body is greater than that of the surrounding earth, the interpretation of the graphs must be made one way; and if the conductivity is less than that of the surrounding earth, the interpretation must be made in the opposite sense.

A word should be said about the receiver. It is a three-stage audio amplifier in which the first stage is push-pull and the next two stages are single sided. The push-pull output transformer between the first and second stages is shielded. So also is the simple transformer between the output tube and the headphones. The amplifier as a whole is shielded, including the transmission line between the first stage and the center of the pick-up rod. The negative ends of the filaments of all the tubes are connected to the shield. All connections are made by separate wires to one point on the encasing shield. The shielding and the grounding to one point are important features, for these precautions help to eliminate stray noises which would seriously interfere with the adjustments to the no-signal condition.

In the grid circuit of the first stage are two equal resistances R of high value. The use of a push-pull is necessary in order to have the center of the rod at ground potential. At the ends of the rod are two large metal balls, the purpose of which is to increase the capacity at the ends and thus to increase the current at the middle of the rod.

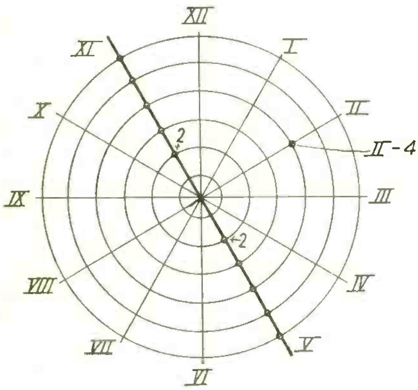


FIG. 11
Rickers method of laying out the field to be explored, in radial lines and concertric circles. Observations are made at all intersections of the circles and the radii.

MAGNETIC FIELD METHOD

Another method of sub-soil exploration utilizing elliptical polarization has been patented by Bieler and Watson. It is similar to the method of Ricker just described, but instead of using the electric field it utilizes the magnetic component. This suggests that loops are used for detecting the signals, and that is just the case.

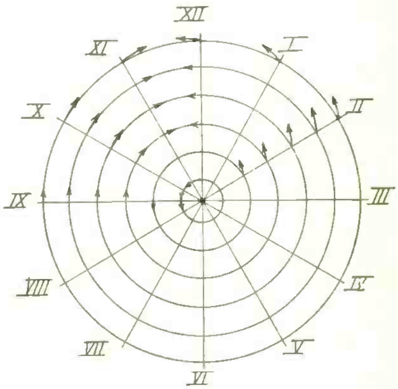


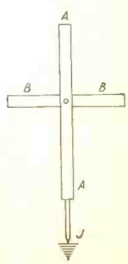
FIG. 12
Method of entering the observed data on a sheet of polar co-ordinate paper. The length of the arrow at any point indicates the amount of deviation of the metal rod from the horizontal and the direction of the arrow indicates whether the deviation was positive or negative. Only part of the data has been entered in the illustrative graph.

The earth currents are excited in the usual way by putting a generator of a suitable frequency in series with two grounded electrodes placed at some distance apart, or they may be induced in subterranean conductors by currents in a circuit not grounded. As in other cases, if there is no conductor in the vicinity of the exciting circuit, the earth currents will flow in regular streamlines and the magnetic field will be regular. If there are conducting masses in the ground, however, the field will be distorted and the problem is to determine the na-

(Continued on next page)

FIG. 13.
This illustrates elliptical polarization of the magnetic component of an electro-magnetic wave. CD is a line of magnetic force in an unpolarized field. The ellipse approaches this line as the intensity of polarization decreases.

FIG. 14
A pivoted loop assembly consisting of two loops, A and B, mounted at right angles to each other, which may be used for measuring the degree of polarization due to a secondary or induced current.



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ture and intensity of the distortion at many points in the region to be explored.

Since in the presence of a conducting body there will be elliptical polarization of the magnetic field at the surface of the earth, it is possible to determine the position and the extent of the conductor that is responsible for that polarization.

THE UNPOLARIZED FIELD

Suppose the magnetic field is not polarized. In that case if a loop is placed so that its plane is parallel with the field, no voltage is induced in the loop, because no lines of magnetic force thread the loop circuit. On the other hand, if the loop is placed so that its plane is at right angles with the field, a maximum number of lines of force will thread the loop and the induced voltage will be maximum. The null point is the most definitive and for that reason an observation would be made so that there is no signal in the receiver attached to the loop. If a null point can be found without further ado, the conclusion must be that there is no conductive body below the loop or in its immediate vicinity.

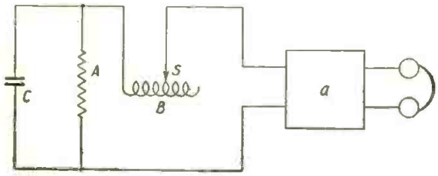

Fig. 15.
This circuit shows schematically how the two loops are connected together and how they are connected to the amplifier. Switch S is for varying the number of turns on loop B.

When there is elliptic polarization there is no position in which the loop will not pick up a signal. Why this is so may be illustrated by Fig. 13. The line CD represents an undistorted magnetic line of force in the field. If the loop is placed parallel to that no voltage will be induced. But if there is elliptic polarization, there will be a component of the field at right angles to the loop when it is placed with its plane parallel with CD. There is no way of mounting the loop in which it will not pick up something. It can only be placed so that the pick-up is minimum. This minimum, obviously, is a measure of the polarization.

THE COMPOUND LOOPS

Although the loop cannot be turned so as to reduce the signal to zero, the minimum signal can be balanced out, and the amount required to balance it out can be measured. In that way the polarization can be measured by means of a null setting of the apparatus. The balancing is done by means of a second loop permanently mounted at right angles to the main loop and in such a way that their centers coincide.

A simple sketch of the compound loop is given in Fig. 14. A is the main loop and B is the compensating loop. The assembly is pivoted in the ground at J. About this pivot the loop can be turned or tilted in any desired direction. Thus it is possible to place the plane of A so that it is parallel with the magnetic field, if that field is not polarized, and in parallel with the major axis of the ellipse in case the field is elliptically polarized. When the compound loop is placed in this manner, A does not pick up any part of the major axis component but it does pick up the minor axis component. This results in the minimum sound. The loop B is now at right angles to CD and therefore it picks up a maximum of the major axis component. It picks up nothing of the minor axis component.

Loops A and B are connected in series as indicated in Fig. 15. Therefore the voltages picked up by the two loops add up algebraically. That is, they either add up arithmetically or they partly cancel each other. If the phase is right there will be partial cancellation, and it is always possible to bring about this phase relation by reversing one of the coils with respect to the other if that is necessary. Since the voltage picked up by B depends on the number of turns, being directly proportional to the number, this voltage can be varied by varying the turns. For this purpose a switch S is provided. By selecting the right number of turns the voltage induced in B can be made exactly equal to that induced in A. It is then known that minor axis component, which is due to the conductivity of the orebody sought, is equal to the voltage in B. This may be measured by means of a sensitive vacuum tube voltmeter, or the number of turns left on B may be taken as the measure of the polarization.

INVENTORS' EXPLANATION

The theory involved here is a bit abstruse and it is not easy to follow it the first time. Let us therefore repeat the explanation in the words of the inventors themselves, with slight modifications.

Turn the loops A and B about the pivot J until the sound in the telephones is a minimum. What sound is left is due to the field being elliptically polarized and owes its existence to the component of the oscillating magnetic field along the minor axis of the ellipse of polarization. The intensity of the sound is therefore a measure of the component of the secondary field at the point being examined. This may be balanced by sliding the switch S until the sound vanishes entirely.

Because of the arrangement of the coils, the voltage induced in B is proportional to the major axis of the polarization ellipse and the voltage induced in A to that part of the minor axis lying in the plane containing the axes of the coils A and B. By a phase-shifting device these voltages may be made 180 degrees out of time phase. By varying one voltage, that in B in this case, they may be made to nullify each other. The number of turns used on B is a measure of ratio of magnitude of major and minor axes of the polarization ellipse in the plane containing the axes of the coils A and B.

The direction of this minor axis is determined from the knowledge of the manner in which the coil B is included in the circuit.

RATIO DETERMINED

Since the actual direction of the minor axis (secondary field) at any point is originally unknown, it is found advisable to determine

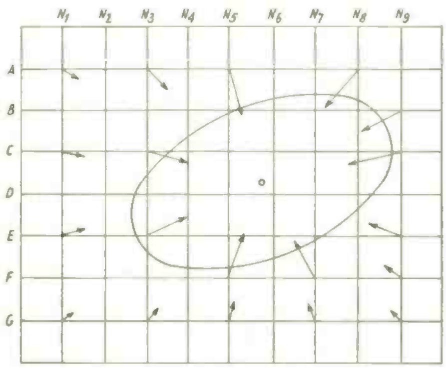

Fig. 16.

A sample plot of the data collected in the field by the arrangement in Figs. 14 and 15. The arrows point toward the underground conducting body.

the ratio for two different directions, preferably at right angles to each other and to compound the resulting values geometrically to get the resulting ratio and direction. These readings are made at a number of points over the area to be explored and the results of such measure of ratio and direction plotted on a map. The position and extent of any conductive body in the area can be deduced from such a map.

If the observed point is far from the conductive body, the minor axis is very small. The direction of minor axis is toward the conductive body.

THE DETECTING CIRCUIT

The collection of the data should proceed systematically along straight lines in the manner suggested in Fig. 16. The observation points, both along the abscissas and the ordinates are equally spaced. For convenience merely in transferring data from field sheets to the map, or for reference, the points are designated by letters and subscripted numerals, or by any other simple method. In the figure an outline is made of a supposed orebody and the arrows for some of the observation points are sketched in.

A word or two more might be said about the detecting circuit, Fig. 15. Loop A is permanently tuned by means of condenser C to the frequency of the driving voltage. This is to increase the sensitivity of the instrument and to eliminate disturbing stray effects. The amplifier (a) should be a sensitive one. It should also be well shielded from stray disturbances. These precautions are necessary because the method requires adjustment to zero sound. Any noises originating in the amplifier or externally would seriously interfere with precise settings. It may also be necessary to take readings at points where even the maximum signal strength is weak.

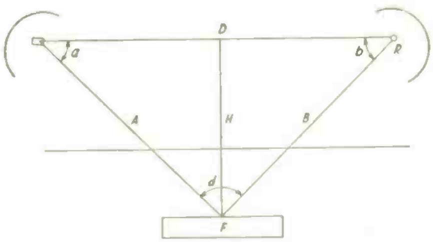

FIG. 17

This illustrates the principle of measuring the depth of a conducting layer in the ground by means of directed short wave transmission and reception.

The method described here is simple to build, to understand, and to operate. In many methods of this kind the source of the sound is a buzzer. Hence the transmitter is inexpensive also.

In Fig. 17 is illustrated a method of prospecting based on optics. A high-frequency transmitting antenna is placed horizontally in the focus of a parabolic cylinder and orientated so that most of the radiant energy is directed downward along the beam aAF. F is a conducting body and therefore a reflector of the radio wave that is incident on its upper surface. The greater part of the energy is reflected along the beam FBR. At R is a receiver which is built the same way as the transmitter. The transmitter and the receiver can be turned so that strong signals will be received. When this adjustment has been effected the angles *a* and *b* are measured, a circular scale being attached to the axis of each parabola. The distance D between T and R is known by measurement. From the distance D and the two angles it is possible to compute the height H, the distance between the line connecting the instruments and the upper surface of the conducting body. Thus the depth of the ore can be determined, for H is practically the same as the distance between the surface of the earth and orebody.

[*Next month Mr. Anderson will discuss this method in detail together with several treasure finders not expounded in the foregoing article.* —EDITOR.]

Dowsing for Cable

Path and Depth Found Electromagnetically

By R. I. Crisfield

Outside Plant Development, Bell Telephone Laboratories, Inc.

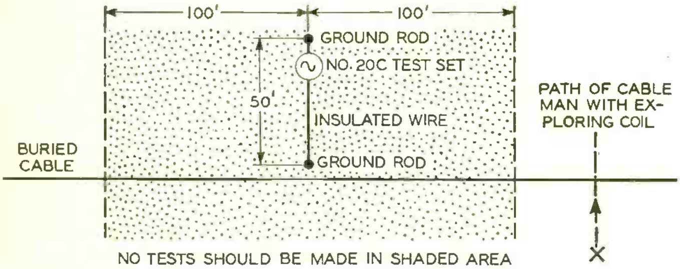

FIG. 1
Two rods, fifty feet apart, driven into the ground in a line at right angles to the cable, serve to lead the tracer current to the sheath. Tracer current is supplied by the 20C Test Set.

WITH any cable system the route followed must be known so that the position of any fault that may develop in the cable, which will be located by bridge measurement, may be reached with a minimum of delay. Aerial cable is visible, of course, and its path can readily be followed by the test man. Because of more or less closely spaced manholes, the path of underground cable in duct can also be easily traced. Where armored* or other cable buried directly in the ground is employed, its exact course is not so definitely fixed. When such cable is laid, its path is indicated by substantial markers placed at road crossings, fence lines, loading points, or where the direction of path is changed. It has been found, however, that these markers may deteriorate, be removed, or become covered with snow, so that in many sections the route of the cable may be known only in a general way. The need for an accurate method of following the path of such a cable is therefore evident.

Problem Simplified

The recent development of a method for locating and tracing the path of buried cable from above ground has greatly simplified the problem of maintaining such cable. The method devised involves the use of a tracer current flowing along the sheath, and an exploring coil with an amplifier and telephone receivers. The exploring coil is essentially a loop antenna and, serving somewhat as a radio compass, may be employed to determine not only the path of the cable but its approximate depth beneath the surface. In this system, the tracer current does not produce any interfering effects in the circuits carried by the cable.

To impress the tracer current on the sheath, two rods are driven into the ground as shown in Fig. 1. These rods should be placed about fifty feet apart, as nearly as possible at right angles to the path of the cable, and both on the same side of it. In developing the method various positions were tried for the rods, but that shown in the illustration proved the most effective. A 20C test set, which is standard equipment with the maintenance forces, is connected to the two rods and provides an interrupted buzzer tone. The current enters the sheath from one of the rods, passes along the sheath in both directions, and ultimately leaves it to return to the other ground rod.

Bicycle Wheel Coil

The exploring coil is made by winding a large number of turns of fine wire on the wood rim of a bicycle wheel. The ends of the wire are brought out to binding posts, and then the rim with its winding is wrapped with rubber and friction tape to protect the wire and keep out moisture. A 4B amplifier, also standard equipment, amplifies the current picked up, and the buzzer tone is heard through the ordinary headset receivers.

After the ground rods have been driven and connected to the test set, the exploring coil is carried to a point, such as X on Fig. 1. To avoid interference from the field of the wire connected to the ground rods, this point should be at least 100 feet from the rods. The coil is then placed in a horizontal position, and is turned slowly around a horizontal axis approximately parallel to the cable, and the change in volume of the tone is noted. This volume will be greatest when the greatest number of the lines of force caused by the current in the sheath passes through the exploring coil. This will happen when the plane of the loop passes through the cable. By similarly rotating the loop about a vertical axis maximum tone will be

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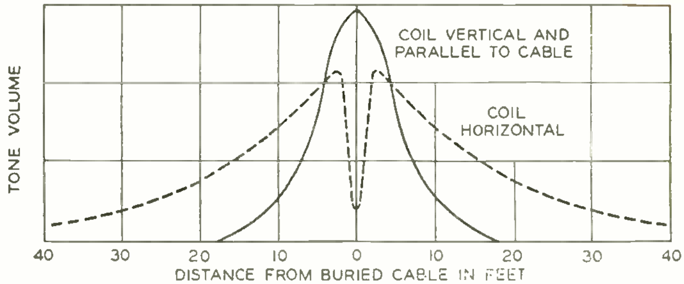
Bell Laboratories Record, June, 1930, p. 465.

FIG. 2
Variation of tone with distance for a horizontal and vertical coil.



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heard when the plane of the coil is parallel to the direction of the cable. These conditions are indicated in the drawing at the head of this article.

Operating Procedure

After this preliminary location, the test man holds the coil in a horizontal position and walks toward the cable in a direction as nearly as can be determined at right angles to it. The tone will increase as the cable is approached until the coil is nearly over it, and will suddenly decrease when the cable is directly under the center of the coil. As an alternative method the coil may be held vertically with its plane approximately parallel to the cable. With the coil in this position, the tone increases steadily as the cable is approached and becomes a maximum when the cable is directly beneath the coil. Curves of tone volume and distance for the two methods are shown in Fig. 2. The minimum tone position, with the coil horizontal, is very sensitive, and will locate the cable within a few inches.

After the cable has been located in this manner, its path may be readily followed by walking along with the coil in a horizontal position, and proceeding so as to maintain the tone at the minimum level. The path of the cable may usually be followed in this manner for a distance of about 500 feet each side of the ground rods—the actual distance depending on soil conductivity, noise conditions, and other factors. Having thus accurately located the path of the cable in the neighborhood of the fault, it is a comparatively simple matter to dig up a section for repair or further fault locating tests.

Marking Process

The exploring coil also provides a simple means of determining the depth of the cable, as indicated in Fig. 3. The coil is held in a horizontal position directly over the cable, and a stake or stone is placed to indicate the spot. Then the test man, holding the coil with its plane parallel to the cable and at an angle of 45 degrees with the vertical, moves slowly away from the cable in a direction at right angles to its path.

At the position of minimum tone, a line from the cable to the center of the coil will make a 45-degree angle with the horizontal as indicated in the illustration.

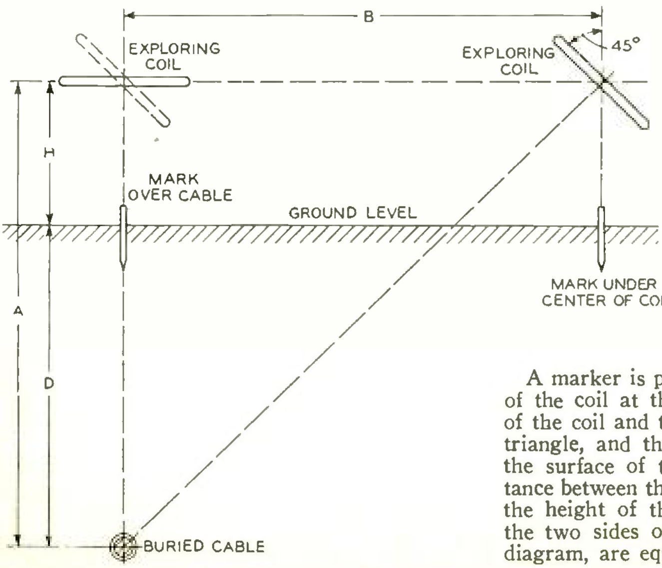


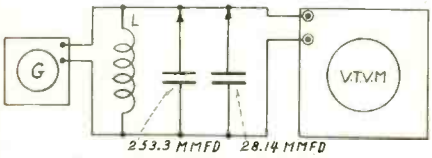
FIG. 3
The depth of the cable may be readily found by determining the position of minimum tone, first with the coil horizontal and then when it is held at an angle of 45 degrees.

A marker is placed directly beneath the center of the coil at this position. The two positions of the coil and the cable form a 45-degree right triangle, and the distance of the cable beneath the surface of the ground is equal to the distance between the two positions of the coil minus the height of the coil above the ground, since the two sides of the triangle, A and B in the diagram, are equal.

Two Expediting Capacities

How They Are Used for Inductance Tests

By Herman Bernard



The two "expediting capacities" for inductance measurement are 253.3 mmfd. and 281.4 mmfd. Here is a way to have both. Add 28.1 to 253.3 and have 281.4 Switch in 253.3 for its value alone, or use 28.1 alone, then switch in the other, for 10-to-1 capacity ratio.

TWO special fixed condensers have been recommended in connection with the measurement of inductance, one being 253.3 mmfd., for use where frequencies squared are known, and the other 281.4 mmfd., where wavelengths squared are known. The object of introducing these capacities is to change the capacity across an unknown coil by the specified quantity, to simplify the formula by thus causing in one instance the numerator, in the other the denominator to equal unity, and to some extent to make a direct-reading dial practical. Such reading would obtain under the wavelength practice.

The methods enable the solution of pure inductance, the distributed capacity of the coil not entering into the accounting, since it is an absolute capacity, and the methods depend on capacity *difference*. Any amount of other capacity may be in circuit, so long as it remains there all the time.

Previously we have discussed inductance measurement by using a calibrated condenser at two settings,* but this time we are substituting the fixed condensers, usually consisting of variables fixed and locked at the desired capacity.

Considering first the simplest case, with 281.4 mmfd. change in capacity across the unknown coil, the wavelengths to which the unknown circuit responds with the fixed capacity in, and again with it out, may be measured, each value squared, and the smaller squared quantity subtracted from the larger. The answer is the inductance in centimeters. There are 1,000 centimeters to one microhenry, therefore move the decimal point three places to the left. A device incorporating this method may be classified as semi-direct reading in inductance in centimeters, particularly if the generator used for the measurements is calibrated in wavelengths squared.

*July and August, 1936, issues RADIO WORLD.

Extension of Frequency Field

Of course such a calibrated instrument would be hard to find. However, one may calibrate his own, by converting known frequencies to wavelengths and multiplying each resulting wavelength by itself. The wavelength in meters is equal to the frequency in kilocycles divided into 299,820.

$$\lambda m = \frac{299{,}820}{f_{kc}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where λm is the wavelength in meters and f_{kc} is the frequency in kilocycles

$$L_{cm} = \lambda_2^2 - \lambda_1^2 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

where L_{cm} is the inductance in centimeters and λ_2 and λ_1 are the wavelengths.

There is nothing that can be done to simplify the inductance formula based on difference in squared wavelengths, or to make its use handier, so far as exhaustive attempts have disclosed, although something may be done on the frequency squared basis to improve operating practice.

It will be noted that two *different* fixed capacities have to be used if one is to deal in wavelengths and frequencies, and it is well to have both of them available in any inductance measurement equipment based on the expositions herein given.

Both Readily Obtained

A simple way have been found to have both. One must be 253.3 mmfd., the other 281.4 mmfd., and the difference is 28.1 mmfd., or one-tenth the larger. Hence the 253.3 mmfd. condenser alone will serve its purpose, and when 28.1 mmfd. is switched across it alone, the fixed capacity is raised to the required higher amount.

Incidentally, since the capacity ratio of 281.4 to 28.1 is close enough to 10, we may insert the smaller of these alone as a variable at proper setting, then the total, and have a definite ratio on the basis of which we may measure also distributed capacity of the coil, at least for values below the 28.1 mmfd.

$$C_o = 28.1 - C_{min}$$

where C_o is the distributed capacity in micromicrofarads, and C_{min} is the capacity read on the small variable condenser, the two responses now being due to wavelengths squared. If one response due to 500 meters squared, or 250,000, the other is due to one-tenth that, or 25,000, which is the square of 158 meters.

Whenever dealing with units of inductance, found from frequencies or wavelengths, the other mentioned terms are squared.

Proceeding to Harmonics

For instance, take the example of a change of 253.3 mmfd. to enable use of frequencies in measuring an unknown coil's inductance. The formula is

$$L = \left(\frac{1}{F_1^2} - \frac{1}{F_2^2} \right) 10^8 \ldots\ldots (3)$$

where L is the inductance in microhenries, and F represents frequency, higher subscript for higher frequency.

In the wavelength example, the form was so simple that direct knowledge of wavelengths squared was requisite, but with frequencies, since again frequencies squared will not be known directly we may change the frequency formula (3) to read

$$L = \frac{(F_2^2 - F_1^2)\ 10^8}{F_2^2 F_1^2} \ldots\ldots (4)$$

The next step is to use harmonics instead of fundamentals, so that if one has access to calibrations in kilocycles the inductance may be determined without requiring any new calibration and, more important, the range of inductance measurement may be very large, although the source of frequencies covers only one band.

Harmonic Formula

An unknown frequency may be measured in terms of harmonics of two related lower frequencies. The unknown is equal to the product of either low frequency and its harmonic order. Therefore the product of the two harmonic orders and the two low frequencies equals the square of the unknown frequency. Hence formula (4) becomes

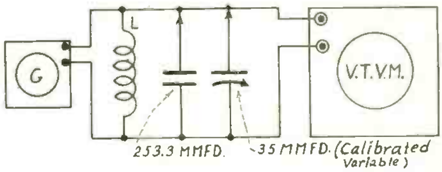
$$L = \frac{[(m)\ (f_4 f_3)] - [(n)\ f_2 f_1]\ 10^8}{[(m)\ (f_4 f_3)]\ [(n)\ (f_2 f_1)]} \quad (5)$$

Where L is the inductance in microhenries, m is the product of the harmonic orders of two low frequencies, f_4 and f_3, and n is the product of the harmonic orders of two other low frequencies, f_2 and f_1. It is handy to consider the responses in the unknown or receiver circuit to be due to consecutive low frequencies, though the change may be either from higher to lower or from lower to higher frequencies. Note that *there are two high frequencies,* and as there are two low frequencies for each high frequency, *there are four low frequencies,* in two pairs. One pair represents consecutive low frequencies creating responses in the unknown for one high frequency, the other pair represents two other low frequencies creating responses at the second high frequency, due to the specified capacity now being introduced in the unknown circuit.

The Harmonic Orders

It is necessary, of course, to know the harmonic orders, therefore, familiarity with their determination is essential. There are five methods of solution. The reader may find one of them more to his liking than another.

(a) Product of two low frequencies divided by difference equals the unknown high frequency, hence harmonic orders are unknown high frequency divided by one low frequency and by the other low frequency. Example: Low frequencies are 150 kc and 200 kc. Product is 30,000, difference is 50, unknown is 30,000/50, or 600 kc, and harmonic orders are 600/150, or 4, and 600/200, or 3.



If instead of a fixed capacity of 28.1 mmfd., a calibrated variable is used, which may be set at that value, then distributed capacity as well as inductance of the unknown coil L may be measured. VTVM is a vacuum tube voltmeter. Suitable circuits for VTVM are in this issue.

(b) Harmonic orders are equal to difference between the two low frequencies divided into one low frequency, then into the other low frequency, the division into one representing the harmonic order of the other. Example: Low frequencies are 150 kc and 200 kc. The difference is 50 kc. Divide 50 into 150, harmonic order is 3, applied to the other frequency, 200 kc, not to 150 kc. Harmonic in the other example is 200/5, or 4, applied to 150. The unknown high frequency is the product of the low frequency and its pertinent harmonic order, e.g., 200 x 3 or 150 x 4 = 600 kc.

(c) The sum of the two low frequencies divided by the difference yields the sum of the harmonic orders. As consecutive harmonic orders alone are considered in this entire discussion, the harmonic orders are in one instance this sum plus one, divided by 2, $[(n+1)/2]$ and in the other, this sum minus one, divided by 2, $[(n-1)/2]$. By mere inspection these values are apparent. Example: Low frequencies are 150 kc and 200 kc. The sum is 350 kc. The difference is 50 kc. The dividend of sum and difference is 350/50 or 7. The

(*Continued on page* 24)

Conversion Graph, F to F^2, F to λ^2

The graph on the opposite page converts frequencies in kilocycles to wavelengths squared and to frequencies squared.

The squared wavelength curve is the line identified at left top by λ^2, while the squared frequency curve is identified at right top by f^2. Be careful not to read the wrong curve.

The two curves, or straight lines, constitute reciprocals, i.e., when one squared quantity is higher the other squared quantity is lower. If the two lines are made to cross, the ordinates for both will have an ascending order from bottom to top, as is done in the graph.

The accuracy is one per cent. This may be checked conveniently for the f^2 line. Take 200 kc, the square of which is 40,000, and starting from 200 at the bottom go up until the f^2 line is intersected, then straight across to the left, and the answer happens to be exactly 40,000. The same is true of $300^2 = 90,000$, though 400^2 reads about 16,100 instead of 16,000, an error of about .6 per cent. whereas 500^2 reads 250,000; 600^2 reads about 2,500 too high, or 362,500 instead of 360,000, error of about .7 per cent., etc., so that the accuracy is well within one per cent.

The wavelength squared line can not be checked so readily by mental arithmetic, but has the same order of accuracy as the other.

It is not intended that the formulas be worked at f^2 or λ^2 accuracy as poor as one per cent, as by calculation or calibration the accuracy should be much higher, nearly perfect, and the unavoidable inaccuracies then would be due to the capacities. This makes it doubly necessary to have accurate capacities, because a given percentage of inaccuracy in the capacities is more upsetting than the same percentage of error in the frequencies or wavelengths.

Curves Universally Extendable

While only the frequency range of 95 to 950 kc is used for λ^2, and 100 to 1,000 kc for f^2, any and all frequencies may be converted by use of the table.

The universality of the graph is due to the coverage of a complete logarithmic cycle in either instance, so that decimal point location is the only requirement for frequencies higher than those encompassed on the ordinates. It is assumed that there would be small need for considering frequencies lower than 100 kc, but if the need arises, the decimal point is moved in the opposite direction from that about to be set forth.

Suppose that the frequency is ten times as high as one that appears on the ordinate (base line). Since $10^2 = 100$, read on the λ^2 the number as one one-hundredth of what appears, in other words, move the decimal point two places to the left. Remember always that *when the frequency is higher the wavelength is lower.*

Curve versus Computation

Take 3,300 kc as an example. Read 330 on the kilocycle line. The real frequency is ten times the plotted frequency, so whatever is read in wavelengths squared for 330 is divided by 10^2, i.e., 100. Read 830,000 as "wavelengths squared," divide by 100, and the answer is 8,300.

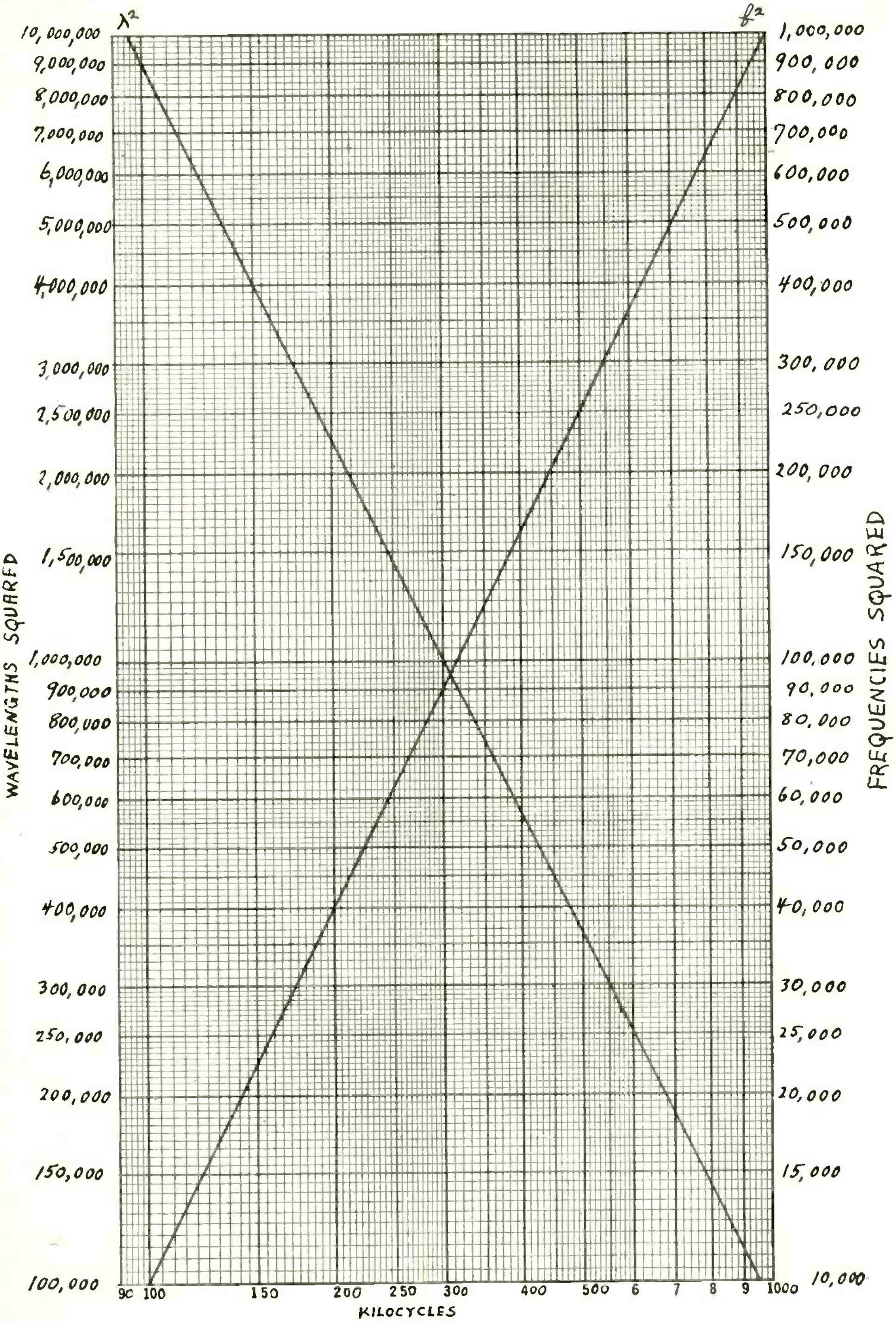
See what the answer is by computation. For 330 kc the equivalent wavelength in meters is 908.6 (see chart on page 25). The square of 908.6 is 825,553.96, the curve reading is off by 4,446, and the percentage accuracy is 825,554/4,446 or .54 per cent.

Now let us take an example for f^2. Suppose that the frequency is 16,500 kc. Read 165 on the abscissa, the real frequency is 100 times as great, the square of the real frequency will be 100^2 or 10,000 times as great as what is read. Remember frequencies and their squares change in the same direction! Therefore select 165 on the base line, follow the line straight up to the intersection with the f^2 line, and go straight to left, reading 270,000. Multiply this by 100 and the answer is 270,000,000.

The computation to check this is $16,500 \times 16,500 = 272,250,000$. The difference is 2,250,000 and the error is .74 per cent.

Now let us work an example from the curve, realizing the inductance accuracy will not be so high. The frequencies are 600 kc and 852 kc. These appear directly on the ordinate. The square of the first is read as 360,000 and of the second is read as 720,000 and the inductance in microhenries is $[(72-36)/(72 \times 36)]\ 10^4 = 138.5$ microhenries. The true inductance is 140 microhenries, and the percentage error is 1.7.

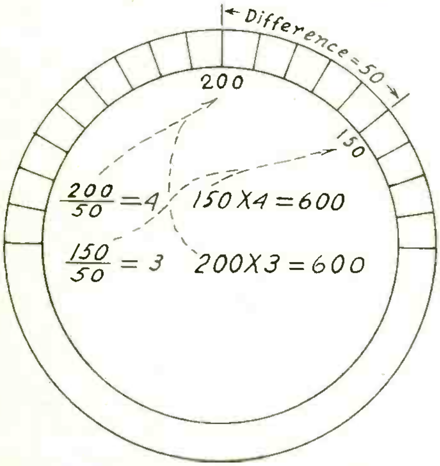
The f^2 curve may be used generally for squares of units, or for extracting square roots, with slide-rule accuracy.



Decimal-repeating conversion graph, frequencies to wavelengths squared, frequencies to frequencies squared. Be careful to read the right curve. See identifications at top.

(*Continued from page 21*)
harmonic orders are $(7+1)/2$, or 4, and $(7-1)/2$, or 3.

(d) The dividend of the harmonic orders equals the frequency ratio. Thus the lower of the two low frequencies is divided into the higher, the frequency ratio is thus established, and the dividend of the harmonic orders is the same number. Example: Low frequencies are 150 kc and 200 kc. The frequency ratio is 200/150 or 1.333, and the harmonic orders are 4 and 3, the ratio of which is also 1.333. It is rather awkward to derive the harmonic orders from the frequency ratio by factoring, so a



An example of harmonic use. Generator fundamentals are 200 and 150 kc, difference is 50 kc, divided into one (200) = 4, the harmonic order of the other. So 150/50 = 3. The unknown is 4 x 150 = 3 x 200 = 600 kc.

table is given that tells the harmonic orders for the readily determined frequency ratio, and also gives the product of the harmonic orders, as this is important to the inductance measurement, formula (5).

(e) The table also gives the capacity ratio, which is the square of the frequency ratio, in relation to the harmonic orders, for the benefit of those who use a generator with capacity-calibrated condenser.

From the foregoing, or the table, the harmonic orders, and their product, may be determined. Since there are two high frequencies, hence four low frequencies, one pair of low frequencies may have on occasion the same pair of harmonic orders as has the other low frequencies, whereupon m and n would be equal in formula (5).

TABLE I.

Determination of Consecutive Harmonic Orders from Frequency Ratios or Capacity Ratios

Frequency Ratio	*Capacity Ratio*	*Harmonic Orders*	*Product of Harmonic Orders*
2.000	4.000	1 & 2	2
1.500	2.250	2 & 3	6
1.333	1.787	3 & 4	12
1.250	1.562	4 & 5	20
1.200	1.440	5 & 6	30
1.166	1.361	6 & 7	42
1.143	1.306	7 & 8	56
1.125	1.266	8 & 9	72
1.111	1.232	9 & 10	90
1.100	1.210	10 & 11	110

The nature of the change is such that there is hardly any spreadout finally, even by using the squared terms of capacity ratio, instead of the frequency ratio. The differences become so narrow that the combination of ninth and tenth harmonics is practically the final one that would be used. The combination of tenth and eleventh harmonics is listed merely to illustrate this point.

Let us take the same pair of low frequencies we have been using, 150 kc and 200 kc, the harmonic orders of which are 3 and 4, the product of the harmonic orders 12, and the unknown high frequency, which does not directly appear in the formula, 600 kc. These two low frequencies would serve then for the case of 253.3 mmfd. in circuit, across the unknown coil (parallel connection). Now for the second pair of low frequencies, determined when the 253.3 mmfd. condenser is cut out of circuit, let us use 142 kc and 170.4 kc.

We have yet to determine the harmonic orders, and the product of these orders, for the new pair of low frequencies. The ratio is 170.4/142 or 1.2, so the harmonic orders, as read from the table, are 5 and 6, and their product is 30.

Therefore the values to be assigned to the symbols in formula (5) are

$m = 30$ $f_3 = 142$ kc $f_2 = 200$ kc
$f_4 = 170.4$ kc $n = 12$ $f_1 = 150$ kc

(*Continued on page 26*)

Reversible Meters—Kilocycles Chart

The chart on the opposite page gives values, 10 to 29,982, for meters to kilocycles, and kilocycles to meters. Known values may be located at any place and answers of unknown obtained, moving decimal points oppositely, where multiples of other than ten apply to the known. Prepared by National Bureau of Standards, U. S. Department of Commerce. Reprinted by permission of Government Printing Office.

kc or m	m or kc	kc or m	m or kc	kc or m	m or kc	kc or m	m or kc	kc or m	m or kc	kc or m	m or kc	kc or m	m or kc	kc or m	m or kc	kc or m	m or kc	kc or m	m or kc
10	29,982	1,010	296.9	2,010	149.2	3,010	99.61	4,010	74.77	5,010	59.84	6,010	49.89	7,010	42.77	8,010	37.43	9,010	33.28
20	14,991	1,020	293.9	2,020	148.4	3,020	99.28	4,020	74.58	5,020	59.73	6,020	49.80	7,020	42.71	8,020	37.38	9,020	33.24
30	9,994	1,030	291.1	2,030	147.7	3,030	98.95	4,030	74.40	5,030	59.61	6,030	49.72	7,030	42.65	8,030	37.34	9,030	33.20
40	7,496	1,040	288.3	2,040	147.0	3,040	98.62	4,040	74.21	5,040	59.49	6,040	49.64	7,040	42.59	8,040	37.29	9,040	33.17
50	5,996	1,050	285.5	2,050	146.3	3,050	98.30	4,050	74.03	5,050	59.37	6,050	49.56	7,050	42.53	8,050	37.24	9,050	33.13
60	4,997	1,060	282.8	2,060	145.5	3,060	97.98	4,060	73.85	5,060	59.25	6,060	49.48	7,060	42.47	8,060	37.20	9,060	33.09
70	4,283	1,070	280.2	2,070	144.8	3,070	97.66	4,070	73.67	5,070	59.13	6,070	49.39	7,070	42.41	8,070	37.15	9,070	33.06
80	3,748	1,080	277.6	2,080	144.1	3,080	97.34	4,080	73.49	5,080	59.02	6,080	49.31	7,080	42.35	8,080	37.11	9,080	33.02
90	3,331	1,090	275.1	2,090	143.5	3,090	97.03	4,090	73.31	5,090	58.90	6,090	49.23	7,090	42.29	8,090	37.06	9,090	32.98
100	2,998	1,100	272.6	2,100	142.8	3,100	96.72	4,100	73.13	5,100	58.79	6,100	49.15	7,100	42.23	8,100	37.01	9,100	32.95
110	2,726	1,110	270.1	2,110	142.1	3,110	96.41	4,110	72.95	5,110	58.67	6,110	49.07	7,110	42.17	8,110	36.97	9,110	32.91
120	2,499	1,120	267.7	2,120	141.4	3,120	96.10	4,120	72.77	5,120	58.56	6,120	48.99	7,120	42.11	8,120	36.92	9,120	32.88
130	2,306	1,130	265.3	2,130	140.8	3,130	95.79	4,130	72.60	5,130	58.44	6,130	48.91	7,130	42.05	8,130	36.88	9,130	32.84
140	2,142	1,140	263.0	2,140	140.1	3,140	95.48	4,140	72.42	5,140	58.33	6,140	48.83	7,140	41.99	8,140	36.83	9,140	32.80
150	1,999	1,150	260.7	2,150	139.5	3,150	95.18	4,150	72.25	5,150	58.22	6,150	48.75	7,150	41.93	8,150	36.79	9,150	32.77
160	1,874	1,160	258.5	2,160	138.8	3,160	94.88	4,160	72.07	5,160	58.10	6,160	48.67	7,160	41.87	8,160	36.74	9,160	32.73
170	1,764	1,170	256.3	2,170	138.1	3,170	94.58	4,170	71.90	5,170	57.99	6,170	48.59	7,170	41.82	8,170	36.70	9,170	32.70
180	1,666	1,180	254.1	2,180	137.5	3,180	94.28	4,180	71.73	5,180	57.88	6,180	48.51	7,180	41.76	8,180	36.65	9,180	32.66
190	1,578	1,190	252.0	2,190	136.9	3,190	93.99	4,190	71.56	5,190	57.77	6,190	48.44	7,190	41.70	8,190	36.61	9,190	32.62
200	1,499	1,200	249.9	2,200	136.3	3,200	93.69	4,200	71.39	5,200	57.66	6,200	48.36	7,200	41.64	8,200	36.56	9,200	32.59
210	1,428	1,210	247.8	2,210	135.7	3,210	93.40	4,210	71.22	5,210	57.55	6,210	48.28	7,210	41.58	8,210	36.52	9,210	32.55
220	1,363	1,220	245.8	2,220	135.1	3,220	93.11	4,220	71.05	5,220	57.44	6,220	48.20	7,220	41.53	8,220	36.47	9,220	32.52
230	1,304	1,230	243.8	2,230	134.4	3,230	92.82	4,230	70.88	5,230	57.33	6,230	48.13	7,230	41.47	8,230	36.43	9,230	32.48
240	1,249	1,240	241.8	2,240	133.8	3,240	92.54	4,240	70.71	5,240	57.22	6,240	48.05	7,240	41.41	8,240	36.39	9,240	32.45
250	1,199	1,250	239.9	2,250	133.3	3,250	92.25	4,250	70.55	5,250	57.11	6,250	47.97	7,250	41.35	8,250	36.34	9,250	32.41
260	1,153	1,260	238.0	2,260	132.7	3,260	91.97	4,260	70.38	5,260	57.00	6,260	47.89	7,260	41.30	8,260	36.30	9,260	32.38
270	1,110	1,270	236.1	2,270	132.1	3,270	91.69	4,270	70.22	5,270	56.89	6,270	47.82	7,270	41.24	8,270	36.25	9,270	32.34
280	1,071	1,280	234.2	2,280	131.5	3,280	91.41	4,280	70.05	5,280	56.78	6,280	47.74	7,280	41.18	8,280	36.21	9,280	32.31
290	1,034	1,290	232.4	2,290	130.9	3,290	91.13	4,290	69.89	5,290	56.68	6,290	47.67	7,290	41.13	8,290	36.17	9,290	32.27
300	999.4	1,300	230.6	2,300	130.4	3,300	90.86	4,300	69.73	5,300	56.57	6,300	47.59	7,300	41.07	8,300	36.12	9,300	32.24
310	967.2	1,310	228.9	2,310	129.8	3,310	90.58	4,310	69.56	5,310	56.46	6,310	47.52	7,310	41.02	8,310	36.08	9,310	32.20
320	936.9	1,320	227.1	2,320	129.2	3,320	90.31	4,320	69.40	5,320	56.36	6,320	47.44	7,320	40.96	8,320	36.04	9,320	32.17
330	908.6	1,330	225.4	2,330	128.7	3,330	90.04	4,330	69.24	5,330	56.25	6,330	47.36	7,330	40.90	8,330	35.99	9,330	32.14
340	881.8	1,340	223.7	2,340	128.1	3,340	89.77	4,340	69.08	5,340	56.15	6,340	47.29	7,340	40.85	8,340	35.95	9,340	32.10
350	856.6	1,350	222.1	2,350	127.6	3,350	89.50	4,350	68.92	5,350	56.04	6,350	47.22	7,350	40.79	8,350	35.91	9,350	32.07
360	832.8	1,360	220.4	2,360	127.0	3,360	89.23	4,360	68.77	5,360	55.94	6,360	47.14	7,360	40.74	8,360	35.86	9,360	32.03
370	810.3	1,370	218.8	2,370	126.5	3,370	88.97	4,370	68.61	5,370	55.83	6,370	47.07	7,370	40.68	8,370	35.82	9,370	32.00
380	789.0	1,380	217.3	2,380	126.0	3,380	88.70	4,380	68.45	5,380	65.73	6,380	46.99	7,380	40.63	8,380	35.78	9,380	31.96
390	768.8	1,390	215.7	2,390	125.4	3,390	88.44	4,390	68.30	5,390	55.63	6,390	46.92	7,390	40.57	8,390	35.74	9,390	31.93
400	749.6	1,400	214.2	2,400	124.9	3,400	88.18	4,400	68.14	5,400	55.52	6,400	46.85	7,400	40.52	8,400	35.69	9,400	31.90
410	731.3	1,410	212.6	2,410	124.4	3,410	87.92	4,410	67.99	5,410	55.42	6,410	46.77	7,410	40.46	8,410	35.65	9,410	31.86
420	713.9	1,420	211.1	2,420	123.9	3,420	87.67	4,420	67.83	5,420	55.32	6,420	46.70	7,420	40.41	8,420	35.61	9,420	31.83
430	697.3	1,430	209.7	2,430	123.4	3,430	87.41	4,430	67.68	5,430	55.22	6,430	46.63	7,430	40.35	8,430	35.57	9,430	31.79
440	681.4	1,440	208.2	2,440	122.9	3,440	87.16	4,440	67.53	5,440	55.11	6,440	46.56	7,440	40.30	8,440	35.52	9,440	31.76
450	666.3	1,450	206.8	2,450	122.4	3,450	86.90	4,450	67.38	5,450	55.01	6,450	46.48	7,450	40.24	8,450	35.48	9,450	31.73
460	651.8	1,460	205.4	2,460	121.9	3,460	86.65	4,460	67.22	5,460	54.91	6,460	46.41	7,460	40.19	8,460	35.44	9,460	31.69
470	637.9	1,470	204.0	2,470	121.4	3,470	86.40	4,470	67.07	5,470	54.81	6,470	46.34	7,470	40.14	8,470	35.40	9,470	31.66
480	624.6	1,480	202.6	2,480	120.9	3,480	86.16	4,480	66.92	5,480	54.71	6,480	46.27	7,480	40.08	8,480	35.36	9,480	31.63
490	611.9	1,490	201.2	2,490	120.4	3,490	85.91	4,490	66.78	5,490	54.61	6,490	46.20	7,490	40.03	8,490	35.31	9,490	31.59
500	599.6	1,500	199.9	2,500	119.9	3,500	85.66	4,500	66.63	5,500	54.51	6,500	46.13	7,500	39.98	8,500	35.27	9,500	31.56
510	587.9	1,510	198.6	2,510	119.5	3,510	85.42	4,510	66.48	5,510	54.41	6,510	46.06	7,510	39.92	8,510	35.23	9,510	31.53
520	576.6	1,520	197.2	2,520	119.0	3,520	85.18	4,520	66.33	5,520	54.32	6,520	45.98	7,520	39.87	8,520	35.19	9,520	31.49
530	565.7	1,530	196.0	2,530	118.5	3,530	84.94	4,530	66.19	5,530	54.22	6,530	45.91	7,530	39.82	8,530	35.15	9,530	31.46
540	555.2	1,540	194.7	2,540	118.0	3,540	84.70	4,540	66.04	5,540	54.12	6,540	45.84	7,540	39.76	8,540	35.11	9,540	31.43
550	545.1	1,550	193.4	2,550	117.6	3,550	84.46	4,550	65.89	5,550	54.02	6,550	45.77	7,550	39.71	8,550	35.07	9,550	31.39
560	535.4	1,560	192.2	2,560	117.1	3,560	84.22	4,560	65.75	5,560	53.92	6,560	45.70	7,560	39.66	8,560	35.03	9,560	31.36
570	526.0	1,570	191.0	2,570	116.7	3,570	83.98	4,570	65.61	5,570	53.83	6,570	45.63	7,570	39.61	8,570	34.98	9,570	31.33
580	516.9	1,580	189.8	2,580	116.2	3,580	83.75	4,580	65.46	5,580	53.73	6,580	45.57	7,580	39.55	8,580	34.94	9,580	31.30
590	508.2	1,590	188.6	2,590	115.8	3,590	83.52	4,590	65.32	5,590	53.64	6,590	45.50	7,590	39.50	8,590	34.90	9,590	31.26
600	499.7	1,600	187.4	2,600	115.3	3,600	83.28	4,600	65.18	5,600	53.54	6,600	45.43	7,600	39.45	8,600	34.86	9,600	31.23
610	491.5	1,610	186.2	2,610	114.9	3,610	83.05	4,610	65.04	5,610	53.44	6,610	45.36	7,610	39.40	8,610	34.82	9,610	31.20
620	483.6	1,620	185.1	2,620	114.4	3,620	82.82	4,620	64.90	5,620	53.35	6,620	45.29	7,620	39.35	8,620	34.78	9,620	31.17
630	475.9	1,630	183.9	2,630	114.0	3,630	82.60	4,630	64.76	5,630	53.25	6,630	45.22	7,630	39.29	8,630	34.74	9,630	31.13
640	468.5	1,640	182.8	2,640	113.6	3,640	82.37	4,640	64.62	5,640	53.16	6,640	45.15	7,640	39.24	8,640	34.70	9,640	31.10
650	461.3	1,650	181.7	2,650	113.1	3,650	82.14	4,650	64.48	5,650	53.07	6,650	45.09	7,650	39.19	8,650	34.66	9,650	31.07
660	454.3	1,660	180.6	2,660	112.7	3,660	81.92	4,660	64.34	5,660	52.97	6,660	45.02	7,660	39.14	8,660	34.62	9,660	31.04
670	447.5	1,670	179.5	2,670	112.3	3,670	81.70	4,670	64.20	5,670	52.88	6,670	44.95	7,670	39.09	8,670	34.58	9,670	31.01
680	440.9	1,680	178.5	2,680	111.9	3,680	81.47	4,680	64.06	5,680	52.79	6,680	44.88	7,680	39.04	8,680	34.54	9,680	30.97
690	434.5	1,690	177.4	2,690	111.5	3,690	81.25	4,690	63.93	5,690	52.69	6,690	44.82	7,690	38.99	8,690	34.50	9,690	30.94
700	428.3	1,700	176.4	2,700	111.0	3,700	81.03	4,700	63.79	5,700	52.60	6,700	44.75	7,700	38.94	8,700	34.46	9,700	30.91
710	422.3	1,710	175.3	2,710	110.6	3,710	80.81	4,710	63.66	5,710	52.51	6,710	44.68	7,710	38.89	8,710	34.42	9,710	30.88
720	416.4	1,720	174.3	2,720	110.2	3,720	80.60	4,720	63.52	5,720	52.42	6,720	44.62	7,720	38.84	8,720	34.38	9,720	30.85
730	410.7	1,730	173.3	2,730	109.8	3,730	80.38	4,730	63.39	5,730	52.32	6,730	44.55	7,730	38.79	8,730	34.34	9,730	30.81
740	405.2	1,740	172.3	2,740	109.4	3,740	80.17	4,740	63.25	5,740	52.23	6,740	44.48	7,740	38.74	8,740	34.30	9,740	30.78
750	399.8	1,750	171.3	2,750	109.0	3,750	79.95	4,750	63.12	5,750	52.14	6,750	44.42	7,750	38.69	8,750	34.27	9,750	30.75
760	394.5	1,760	170.4	2,760	108.6	3,760	79.74	4,760	62.99	5,760	52.05	6,760	44.35	7,760	38.64	8,760	34.23	9,760	30.72
770	389.4	1,770	169.4	2,770	108.2	3,770	79.53	4,770	62.86	5,770	51.96	6,770	44.29	7,770	38.59	8,770	34.19	9,770	30.69
780	384.4	1,780	168.4	2,780	107.8	3,780	79.32	4,780	62.72	5,780	51.87	6,780	44.22	7,780	38.54	8,780	34.15	9,780	30.66
790	379.5	1,790	167.5	2,790	107.5	3,790	79.11	4,790	62.59	5,790	51.78	6,790	44.16	7,790	38.49	8,790	34.11	9,790	30.63
800	374.8	1,800	166.6	2,800	107.1	3,800	78.90	4,800	62.46	5,800	51.69	6,800	44.09	7,800	38.44	8,800	34.07	9,800	30.59
810	370.2	1,810	165.6	2,810	106.7	3,810	78.69	4,810	62.33	5,810	51.60	6,810	44.03	7,810	38.39	8,810	34.03	9,810	30.56
820	365.6	1,820	164.7	2,820	106.3	3,820	78.49	4,820	62.20	5,820	51.52	6,820	43.96	7,820	38.34	8,820	33.99	9,820	30.53
830	361.2	1,830	163.8	2,830	105.9	3,830	78.28	4,830	62.07	5,830	51.43	6,830	43.90	7,830	38.29	8,830	33.95	9,830	30.50
840	356.9	1,840	162.9	2,840	105.6	3,840	78.08	4,840	61.95	5,840	51.34	6,840	43.83	7,840	38.24	8,840	33.92	9,840	30.47
850	352.7	1,850	162.1	2,850	105.2	3,850	77.88	4,850	61.82	5,850	51.25	6,850	43.77	7,850	38.19	8,850	33.88	9,850	30.44
860	348.6	1,860	161.2	2,860	104.8	3,860	77.67	4,860	61.69	5,860	51.16	6,860	43.71	7,860	38.14	8,860	33.84	9,860	30.41
870	344.6	1,870	160.3	2,870	104.5	3,870	77.47	4,870	61.56	5,870	51.08	6,870	43.64	7,870	38.10	8,870	33.80	9,870	30.38
880	340.7	1,880	159.5	2,880	104.1	3,880	77.27	4,880	61.44	5,880	50.99	6,880	43.58	7,880	38.05	8,880	33.76	9,880	30.35
890	336.9	1,890	158.6	2,890	103.7	3,890	77.07	4,890	61.31	5,890	50.90	6,890	43.52	7,890	38.00	8,890	33.73	9,890	30.32
900	333.1	1,900	157.8	2,900	103.4	3,900	76.88	4,900	61.19	5,900	50.82	6,900	43.45	7,900	37.95	8,900	33.69	9,900	30.28
910	329.5	1,910	157.0	2,910	103.0	3,910	76.68	4,910	61.06	5,910	50.73	6,910	43.39	7,910	37.90	8,910	33.65	9,910	30.25
920	325.9	1,920	156.2	2,920	102.7	3,920	76.48	4,920	60.94	5,920	50.65	6,920	43.33	7,920	37.86	8,920	33.61	9,920	30.22
930	322.4	1,930	155.3	2,930	102.3	3,930	76.29	4,930	60.82	5,930	50.56	6,930	43.26	7,930	37.81	8,930	33.57	9,930	30.19
940	319.0	1,940	154.5	2,940	102.0	3,940	76.10	4,940	60.69	5,940	50.47	6,940	43.20	7,940	37.76	8,940	33.54	9,940	30.16
950	315.6	1,950	153.8	2,950	101.6	3,950	75.90	4,950	60.57	5,950	50.39	6,950	43.14	7,950	37.71	8,950	33.50	9,960	30.13
960	312.3	1,960	153.0	2,960	101.3	3,960	75.71	4,960	60.45	5,960	50.31	6,960	43.08	7,960	37.67	8,960	33.46	9,960	30.10
970	309.1	1,970	152.2	2,970	100.9	3,970	75.52	4,970	60.33	5,970	50.22	6,970	43.02	7,970	37.62	8,970	33.42	9,970	30.07
980	303.0	1,980	151.4	2,980	100.6	3,980	75.33	4,980	60.20	5,980	50.14	6,980	42.95	7,980	37.57	8,980	33.39	9,980	30.04
990	302.8	1,990	150.7	2,990	100.3	3,990	75.14	4,990	60.08	5,990	50.05	6,990	42.89	7,990	37.52	8,990	33.35	9,990	30.01
1,000	299.8	2,000	149.9	3,000	99.94	4,000	74.96	5,000	59.96	6,000	49.97	7,000	42.83	8,000	37.48	9,000	33.31	10,000	29.98

Ten columns, each consisting of two subdivisions, are shown. Either component in any column may be read as frequency in kilocycles, and the companion value is wavelength in meters.

(*Continued from page 24*)

And we have

$$L = \frac{[(30 \times 170.4 \times 142) - (12 \times 200 \times 150)]\ 10^8}{(30 \times 170.4 \times 142 \times 12 \times 200 \times 150)}$$

$$L = \frac{(725{,}904 - 360{,}000) \times 10^8}{261{,}325{,}440{,}000} =$$

$$\frac{365{,}904 \times 10^4}{261{,}325.44} = 140.02 \text{ microhenries}$$

Squared Frequencies Verified

The values 360,000 and 725,904 represent the squares of the high frequencies, although these high frequencies themselves do not appear in the formula directly. One high frequency was 600 kc, the square of which is 360,000. The other high frequency is 852 kc [(170.4 × 142)/(170.4—142) = 852] and the square of 852 is 725,904.

Applying formula (4), assigning the above values, we have:

$F_2^2 = 725{,}904$
$F_1^2 = 300{,}000$
therefore

$$L = \frac{(725{,}904 - 360{,}000)\ 10^8}{261{,}325{,}440{,}000} =$$

$$\frac{365{,}904 \times 10^4}{26{,}132{,}544} = 140.02 \text{ microhenries}$$

Application of wavelengths is as follows, where the capacity difference is 281.4 mmfd.:

$\lambda_2 = 547.8$ meters $\quad \lambda_2^2 = 300{,}094.64$
$\lambda_1 = 400$ meters $\quad \lambda_1^2 = 160{,}000.00$

$L = \lambda_2^2 - \lambda_1^2 = 300{,}094.64 - 160{,}000.00 =$ 140,094 centimeters = 140.09 microhenries.

The capacity value used was 281.4 mmfd., and the inductance determination was 140.09, as compared to 140.02 microhenries for the frequency basis (253.3 mmfd.). The difference is less than 0.1%, hence is negligible, nor would the instruments permit accuracy of such high order. The 281.4 mmfd. value also works nicely into the 10-to-1 capacity ratio for distributed capacity measurement. However, 281.73 mmfd. is the more accurate capacity, and its derivation is explained in the next column.

Over-Sensitive Sets Are Noise Producers

Noise of a type called hash may be heard in a receiver that is too sensitive. If there is an r.f. sensitivity control, always turn it down to make the set operate below this noise level.

Also what one does then is to get rid of hiss. If there is no such control, the receiver sensitivity may be reduced permanently by some voltage or other adjustment inside, until results are in agreement with the user's desires.

Origin of Simplifying Capacities Explained

When inductance is to be measured in terms of frequency and capacity, then $F^2 = 1/4\pi^2CL$ is necessarily involved. Unless otherwise stated, the units in the formula are cycles per second, farads, and henries. Since the reciprocal of $4\pi^2$ is 0.02533, the formula becomes $L = .02533/CF^2$, in which case L is explicitly expressed in terms of C and F. If L is measured in microhenries, C in micromicrofarads, and F in megacycles per second, the formula for L may be written $L = 25{,}330/CF^2$.

Now if a calibrated oscillator is used for making the measurement, C may be a constant. A convenient value to choose is 253.3 micromicrofarads, for that reduces the formula to $L = (10/F)^2$. If the selected capacity were ten times greater, that is, 2,533 micromicrofarads (.002533), the formula would be $L = 1/F^2$.

Sometimes the oscillator is calibrated in wavelengths. The formula for L can then be written in a slightly different form. Since the velocity, V, of a wave is equal to the product of the frequency and the length of the wave, we have $F = V/\lambda$. When this is substituted for the value of L we obtain $L = 0.02533\lambda^2/V^2C$. The units are understood to be henries, meters, meters per second, and farads. For the case of radio waves V = 299,820,000 meters per second. If the square of this is divided into 0.02533 we obtain 2.8173×10^{-19}. If C is expressed in micromicrofarads and L in centimeters (1,000 cm = 1 microhenry), then the formula reduces to $L = 281.73\lambda^2/C$. Finally, if C be chosen 281.73 micromicrofarads we have $L = \lambda^2$. It will be remembered that L is in centimeters and λ is in meters.

In most cases C cannot be known accurately, for it consists not only of the known capacity added to the circuit but also the distributed capacity externally to the condenser of known capacity. To eliminate the effect of the distributed capacity, make two frequency observations and take the difference between them.

When the added capacity is 253.3 mmfd. and the frequency is lowered from F_1 to F_2 megacycles, the inductance can be obtained from $L = 100/F_2^2 - 100/F_1^2$. Likewise, when the capacity added to a circuit is 281.73 micromicrofarads and it increases the wavelength from λ_1 to λ_2, the inductance may be obtained from $L = \lambda_2^2 - \lambda_1^2$.

Reverse Feedback Avoided

In High-Gain Single-Tube Phase Inverter

TO operate two tubes in push-pull it is necessary to furnish the grids of these tubes with signal voltages that are equal in magnitude and 180 degrees out of phase. Practically, this requirement is satisfied when the single-voltage output of a second detector or a.f. amplifier is converted into two voltages of proper magnitude and phase by means of either a suitable transformer or a resistance-capacitance network. The resistance-coupled arrangement, called a phase inverter, is often preferable for reasons of economy.

Phase inverters may be divided into two kinds: (1) those requiring two tubes and (2) those requiring only one tube. A disadvantage of the two-tube type is the relatively high circuit cost. The disadvantage of the usual single-tube type is that the gain due to regeneration in the cathode circuit is sacrificed. In some instances, it is necessary to compensate for this loss by an additional stage of amplification. The single-tube phase inverter described herewith is non-degenerative and is capable of driving two 6F6's or 6L6's to rated Class A output.

Input and Output

The circuit of the proposed phase inverter is shown in the diagram. The secondary of the i.f. transformer feeds the diode (D_1) of a 6H6 to supply audio voltage; the primary of the transformer feeds the diode (D_2) to supply a.v.c. voltage. The audio voltage that appears across R_2 is fed to the grid of a 6F5 through a coupling condenser (C_2). The output of the 6F5 appears across resistors R_5 and R_6. Because the potentials of points (e) and (f) are equal in magnitude and opposite in polarity with respect to ground, the output tubes operate in push-pull.

So that the a.c. voltages across R_6 and R_6 will be equal in magnitude and 180 degrees out of phase, the capacitance across R_5 must be equal to that across R_6. This requirement places restrictions on the assembly and the physical size of the components. Condenser C_3 should be physically small and should be mounted as far from large grounded objects as space permits. R_1, R_2, R_3, C_1, and C_2 should be mounted close to the sockets of the 6H6 and the output tubes and to the volume control (R_4); it may be necessary to extend the shaft of the volume control in order that the control be placed in the most desirable location. The lead to the cap of the 6F5 should not be shielded.

R_1 and R_3 are filter resistors. They serve to minimize the r.f. voltage that can appear across the volume control and to reduce the effects of capacitance from point (a) or (b) to ground. If point (c) or (d) should have a large capacitance to ground, the magnitude and phase of the signal voltage across R_6 will be changed. A shift in magnitude or phase of the voltage across R_6 is manifested by a decrease in power output, especially at high audio frequencies.

Capacity Effect Determined

To determine the effects of stray capacitances on the operation of the phase inverter, a detector-amplifier was constructed as diagramed. Those components whose capacitances to ground might adversely affect performance were mounted at least one-half inch from the chassis. A cathode-ray oscillograph was connected to the grids of the output tube in order to determine the magnitude of each grid voltage and the phase angle between them. A modulated r.f. signal was applied to the i.f. transformer.

The voltages at the grids of the output tubes were very nearly equal in magnitude and 180

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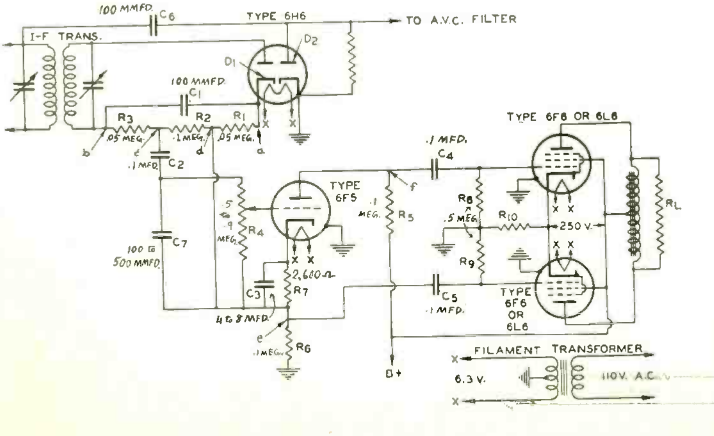
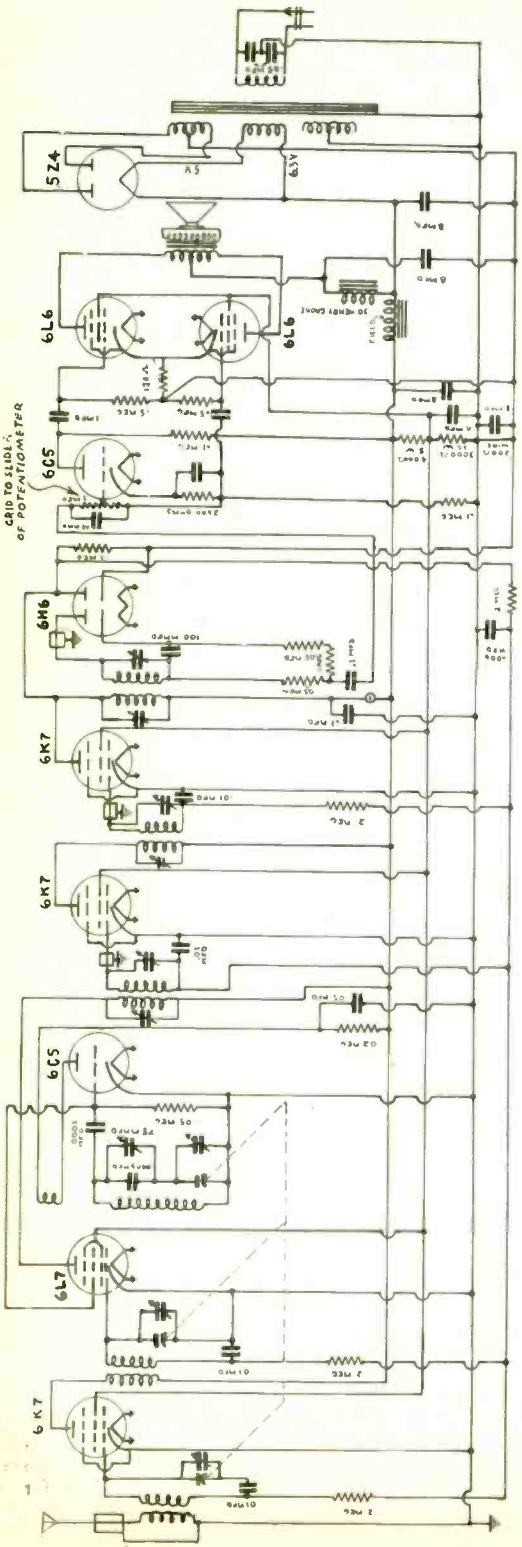


The 6F5 high-mu triode ($\mu = 100$) is used as single inverter tube for developing transformerless push-pull-interstage coupling. The 6H6 twin diode is used as signal detector (D_1) and as rectifier for automatic volume control. note that the signal detector is fed by the secondary, the a.v.c. rectifier by the primary, through R_6. R_L across the output choke. R_L represents normal plate-to-plate load. $R_1 = 125$ ohms for 6L6's, 200 ohms for 6F6's.



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degrees out of phase at 400 cycles. This relationship was indicated on the cathode-ray tube by a single-line trace, which was inclined 45 degrees. At 7,000 cycles, the output was 6 db lower than the output at 400 cycles. The trace on the cathode-ray tube was then a narrow ellipse; the slope of the major axis of this ellipse was slightly different from the slope of the single-line trace observed at 400 cycles. This difference indicated that a relative shift in magnitude and phase of one voltage had taken place.

Below 100 cycles, the trace was also a narrow ellipse, the slope of the major axis of the ellipse was nearly the same as that of the straight-line trace observed at 400 cycles. The length of the major axis of the ellipse was slightly less than the length of the straight-line trace. These differences indicated that the phase of one voltage had shifted slightly and that the magnitude of both voltages were reduced by the same amount. The output was down less than 1 db at 100 cycles compared to the output at 400 cycles. It should be noted, however, that the selectivity of the i.f. transformer affected the frequency characteristic of the phase-inverter circuit.

Serves Class AB_1

With the volume control set at the maximum-output position, about 20 mmfd. of capacitance, in addition to the stray capacitances that were inherent in the system, could be connected from point (b) to ground before the output at 6,000 cycles dropped 2 db below the normal 6,000-cycle output. With normal plate-to-plate load (R_L), rated power output could be obtained at 400 cycles. The voltage applied to the grid of the 6F5 is $R2/(R_1 + R_2 + R_3) \times E_a$, where E_a is the total audio voltage developed by the diode. For the values specified in the figure, $R_2/(R_1 + R_2 + R_3) = 0.5$. Thus, although only 50 percent of the available audio voltage is used, the high gain of the 6F5 permits the output tubes to be driven to full output.

This phase-inverter circuit may be used with any of the recommended Class AB_1 ratings of the 6F6 or 6L6.

Complete Circuit Using 676 Push-Pull Output

The method of establishing transformless push-pull input as described in the article on negative feedback avoidance is included in the diagram of a complete receiver in the column at left. The circuit ahead of the audio follows one used in Radio World's laboratory. The power tubes' self-biasing resistor may be 120 to 125 ohms, 10 watts.

GUNDERSON'S IDEA

The idea about a clearance strip to protect a set's a. c. cable, illustrated in the July issue, was due to E. T. Gunderson of Humboldt, Ia.

A New Television Motor

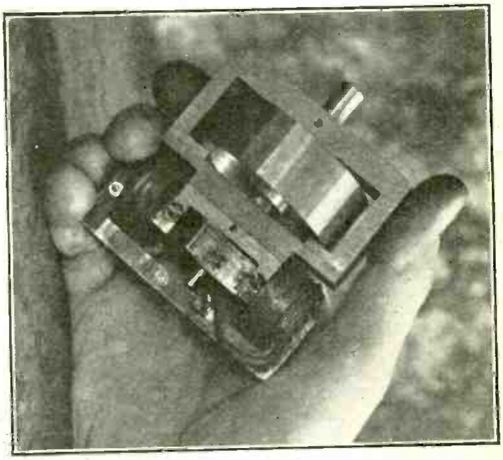
Peck's Device Synchronizes Transmission

By Robert Eichberg

A SCANNING system so small that, complete with motor, it can be slipped into a coat pocket, or carried in the palm of a man's hand, is the latest development by William Hoyt Peck, president and chief engineer of Peck Television Corporation, 51 Vesey Street, New York City.

Still adhering to the optical-mechanical method of scanning, in which he reports numerous advantages over the cathode-ray systems, Mr. Peck has now devised a scanning disc which measures only 2 inches in diameter, and weighs but 1¾ ounce.

Obviously, no great power is required to operate a disc of such small size and weight, and a motor has consequently been designed and built for this specific purpose.



The new Peck scanner and motor is small enough to be carried in the palm or slipped into a coat pocket. The scanning disc is 2 inches in diameter and weighs 1¾ ounces.

PERMITS SYNCHRONIZATION

The new motor might well be called a marvel of electromechanical engineering for, despite its small size, it does more than many motors of several hundred times its weight and power.

Known as a multi-speed synchronous motor, it enables a mechanical scanning system to synchronize automatically with any television transmission, irrespective of the number of lines per frame or frames per second being sent, or whether the transmission is intended for mechanical or cathode-ray reception.

Mr. Peck said:

"Every one is familiar with the principle on which any motor—such as in electric clocks, for example—is caused to run at constant speed. Briefly, each a.c. pulsation imparts an impulse to the rotor of the motor, which is so designed as to follow exactly the impulse rate.

"Now, while the transmission of television signals may be accomplished on any frequency assigned to the station sending such programs, this radio frequency is modulated by an audio frequency dependent on the number of lines per image and images per second which are scanned.

"As a rough illustration, suppose an image in the proportion of 10x12 inches, composed of 200 lines and scanned at 30 frames per second. If there are thus 20 lines to the inch vertically, there will be a like number horizontally. In other words, there will be 400 picture elements to the square inch. Multiply this by 120 (the number of square inches) and you find 48,000 picture elements to the frame. Then multiply this figure by 30, the number of frames per second, and you have 1,440,000 cycles.

END IMPULSES USED

"It is obviously impossible at present to drive a motor with such a high frequency, so instead we use only the impulses at the ends of the lines, thus getting a frequency of but 200 × 30, or 6,000 cycles.

"The same degree of synchronism is possible when the line impulses are used as when every picture element is utilized. Furthermore, as detail is increased, the number of lines increases arithmetically, while the number of picture elements increases geometrically, so, by using only the line impulses, we avoid the losses of high-frequency a.c. circuits."

Mr. Peck added in his new receivers the incoming signal is amplified at radio frequencies and detected in the usual way, after which it is divided between two audio amplifiers. One feeds the signal into the light modulator tube which controls the brilliance of the individual picture elements on the screen. The other triggers a low voltage d.c., changing it to a.c. of a frequency identical with the rectified component received. A simple filtering system cuts out all modulations save those of the frame lines, and, as a result, the locally generated a.c. which drives the scanning motor is governed entirely by the signal received.

The motor, Mr. Peck reports, will synchronize with anything from a 45-line, 12-frame transmission to one of 450 lines at 60 frames per second. These represent the extremes so far tested.

"With this degree of simplicity in operation, coupled with its brilliant, large size images, the mechanical system produced by Mr. Peck appears to offer a really practical solution to the problems which have hitherto confronted the manufacturers of home television receivers," said an announcement from the corporation.

A Single-Sideband Feat

Difficulty Solved for Short-Waves

By George Rodwin

Radio Research, Bell Telephone Laboratories, Inc.

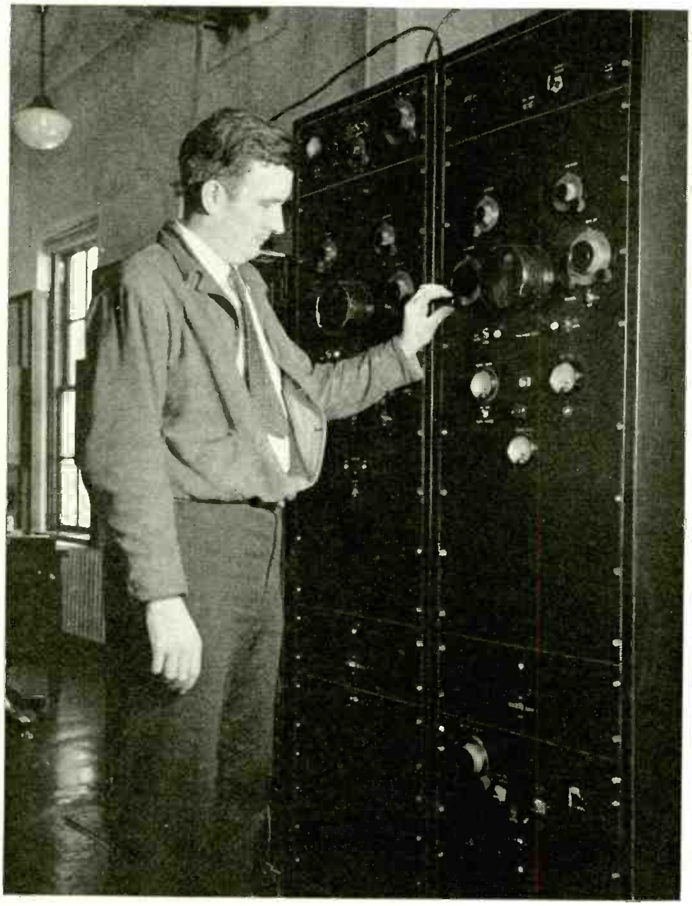


FIG. 1
The complete single-sideband receiver is housed in a single steel cabinet which is about twenty inches in width.

THE desirability of employing single-sideband transmission for radio communication has long been realized, and such a system has been employed for some years in the long-wave trans-atlantic service. Studies showed that similar advantages would accrue from operating short-wave circuits by the single-sideband method, and preliminary tests indicated that the theoretical gains could be realized in practice. Maintenance of the correct adjustment of the resupplied carrier at the receiver, however, is difficult at these high frequencies, and so it seemed desirable to build a system with which several variations of single-sideband transmission could be studied. Through the co-operation of the British Post Office a transmitter was set up in England which radiated a single sideband and a carrier reduced to about one-sixth of its normal value. This small value of carrier does not detract from the advantages of a single-sideband system, and has the advantage of supplying a basis for the resupplied carrier present at the receiver.

It was felt that a single-sideband receiver should be designed so as not to require any more attention in operation than an ordinary double-sideband type, and with this in mind the resupplied carrier adjusting features were made automatic. The complete receiver, mounted in a steel cabinet seven feet high, is shown in Fig. 1. It is of the double detection variety, and consists of a high-frequency amplifier stage, a balanced first demodulator, a three-stage intermediate-frequency amplifier, and a balanced second demodulator and low-frequency amplifier, with the addition of circuits and apparatus for resupplying the carrier. To widen the scope of the studies, two methods of carrier supply were provided. One utilized the transmitted carrier after it had been reconditioned, and the other employed a local oscillator for the carrier resupply, using the incoming carrier to control the frequency of the local oscillator.

THE BLOCK DIAGRAM EXPLAINED

A simplified block schematic of the system is shown in Fig. 2. A beating oscillator supplying the first demodulator reduces the incoming signal and carrier to the intermediate frequency. A branch circuit from the grid of the third intermediate-frequency amplifier tube contains a narrow-band crystal filter, which selects the carrier without passing the sideband. This filtered carrier is used for gain control, for tuning the beating oscillator, and to supply carrier to the second demodulator, either directly or by controlling the frequency of a local beating oscillator.

For purposes of gain control, the filtered carrier is passed to the gain control rectifier, and the rectified output is then distributed to the distortion products. As the result of the partial balancing of the distortion products, and of supplying the carrier some 20 db above the sideband, the receiver contributes no appreciable distortion to the overall circuit.

Since the carrier from the crystal filter is employed for all the various control purposes, it is essential that the intermediate frequency be at the correct value to pass through this very narrow filter. To secure this result, the beating oscillator must be controlled so that its frequency is always a definite amount above or below that of the incoming carrier, because the

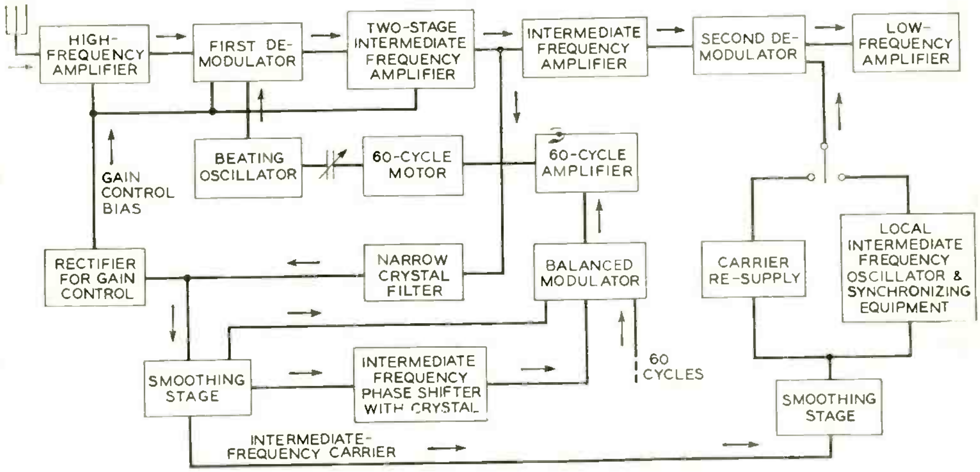


FIG. 2
Block schematic of the single-sideband receiver.

high-frequency amplifier, the first demodulator, and the first two stages of the intermediate-frequency amplifier. The circuit has a time-constant of about a second so that the gain of the receiver is not affected by momentary fading of the carrier.

SMOOTHING STAGES USED

For purposes of resupply, the carrier from the crystal filter is passed through two smoothing stages which smooth out variations in the carrier amplitude, and pass the carrier to the second demodulator at a level about ten times that of the signal. The circuit of the second demodulator is shown in Fig. 3.

The sideband is put on the two grids in opposite phase while the carrier is put on the grids in the same phase. The outputs of the two tubes, due to beating of the carrier and signal frequencies, add in the output circuit, while beats between frequencies in the sideband itself will leave the tubes in opposite phase and thus will balance out. This balance cannot be made perfect in practice, and the resulting beat products of signal frequencies form the major source of distortion in the single-sideband receiver.

By making the resupplied carrier large compared to the sideband, however, the desired signal can be made large with respect to these difference between the frequency of the incoming carrier and that of the beating oscillator determines the intermediate frequency.

WATT-HOUR METER CONTROL

The general method of control employed is to tune the beating oscillator by an adjustable condenser driven by the rotating element of a watt-hour meter, which acts as a sixty-cycle motor. This arrangement is shown with copper shielding cover removed in Fig. 4. The motor, in turn, is connected to a circuit which supplies no input when the frequency of the beating oscillator is the correct amount above or below that of the incoming carrier, and which supplies an input tending to rotate the motor in a direction to bring the oscillator to the correct value when the difference-frequency varies. The input to the motor increases in proportion to the deviation of the difference frequency, so that the greater the error in the difference frequency, the greater will be the speed of correction.

A schematic of the balanced modulator circuit and associated phase-shifter with crystal, which supply the driving current for the motor, is shown in Fig. 5. The carrier from the crystal filter passes through one smoothing stage and is then fed to the grids of the balanced modu-

(Continued on next page)

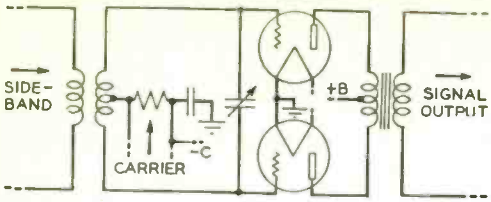


FIG. 3
Simplified schematic diagram of the second demodulator circuit.

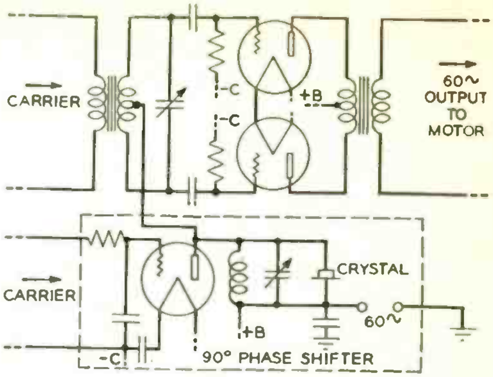


FIG. 5
Simplified schematic of the phase shifter, crystal, and balanced modulator used for tuning the beating oscillator.

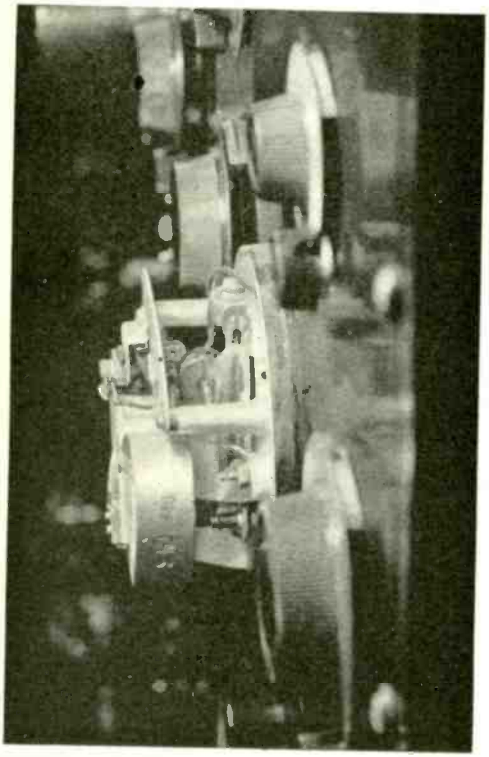


FIG. 4
A modified watt-hour meter serves as a motor to drive the vernier tuning condenser of the beating oscillator.

(Continued from preceding page)
lator over two circuits. One circuit applies carrier to the grids through a coupling transformer, thus supplying the two grids in phase opposition. The other circuit takes the same carrier but shifts it ninety degrees, amplifies it, and applies it to the two grids in the same phase. The phase relationships of the two carrier-frequency supplies to the modulator grids when the intermediate frequency is at the correct value are shown at the left in Fig. 6. A and A_1 are the two direct feeds and are in opposition to the two tubes, while B and B_1 are the two quadrature components, and are in the same phase at the grids.

The resultant voltages on the grids are C

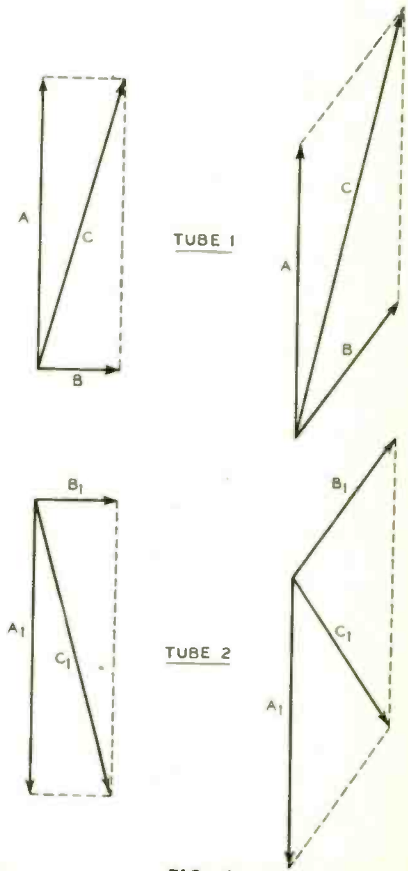


FIG. 6
Phase relationships of the two carrier frequencies supplied to the grids of the modulator. (Left) when the intermediate frequency is correct; (right) when the intermediate frequency is incorrect.

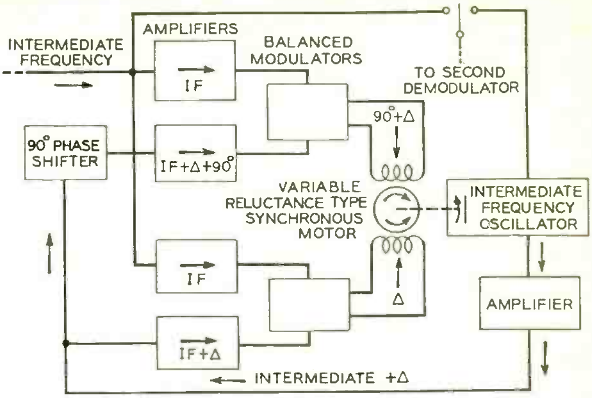


FIG. 7

The synchronizing circuit which holds the incoming carrier and the local oscillator equal. The two are heterodyned together in two modulators having outputs in quadrature. The beat current between the two drives a two-phase motor which runs until the beat frequency is zero. The speed of the motor varies directly with the frequency and so the greater the beat frequency the more rapid is its reduction to zero.

and C_1, each of which is the vector sum of the two components. These are of equal magnitude. A sixty-cycle supply is also connected to the two grids at the same point as the quadrature high-frequency current. The sixty-cycle component is in phase on the two grids, and the amount that will appear in the output circuits is a function of the high-frequency grid potentials C and C_1—equal amounts of the sixty-cycle components will appear in the output when C and C_1 are equal, and unequal amounts when they are unequal. When the intermediate frequency is at the correct value, C and C_1 are equal in magnitude, and as a result equal amounts of the sixty-cycle component will appear in the output of each tube where they will be balanced out because of the ninety-degree difference in phase.

Shunting the circuit of the quadrature component between the phase shifter and modulator is a crystal sharply tuned to the desired intermediate frequency, which is also that of the narrow crystal filter. This crystal has no effect on the phase of this quadrature component as long as its frequency is at the correct value. When it deviates from this value, however, the crystal acts as a phase shifter, and shifts the phase and amplitude of this component by relatively large amounts for a small deviation from the correct value. The effect of this shift on the resultant voltage on the grids of the modulator tubes is shown at the right of Fig. 6. A and A_1 are not changed because they do not pass through this crystal circuit, but B and B_1 are. The effect of the phase and amplitude shift of the B components is to give a large difference in the resultants C and C_1 as indicated. This unbalances the modulator with the result that the sixty-cycle component is no longer balanced out, but gives a sixty-cycle output to operate the tuning motor. As may be noted, the amplitude change in B and B_1 in the out-of-tune condition aids in unbalancing the modulator. Depending on whether the intermediate frequency was greater or less than the desired frequency, the C or C_1 resultant will be the larger. In one case the sixty-cycle output will drive the motor in one direction, and in the other, in the opposite direction. This circuit acts rapidly, and operates very effectively to hold the intermediate frequency at the correct value.

To be able to compare reception using a reconditioned carrier with that when the carrier is supplied by a local oscillator, an optional arrangement was provided for furnishing carrier to the second demodulator. This arrangement requires a tuning control for the oscillator, but the problem differs from that encountered in tuning the beating oscillator in that the frequency for this resupply oscillator must be held to a value approximately the same as the intermediate frequency, while the frequency of the beating oscillator must be held at a frequency differing from it by a constant amount.

The tuning of the local oscillator is obtained by a circuit shown in the block diagram of Fig. 7. It is similar to the equipment that has been used for synchronizing broadcast stations. The incoming carrier and the local oscillator are beat together in two modulators whose outputs are in quadrature. The resulting beat drives a compactly-built two-phase motor that operates until the beat-frequency becomes zero. The speed of the motor varies directly with frequency, and so the larger the deviation in frequency, the more rapidly will the correction be made. The action of this synchronizing circuit is slower and more precise than that of the automatic tuning of the beating oscillator, so that when a change in the incoming carrier or the beating oscillator occurs the automatic tuning control of the beating oscillator will act to bring the intermediate frequency to the correct value to pass the crystal filter. The synchronizing apparatus will make what further adjustment is needed to hold the local oscillator at this value.

This single-sideband receiver has proven very satisfactory in preliminary tests, and from studies made with it a large amount of information has been gathered on single-sideband transmission, some of which was discussed in an article in the May issue of the "Record." Tests on single-sideband operation on short waves are in progress, and although results so far have been favorable, there are still some unsettled points. Only one-direction transmission has been tested between England and New York.

A BEGINNER'S CRY

Simple Circuit In

By M. N

Engineer, A

AMATEUR station W9UWK proves that it is possible to construct a transmitter that really performs, from many old parts and a few inexpensive new units. The circuit used is very simple and is extremely easy to adjust for operation. A type 47 tube is used as crystal-controlled oscillator, giving the station stability. A 40 meter crystal is used, ± 10 kc. This stage is followed by a type 46 tube, having its grids tied together, used either as a buffer on 40 meters or as a doubler for 20-meter operation.

In the final stage a 10 tube is used with 20 watts input. Only 700 volts are required for this stage. Figuring 70% efficiency this transmitter will put on the air 14 real watts of c.w.

The panel is made from a single piece of three-ply wood and is attractively finished in black. Shiny dial plates and black knobs add to the professional appearance. The meters mounted in the upper section are of Readrite manufacture and may be switched into the dif-

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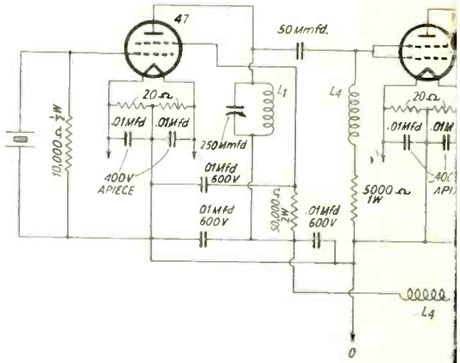


The transmitter proper consists of a 47 shown at extreme left), a 46 buffer and, if intended principally for c. w., key connect key-click filter (not shown) is advisable. A

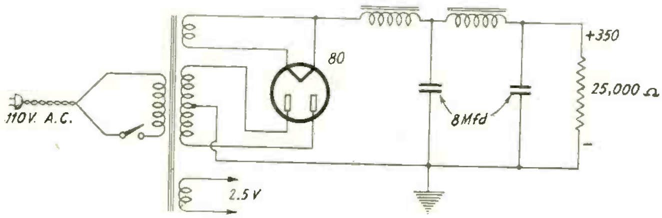
COIL-WIN

Coil	L_1	L_2
40 meter......	19 turns #16 DCC. Spaced one diam.	21 turns # DCC. Spac one diam.
20 meter......	11 turns #16 DCC. Spaced one diam.	8 turns # DCC. Space one diam.

LIST OF PARTS

Power Supply for Oscillator and Buffer-Doubler

One power transformer with 2.5 volt, 3.5 amp.; 5 volt, 2 amp.; 400-0-400 volts, 90 M.A. windings
One a.c. cord and plug
One S. P. S. T. toggle switch
One 7x9x2" metal chassis
One 4-prong wafer socket
One dual 8 mfd. 525-volt electrolytic condenser (Cat. EG-9808)
Two chokes, 90 ma. rating or higher
One 25,000-ohm, 25-watt resistor
One type 80 Sylvania tube
Hook-up wire and connecting cable.



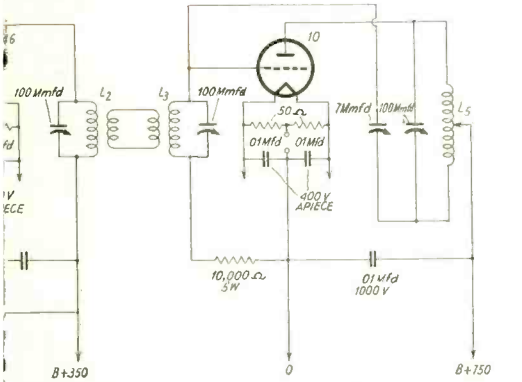
The power sup tor and buffer around a Sylv dual 8 mfd. Co trolytic unit capacity. More for the supply which has two and two 1,000 biller filter co the 7.5-volt se the 81's, the tube in

STAL TRANSMITTER

expensive to Build

I. Beitman

lied Radio Corp.



crystal-controlled oscillator (40-meter crystal need be, doubler, and a 10 "final." The set is ed to posts under the 10 tube. A standard t 70% efficiency, output on c. w. is 14 watts.

DING DATA

	L_3	L_4	L_5
14 ed	The same as L_2	R.F. Choke	28 turns 1/8" tubing. Spaced L_5 is center tapped.
14 d	The same as L_2	R.F. Choke as above	12 turns 1/8" tubing. Spaced

ly for the oscilla- -doubler is built ania 80 tube. A rnell-Dubilier elec- serves as filter power is needed to the final stage. Sylvania 81 tubes -volt Cornell-Du- densers. One of econdaries is for other for the 10 he "final."

LIST OF PARTS

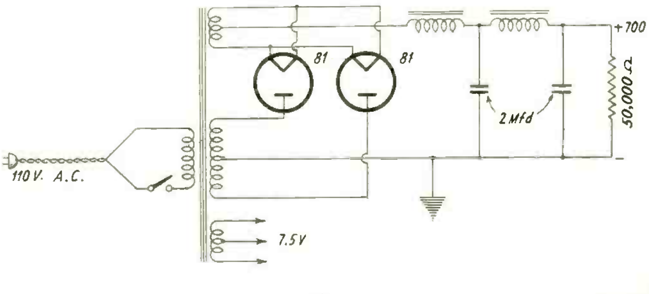
For Transmitter

Three .01 mfd. 600-volt condensers.
One .01 mfd. 400-volt condenser.
One .01 mfd. 1,000-volt condenser.
One 50 mmfd. condenser.
One 7 mmfd. variable condenser.
[Fixed condensers, Cornell-Dubilier]
One 100 mmfd. variable condenser, transmitting type.
Two 100 mmfd. variable condensers.
One 250 mmfd. variable condenser.
[Variable condensers, National Company]
One 10,000-ohm, ½-watt resistor.
One 50,000-ohm, 2-watt resistor.
Two 20-ohm center-tapped resistors.
One 50-ohm center-tapped resistor.
One 10,000-ohm, 5-watt resistor.
One 5,000-ohm, 1-watt resistor.
One 80-meter crystal and holder.
Two five-prong sockets.
One four-prong socket.
Dials, hook-up wire, tubes, coil forms, coil sockets, hardware, etc.

LIST OF PARTS

Power Supply for the Final Stage

One a.c. cord and plug
One S. P. S. T. toggle switch
One 7x11x2" metal chassis
One power transformer, 7.5 volts, 2.5 amp.; 7.5 volts, 1.25 amp.; and 750-0-750 volts
Two 4-prong wafer sockets
One swinging choke
One filter choke
Two 2 mfd. 1,000 volt paper condensers (Cornell-Dubilier Cat. F-10020)
One 50,000-ohm, 25 watt resistor
Two type 81 Sylvania tubes
Hook-up wire, connecting cable, etc.

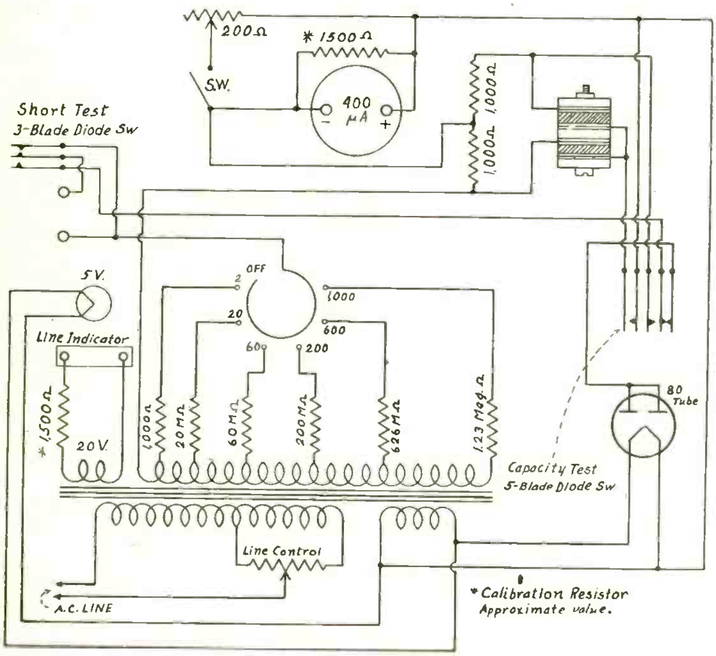


Capacity Meters

Circuits Used by Triplett, Tobe, Supreme, Weston, Hickok and Others

By Decatur Wadsworth

MERIT, CAPACITY, AC VOLTS ACCURATELY CHECKED



The latest condenser testing device, Triplett Model 1240, not only measures capacity, from .001 mfd. to 10 mfd., but also tests condensers of all types for shorts, opens, leakage and breakdowns.

THE latest condenser checker announced by the trade is Model 1240, manufactured by Triplett Electrical Instrument Co., 277 Harmon Drive, Bluffton, O. It features all-inclusive tests of condensers, that is, serves not only as a capacity meter but also as a checker of shorts, opens, leakage, etc., and a.c. volts.

A condenser tester must do more than check capacity, relatively unimportant since the capacity is generally marked on the covering and very seldom changes. Also a shorted or open condenser will throw the radio circuit out of order, making the trouble easy to find with even the simplest test equipment. By far the greatest

Crystal Transmitter for Beginners

(Continued from preceding page)

ferent circuits of the transmitter for quick measurements.

Two individual, well-designed power supplies are used. These are mounted in the lower sections of the shelves built up in the back of the panel. The a.c. line switches are brought out to the panel for easy control. The smaller power supply serves the oscillator and buffer and uses an 80 tube. The larger unit uses 81's as rectifiers in a full-wave circuit and supplies the final stage. The use of large chokes and condensers helps to create a very good, steady signal.

All the coils, except for the final tank coil, are wound on 1½ inch plugin forms for easy interchange between 20 and 40 meter operation. The tank coil is wound with copper tubing, ⅛ inch size, on a 3 inch form. Coil winding data are given in the table.

Last month, in the August issue, the theory of capacity measurements was described, circuits and formulas given, and filter capacities stressed, though measurement of mica values and even tiny ones was included. Herewith are given data on commercial type capacity meters, embodying in general the principals set forth last month, though some commercial apparatus includes original application.—EDITOR.

amount of troubles which occur in condensers are not so simple and require test equipment specially designed to easily locate their defects, namely—intermittent shorts or opens and high resistance leakages. These troubles are only too familiar, but the following is a brief review:

An intermittent short causes eratic operation, motorboating, parasitic oscillation, signal cutting in and out, all of which troubles are very hard to locate. The usual way to remedy this type of trouble is substituting condensers by the cut and try method which is very slow and the trouble is never positively corrected but might lie dormant to occur at some future date. However, the best method is to test the condenser on a good condenser tester, which must have sufficient voltage available in order to test the condenser for breakdown. For some condensers this will call for 1,000 volts d.c. When making breakdown tests with high voltage, a test will also be made on the condenser for shorts. Any intermittent short will burn through and the condenser is definitely placed as bad.

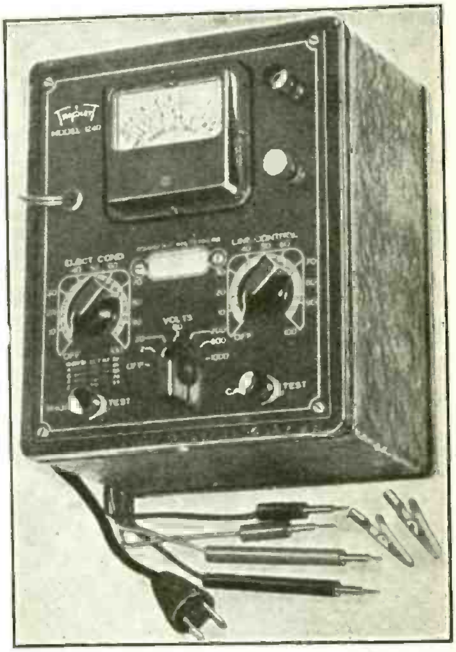
TESTING FOR MERIT

The short and breakdown test is accomplished in the Model 1240 by applying d.c. voltage to the condenser under test. With a leaking condenser connected across the binding post, the current flows from the selected voltage tap of the transformer through the selector switch to one binding post, through the condenser to the rectifier where the current is rectified, to the positive meter terminal, through the meter and shunt then through the 1,000-ohm resistor and back to the common terminal of the transformer. Thus, if the condenser is leaking, current will flow through the condenser and the meter will indicate. A "short test" button is used to complete this circuit and to discharge the condenser when the button is released. When the "capacity test" button is not depressed the Type 80 tube rectifier is placed in the circuit, but when it is depressed the a.c. circuit is connected for other tests.

Intermittent open condensers will have the same symptoms as above and in addition, that of blocking. The remedy in this case is to test for breakdown, then to test for open by using a.c. voltage. Always test paper condensers for shorts or opens with voltages as high, or slightly higher than the rated voltage of the condenser. Due to the leakage factor of the electrolytic condenser and the resistance which is used to protect the meter, the voltage never exceeds the safe value of the electrolytic condenser no matter what voltage is applied within the range of the Triplett Model 1240. The circuit used for this test is the same as that used for capacity measurement.

Condensers with high resistance leakage in the order of 10 megohms or more, used in certain parts of critical sets, will cause an intermittent oscillation which is very hard to locate. When tests as described are applied location of such defects is assured.

Certain condensers in radio sets are critical as to their leakage or dielectric resistance. Such condensers are generally used in blocking circuits and any condenser which shows a leakage factor of below 30 meg. will cause the grid of the amplifier tube to be from three to four volts



View of the Triplett instrument, which has a good-bad scale for merit test of condensers, three basic capacity scales, also a. c. voltages, 0-2-20-600 volts.

more positive than that for which the set was designed. This will naturally upset the circuit.

In preamplifiers of a microphone circuit the condenser leakage must be above 50 megohms. The same is true with the a.v.c. circuit as the condensers in this type of circuit must have extremely low leakage value, since the small currents and voltages available in the direct circuit are very easily upset by the bucking voltage which would be caused by a leaking condenser.

The d.c. leakage phenomenon of a condenser causes a lower or higher voltage at the tube element and upsets the circuit. However, it is not possible to set up a fixed resistance for various functions of condensers but the user's knowledge of radio must tell him when to discard. Due to the low resistance and high voltages involved in a bypass condenser circuit, the leakage factor of a bypass condenser can go

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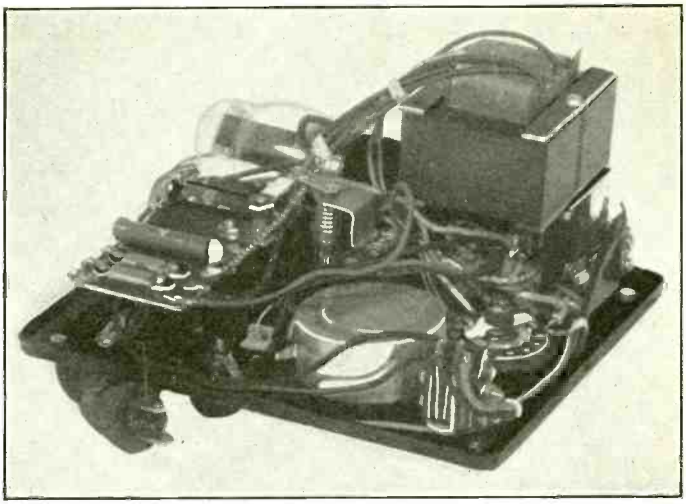


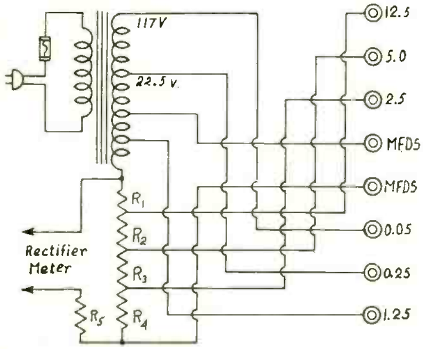
View of the interior of the Triplett condenser tester, just put on the marke. Besides measuring capaciy over a wide range this instrument tests for leakage at high sensitivity, also breakdown, with "good-bad" reading, and reads wide range a.c. volts.

(*Continued from preceding page*)

as low as one megohm without upsetting the circuit more than a fraction of a volt. This small fraction of a volt will not seriously upset the circuit, since it is but a small part of a percent of the actual voltage being developed across the condenser.

NOW FOR CAPACITY METER

After the above tests have been made on the condenser it may be tested for capacity by the Model 1240.



The capacity meter diagrammed above is the one used in a Supreme analyzer.

A condenser of a certain capacity will have a specific reactance and will do a specific job of filtering the 120 cycle ripple in an a.c. power pack. The filtering action of the condenser is controlled by the power factor or phase angle. The effect of power factor on filtering efficiency can easily be determined as zero power factor has 100 per cent filtering efficiency for the capacity used. Seventy-five per cent power factor gives a filtering efficiency of approximately 60 per cent. A condenser of 75 per cent power factor would have to be nearly twice as large as a condenser of zero power factor to perform the same amount of work. As we are interested only in the filtering efficiency when testing electrolytic condensers, it is necessary that some means be provided to determine the filtering work electrolytics will accomplish.

This is accomplished in the Triplett Model 1240 Tester by connecting 60 or 200 volts of unfiltered, half-wave rectified, 60 cycle current across the condenser and measuring the reactance of the condenser on the d.c. meter scale either as a good or bad condenser.

The Triplett Model 1240 Condenser Checker will perform breakdown, open and short tests, as well as capacity tests on a single meter. D.c. voltages are available for breakdown test up to 1,000 volts, in steps of 2, 20, 60, 200, 600 and 1,000. A.c. voltages are available in the same ranges.

Voltages are supplied by a power transformer with the necessary winding and a selector switch to choose the proper range. The primary winding is tapped at 97 and 133 volts across which is placed the line control potentiometer, which is used to set the shadow of the line control meter directly beneath the red line. This is a very important adjustment as all the electrical circuits of the tester have been worked out so that the tester is very accurate and this accuracy must be maintained over a long period.

One secondary winding consists of a 5-volt 3-ampere winding to excite the heater of the 80 rectifier tube and the filament of the pilot line control meter lamp. Another secondary winding consists of a 1,000 volt winding tapped at 2, 20, 60, 200, 600 and 1,000 volts. This is to provide the voltage for the capacity, breakdown, short and leakage tests of paper and electrolytic condensers.

CIRCUIT SUPREME USES

When a meter is used for capacity measurements, says Supreme, the resistance value of the meter and of the shunt and multiplier resistors associated with the measuring circuit constitutes one leg of an impedance triangle similar to that heretofore discussed for a.c. potential measurements. The reactance of a capacitor of unknown value, which may be connected into the measuring circuits for the purpose of determining its value, constitutes another leg of the same impedance triangle.

It is obvious that the resistance value of the meter and of its associated shunt and multiplier resistors is a constant value for any particular capacity-measuring range, regardless of the capacitive value of any capacitor which may be connected to that range, and that the capacitive reactance, in every case, is determined by the capacitive value of the capacitor which may be subjected to the measurement; therefore, the capacitive leg of the triangle is the variable element. It is further obvious that the meter is related directly to the hypotenuse of the impedance triangle and will not, therefore, have a linear relationship to capacitive values. For example, let's assume that we have an impedance triangle in which a full-scale meter current corresponds to a certain hypotenuse length and in which the reactance leg corresponds to a capacitive value of 5.0 microfarads; if we remove the 5.0-mfd. capacitor and put in its place a 2.5-mfd. capacitor, the length of the reactive leg of the triangle will be doubled, but the length of the hypotenuse will not be doubled and, therefore, the meter current will not be reduced to one-half of its former full scale value. In other words, a linear or evenly divided scale cannot be used on the basis of fixed resistance values for the meter and its associated shunt and multiplier resistors.

LINEAR SCALE EXPLAINED

From what has just been explained, it is natural to ask a question as to how capacitive measurements are enabled on an evenly divided scale in this tester. The answer lies in the fact that, although the meter, shunt and multiplier resistance values constitute a fixed resistive value for each capacity-measuring range, a variable resistive value is introduced by the full wave instrument rectifier employed, and shunts and multipliers are employed of such values as will enable the variable element of the rectifier resistance to approximately counter-balance the variable reactive element introduced by the different capacitive values which may be encountered for measurement.

In other words, the divisions of a meter scale could be crowded on the upper end of the scale for capacitive measurements if the rectifier were linear in its characteristics, and the non-linear

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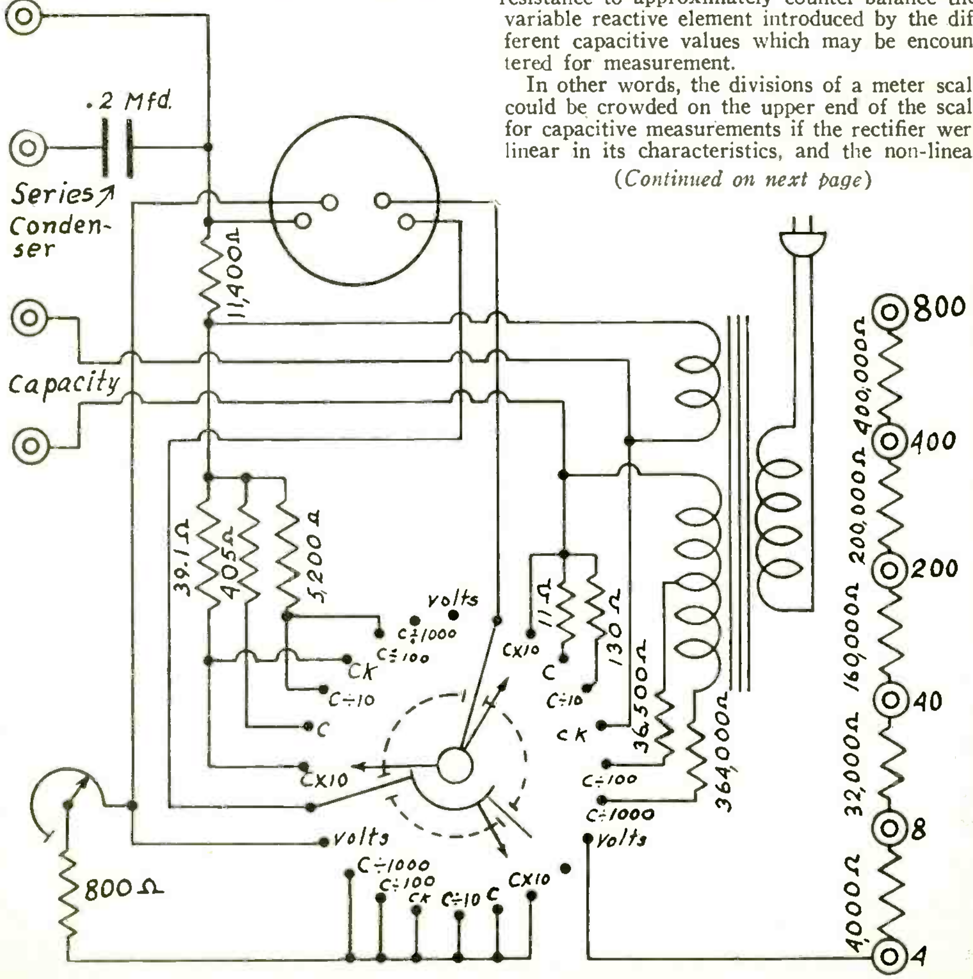
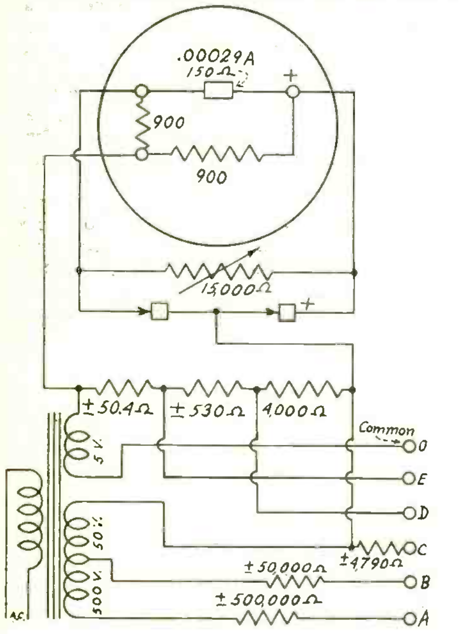


Weston's capacity meter uses this circuit.

(Continued from preceding page)
characteristics of the rectifier would cause the divisions of the meter scale to be crowded on the lower end of the scale if no capacitive variable elements are introduced into the circuit; but when both variable elements are introduced into the circuit in approximately equal and opposite proportions, the meter scale divisions can be equally separated across the whole scale or, what amounts to the same thing, the regular evenly divided scales can be utilized for capacitive measurements.

For the measurement of electrostatic (paper) capacitive values, comparatively high a.c. potentials are used, but it is necessary to use comparatively low a.c. potential values for the measurement of electrolytic capacitive values, so as not to puncture the electrolytic film around the electrodes. Actually, the a.c. poten-



Hickok's capacity meter.

tial applied to electrolytic capacitors in the 0/1.25/2.5/12.5-mfd. ranges is about 9 volts.

WESTON'S INSTRUMENT

The Weston Model 664 Capacity Meter, when readings are taken in the best part of the scale, confines errors to less than 5 per cent., says the maker.

The instrument is a rectifier type milliammeter with a full-scale sensitivity of 250 microamperes. Reference to the wiring diagram will show the several circuits which are arranged by the switch.

The power source is a small transformer designed to furnish the correct potentials with negligible drop from an alternating current line. The basic design is for 60 cycles, but instruments with scales giving correct capacity indications on 50 cycles are manufactured also.

Essentially the capacity reactance of the condenser under test is placed in series and the resulting current is measured. To take care of line voltage variations, the instrument itself is adjusted by means of a shunt rheostat to top mark on the existing line voltage.

The direct capacity reading is taken with the instrument adjusted, by means of a shunt, to 10 m.a. at 4 volts and a 4-volt tap on the transformer is used. The voltage applied to the condenser under these conditions is something under 4 volts. With such a low potential, readings on electrolytic condensers having a 10-volt rating or higher can be had directly and without any d.c. bias.

RANGES EXPLAINED

The high range C x 10 is obtained by shunting the instrument to 100 m.a. and maintaining the 4 volts.

The C ÷ 10 range, with 0.4 mfd. at center, is obtained by shunting the instrument to 1 ma. and using the 4-volt transformer tap.

The ranges, C ÷ 10, direct, and C x 10, are all applicable to testing directly electrolytic condensers rated for 10 volts or over.

The C ÷ 100 range is also obtained with a 1 ma. sensitivity, but the voltage is increased to 40 volts.

The C ÷ 1000 range is obtained by using the basic instrument sensitivity of ¼ ma. and 100 volts from the transformer.

Since the 100-volt potential is applied only on the very lowest capacity range, and most condensers in this group being of the moulded type using mica for a dielectric, no difficulty will ordinarily be had with breakdowns. Higher ranges where paper condensers may apply use a still lower voltage and paper condensers as such will stand this potential quite satisfactorily. Hence the device measures all types of condensers.

Accordingly, the device may be used without fear of breaking down any condenser in ordinary use, says the manufacturer, adding:

Shorted condensers will merely cause the instrument to read full scale and testing shorted units can cause no damage to the instrument on any range.

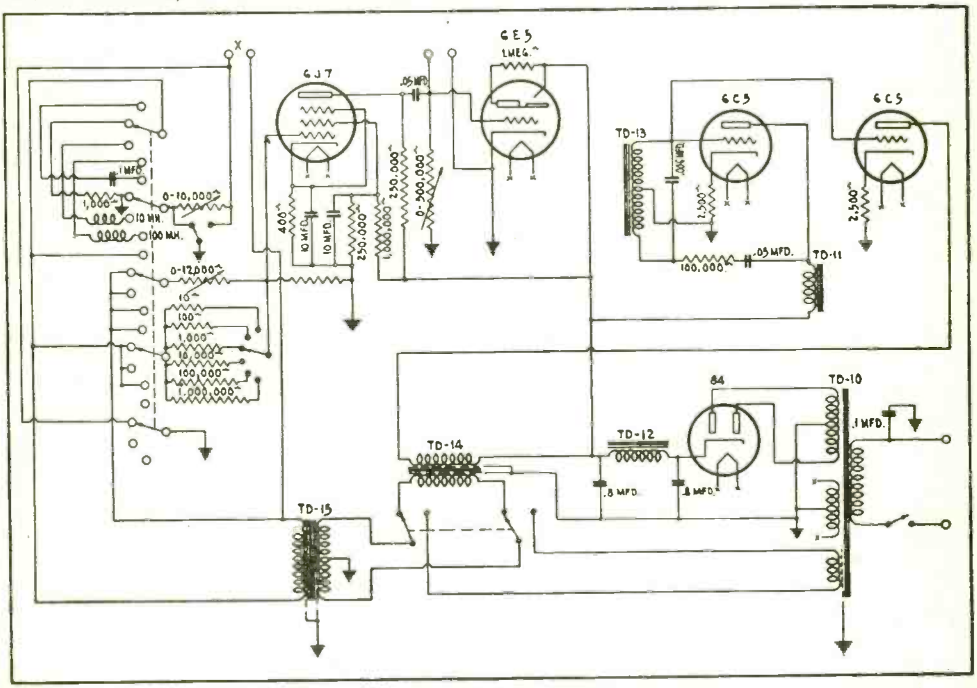
Since the device functions on the current flow on alternating current, condensers with a very poor power factor, or which have a high leakage, may show a reading slightly higher than their true capacity; electrolytic condensers fall into this class but in general will be well within the accuracy of the device.

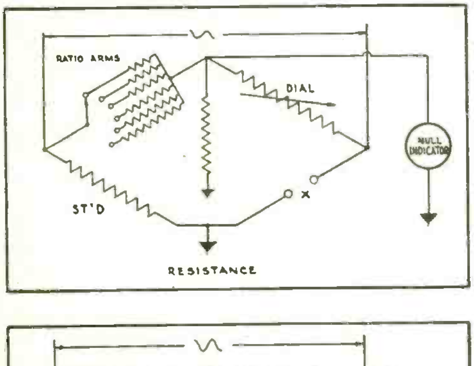
READS A.C. VOLTAGES, TOO

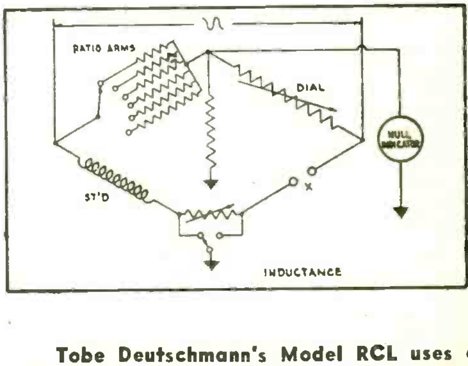
The a.c. voltage ranges have been added to increase the general utility of the unit and when the switch is in the position for reading voltage, the instrument is adjusted to 1 ma. full scale and the compensating rheostat for line voltage is taken out of the circuit. The several ranges are then obtained at the pin jacks through suitable series resistance, the resistance of all ranges being 1,000 ohms per volt.

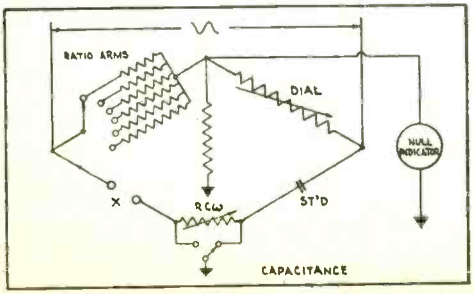
If an attempt is made to check the calculated values of resistance shown in the diagram, it may be noted that they are slightly less than theory would indicate; this is due to the fact that the transformer windings have a small drop in them and this resistance is considered as part of the total series resistance, making the resistance units themselves of a slightly lower value in order to get most accurate overall readings.

Should occasion be had to use this instrument on a frequency other than that for which the scale is calibrated, as for instance using a 60 cycle instrument on 50 cycles, accurate readings may be had by considering that the reading is lower than the true value of the condenser by the same proportion as the frequency. That is, a 1 mfd. condenser, tested on a 60-cycle device on a 50-cycle line, will indicate 5/6 mfd. This proportion holds throughout and may be of some value in districts where two frequencies are used. The standard transformer, however, is not made to function below 50 cycles.







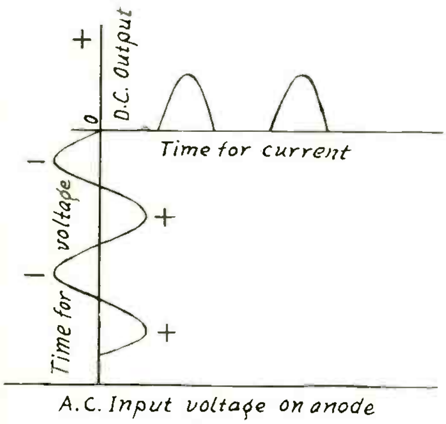


Tobe Deutschmann's Model RCL uses a bridge to measure inductance, capacity, resistance, efficiency of coils and power factor of condensers. There is a combination of three bridge circuits, for capacity, inductance, and resistance. It can be operated with a Wagner ground for precision measurements. Ranges: 10 mmfd. to 100 mfd.; 1 ohm to 1 meg.; 10 microhenries to 100 henries. It uses one each 84, 6E5, 6J7, and 6C5.

Simple Tube Voltmeters

The Outstanding Measuring Instrument Analyzed

By Herman Bernard



Diode half-wave rectification. The sine wave input produces an output response only for its positive alternation (+), so the negative half wave (—) is wiped out. The d.c. pulses, only above axis, disclose this. If the time is one second, the a.c. frequency is two cycles and there are also two d.c. pulses per second. See Table I, line 1.

ALTHOUGH the vacuum tube voltmeter is the most useful and important of all radio and audio measuring instruments, not until recent months has any sign of material recognition of this fact become manifest.

When the tube voltmeter is needed there is no instrument that can satisfactorily be substituted, hence it makes measurements that no other instrument makes as well or at all. It has an extremely wide frequency range, from a fraction of a cycle to 30 megacycles (10 meters), for which a given calibration, made at any frequency within the range, will hold, hence the device is practically independent of frequency, or non-reactive.

Moreover, it may have an almost unlimited voltage range, although generally most suitable for medium voltages, and introducing some problems for retention of accuracy at very low voltages. It can be used for measuring not only a.c. but also d.c., and as a voltmeter may have a practically infinite resistance, hence drawing no significant current from the measured circuit. Accuracy normally is around 6 per cent., for design and construction that do not introduce corrective factors, but may be improved greatly, to one per cent. or better, the highest accuracies then depending largely on the accuracy of the voltages used as standards in calibration. Thus the difficulties as to accuracy may be narrowed down to a single one, the standard voltages.

A vacuum tube voltmeter is a vacuum tube producing change in direct current in the output when a change of voltage is effected at the input, and including an indicator of the direct-current change, with known ratio or ratios between the two changes.

Linear or Square Law

Various laws govern the relationships between the input volts and the resultant direct current output, depending on the type of tube used and the manner of its d.c. voltaging. In general, the response will be either linear or according to the square law, although in certain applications the relationship in a single circuit changes from one to the other.

The relationship is said to be linear when the output current is directly or inversely proportionate to the input voltage. Square law applies when the response is proportionate to the square of the input voltage.

For instance, there may be an input voltage of 2 volts a.c., peak, r.m.s. or average, and there will be a certain direct current diode output, say, 122 microamperes. Thus the relationship of input voltage to output current, comparing volts and microamperes, is 2/122, or 1/61, or .014754. For direct relationship, meaning that the current increases with rise of input voltage, the input volts are determined as .014754 of the direct current in microamperes. If increase of input volts causes a decrease of measured direct current, and linearity prevails, an example of the inverse linear proportion, then the relationship is expressed as 1 minus .014754, taking the figure from the previous example, so that smaller plate current accounts for a larger input voltage, and the device is not self-calibrating.

Self-Calibrating

The principal wide-range tube voltmeter that has a linear characteristic is the diode, classified as a rectifier type VTVM. Associated with the diode is a series resistance, known as the load resistor, and if this is selected of a high enough value, say, 50,000 ohms or more for linearity, and also is related to the d.c. meter sensitivity so as to serve as multiplier of the meter scale, the d.c. current meter is used as a voltmeter and the voltage read equals the a.c. input volts to the tube voltmeter.

Principally a.c. volts will be measured with all tube voltmeters, except where the measured circuit in which d.c. flows has such a high resistance that usual meters can not make the measurement, because they draw so much current as to upset the voltage attempted to be read. Since the diode or rectifier type tube voltmeter always draws current, it would not be serviceable for measuring either direct or alternating current, where the tube voltmeter current was even one-tenth that ordinarily flowing in the circuit attempted to be measured. Besides, for d.c. purposes the electromagnetic meter, used independently, would be preferable, for it draws no more current, and the tube is superfluous.

If the d.c. meter in the diode leg is limited by a resistor that serves as scale multiplier, so that the rectified voltage is read directly, the determination of the factor, such as .014754, is unnecessary, because the voltage as read equals the a.c. voltage across the input terminals. Therefore the rectifier type VTVM requires no calibration.

Needs 0-100 Microammeter

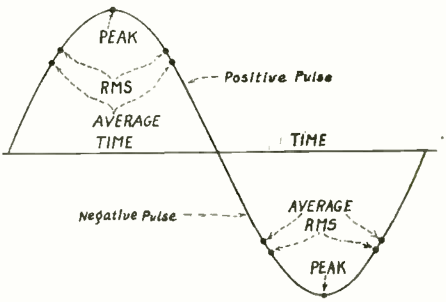
Due to the necessity of a high limiting resistor, no lower than 50,000 ohms for the lowest voltage range for linearity, a sensitive electromagnetic instrument is required for the all-important low voltage arnge. Thus, if a 5-volt full-scale deflection is selected, the meter would have to be a 0-100 microammeter, hence as a voltmeter has a rating of 10,000 ohms per volt, the same rating being applicable to the tube voltmeter. The requirement of a sensitive d.c. meter in the rectification circuit is a firm one for the diode, if low voltages are to be read linearly, and even for the higher voltage ranges no instrument of less sensitivity would suffice, because of the unrelenting requirement that the ohms per volt be just as great for the other ranges as for the lowest range.

When there is linearity the electromagnetic meter, with suitable multiplier of the scale reading, may be used, and its calibration holds for the a.c. input, as well, and this applies no less to linear tubes other than diodes. For instance, a triode of the leak-condenser type, really the equivalent of diode with amplifier, will contribute to the self-calibrating boon, as will a medium-biased non-current-drawing triode, where again there is linearity, in both instances for low amplitudes only. But most tube voltmeters do not follow the linear law, hence calibration is necessary, although even this may be reduced to a very few points. Sometimes there are mixed results, one type of detection over part of the reading, say, linearity over the lower part of a scale, with square law operation for higher amplitudes.

Diodes Are Linear

Diodes follow the linear law. Triodes and other tubes with more numerous elements, that have amplification properties, of which the diode has none, usually follow the square law. While the diodes are classed as the rectifier type VTVM, the tubes with amplifying capabilities are called detector type.

A square law detector is one in which the plate current change is proportionate to the square of the input voltage change. Therefore the input voltage change is proportionate to the square root of the plate current change. The change, or difference, in the input voltage is simply equal to the input voltage, since at no connection of the unknown to the circuit, the input voltage should be zero. With the plate current the situation is different, because there is a current flow due to the plate resistance across which is the d.c. B voltage. No such voltage was required for the diode, but there must be a positive voltage on the plate of detector type voltmeters. It is possible to balance out this quiescent plate current, or dead current, and make the meter in series with the plate circuit read zero at no a.c. input, therefore two differences arise directly, although their relationship still has to be established. Calibration is necessary.



If the time is one second the frequency is one cycle per second for this sine wave. The positive and negative peak volts are indicated, also the r.m.s. volts for both alternations. The average voltage applies to either alternation only, hence is confined to half-wave rectification, as the average for the full cycle is zero.

The Two Main Groups

So all tube voltmeters are grouped into two main classes (1), rectifiers; (2), detectors. The rectifier type draws current from the measured source. A detector may or may not draw current, depending particularly on the negative bias.

There is hardly enough difference between a rectifier and a detector to enable fundamental definitions distinguishing them. Both types depend on the fact that the tube is a conductor more freely in one direction than in the other, and the difference represents the d.c., because for maintenance of a.c. the movment would have to be equal in two directions. A tube that draws current when changing a.c. to d.c., and that has no amplifying capabilities, is a rectifier.

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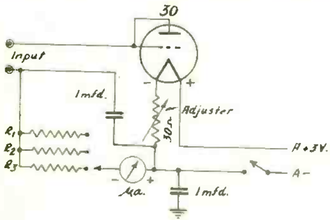
More simply, the diode is the only rectifier, particularly as it passes current in one direction and none in the opposite direction. All the rest are detectors, thence a detector is a tube changing a.c. to d.c. by reason of curvature of the characteristic, drawing no current from the circuit, and passing some current usually in both directions.

So the operation of tube voltmeters may be followed, if it is necessary to appreciate what causes the change from a.c. to d.c., what the relationship between a.c. input and d.c. output is, and how the services of the various types of VTVM are influenced by the operating conditions.

Open and Closed

The diode, with a.c. input between anode and one side of the load resistor, is a half-wave rectifier.

Each a.c. cycle consists of two alternations, the positive and the negative, assumed to be equal in amplitude. An alternation is therefore a half cycle, or half wave. Only the positive alternation activates the diode, because the diode is an open circuit when a negative voltage is applied to its anode, and a conductor when the applied voltage is positive. Therefore nothing appears in the direct current output that reflects in any way the presence of the negative cycle in the original a.c. wave. The negative cycle is wiped out, direct current exists now, and while it may not be free of ripple, the interference is in the form of pulses of d.c., and a condenser serves to remove or bypass these. Thus in tube voltmeters, the load resistor of the diode, or in detectors the plate-to-cathode resistance, should have a capacity across it sufficiently large to bypass alternating current of the lowest frequency to be measured.



Self-calibrating tube voltmeter, using a triode tube in diode fashion. Three ranges are provided. If R_1 is 50,000 ohms = 0-5 volts, R_2 500,000 ohms = 0-50 volts, R_3 5,000,000 ohms = 0-500 volts, μA is a 0-100 microammeter. See Table I, line 1.

If the a.c. voltage input is increased, the rectified current increases, because positive voltage on the anode makes the tube conductive, and the more positive the voltage the more conductive the tube, so the larger the direct current.

The Three A.C. Classes

The relationship between input a.c. volts and output direct current, or d.c. volts across a load resistor, is said to be linear, but there are three classifications of a.c. volts, and to which of these is the diode output linear? It is linear to all of them. The proportionality or factor differs, but the linearity is constant.

First, we have as the highest magnitude of an a.c. cycle, the peak voltage, representing measurement made from crest of the wave to the zero axis. Next in order of magnitude we have the root-mean-square voltage. Finally we have the average voltage. If the rectifier is linear to one it is linear to all, because there is a fixed relationship among the three, although only one of the three permits reading the a.c. on the d.c. meter without resort to calibration or compensation, and in the case of the diode that one is the average a.c. voltage of the positive alteration.

Only in connection with less than the complete cycle can the average of the a.c. voltage have significance, because for a complete cycle of a sine wave the average is equal to the difference between positive and negative values of equal magnitude, which is zero.

So when the meter scale becomes the calibration for the diode rectifier, the reading is of average volts of the positive cycle, and the reason why this is known is that many have checked the rectified current against a precisely determined a.c. voltage and found that to be the case. The same conclusion is arrived at theoretically from tube geometry.

We know now that the alternating current wave is not of a constant voltage or constant current value, but that the values are changing during the cycle, from maximum, called peak, to minimum, called zero.

R.M.S. and AVERAGE

Next in line is the r.m.s. voltage. This is the a.c. voltage that causes the dissipation of exactly the same amount of heat in a given resistor as does an equal number of d.c. volts. So if x volts a.c. and 8 volts d.c. each results in the same heat dissipation in a given resistor, we know x = 8 volts r.m.s. The magnitude of the voltage meant by r.m.s. is equal to the square root of the sum of the squares of a large number of equally spaced voltage readings taken over the cycle.

Third is the average value of a.c. This refers to one alternation or the other, hence applies to a half-wave or full-wave rectifier. The average value is the sum of a large number of equally spaced voltage readings taken along the half-cycle, and divided by the number of readings.

The relationships among these three expressions of a.c. voltage (or current) are fixed. If E_{pk} is the peak voltage, E_{rms} the root-mean-square voltage, and E_{av} the average voltage, then

$$E_{pk} = 1.414\ E_{rms} = 1.565\ E_{av}$$
$$R_{rms} = .707\ E_{pk} = 1.11\ E_{av}$$
$$E_{av} = .604\ E_{pk} = .9\ E_{rms}$$

RANGE EXTENSION

The application of one factor or another does not change linearity in a rectifier in any way, but avoids self-calibration. Factors could be applied to the readings for determination of values in peak or r.m.s. volts, if these are desired, or the circuit may be arranged so as any one of the three quantities is read, as is explained in an adjoining box.

By use of multiplier resistors, the voltage range is extended, and there is almost no limit, so that the diode offers two attractions at least: facility of wide voltage range and self-calibration. The resistors could be 50,000, 500,000 and 5,000,000 ohms, for ranges of 0-5, 0-50 and 0-500 volts, using a 0-100 microammeter. The range can not be decreased below 0-5 volts without requiring a still more sensitive d.c. meter, to adhere to the requirement that the load resistance be at least 50,000 ohms. For the 0-5 volt range, readings below .5 volts are not very reliable, but an improvement can be introduced by annulling the spurious current that flows when the input terminals are shorted. The freest electrons emitted by the filament strike the cathode and they constitute the dead current. There is a potential gradient along this internal path, and if just enough negative bias is supplied externally to the plate, the effect is to make these electrons stay in their proper place.

SIMPLE ANNULMENT METHOD

Therefore the d.c. meter will deflect on no input and the delay voltage is applied to the anode until the meter reads zero for shorted input. In battery type tube voltmeters, the only ones illustrating this article, the bucking potential may be obtained from a filament rheostat, especially if the A supply voltage exceeds the rated filament voltage. If the drop in the rheostat has to be so high, say, 1.5 volts, as to cause subnormal filament voltage from a 3-volt supply, the drop should be countenanced by all means, as it is permissible to operate a tube at less than rated filament voltage for tube voltmeter use, and overwhelming importance attaches to the cancellation of the dead current.

Unless the correction is made the self-calibrating feature of the diode is of reduced reliability for the lower voltage readings of the lowest range.

Tubes of the quadrode or pentode special detector types usually suffer least current flow at shorted input due to the initial velocity of electrons, true even when the tubes are used as diodes, with all elements other than the filament or other than heater and cathode interconnected for diode service. Such tubes include the 57, 77, 6C6 and 6J7 of the heater type, and 1B4 of the battery type.

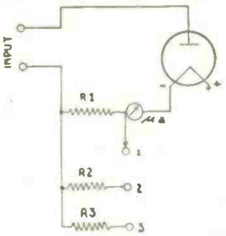
DRY CELLS FOR CHECKING

If one includes a 0-100 microammeter and precision scale-multiplying resistor used as diode load, the electromagnetic meter reading equals the average a.c. voltage at the input terminals, but if there is some error in the arrangement it is permanent. While there is no chance of a mistake if a good meter is properly loaded, and the tube is in good condition, at least some check should be made against the assumption that everything is all right.

(Continued on next page)

Rectifier Made to Read Average, Peak, R.M.S.

The fact that any tube voltmeter responds so that the resultant rectified current bears a constant proportion to some particular rating of a.c. intput volts defines the relationship between cause and effect, but does not mean that the voltmeter may not be so constituted to read any desired rating of a.c. volts. In fact, the tube voltmeter, of whatever type, however influenced, may be so calibrated as to read peak, r.m.s. and average volts.



The three values. R_1 would be used for average, switch at 1; next R_2 would R_1 to increase the microammeter reading from average half scale to 55.5 μa, switch at 2; and R_3 increase average half scale reading to 78 μa, switch at 3.

For instance, in a full-wave type diode rectifier, where the average of the positive alternation of the a.c. is expressed directly by the d.c. microammeter in series witn the multiplier load resistor, the direct reading under usual circumstances is of average volts, and as average volts are less than r.m.s. or peak volts, by known factors, the load resistance for average may be decreased by the same factors to yield readings also in r.m.s. and peak volts.

Taking average volts as the basis, r.m.s. are 1.11 times the average, while peaks are 1.565 times the average. Evidently more current must flow to compensate for the differences between average and peak and average and r.m.s., hence the diode load resistor is decreased. The reciprocals of the factors 1.11 and 1.565 then are used, that is, 1/1.1=0.9, and 1/1.565=0.6, so if the average volts the load resistor for the 5-volt scale is 50,000 ohms, for the same scale, reading r.m.s., the resistance would be made .9 x 50,000=45,000 ohms, and for reading peak volts would be made .6 x 50,000 =30,000 ohms. It would be practical to switch in the proper resistors for direct reading of these values without calibration. For half wave the scale reading must be doubled because response quantity is halved.

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Mention has been made of the difficulty of obtaining precise standards, but even in the case of the circuit that requires no calibration, some standard should be introduced as a check. It is proposed that fresh dry cells of reputable manufacture be used, for while they are not precision standards, at least they are fairly reliable, and will disclose any serious error.

Therefore the diode is set up as an average voltmeter and used on any range for which you have sufficient voltage derived from fresh 1.5-volt dry cells to attain a value close to full-scale deflection of the microammeter. What the current should be for any voltage is computable (voltage in volts divided by resistance in ohms) on the basis of the load multiplier resistor alone, but both the microammeter and the tube have resistance, and it may be worth while to compensate for these, even if the other factors are correct.

CELL VOLTAGE INFORMATION

The cells mentioned may be separate, and connected in series, or may be the cells of a battery, though each cell should be accessible for separate test. The microammeter with multiplier is used as a voltmeter, to check that each cell yields the same reading.

While the cells are commercially rated at 1.5 volts each, experience shows that fresh cells have 1.58 electrostatic volts each. So, using three series cells to check a 0-5 volt range, the voltage instead of being 3 x 1.5=4.5 volts will be 3 x 1.58=1.74 volts, considered as 1.75 volts.

It is not necessary to ascertain separately the resistance values of the microammeter and the diode, but only the sum of these resistances, since the multiplier resistor is deemed known, and the rest of the resistance is the difference. Suppose the current through the microammeter reads 86 microamperes. The voltage is 4.75 volts. So the total resistance is 4.75/.000086 = 55,232 ohms. If the multiplier resistor is 50,000, the microammeter and diode contribute the difference or 5,232 ohms. So the test indicates the multiplier should be reduced accordingly.

Another way of considering the same circumstances is to compute the current that should flow for a known applied potential, e.g., for 4.75 volts, and a known multiplier. Assuming 50,000 ohms again for the multiplier, the current should be 4.75/50,000 or .000095 ampere =95 microamperes. If the reading is less than that, the indication is that the multiplier should be reduced or, if the reading exceeds 85 that the multiplier should be increased, in both instances the objective being to register just 95 when the potential is applied. The ratio as for full-wave rectifier (no scale-reading doubling) applies.

STILL MORE SENSITIVE METERS

For the case of the meter reading too high, say, 98 instead of 95, it is practical to shunt the meter with a resistor high compared to the meter resistance, to avoid tampering with the series resistance, but this remedy would apply only to the single range, the shunt would have to be removed for the next range, or, if the method is to be renewed for the following range, a different shunt would be substituted, usually of higher resistance than the first. This general method also reduces slightly the sensitivity of the tube voltmeter.

The 0-100 microammeter has been mentioned because a likely choice, but if still less current is to be drawn from the measured circuit, and the extra cost of a more sensitive microammeter and the required higher resistance multipliers is not a deterrent, the circuit could be set up to advantage even with a 0-20 microammeter, operating then at 50,000 ohms per volt, or 0-1 volt for 50,000 ohm load, when even the diode current-drawing tube voltmeter would have some application to measurements of higher resistance circuits in which small current flows.

In general, however, proceeding on the basis of the 0-100 microammeter, the diode average voltmeter would not be used for a.c. measurements of very high resistance circuits.

Not all circuits to be measured have a conductive path for d.c., and as such continuity is required for rectification a means of closing the d.c. circuit must be provided.

LOAD RESISTOR DOUBLING

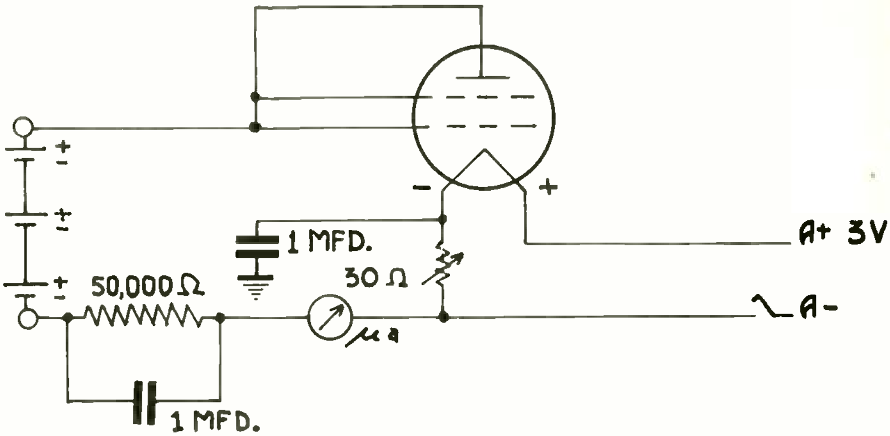
Therefore a resistor is selected equal to the total, limiting the microammeter, and placed across the input terminals. A condenser is connected from the anode input terminal to one side of the unknown, and the other side of the unknown is connected to the other input terminal. The condenser should be 4 mfd., paper dielectric, high resistance to leakage, for audio frequencies, and .02 mfd., mica dielectric, for radio frequencies. This arrangement is provided outside the voltmeter box. The voltage read is 50 per cent. too low, because for the range considered, the total limiting resistance has been doubled to 0-10 volts. So divide the voltage reading by two.

The diode voltmeter may be used as a listening post, by connecting earphones in series with the load resistor, opening the joint of filament and load. Put a .002 mfd. mica dielectric condenser across the 'phones. If the 'phones have a high d.c. resistance so as to change the

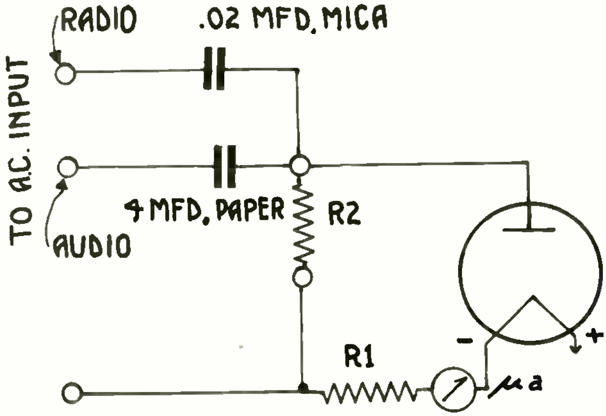
(*Continued on next page*)

Only One VTVM Proves Fully Self-Calibrating

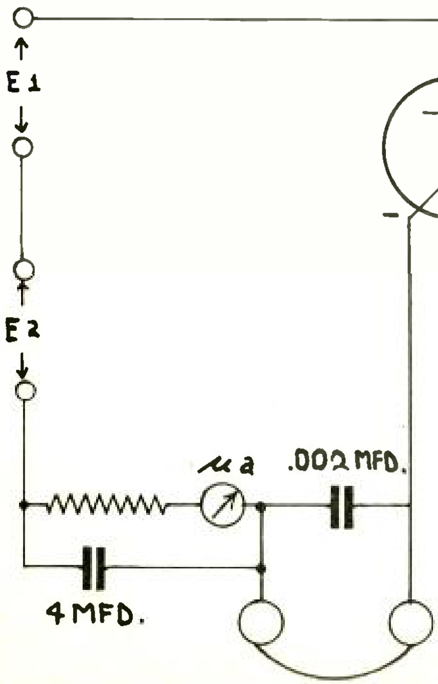
There is only one self-calibrating, or so-called direct-reading, type of tube voltmeter, and that is the diode. The peak type voltmeter, almost self-calibrating, because the peaks of the unknown a.c. almost equal the difference between two readings on a d.c. meter, nevertheless has to be calibrated for high accuracy. For the half-wave diode multiply scale readings by two.



Above, checking with three dry cells.



At right, circuit for use when measured part is open to d.c. The large condenser (4 mfd.) is for audio frequencies, but for radio frequencies a mica dielectric condenser is far preferable, and the capacity is naturally smaller.



At left, how to oscillating voltages are introduced, E_1 and E_2, the connection being in series, so beats may be heard or observed.

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meter reading, add to the observed voltage reading the d.c. voltage drop across the 'phones. The d.c. resistance of the 'phones is known or measured, and the voltage drop across them is the current in amperes divided by the resistance in ohms. Any form of ordinary modulation can be detected this way, except c.w.

If two oscillators are beating, and one of them may be a station brought in on a receiver, the finite beats may be heard, or, for audio work or closer resolution toward zero beat, the microammeter needle may be watched, as for beats below 20 cycles the needle will vibrate visibly, and for much slower beats the difference frequency may be measured by counting the

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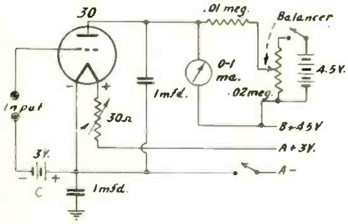
number of times the needle makes a return trip, comparison being made over a period of exactly 60 seconds, and the total number of return trips divided into 60, for ascertainment of the beat frequency.

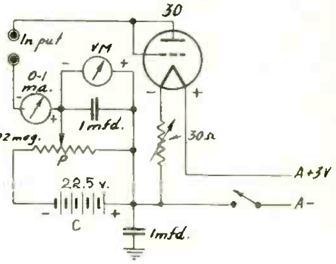
ODD FACTS ON BEATS

As it is usually very hard, next to impossible, to establish true zero beat for mechanical reasons, as well as difficulty of determination, when the needle again stands substantially still on reduction of the difference frequency, passable zero beat has been established. It is an uncommon thing to produce true zero beat, especially when one considers that beats as low as one a minute may arise. That is the barest possibility also, as it requires a looseness of coupling between the oscillators, and a degree of stability of both oscillators, that hardly can be expected to be achieved outside a precision laboratory.



A method of balancing out the dead current through the d.c. meter. The rheostat, 30 ohms, is used for establishing rated filament voltage, 2 volts, and is in the positive leg this time. The negative bias may be three volts for this circuit; for better spreadout of small voltage differences; positive of the 4.5-volt battery is toward the plate.

General measurements of all a.c. voltages, within the voltage range provided, and covering from a few cycles to 30 mc, may be accomplished, with the proviso that care be exercised not to rely on measurements of circuits having a resistance per volt anywhere near as low as that of the tube voltmeter.



Slideback type peak voltmeter, using a diode as indicator-detector. The input is shorted and the 30-ohm rheostat adjusted for zero reading on the microammeter with P at negative A battery. P is moved toward negative polarization of anode until the current just disappears. Greater accuracy may obtain if, after passing the disappearance point, P is returned until recurrent tiny flow is read each time, e.g., one microampere. See Table I, line 2.

SIDELIGHT ON LEAK VOLTMETER

The grid leak type tube voltmeter is classified in Table I as a rectifier because the positive part of the alternating voltage input acts upon the grid-to-cathode circuit, which provides rectification just as does a diode, which in reality the grid-to-cathode circuit is. Also,

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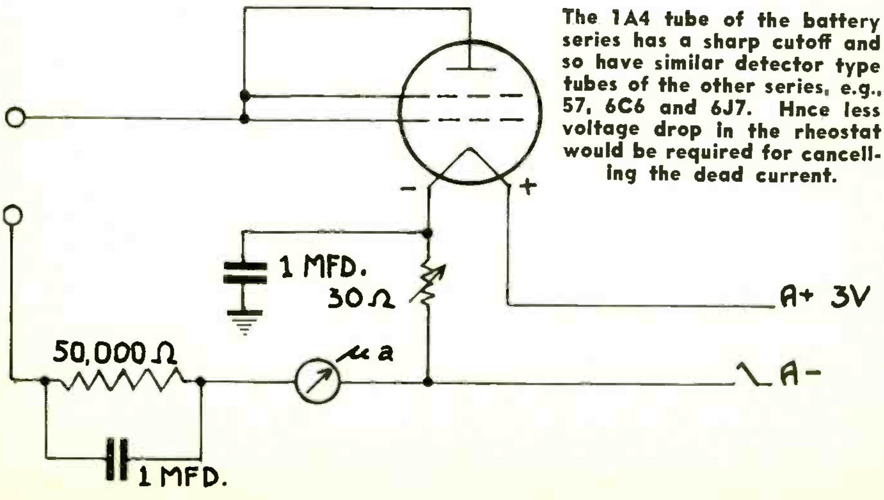
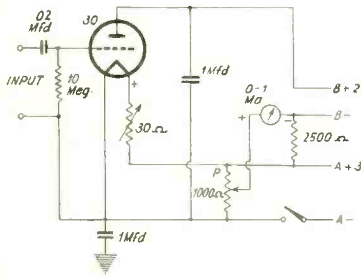


The 1A4 tube of the battery series has a sharp cutoff and so have similar detector type tubes of the other series, e.g., 57, 6C6 and 6J7. Hnce less voltage drop in the rheostat would be required for cancelling the dead current.

since the grid as a grid, rather than as an anode, is common to the amplifier, the alternating voltage is put into the amplifier as well. The amplifier is always diode-biased. The unknown a.c. therefore provides the rectification from which the bias is derived, and that is what is meant when the leak type voltmeter is classified as signal biased.

It is not necessary to retain the alternating current input to the amplifier, or triode-performing circuit, as the same practice as obtains with regular diodes may be followed, of putting the load resistor at the low a.c. end, and bypassing it with a large capacity condenser. Then the d.c. alone is put into the triode, that is, only the bias is delivered to



A method of annulling the d. c. meter current so that when input posts are shorted meter reads zero, without introducing an extra battery for the purpose. The potentiometer P is slid until this occurs. Locate the filament rheostat in the positive leg and adjust filament to two volts or with ammeter to 60 ma.

the literal grid circuit, and, strictly speaking, no a.c. The fact is mentioned without any intention to attach particular significance to it, because circuited either way it was practically impossible to observe any difference in the final performance, probably because the output circuit, plate to cathode, also has a large capacity across it, and the presence or absence of a.c. in the amplifier portion is immaterial for absence from the output in either instance.

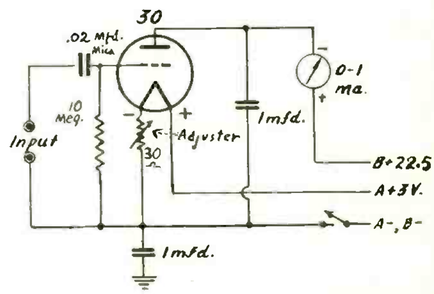
DIODE PEAK VOLTMETER

The diode also may be used as a peak voltmeter. When this is done the anode is given a negative bias, the unknown a.c. is introduced, if there is some deflection the negative bias is made still higher until no current is read, and bias is gradually reduced until a sensitive microammeter just barely discloses the beginning of current flow. Then the peak voltage of the unknown a.c. is equal to the d.c. voltage of the bias supply. This method requires two meters, one for current indication, the other for voltage indication. While it would be possible to utilize a single meter, and switch it from one service to the other, some accuracy might be sacrificed, because the voltage of the bias source might be different when the meter was being used for potential measurement than when the meter was removed, due to the current drawn by the electromagnetic voltmeter causing a potential drop across the resistance of the bias supply source, particularly upsetting when the biasing batteries are nearing the end of their useful life, when they may have quite high resistance.

The biasing voltages may be obtained by putting a potentiometer across this supply, and connecting meter between moving arm and the positive side of the biasing battery. One of the input terminals also is connected to this arm.

REPORT ON ACCURACY

Increasing the negative bias until the rectified current produced by the a.c. is cancelled is



The grid leak type should have a high resistance load. To maintain the input impedance high the leak may be as much as 10 meg. Shunt connection is shown. This insures d. c. continuity.

known as the slideback method. It is more often used with detector voltmeters. In diodes there is or should be cutoff at zero input, in detectors a high negative bias produces cutoff, slideback bias being additional.

Even assuming an initial negative bias is established to annul the dead current, the accuracy of the peak type diode voltmeter is not so good in practice for determination on the basis of restoration of cutoff of current as it is if the potentiometer arm is slid to over cancel the current, and then is slowly and gradually brought back until just the barest trace of restoration of current is observed. That is, the accuracy is higher in practice if instead of operation of the device as non-current-drawing it is operated as current-drawing. The current is made tiny, the same for all readings.

Experience shows that for the same a.c. voltage applied, the same reading is more closely repeated by the current-drawing method, whereas for establishment of cutoff of current, and using this as the reading basis, not always the same measurement obtains for the same input voltage. This may be just a quirk of the system, but it is reasonable to suppose that valid theory supports the practice, for instance, that the stoppage of current is more difficult to define sharply by observation, and continues to exist also for bias values more negative than required, whereas the barest trace of restoration of current, followed by overstepping the

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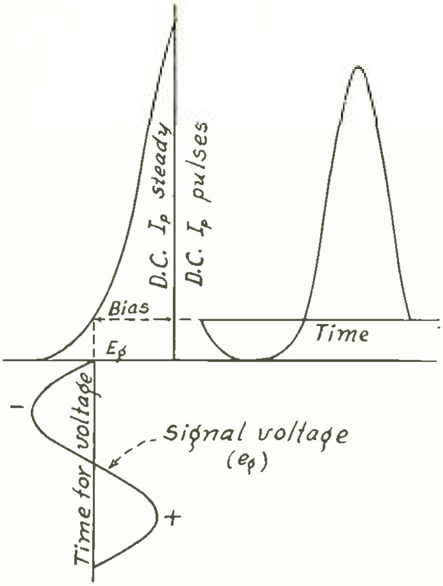


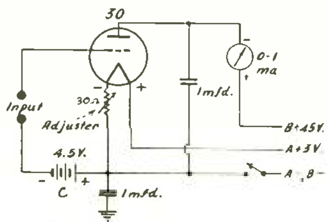
Plate bend rectification.

(*Continued from preceding page*)

bias reduction, produces more and more current, the greater the overshooting, hence is accompanied by a warning.

NO CALIBRATION HERE, EITHER

The peak diode voltmeter is linear, although the tube is not the reason, and can be arranged so as to read, besides peaks, the r.m.s. and the average a.c. volts. This is done by shunting d.c. voltmeter .3 full-scale current around the meter, for peaks to r.m.s. Peaks to average, an academic value, would require .4 shunted. With diode load resistor or without it, the potentiometer is adjusted until almost no current flows, the tiniest observable trace, and this is the only setting practical, for the voltage drop in a 50,000-ohm resistor under the deciding current is negligible (.05 volt) for even one microampere. Such a resistor, not necessarily precision, should be included to help protect the microammeter. For peaks, scale reading is not doubled, as another instrument (voltmeter) is used in another circuit.

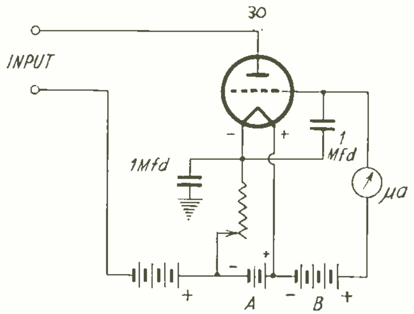


A 0-1 milliammeter may be used in this detector type of tube voltmeter. The current read on the meter ma is not taken from the measured circuit but supplied by the B battery. See Table I, line 6.

The peak diode voltmeter does require calibration, since the electromagnetic voltmeter reading discloses the negative d.c. bias voltage required for barest current through the microammeter, but the peak voltage exceeds the voltage read on the electromagnetic voltmeter. This particular meter need not be highly sensitive, because the voltage will be what is read, even though more current is drawn from the C supply than normally is done. This has nothing directly to do with the current drawn by the tube voltmeter proper, for ordinarily when current drain is mentioned, current taken from the measured a.c. source is meant.

Use of a diode peak voltmeter is rather uncommon, especially as peaks in resonant circuits generally represent a slow change, much greater steepness being present at the sides of the selectivity curve. Especially does the diode type peak voltmeter favor the broad tops, and therefore measurements are made handily in circuits having flat-top characteristic, and the instrument is not suitable where there is a band-pass filter producing more than one peak.

In flat-top circuits, the diode peak voltmeter may be used for measuring the amplitude of the flat top, and also for disclosing the percentage modulation. For the case of modulation two readings are taken, one of carrier alone, the other with carrier modulated with a single tone. If Ec is the voltage reading of carrier alone, and d is the difference between the carrier and Ec, then the percentage modulation is 100d/Ec.



The general advice regarding tube voltmeters is to "ground the cathode." This is suitably done through a condenser of large enough capacity to prevent introduction of stray r. f. voltages. Since in battery tubes filament is cathode, negative filament may be grounded, as shown here, or negative of A battery, as is done in other diagrams.

DETECTOR TYPE VOLTMETERS

So far we have considered only the linear rectifier, and only the diode. It will be remembered that linear implies that the rectified current is directly or inversely proportionate to the exciting a.c. voltage. The full-wave diode rectifier reads average volts directly, the linearity would apply also for peak volts or r.m.s., only the instrument would not be self-calibrating, unless there were current compensation for these other ratings of a.c. voltage. A method of attaining r.m.s. and peak readings for the average diode type is given separately herewith. It is advisable to remember well that linearity for one purpose constitutes linearity for all purposes, in the absence of overmodulation. So even the peak diode voltmeter is linear in effect, because the d.c. voltmeter across a battery potentiometer reads the peak volts, and the tube itself is no contributant to linearity this time. That is true of all peak voltmeters.

SQUARE LAW DEFINED

Getting into the classification of detector type tube voltmeters, the grid leak-condenser form of circuit also is linear, usually for about three-quarters of the scale, then tends to follow the square law, because for large amplitudes of a.c. input the operation is near cutoff bias. However, the a.c. voltage that actuates the device is the average voltage, that charges the grid condenser, and the plate current changes linearly. Excellent sensitivity denotes the presence of amplification. While the leak type detector is more sensitive than any other single tube type voltmeter, the fact that it draws current, whereas other vacuum tube voltmeters may draw none, and also the fact that without special calibration the device cannot be worked over the full range, due to change from linearity to square law, must be considered.

The difference between the two is that a linear device causes response directly proportionate to the excitation, whereas a square law detector causes the plate current to vary according to the square of the input a.c. voltage. Therefore square law devices are not self-calibrating and one would have to read the square root of the plate current change to ascertain the a.c. input voltage change. For the input the change is simple, and would be from zero to whatever is put in, hence equals the input voltage, but the plate current change would be the difference between the quiescent plate current and the smaller plate current due to a.c. excitation. The plate current decreases instead of increasing because the greater the input the greater the grid current, higher the negative bias and higher the plate resistance.

DETERMINATION OF CONSTANT

Just as there was what amounted to a quiescent plate current in the diode—due to the initial velocity of the electrons emitted by the filament—so now there is a barrier current, due to two causes, one the same as existed in the diode case, and the other the plate current flow due to the tube plate resistance being across the B supply. In this instance the two effects may be eradicated from meter indication by applying to the meter in reverse a voltage sufficient to annul the dead current, therefore the meter will read zero at no a.c. input, and at any input volts the meter will read the differential d.c. Thus the net change on the a.c. side may be compared to the net change in the d.c. side, although it is the square root of the plate current change that permits the calibration of the a.c. volts on an integral basis.

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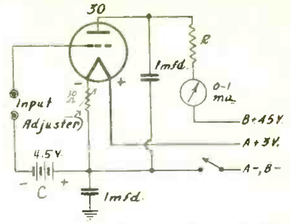
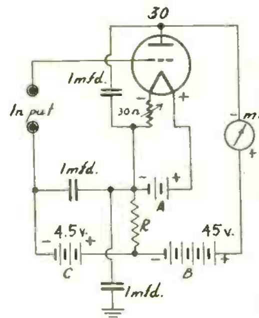
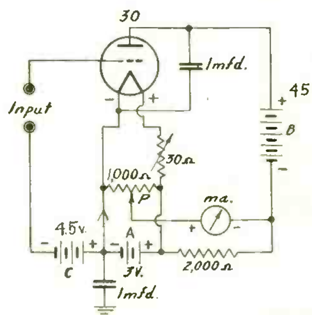


A series resistance R may be put in the plate circuit, to make even differences of input volts produce more nearly even differences of meter readings. This tends to work as a peak voltmeter because the high input amplitudes reduce the effective plate voltage, and thus relatively increase the negative bias.



If the plate current is passed through R, to the lower end of which the a.c. input is finally returned, the voltage range is extended, because increased input increases the drop through R, making the grid more negative than if R were absent. This is called reflexing. R may be very high for large voltages at input. The device tends to act as a peak voltmeter and is not classified in Table I.

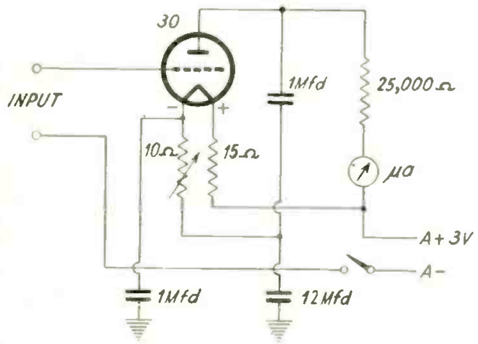


Where calibration is required anyway, as in this square-low, half-wave tube voltmeter, the d.c. microammeter is used as voltmeter where the microammeter's internal resistance is the multiplier. The plate current is passed through a 2,000-ohm resistor, the dead current is balanced out by P, when input terminals are shorted, and an a. c. input causes the needle to deflect. The 30-ohm rheostat fixes the filament voltage at 2 volts. Refer to line 6, Table I.

(Continued from preceding page)

If the plate current change is 4 milliamperes, the a.c. volts equal k√4, or k-2, where k is a constant. What this constant is may be determined from a single measurement, by using a known a.c. input, and dividing it into the square root of the plate current reading, which will be recalled as a difference now. Many who manipulate slide rules use this constant k, after determining its value before each series of tests, since k may change slightly from day to day.

The leak type tube voltmeter is notorious for the large amount of plate current it draws. At no a.c. input, terminals shorted, practically the full zero bias plate current flows, or saturation current, and the greater the amplitude of the a.c. input to the unknown terminals, the smaller the plate current. For several reasons the large



Three volts d. c. are apportioned to filament and plate. The rheostat is set so the microammeter reads zero with input posts shorted. The response is linear for the last three-quarters of the scale, but not so for 0 to one-quarter scale. Response is according to r.m.s., but calibration is necessary. A more sensitive microammeter is needed than used in other circuits.

amplitude a.c. values are uncertainly determined and the meter is useful rather for small amplitudes, where some current drain from the measured circuit is of little, if any, consequence.

Since the circuit will be inherently more sensitive, the greater the electromagnetic meter's sensitivity, some dead plate current should be bucked out. In this instance not all of it can be removed, because for meter reading zero at no a.c. input there would be no deflection for any a.c. input. If a 0-100 microammeter is to be used finally, a 0-10 milliammeter may be put in at first, and the current bucked so meter reads zero, and then the more sensitive meter introduced, without danger of damaging it, a final readjustment being made to full scale deflection.

LEAK-CONDENSER THEORY

Except for the extra sensitivity, there is no appeal in the leak type tube voltmeter. Nevertheless an appreciation of the theory of its operation is valuable and aids one to understand the circumstances that might dictate the choice of such an instrument for special measurements. Primarily the leak-condenser detector is a diode-biased triode, therefore it resembles fundamentally a diode that has an amplifier stage and the reason for linearity is related to diode performance. Departure is related to triode distortion. The fact that sensitivity is greater suggests there must be amplification, since a diode alone has none. Therefore the single tube may be analyzed as follows: (a) diode, composed of grid to cathode circuit; (b) triode, composed of grid-to-cathode circuit and plate-to-cathode circuit, with the space stream uniting grid and plate circuits. The diode action and reality are obvious when one considers that the a.c. introduced drives the grid positive on the positive alternations, just as in the example of the diode, and grid current flows, the grid leak being the diode resistor, and since the rectified current is positive at cathode and negative at grid, the amplifier grid is negatively biased. The same element serves two purposes: diode anode, triode true grid.

In the usual small receiving tubes the grid is not an element with large total surface, and no great current may flow without overload and consequent distortion, so this is a weak signal detector, with an amplifier in which the amplification will be inconstant when the a.c. input amplitude is large, so the limitation to small input is clinching. With small changes, hence low range, the system has some merit.

GRID CIRCUIT RATIO

The direct current flowing from the grid circuit is a.c. taken from the measured circuit and rectified. There is always a condenser in series with the unknown and the grid, and the leak may be across this condenser, or from grid to cathode, that is, shunting the unknown circuit. For the wide frequency range in mind, this condenser should be large, and its leakage should be minimum. Also to maintain a sizeable input impedance, the grid leak should be large, the leak resistance being at least ten times as great as the condenser reactance at the lowest frequency to be measured.

The unknown a.c. charges the series condenser, which discharges through the leak. Thus the grid is made positive by the displacement current from the condenser, grid current flows, which is d.c., hence there is grid rectification, and with high resistance leak linearity is preserved.

We have so far considered only half wave rectifiers and detectors, but it is possible to use full-wave amplification for its stray or residual detection without resort to any center-tapped input device, or circuit balanced by external loading, but simply by selecting the negative bias.

EARLY SATURATION

Suppose a triode is used at a very low negative bias, other voltages normal for normally higher bias. This has about the same characteristics as if a very high negative bias were used, with higher plate voltage, for at low bias the input a.c. prematurely drives the effective operating point of the tube to that part of the characteristic where the plate current no longer changes for increase in a.c. input, hence the positive alternation, or much of it, is wiped out, and we have a half-wave detector. The early part of the operation (low input voltages) may be linear, but soon a region useless for calibration is reached, because uncertain or introducing imperceptible rectified changes for considerable a.c. input changes. This type of voltmeter has no wide use.

Now, if the negative bias is made medium, so that the operating point is about midway on the steep portion of the characteristic grid voltage-plate current curve, then we have full-wave square law amplification, with residual detection for small or medium values of a.c. input, though sensitivity is reduced.

Full-wave detection results because when the positive alternation is influencing the grid circuit the plate current rises, since the a.c. input is in effect reducing the negativity of the grid, while when the grid is receiving the negative alternation the plate current is decreasing, because the a.c. is additive to the steady bias, both negative.

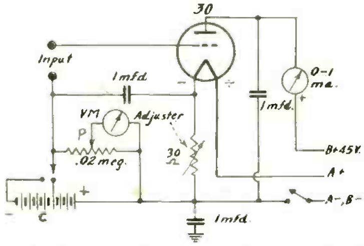
IMAGINARY DEFEAT

It would be theoretically possible for the effect of both alternations of a sine wave on the plate current to be exactly of the same magnitude, though opposite in phase, so that despite the a.c. input there would be no difference at all, nothing to read. This exists in imagination only, since such supernatural equality does not arise by chance and could not be achieved by tube design. There is always enough difference in the geometry of the tube, or the shape of the wave, or in other helpful directions, to insure some difference in plate current for a change in a.c. input voltage, hence the system of medium bias works, and because the full cycle affects the operation, the detection is of the full-wave type.

While the sensitivity is not high, the full-wave square law detector offers very tempting service. One consideration of moment is that the plate current change is proportionate to the square of the r.m.s. of the input, or the square root of the plate current change reflects the r.m.s. input volts, in terms of a factor k. As before, take the square root of the plate current difference, for a circuit with dead current in the meter nullified, multiply by k, and the answer is r.m.s. input. Also, for highest accuracy a test application for determination of k may be made prior to any run of measurements, where a known a.c. voltage (e) is put into the tube, the square root of the observed plate current ($\sqrt{I_d}$) extracted, so $k = \sqrt{I_d}/e$.

NO TURNOVER

This circuit has another advantage, shared with the diode average rectifier and the leak-condenser detector, that the measurement is correct for all wave forms, calibration for one is calibration for all, hence there is no error introduced by harmonics or other distortion in the source, and readings are the same for both possible combinations of input connections. With some tube voltmeters a certain reading obtains when the connection is one way, another reading resulting from reversal at terminals, the difference denoting the presence of even order harmonics. The true voltage can not then be determined with precision, so one averages the two readings as a best approximation. This reversibility and contradiction



Slideback type voltmeter, using a triode. The potentiometer, P, is first slid toward C minus, with input posts shorted, until plate current almost disappears. Read V. M. This point must be definite and recurrent. Next the a. c. is applied and P slid to a more negative position (to left), to restore recurrence. Again read V. M. The peak of the unknown is virtually equal to the difference of the d. c. voltages read on V. M. Calibration is advisable, as the a. c. is higher than V M. indicates differentially

of readings is known as harmonic turnover. The full-wave square law detector has none of that.

Because it is square law and not linear the device is not self-calibrating, or direct-reading, as the expression is used for tube voltmeters. However, a calibration may be run, even if based on only a single observation, although preferably on at least two, toward one and the other end of the voltage range the instrument is to cover for a given set of conditions. Due to the square term, if the active plate current and r.m.s. input volts are plotted on cross-section paper of the log-log type, the resultant curve is a straight line.

Also, in this case, as in the other examples of non-linearity, a meter scale itself may be prepared from a curve, and direct reading prevail, in the sense that the meter now being calibrated, the a.c. input volts are read from the meter. The calibration may be for peaks or r.m.s., and interchangeable measurements are possible by methods already proposed.

The correction for the initial velocity of electrons should be made for both of the diode rectifiers, not only the average type, but also the peak type, also for the detector type voltmeters. For the battery type tubes the filament rheostat in the negative leg, with anode returned to A minus, provides sufficient means of attain-

(Continued on page 55)

Table I

Functional Analysis of Vacuum Tube Voltmeters

Rectifier	*Detector*	*Bias*	*Activity*	*Follows*	*Response*	*Direct Reading?*	*Draws Current?*	*Turnover?**
1.—Diode	......	Signal	Half-wave	Av./2	Linear	Yes	Yes	No
2.—......	Indicator	Slideback	Half-wave	Peaks	Linear	Yes	Opt.	Yes
3.—Grid Leak	......	Signal	Half-wave	$(Av./2)\mu$	Linear§	Yes	Yes	No
4.—......	Plate Bend	Small	Half-wave	R.m.s.	Linear	Yes	No	Yes
5.—......	Plate Bend	Medium	Full-wave	R.m.s.	Square Law	No	No	No
6.—......	Plate Bend	Cutoff	Half-wave	R.m.s.	Square Law	No	No	Yes
7.—......	Indicator	Slideback	Half-wave	Peaks	Linear	Yes	No	Yes
8.—......	Inverted	Plate Neg.	Half-wave	R.m.s.	Square Law	No	No	Yes

*Turnover means that phase and amplitude of even harmonics cause the readings to differ when the input terminals are reversed across the unknown. A calibration made for one wave form would not hold for other forms. Hence "no" is the preferred answer under this heading.

§For small amplitudes only.

Explanation of Table I

For convenience the rectifier type voltmeter is restricted to the diode. This is done to afford a sharp distinction between rectifier and detector type VTVM. The grid-leak type VTVM is rated as a rectifier type because grid rectification is simply diode rectification, also half-wave, linear and direct-reading, and the triode is merely an amplifier. Plate current must be reduced so the d.c. meter will read only maximum at no a.c. input. The grid leak should be high for the same reason of linearity that a diode load resistor should be high.

The detector type voltmeter is based on an amplifier tube biased for detection and represents the non-current-drawing type. The diode of course draws current, hence rectifier type may be classified on that basis, which is about the same as was stated before. Normally a rectifier is a device that passes current in one direction, none in the other.

The slideback type voltmeter, whether diode, triode, tetrode or pentode, is simply an indicator, and thus does not naturally fall into either the rectifier or detector classifications. However, since it may be used without drawing any current, it is sometimes called a detector type, although improved accuracy may prevail if a constant very small current is allowed as indicating level (one microampere or less).

The response is called linear for cases where linearity prevails, even if this is true for only small amplitudes. The tube voltmeter should then be worked only over that portion of the curve that is linear, for self-calibration objective. Of course the rest of the curve may be calibrated specially.

The slideback types are classed as linear although no performance of the tube in either instance plays any part in this effect. Since the unknown voltage equals that read on the d.c. voltmeter, the designation linearity is preserved for convenience. Otherwise there could not be any classification on this score.

The full-wave square law detector is really an amplifier, because biased in the middle of the straight part of the characteristic of grid voltage-plate current. What detection obtains is due to unavoidable absence of straightness.

No current is to be drawn by the detector type voltmeters, hence they present a practically infinite resistance to the measured circuit.

Significance of Behavior of Tube Voltmeter

The behavior or activity of the tube voltmeter discloses what degree of the a.c. input voltage will be practically an integral multiple of the resultant direct current. A striking example of this is found in the diode, where the integer is taken for granted and load resistors selected only on the basis of the d.c. meter sensitivity and the range desired. With the full-wave diode the degree of a.c. input voltage is the average voltage; half wave, half average.

Other tube voltmeters behave according to the square law, and again an integer pretty generally obtains, but this time the a.c. reference value that produces such integer is a difference in the r.m.s., compared to a difference in plate current, requiring two different input voltages. Because a squared term enters, if only one point quite near the highest-reading end is calibrated, a straight line may be drawn on log-log cross-section paper to intersecting zero for both unknown and known, and all points thus will be established.

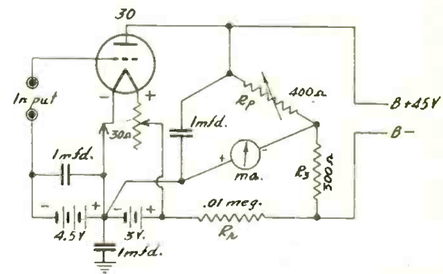
It will be appreciated that the elimination of calibration, or reduction of calibration necessity to only a single point, is what makes the type of activity significant. Other type voltmeters, having mixed or inconstant activity, require full calibration. Any type of voltmeter may be used for measuring any degree of a.c. input voltage for which it is calibrated. Simply the aid of integral values is lacking, but that makes no difference if a calibration has to be run. If one a.c. rating is to be converted to another, this may be done by computation, or, for reading in desired degree of a.c. volts, by resistance adjustment.

ing this end. With meter's needle properly set for zero by the zero adjuster, the presence of spurious current is observed and the rheostat is then used for annuling this current, and may be considered also as an auxiliary zero adjuster.

HALF-WAVE, SQUARE-LAW TYPE

Of the detector type tube voltmeters the half-wave, square law type, biased nearly to cutoff, though requiring calibration, is attractive to those who prefer simple circuits. The negative bias necessary for cutoff is equal to the plate voltage divided by the mu of the tube. Thus, for 45 volts applied to a 30 tube having a mu of 8, the bias necessary for cutoff is $45/8 = 5.62$ volts.

If the filament voltage is below the rated value the mu will be higher and the required negative bias for cutoff will be less. Also, with no grid bias and no plate voltage, grid and plate



Another method of cancelling the quiescent plate current is to use a bridge.. The circuit is balanced when the d. c. meter reads zero. Then any a. c input causes the needle to deflect.

returned to negative filament, if there is any indication of current, using a very sensitive

(*Continued on next page*)

Once a Voltmeter, Always a Voltmeter

The single d.c. meter used in a tube voltmeter is always used as a voltmeter, never as a current meter. The reason is that we are measuring volts and therefore we read volts. Always the tube is in series with the single d.c. meter, but the tube voltmeter is in parallel with the unknown a.c. An apparent exception is the peak type tube voltmeter, but that has two d.c. meters, and the one on which disclosure depends is an out-and-out d.c. voltmeter.

From the foregoing one may understand better why in tube voltmeter parlance the expression direct reading has a special significance, different than applied to an ohmmeter or a signal generator. In the tube voltmeter sense, no ohmmeter or signal generator ever is direct-reading, because those devices require a special calibration. A tube voltmeter is considered direct-reading only when the unknown a.c. voltages follow the scale of a d.c. meter, in other words, if the tube voltmeter is self-calibrating. No ohmmeter or signal generator is that.

If the calibration is not automatic, a calibration may be run, and curve consulted, or a special scale based on the calibration attached to the meter, so that the unknown voltage is read directly from the d.c. meter, but in the world of tube voltmeters the instrument would not be direct-reading. There had to be a calibration, that's why!

TRADIOGRAMS *of the* MONTH

Static Field Used in New Bruno Microphone

The Bruno Laboratories, Inc., 20 West 22nd St., N. Y. City, announce the Velotron microphone. This is a velocity microphone employing a static rather than a magnetic field. The manufacturer reports the output is much higher than that of the conventional magnetic velocity microphone, being on the order of -50 db. It is high impedance but may be used with cable lengths up to 500 feet, without detriment to the quality of the output. It has approximately the same directional characteristics as the magnetic velocity microphone but the angle of pickup is some degrees wider.

HAND-FINISHED STYLI

Universal Microphone Co., Inglewood, Cal., has added to its recording accessory line professional steel cutting styli to be used in conjunction with its professional blanks, Silveroid discs and all nitrate or acetate records. It is said to be the closest approach to sapphire yet produced commercially. The styli are not mass machine production items, but are entirely hand finished, of special alloy steel, lapped to a mirror polish and razor edge.

SPRAGUE'S DEVICE

Sprague's capacity indicator proceeds along original lines. It contains an assortment of fixed condensers, picked up by switching. There is a surge arrester that tells when more than 450 volts exist across the condenser. The device is intended for correction of troubles due to shorted or otherwise defective condensers. Range is from 250 mmfd. to 16 mfd.

INSTRUCTIONS FOR RECORDING

Universal Microphone Co., Inglewood, Cal., has published instruction sheets for recording on its line of Silveroid blank records. The Silveroid discs can be modulated with full frequencies from 20 to 10,000 cycles and, if properly cut, are unusually brilliant and can be played back without the fuzzy objectionable tone often caused by wave form distortion.

Cornell-Dubilier Lowers Price on "Dwarf Tiger"

Leon L. Adelman, sales manager, jobbers' division of the Cornell-Dubilier Corporation, 4343 Bronx Boulevard, N. Y. City, announces a drastic revision of list prices on their Dwarf Tiger paper tubular condenser line.

"The universal acceptance of C-D products has resulted in our having to revamp our production schedule," said Mr. Adelman. "It has been necessary to add thousands of square feet of factory space, the latest and most modern production facilities, accurate control, larger purchasing volume. All have made it possible to produce a corresponding reduction in manufacturing costs."

"This reduction in manufacturing cost is being passed along to our customers. No compromise with Cornell-Dubilier quality has been considered, the same high standards which have distinguished C-D condensers for twenty-six years will be rigidly adhered to in the future. This step to share the savings resulting from increased efficiency will, we hope, contribute greatly to the relief of the unemployment situation, as it will be necessary to increase our payroll sharply."

"The tremendous rise in the sale of C-D paper tubulars," Mr. Adelman adds, "indicates clearly that the sustained humidities in various parts of the United States has contributed to the failure of inferior condensers. Paper condensers which have not been properly impregnated and are not effectively sealed are prone to failure where unusual conditions of humidity and temperature are met. The C-D line, engineered to anticipate these conditions has been accepted as the reliable replacement condenser line, as is shown by the unusual response from those sections where high humidities have been the rule this summer.

"All of these factors have contributed to our decision to reduce our price schedules, and we look forward to a still further increase in business as a direct result."

COMET ENLARGING

Comet Radio, on Cortlandt Street, New York City, is preparing to increase its space, due to much greater business transacted.

(*Continued from preceding page*)

meter, the rehostat is used for annulling this current. Then when the plate circuit is reinstituted the current flowing at 4.5 volts negative bias will be small, representing less than 25 microamperes, so that this point may be used as reference, or equal to zero a.c. input volts, because just half way between two bars on the meter. The lowest reliable voltage readable is .5 volt under these conditions. The device strictly requires calibration.

[*Next month, VTVM Calibration.*]

RADIO CONSTRUCTION UNIVERSITY

Answers to Questions on the Building and Servicing of Radio and Allied Devices.

DELAYED A.V.C. CONTINUOUS?

KINDLY explain delayed automatic volume control in connection with whether the a.v.c. is always less than the rectified voltage of the second detector proper?—I. W. C.

Delayed automatic volume control consists of postponing the introduction of any a.v.c. until the amplified carrier has attained a certain voltage. This carrier in a superheterodyne is at the intermediate frequency level. Delay is accomplished by having two rectifiers, both diodes, whereby the detection of the amplified carrier takes place at once, whereas the a.v.c. rectifier has a negative d.c. voltage applied to the diode plate, so that no rectification takes place in this tube until the amplified carrier voltage is high enough to overcome the opposing d.c. bias. When the effect takes place it is continuous, in the sense that a.v.c. is less, for besides amounting to removal of a.v.c. on weak carriers, so that these carriers may produce sound quantity finally that is satisfactorily large, it also consists of always applying less than the maximum possible a.v.c., when such a.v.c. is effective. That is, postponement of the time when a.v.c. takes place is accomplished, as well as apportionment of the a.v.c. voltage to less than practical maximum when a.v.c. is present. This reduction below maximum possible a.v.c. is often highly desirable, because too much a.v.c. might be present, and strong locals would cause tubes to be overbiased negatively, and thus impair quality. Also, delayed a.v.c. is distinctly advantageous in systems using a high-gain amplifier tube connected with the diode, because the average input is supposed to be low, and weak stations might be wiped out, because the level was too low, if a.v.c. were applied simultaneously and to the same degree as second detection.

* * *

PREVENTING BOOMINESS

WILL you kindly explain the principle of the boom-preventing method used in the new RCA Victor sets?—P. L. E.

Ordinarily there is boominess in a console, suggestive of a man speaking into a rain-barrel, and certain notes are accentuated. These are in general in the region of the male voice. They thus include musical instrumental frequencies. The effect is due largely to the open rear of the cabinet duplicating the acoustical resonance of a rain-barrel. The effect is emphasized by the method of control in broadcast amplifiers, whereby orchestras, etc., are toned down, and talkers are amplified above normal level. In the sets you mention the rear is closed, to help escape the rain-barrel effect, and besides this sealing to prevent interference between the front and the back waves of the speaker, the back waves are allowed to flow through the bottom, conducted by pipes, the back waves being caused to be in phase with the forward waves, thus reinforcing them. Low-note response is safeguarded also, because of the equivalent substitute of a large baffle. Otherwise a real baffle large enough would not be practical, since to reproduce 50 cycles fairly well the baffle would have to be eleven feet in diameter. Even so the attenuation at 100 cycles, with such a baffle, would be noticeable.

* * *

I. F. OF THREE SETS

PLEASE state the intermediate frequencies of the following commercial receivers: Grigsby-Grunow 55; Gulbransen V6Z2; Halson 520.—W. D.

The i. f. in the order named: 456 kc; 262 kc; 456 kc.

* * *

DYNATRON USE

THE dynatron oscillator has some attractive features and I wonder why it is not used more often in oscillators, especially for service work? It requires only a single-winding coil, hence single-pole switch for band changing, and also may be operated in a stable manner.—R. D.

Two difficulties with the dynatron, despite the advantages you list, are lack of uniformity of the characteristics of tubes of the same type, and change of tube characteristics during use. Hence where a calibration is made of frequencies produced by a coil, variable condenser and tube, the calibration may not hold very long, or, in production, it would be hard to select tubes that enabled close tracking of a direct-reading frequency dial, besides the changes that time and use will produce. The frequency stability may be high by critical selection of supply voltages, otherwise stability will be poor.

* * *

BEAT-NOTE COUPLING

IN the construction of a beat note audio oscillator (using one fixed radio frequency and one span of variable radio frequencies, and

(Continued on next page)

(*Continued from preceding page*)
mixing them for the audio resultant), is it necessary to resort to any extensive shielding?—I. D.

Yes. That is one reason for using tubes that minimize the shielding requirements, that is, tubes with small cathode-to-heater capacity. The amount of carrier current flowing due to this capacity, in numerous systems in which oscillation is present, has not been given all the attention it deserves. In a beat oscillator the control of coupling must be such that there will be no locking-in of the two frequencies, therefore no loss of the beat, due to overcoupling. Otherwise low notes will not be produced, that is, notes below 100 or 150 cycles or so. Stray coupling usually will be found sufficient, and no extra coupling needed, if batteries are used for power supply. The common coupling will be plentiful for uniting the two frequencies without anything on the diagram showing this mixing. Hence do not assume coupling absent because not obvious. If tubes having considerable capacity are used, shielding must include tube, tuning condenser, coil, grid leads, etc., all separately shielded. To avoid most of these shielding requirements, acorn tubes are used.

* * *

T. R. F. SELECTIVITY

WILL a tuned radio frequency set, using a three-gang condenser, be selective enough? Is the high impedance primary method satisfactory for equalizing sensitivity over the tuning range (broadcast band)? If a diode detector will be used, will selectivity be less?—K. E.

The practical selectivity requirements are imposed by the location, so that if one lives at a distance from any broadcasting station, the three-gang condenser, using two t.r.f. stages and tuned input to detector, will suffice. For use in cities a four-gang condenser, with four coils, is advisable. Low-gain primaries should be used in both instances, if selectivity is vital. An exception exists in the case of the antenna coil, provided that it is desired to make the sensitivity practically uniform over the band. Then a high inductance primary is used, and is inductively as well as capacitively coupled to the secondary. Besides the greater gain at low radio frequencies due to the high inductance, the inductive coupling is stronger in this region, whereas at the higher frequencies the capacity coupling is more effective. With the antenna capacity the high inductance primary, usually under one millihenry, is made to resonate broadly below the lowest broadcast frequency. This reduces selectivity a bit at the higher frequencies, but this may be theoretical rather than real, since regeneration begins to set in at these frequencies, and the adjustment can be made just about to equalize the two opposing effects. Where selectivity is of prime importance, the amplifier-detector type tube negatively biased to non-grid-current condition, yields greater selectivity. The diode always draws current when working, and since this is a loading of the secondary of the transformer feeding it, the condition is equivalent to that of a resistance across that secondary, and such a resistance reduces selectivity. But quality is better with a diode, and as t.r.f. sets are meant mostly for quality, it is not a bad idea to use a four-gang condenser, with proper coils, and include the diode. The question of a.v.c. always comes up in connection with t.r.f. sets, and the answer is it may be included, but usually not without reduction of selectivity and unavoidable reduction of sensitivity.

* * *

METAL TWIN TUBES

IS there a metal tube of the twin type and has it any considerable power output?—L. S.

Yes, the 6N7 is a twin triode amplifier, with common cathode connection at base pin (8). Note that the heater current is .8 ampere, not .3 ampere, in case you have series heaters in mind. It is a Class B output tube, for 250 volt or 300 volt B supply, zero grid bias, ohms load 8,000 ohms for the lower voltage, with 8 watts output, and 10,000 ohms for the larger voltage, 10 watts output. Plate-to-plate loads are stated.

* * *

FREQUENCY STANDARD

WILL you kindly state what constitutes the primary standard of frequency, and where is it kept?—R. D. C.

The primary standard of frequency is the period of rotation of the earth about its axis.

* * *

TELLING ACCURACY

WILL you please set forth how to determine the percentage accuracy?—K. D.

Assume that the following are known: what the absolute value should be (e.g., kilocycles, volts, amperes, etc.) and what the reading, or apparent value, is. Then the percentage accuracy, as the term is used in radio and allied practice, is the absolute value, divided into the difference between the apparent value and the absolute value, dividend multiplied by 100, or $\% A = 100\, d/k$. If a frequency a device is measuring is really 500 kc, but the reading is 502 kc, then the difference (d) is 2 kc, and the percentage accuracy (A%) is 100d divided by the true frequency (k), or 200/500, or 0.4 per cent.

* * *

WAVELENGTHS INCONSTANT

IS there a constant relationship between frequency and wavelength, as some of your recent measurement articles seem to infer, or is there a difference in this relationship, caused by any conditions whatever?—T. D.

For the frequencies comprehended by the articles you mention, and for radio purposes generally, the relationship may be taken as constant, and always constant within the percentage accuracy of instruments used in connection with the measurements discussed. The wave velocity is not quite a constant, as at very high frequencies the departure may be measured by very expensive equipment, and therefore the relationship of wavelength and frequency is not a constant, speaking strictly and very technically. However, frequency is a constant, as it depends only on time, and time is constant.

Generator Enables Sharp I.F. Setting

It is advisable to have the intermediate frequency coils sharply tuned, and this is most readily done with a signal generator and output meter. Use the generator at modulated position. If you have a sensitive d.c. meter (.2 ma or better) the adjustment may be made without modulation from the signal generator, for maximum deflection when meter is in series with the potentiometer, say, between one end of the potentiometer and ground. A signal of some intensity may be used and this method works well. Even a station local serves a satisfactory purpose.

An oscilloscope is still better.

Literature Wanted

Readers whose names and addresses are printed herewith desire trade literature on parts and apparatus for use in radio construction. Readers desiring their names and addresses listed should send their request on postcard or in letter to Literature Editor, Radio World, 145 West Forty-fifth Street, New York, N. Y.

J. T. Lambert, 380 W. San Fernando St., San Jose, Calif.
Fred Ratliff, 1952 Alenandrine W., Detroit, Mich.
John R. Bohannan, P. O. Box 44, Ephrata, Wash., on "Ham" transmission equipment.
Walter Klemzak, 61 Natrona St., Natrona, Penna.
John E. Cope, "Boxmoor," Welley Road, Wraysbury Nr. Staines, Middlesex, England, on parts and apparatus for use in radio and television construction.

CLASSIFIED ADVERTISEMENTS

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THREE CAMERAS in one. Takes snapshots, moviebooks, 16mm movies. Springmotor driven. Only $5.00 brand new. Films $1.00. Send no money. Pay postman. Projectors $1.00 up. Free lists. Home Movies, Box 32-RW, Easton, Pa.

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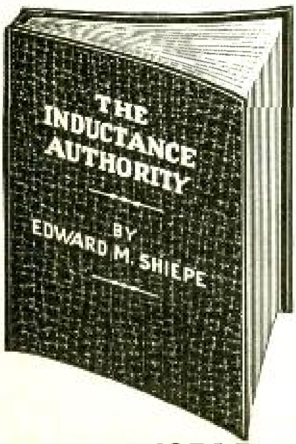
RADIO WORLD, 145 W. 45th St., New York

Coil Winding Made Easy



The biggest help anyone can get who desires to wind radio-frequency coils for any frequency from just below the audio range to the fringe of ultra frequencies is to have a book that tells just what inductance is required for the condenser one possesses, and just how many turns of any kind of wire on any sensible diameter are needed to produce that inductance. "The Inductance Authority," by Edward M. Shiepe, gives you all that information, to an accuracy of one per cent. Send **$2.00** and book will be mailed you postpaid; or send **$5.00** for a two-year subscription for Radio World and this valuable book will be sent **free.**

RADIO WORLD - 145 WEST 45TH STREET, NEW YORK CITY

RADIO WORLD

145 West 45th St., New York City

Rates effective September 1, 1936

Agency Commission, 15%; cash discount, 2% of net, 10 days. Bills rendered monthly.

GENERAL ADVERTISING:

	1 time	12 times
1 page	$90.00	$72.00
½ page	45.00	36.00
¼ page	22.50	18.00
⅛ page	11.25	9.00
One inch	6.00	4.80
Agate line	.50	.40

COVERS: First Cover, no advertising.

Second Cover: 2 colors	$100.00
Third Cover: 2 colors	100.00
Fourth Cover: 2 colors	100.00

OTHER SPECIAL POSITIONS: No extra charge for special positions, if open.

ADVERTISEMENTS IN EXPERIMENTERS MARKET PLACE: 3 columns to page, minimum space, ¼ inch, 1 col. wide, $2.75 an insertion. Less 5% discount 3 insertions; 10% 6 insertions; 20% one year.

CLASSIFIED RATES: .07 word. Minimum charge, $1.00. Cash with order.

READING NOTICES: Identified reading type advertisements acceptable at publisher's option at general advertising rates and marked "Advt."

MINIMUM DEPTH, R.O.P. ADVERTISEMENTS: Minimum space, seven lines.

CONTRACT AND COPY REQUIREMENTS: Advertising of alcoholic beverages not accepted. The publishers will reject objectionable advertisements. No advertisemnts printed on same page as reading matter.

MECHANICAL REQUIREMENTS: Pages are 2 columns wide by 112 lines deep—224 lines to the page.

1 page	5 1/6" x 8"
½ page	5 1/6" x 4"
½ page	2 2/3" x 8"
¼ page	2 2/3" x 4"
¼ page	5 1/6" x 2"
1 inch	2 2/3" x 1"

Halftones, 135 screen. Mats or unmounted electrotypes can be used. Cuts made charged at cost.

ISSUANCE AND CLOSING DATES: Published monthly; issued 22nd of month preceding date of issue. Last forms close 11th of the month preceding date of issue.

PERSONNEL: Publisher and Editor—R. B. Hennessy. Managing Editor—Herman Bernard. Advertising Manager—Herbert E. Hayden.

Established 1922

Single copy, 25c.; per year, $2.50.

A COMBINATION OFFER! RADIO WORLD and "RADIO NEWS"

$3.50

Canadian and Foreign, $1.50 extra on this offer.

You can obtain the two leading radio technical magazines that cater to experimenters, service men and students, for one year each, at a saving of $1.50. The regular mail subscription rate for RADIO WORLD for one year is $2.50. Send in $1.00 extra, get "Radio News" also for a year—a new issue each month for twelve months. Total 24 issues for $3.50 and $5.00 to foreign countries.

RADIO WORLD, 145 West 45th Street, N. Y. City

OCTOBER RADIO WORLD

Next month's issue will contain Intimate Details by J. E. Anderson of Treasure-Seeking with Radio Devices Based on Quasi-Optical and Transient Principles. Order your copy now. 25 cents. RADIO WORLD, 145 West 45th Street, New York City.

Grid Leak in Oscillator

The grid leak acts as a stabilizing agency in an oscillator, because the resistance through which the grid current must flow, being much lower than the tube's input resistance, avoids too great fluctuations.

However, the resistor should be chosen so that the resultant negative bias checks the plate current changes in that otherwise would be of too large an order. Ordinarily 50,000 ohms are used, in shunt with the grid-cathode circuit.

Miniature Grid Caps

Smaller grid caps are needed for the metal tubes than for the old glass ones. The smaller caps are referred to as "miniatures." Use of the large caps, dented in to catch hold of the control grid of the metal tube, is clumsy and unfavorable, often causing noise due to imperfect or intermittent contact.

Aerial No Lightning Peril, NBC Reports

The National Broadcasting Company reports that a radio set, or antenna, does not "attract lightning."

R. M. Morris, NBC development engineer, whose own house was struck a few years ago, says:

"Contrary to popular belief, radios in the home do not attract lightning, nor do radio antennas. In fact, a properly installed radio antenna, with good lightning arresters, serves as a measure of protection to a house during a thunderstorm. The lightning arresters found on most antennas, serve to lessen the force of the lightning, deflecting the dangerous current into the ground where it will do no harm."

HAYNES R-S-R RECEIVER

2½-555 METERS

Regeneration plus Super Regeneration

Combined for the first time in a single receiver with the greatest tuning range ever incorporated in any radio set.

Write for Free Circular

Price of Complete HAYNES R.S.R. RECEIVER—wired and tested in our laboratory—with black crystalline hinged top cabinet, and 5 tubes (2 6K7's, 1 MG 43, 1 MG 25Z5, 1 76) ready to plug in and operate **$24.65**

Complete Kit including wired switch band Coil Assembly, drilled panel and chassis, dynamic speaker, wiring diagram instruction..... **$14.95**

Black crystalline cabinet.... **$2.50**

Five tubes (2 MG 6K7's, 1 MG 43, 1 MG 25Z5, 1 76).. **$3.60**

- ★ 2½-555 meters—complete coverage of this tremendous tuning range with no skips or dead spots.
- ★ Band switching (5 bands)—no plug in coils from 15-555 meters.
- ★ Immediate shift from regeneration to super-regeneration is accomplished by merely turning switch knob under speaker.
- ★ Super-regeneration below 15 meters using simple efficient pin-jack plug in coils.
- ★ Dual regeneration control with hiss reduction control on super-regeneration.
- ★ Adjustable selectivity control.
- ★ Both loud speaker and earphone reception on all bands.

HERE IS WHAT THE RADIO EDITORS SAY ABOUT IT:—

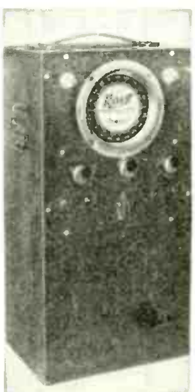
The New York Sun, Mar. 7.—Circuits worthy of space are not numerous this season, but the R-S-R is an exception. When demonstrated to the editors, the receiver functioned so smoothly that it was obvious its many features would appeal to the home experimenter. Here in one cabinet is a receiver that will reach from the top of the broadcast band down through all the short-wave channels to the ultra short-wave band, where the two-way police systems are active and where television will soon be carving its way.—Ed. Note.

Radio News, May.—Under tests in two New York City Listening Posts the receiver considerably exceeded expectations. Short-wave stations were tuned in, all on the loud-speaker, from Spain, Italy, England, France, Germany, Colombia, Cuba, Canada, etc.

These are unbiased statements on actual tests made on the R-S-R.

5 TUBE PERFORMANCE IN 3-TUBE NEW PORTABLE 5 METER GO-GETTER RIG

A powerful oscillator with class B modulation provides sufficient power for excellent portable-mobile work. Completely self contained unit coupled 5 meter transceiver using two 19 tubes and one 30. The maximum practical power for a portable rig.



Two stage push-pull audio, class B, used as both modulator and receiving amplifier gives fine speaker reception and true 5-tube performance. Batteries used: 3-45v and two dry cells.

Complete kit, less cabinet and tubes	$10.95
Wired and tested	3.00
Matched tubes	1.65
Cabinet, as illustrated	1.50
Cabinet with built-in speaker	2.75

NEW POWERFUL A.C. 3-TUBE TRANSCEIVER STABLE, CLEAN MODULATION

Here is a 5 and 10 meter transceiver that is in a class by itself! No skimping or cheap parts are used in its construction. A large center tapped modulation choke accounts for its very fine speech quality, while 20 watts input to the plates of the two 42's puts out a carrier which really goes places.

On reception the gain is such that full volume control is seldom used.

We sincerely believe that this is the finest transceiver available today. Many operators are using it as a fixed transmitter with separate receiver for duplex work.

Uses two 42's and an 80. Speaker is off when phones are plugged in. Has modulation gain control, regeneration control and volume control.

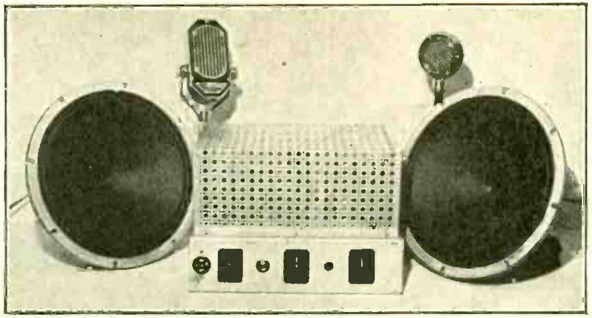
Complete kit; less tubes, cabinet and speaker	$11.50
Portable cabinet with speaker, as pictured	2.75
Smaller cabinet, without speaker	1.50
Kit of 3 tubes, 2-42's, 1-80	1.60
Wired and tested	3.50

RADIO CONSTRUCTORS LAB. 136 LIBERTY STREET NEW YORK, N. Y.

PUBLIC ADDRESS SOUND SYSTEMS THAT DEFY COMPETITION!

20 WATT HIGH GAIN HIGH FIDELITY AMPLIFIER

A complete sound system designed for tremendous volume and real fidelity. Custom-built unit employing 7 of the latest tubes: 1 - 75, 2 - 6A6's, 1 - 83v, 2 - 6B5's Push Pull, 1 - 25Z6. 25 watt peak. Frequency response 40,—12,000 cycles within 2dB. Dual channel input. High gain—124dB for crystal or velocity mike. Low gain—90dB for pickup or tuner. Built in speaker field supply for 1 to 4 speakers with selector switch included. Chassis and metal screen cover finished in special oven baked lifetime finish. Dual channel input with individual controls for fading and mixing permit ideal control. Full-range tone control. Power consumption, 100 watts. 717 amplifier. 5 stage high gain circuit. As described........... **$28.50**

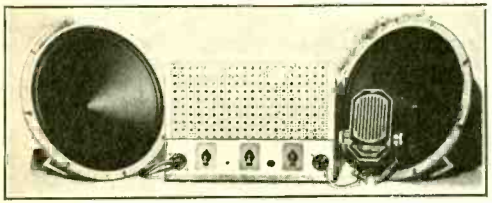


QUALITY COMPONENTS MATCH 20 WATT AMPLIFIER

Items listed may be purchased separately or at complete price marked below.

1 Set of 7 Matched Raytheon Tubes	$6.95
2 Magnavox 12 inch Super Dynamics, $4.45 each....................	8.90
1 Universal Velocity or Shure Crystal Mike	13.50
1 6 ft. Adjustable Shock-Proof Floor Stand	5.90
1 Cable, 25 ft., Shielded for Mike..	1.00
2 Cables, 25 ft. each, for Speaker Extensions	2.50
Complete System—No. 717 Amplifier. All parts as listed and illustrated	$62.60

Shipped Complete—Ready to Operate



15 WATT HIGH GAIN DUAL CHANNEL AMPLIFIER

Six new type tubes deliver 15 watts output, 20 watt peak. Frequency response 40-10,000 cycles within 3dB. Pre-amplification stage for crystal or velocity mike. High gain channel 120dB. Low gain channel 88 dB, both inputs have individual controls for mixing and fading. Full range tone control. Tubes—1 - 75, 2 - 6A6s, 2 - 6B5s, push pull, 1 - 83v. Speaker Field excitation built-in. Heavy metal chassis and ventilating screen cover in over baked lifetime finish. Outlet built for additional speaker. No. 716 Amplifier, as described **$19.95**

Universal Velocity or Shure Crystal Mike	13.50
Set of 6 Matched Raytheon Tubes....	5.95
12 inch Magnavox Super Dynamic Speaker	4.45
6 ft. Adjustable Shock Proof Floor Stand	5.90
25 ft. Speaker Cable—25 ft. Shielded Cable	2.25
Complete System—No. 716 Amplifier. As Illustrated	$48.55

Shipped Complete—Ready to Operate

THOR ENGINEERING SCORES AGAIN!

The house responsible for many new innovations and improvements in receiving and amplifying systems now offers the latest in P.A. sound equipment. The 3 systems described here are the features of our new line. All parts are heavy duty with large safety factors designed for long and constant use. Appearance has been stressed with such features as enamel finish and color markings. For all around utility and value these outfits stand out as the leaders in their field and as usual are backed by Thor's Reliable Guarantee.

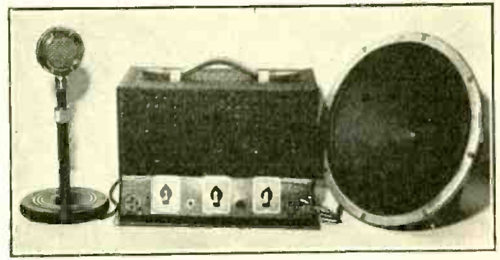
DELUXE SOUND EQUIPMENT

Strong leatherette covered case with heavy nickel corners and handle, to house Amplifier Model No. 716 and one 12 inch speaker.................... $6.50

Three section split case leatherette covered. Heavy nickel corners, lock and handle to house Amplifier Model No. 717 and 2 speakers. 2 sections with speaker grills $8.50

General Electric AC motor with crystal pickup in leatherette covered case. Volume control, switch and leads included. Plays 10 inch or 12 inch records with cover closed................. $16.50

20% deposit required with orders above $10. All merchandise shipped F.O.B. New York. 24 hr. service.



15 WATT, 2 CHANNEL, 2 SPEAKER AMPLIFIER

4 stage high gain dual channel system. Pre-amplification for crystal or velocity mike with low gain input for pickup or tuner. Individual controls for perfect mixing. Field supply for 2 speakers with throwover switch for 1 or 2 speaker operation. 6 tubes: 1 - 75, 2 - 6A6s, 2 - 6B5s push pull, 1 - 83c. 20 watt peak. 40-10,000 cycles within 3dB. Full Range tone control. Heavy gauge steel chassis and screen cover in oven baked crackle. No. 716-D Amplifier, as described **$22.50**

Universal Velocity or Shure Crystal Mike **13.50**

Set of 6 Matched Ratheon Tubes, $5.95; 2—12" Magnavox Super Dynamic Speakers, $8.90; 6 ft. Adjustable Shock Proof Floor Stand, $5.90; 2—25 ft. Speaker Cables—25 ft. Mike Cable, $3.25; Complete System—No. 716-D Amplifier. As Illustrated, $55.50.

THOR RADIO

167 GREENWICH STREET, NEW YORK CITY

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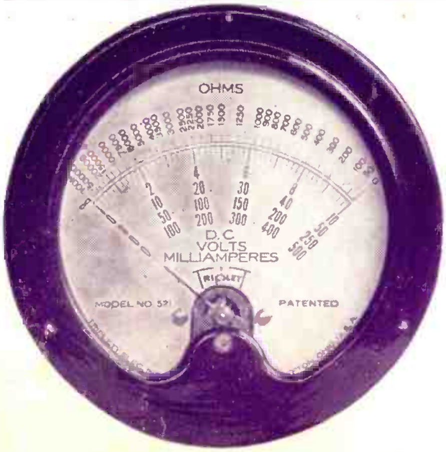
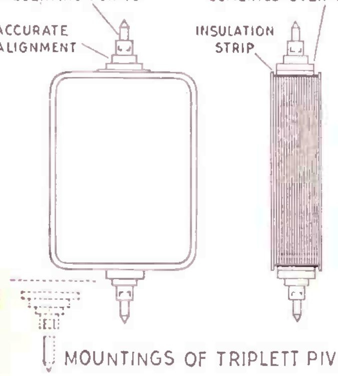


MODERN EXTERNALLY

PRECISION BUILT INTERNALLY



MODEL 521 VOLT-OHM-MILLIAMMETER

Dealer Net Price, $7.00

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No. 11 Shunts mounted on bakelite for 10-50-250 milliamperes. Dealer's Net.................. 3.33

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No. 13 Zero Adjuster with knob for 100,000 ohms. Dealer's Net .... .67

No. 14 Resistor (unmounted) to read to 1,000 volts. Dealer's Net 2.34

No. 15 Shunt, Current Limiting Resistor with Zero Adjuster and knob, to read .5 to 500 ohms (15 ohms at center of scale). Dealer's Net 1.75

No. 15 A.C. Adapter for output measurements, with plug-in tips, spaced ⅝". Dealer's Net 3.50

No. 18 Multi-deck Selector Switch (2 decks). With knob. Dealer's Net.......... 1.67

No. 32 Test Leads. Dealer's Net.......... .50

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