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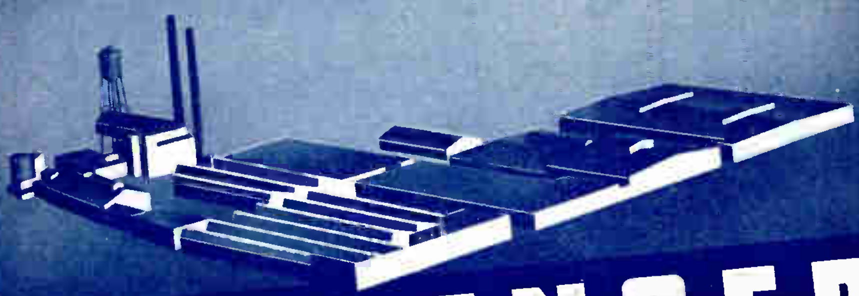

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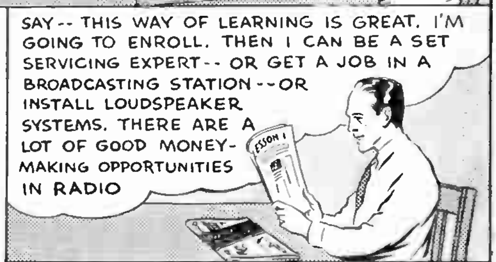

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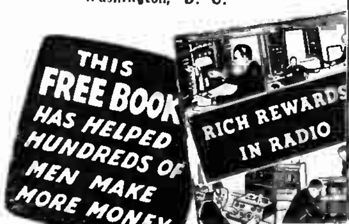

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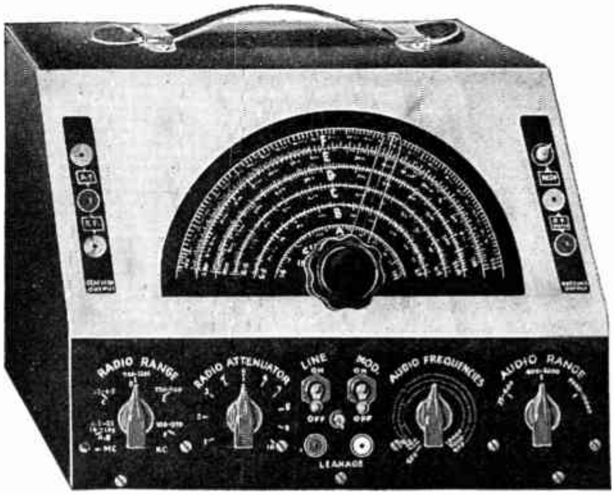

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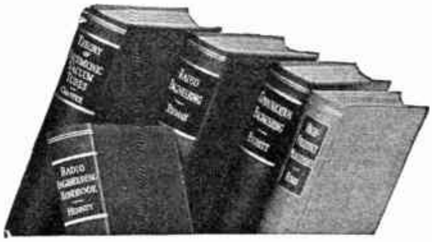

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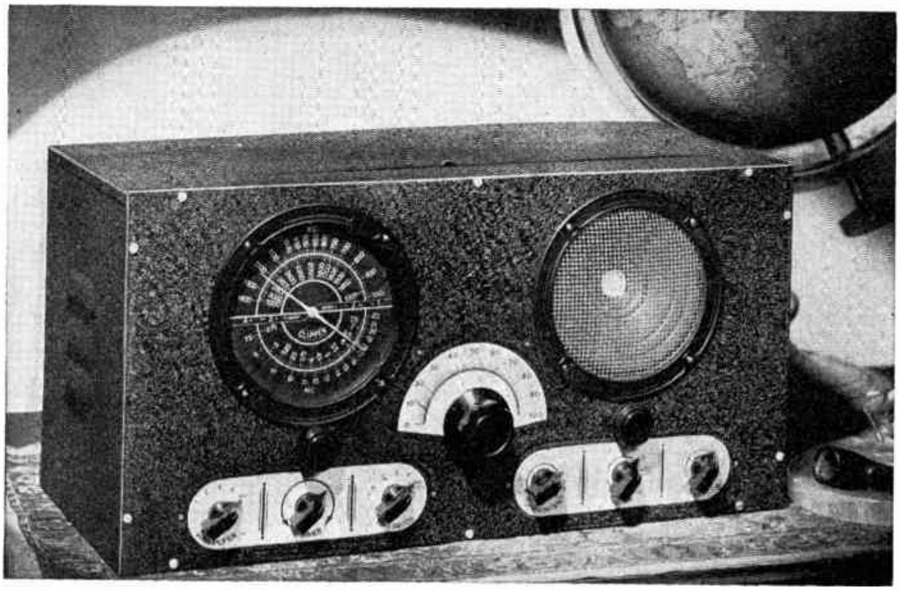

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Vol. XXX, January, 1938. No. 10. Whole No. 712. Radio World, published monthly by Hennessy Radio Publications Corporation, 145 West 45th Street, New York, N. Y. Editorial and executive offices, 145 West 45th Street, New York, N. Y. Executives of Radio World: Roland Burke Hennessy, editor and business manager; H. J. Bernard, publisher; Herbert E. Hayden, advertising manager. Officers of corporation: Roland Burke Hennessy, president-treasurer; Roland Burke Hennessy, Jr., vice-president, H. J. Bernard, secretary. Entered as second-class matter March, 1922, at the Post Office at New York, N. Y., under Act of March 3rd, 1879.

Subscription Rate

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MONEY-BACK GUARANTEE!

THE EARTH AS A TREASURE CHEST

Explored with Radio Devices by Those Seeking Riches

By J. E. Anderson

FIG. 1
All over the world intense experiments are being conducted with devices for detecting the presence of precious ores, oil or water under the earth's surface. Devices are built and then tested in the field. The photograph shows Michael von Sutiak investigating the possibilities of the countryside about Peabody, Mass., and incidentally the merit of his own device, which he is carrying, with indicator in his left hand.

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 non-homogeneous. The valuable deposit may be more dense or less dense than the surrounding earth. It may have greater or less electrical conductivity, specific electric conductivity, mechanical elasticity or 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 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 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 or evaluating 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 orebodies, 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 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 TO 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 sursounding 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 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 reason has never been definitely ascertained.

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 works spectacularly if the twig-twister can "allow" skillfully the twig to turn against much astensible 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 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

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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

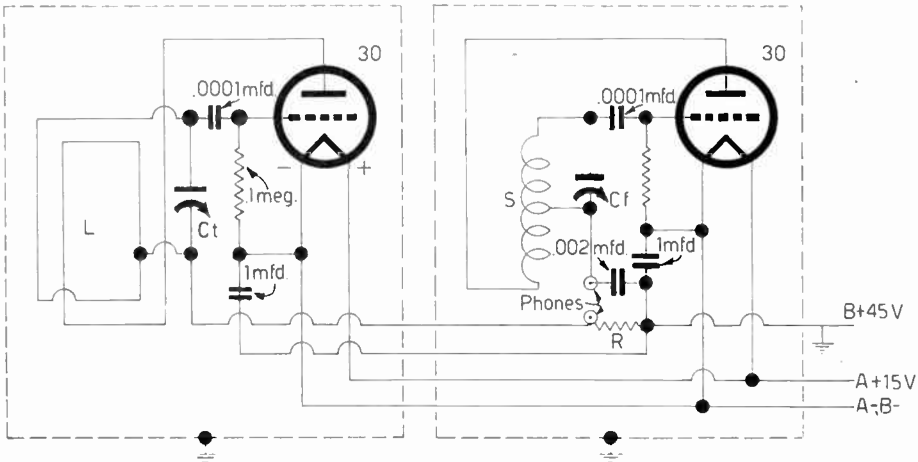

FIG 2

A fundamental method of instituting a treasure-seeking circuit is to have two radio-frequency oscillators, and make determinations on the basis of the audio beat produced by them. The diagram gives a general outline of what is required for such a system. Ct is the variable condenser equal at minimum to Cf. Inductance of loop L equals solenoid S. R. is coupling resistor, about 100 ohms.

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.

THE FRONT COVER ILLUSTRATION

The loop may be wound in any convenient fashion and is frequently circular, as exemplified in the front cover illustration. This shows Michael von Sutiak, of Peabody, Mass., using a standard treasure-seeking circuit, but with electrical constants of his own, and including some innovations for improved sensitivity. Fig. 1 is another view of Mr. Sutiak engaging in field experiments. He is not yet ready to release the circuits and constants, as experimental work is still continuing.

Another 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. 2 gives an outline of what is required for a treasure finder of this simple type.

Another, a low-frequency device, has 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. The circuit is completed through the ground to be explored for minerals, one side of the transformer primary being connected to a grounded electrode and one side of the generator being connected to another electrode. 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 the work 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. 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. A high gain amplifier and a vibration galvanometer, the moving element of which is tuned to the frequency of the current used, are introduced. The tuning not only increases the sensitivity manifold but it also eliminates stray earth currents and harmonics of the generator.

WHEN GALVANOMETER DEFLECTS

If the grounded and spaced electrodes, which may be copper plates, be driven into the ground at random, there will in general be a deflection on the galvanometer. However, for a given position of one such electrode there will be an infinite number of points at which the other may be placed so there will be no deflection. These points all lie on an equipotential line. When one such line has been obtained, the first electrode is moved to another point and the second equipotential line is found by moving the second to points where no deflection occurs. Many such lines should be taken. Lines of current flow may be drawn between 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.

AN IMPEDANCE METHOD

It may not be always 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 by diverting part of the transmitted current to the receiver through transformers, and satisfaction obtained.

Another 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 arrangement are suggested by the inventors, but none is claimed as exclusively corret. 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.

Fig. 3 shows in some detail a transmitter 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 matched set-up transformers are used to transmit the signal to ground and to the de-

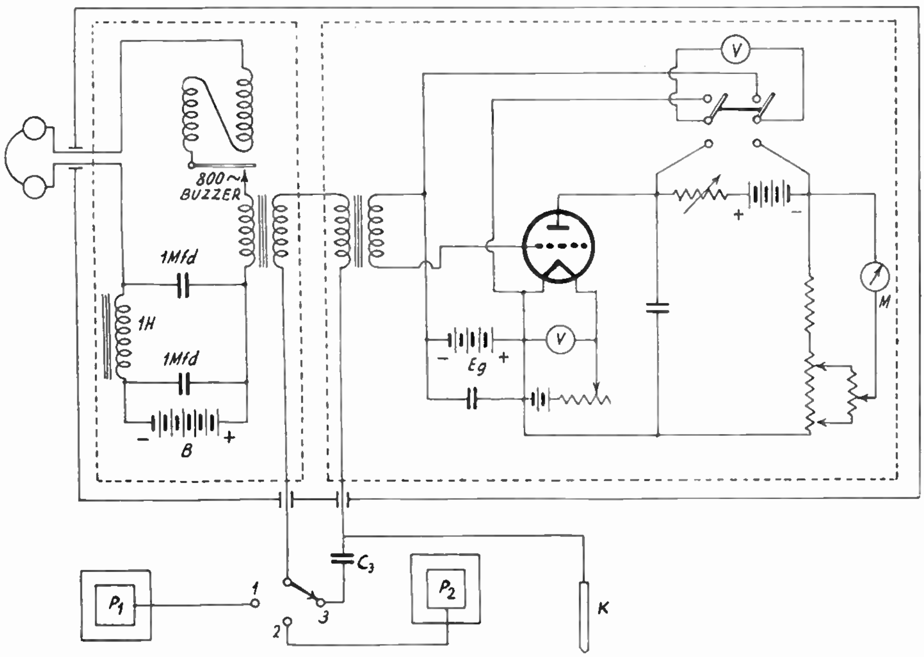

FIG. 3

An 800-cycle battery-powered buzzer is used as the frequency source in this treasure-seeking circuit. The transmitter is E and the receiver-detector is M. Earphones are inserted in the circuit for aural check of oscillations.

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tector. 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. As in all

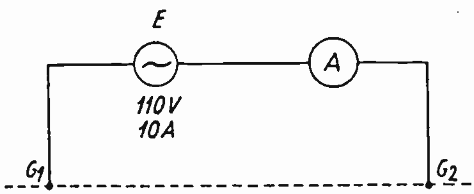

FIG. 4

A method based on finding the normal to the plane of the vibration ellipse is exemplified. An elliptically-polarized electric field is used. An electric current is set up between two points in the earth, G1 and G2. E is the oscillator and A is the ammeter.

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. 4. E is an oscillator generating a strong alternating wave of any frequency 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 between the two grounded electrodes and on the nature of the soil between them.

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 rocks 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.

If, on the other hand, there is a considerable body of comparatively high conductivity in the ground secondary currents will be induced in 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. 5, instead of along a straight line.

If a metal rod dipole antenna, such as DH in Fig. 6, 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. 5, D_1H_1 being at right angles to every line that can be drawn through the center of the ellipse.

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 polarized, the line DH will be inclined from the horizontal by

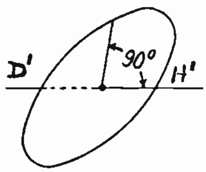

FIG. 5

The vibration ellipse of an ungrounded or dipole system is shown here. There is no current induced when metal rod antenna is perpendicular to the plane of the ellipse, i.e., when D'H' is parallel with that plane, as shown in the dotted line. The secondary electric currents are eliminated by a balanced loop arrangement, consisting really of two loops. See Fig. 6 for circuit.

an amount depending on the polarization, and it will also deviate 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, Fig. 6, 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. 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.

It requires two opposite radial lines to form one survey line.

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.

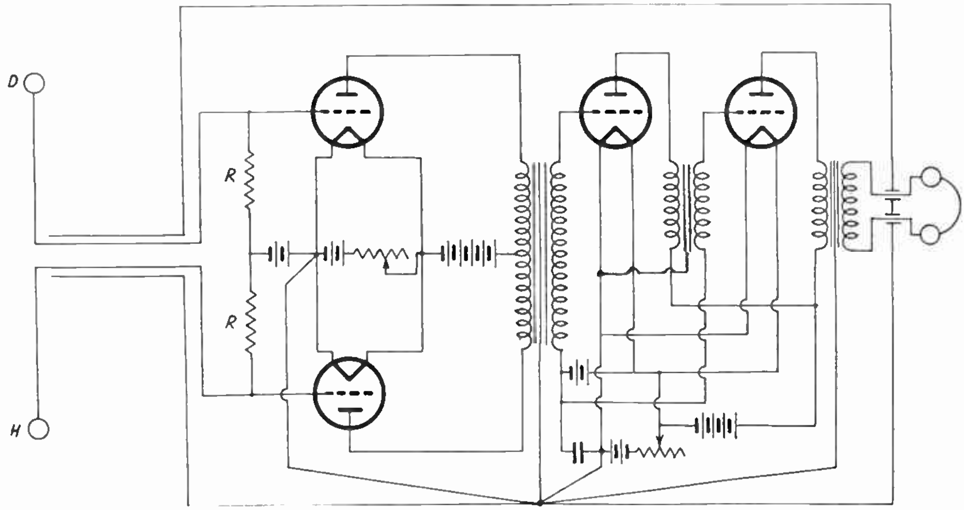

FIG. 6

A metal rod dipole DH is placed in the elliptical polarized field, there is a current induced in the rod, and this may be detected, if an amplifier is used for increasing the voltage. Push-pull is used in this detector-amplifier. DH is mounted on a portable tripod.

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.

Another method of sub-soil exploration utilizes elliptical polarization. It is similar to the method just described, but instead of using the electric field it utilizes the magnetic component. Loops are used in connection with detecting the signals.

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 nature 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.

When there is elliptic polarization there is no position in which the loop will not pick up a signal.

Although the loop cannot be turned so as to reduce the signal to zero, the minimum signal can't 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

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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. 7. A is the main loop and B is

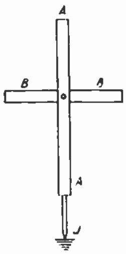

FIG. 7
The double-loop system exemplified.

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. 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.

EXPLANATION OF OPERATION

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 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.

A word or two more might be said about the detecting circuit. 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.

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.

Another method employs a large loop which is laid flat on the ground and supplied with high frequency currents from a spark oscillator. By means of two small exploring coils lines of equal magnetic intensities in the field within the large coil are traced and plotted. The contour of these lines is an index to subterranean formation. The two exploring coils act through a rectifier circuit on a direct current instrument.

A straightforward method of locating minerals, based on optical principles, has been devised.

OPTICAL METHOD

The theory assumes that the radio waves used obey the laws of optics. It is a well known fact that they do provided that the length of the wave used is short compared with the dimensions of the reflectors, both the parabolic cylinders and the ore body. It is not necessary, of course, that the ore body be a perfect reflector. Indeed, any body that is likely to be encountered will depart greatly from a perfect reflector.

There will be two types of departures. One will be diffuse reflection, such as the reflection from a white surface, and the other will be loss of reflection. The reflection surface might, for example, be only 20 per cent efficient, whereas polished silver is about 98 per cent effective on light. There might also be considerable absorption loss in the non-conducting layers above the ore body. Despite all the possible deviations from ideal optical conditions the reflected beam will follow optical laws close enough to give very useful information when applied in the manner here indicated.

To make the parabolic reflectors effective they can be made of tuned rods similar to the radiating rod and spaced along the parabola one-eighth of a wavelength apart or less. If the frequency used is very high the dimensions of the parabolas need not be great and the entire equipment can be made conveniently portable, or at least easily transportable.

The radiating and receiving rods, as well as the directing rods in the parabolas, will be one half wavelength long, as measured on the conductors themselves. As measured in free space they will be slightly less than half wave. The reason for this is that electric waves travel faster in free space than along the rods. The difference might be of the order of 97 per cent. Hence the tuned rods should be made about 97 per cent of the length of half a wave in free space. Provision should be made for easily tuning each rod whether it is placed at the focus of a parabola or in that parabola.

CHANGING FREQUENCY

The reason why the rods should be tunable is not only that it enables adjusting transmitting and receiving antenna to one particular frequency of the oscillator, but that it permits changing the frequency of the oscillator, still leaving the equipment adjustable to highest sensitivity.

Changing the operating frequency is desirable because the reflecting ability of ore bodies depends on the frequency to some extent. This is also true of optical and heat waves, for a polished silver surface is the best reflector of light whereas a polished copper surface is the best reflector for heat waves.

The different reflecting abilities of different conductors offers a means of determining what the underground ore body is. For any particular radio frequency employed, the received signals will be stronger or weaker according to the nature of the reflector. The frequency of the transmitter can then be changed until the strength of the received signal is greatest. The frequency at which this occurs gives an indication of the nature of the ore body.

There will always be some direct transmission, even if the best possible parabolas are used for directing the beams. Besides this direct transmission there will be strays due to diffuse reflection.

CONFUSION AVOIDED

The total stray signal might cause confusion, especially when the desired reflected component is weak because of poor reflecting efficiency in the ore body, much diffuse reflection, much absorption in the intervening strata, and because of great depth. Therefore it is important to counteract as much of the strays as possible. This may be done by conducting part of the energy from the transmitter to the receiver by means of transmission line. This line should itself be free from radiation, that is, it might be one of the concentric type, or shielded pair, or simply a well twisted pair. It is necessary to apply this bucking signal in the correct phase or it might do more harm than good. Therefore there should be a phase shifting device in the transmission line by means of which any desired phase might be brought about.

Also, there should be an intensity control in the line so that the right amount of bucking signal could be had. The phase changer need only have a range from 0 to 180 degrees, because the phase may be changed 180 degrees by simply reversing the leads.

The electrical circuits required for this system are not shown, but they are more or less standard for the frequencies involved. Thus for the oscillator a simple Hartley, or Colpitts, or tuned grid, tuned plate, or Barkhausen-Kurz oscillator can be rigged up, the choice depending largely on the frequency to be employed. The receiver may be a simple regenerative circuit or superregeneration. The least practical power should be used because the less power that is used the less interference will the equipment cause with other services and the easier will it be to manipulate. Medium sized receiving tubes could well be used for the transmitter tubes and the smallest available tubes for the receiver.

A method of exploring the sub-soil for conducting bodies down to considerable depths has been invented. The principle of this method consists of setting up penetrating earth currents between two separated points on the earth's surface and then measuring the resulting magnetic field at many points in the region affected by these currents. The field can be measured either with a bar magnet magnetometer or with a vibrating string magnetometer. The driving electromotive force in the circuit above the surface is either a direct current battery or a low-frequency generator, preferably much less than 100 cycles per second. The voltage required depends on the conductivity of the ground, the distance be-

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tween the two points, and on the sensitivity of the current meter that is available.

Fig. 8 shows the ground and the electrical circuit. A and B are two metal rods driven

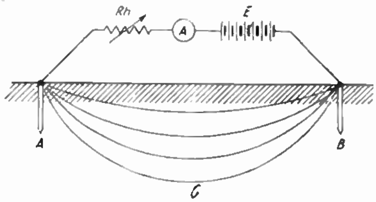

FIG. 8
Ground and electrical circuit, with A and B two metal rods.

into the earth at points separated by 100 to 1,000 feet. Between these two points, above the surface, is connected a circuit consisting of a rheostat Rh, an ammeter A, and a battery E, or a low-frequency generator. When this circuit is closed above ground it will be completed through the ground. The flow lines of electric current will not be straight from A to B, but will be curved as indicated in the figure, ACB being one of the deeper flow lines. In an electrically homogeneous ground these flow lines will approximately follow a hemisphere.

RESULTANT FIELD

In Fig. 9 the superficial circuit and some of the points of measurement are shown. All the measurements are made as nearly as practical half way between the two earthed electrodes, because here the horizontal component of the field is strongest and here it is also the most nearly uniform. Measurements are first made along the line AB and then along lines parallel to this line on both sides of the median line.

The above-ground circuit, lying on the ground, will set up a magnetic field, which is represented by a circle with its center on the ground. At the point of observation this field is vertical, and its direction is represented by an arrow pointing upward. The underground current in the opposite direction will also set up a magnetic field, and this field is represented by a circle with its center below the surface

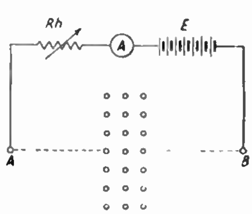

FIG. 9
The superficial circuit and some of the points of measurement.

and with its circumference touching the earth's surface.

At the point of observation the magnetic force due to this field will be horizontal, and it is represented by an arrow pointing to the left. It is the resultants of these two fields that are measured at various observation points approximately half way between A and B. Since the field due to the above-ground part of the circuit can be held constant by holding the current constant, and since the intensity of the magnetic force at the surface due to the underground current will depend on the current distribution, and hence on deviations from electrical homogeneity, the intensity and direction of the measured component of the field give data from which the location and extent of the underground conductor can be determined.

The intensity of the magnetic field at any point is measured by means of the period of swing to the magnet in the magnetometer. The formula connecting the field strength with the magnet properties is $HT^2M = K\pi^2$, in which H is the magnetic field intensity, T is the time required for the magnet to execute one complete vibration, M is the mass of magnet, and K is its moment of inertia about its center of rotation. This applies to the case when the current used is d.c. When alternating current is used, a vibration magnetometer, or string galvanometer, should be used, and then the intensity is determined from the amplitude of the vibration of the string. The sensitivity of this arrangement may be greatly increased by tuning the string to the frequency used.

FIELD COMPENSATION

No matter where the receiving apparatus is set up the magnetometer will be interfered with by the earth's magnetic field. To eliminate this effect, a compensating coil is used. How this is done is illustrated in Fig. 10. A bar magnet is suspended on a thin wire so that it may swing freely about an axis through its bar magnet and at right angles to its length. Concentric with the magnet in its right position is a compensating coil, shown at the right in Fig. 9. The current in this coil is adjusted until its field at the center of the magnet is just equal to the earth's field at that point, and opposite in direction. The compensating

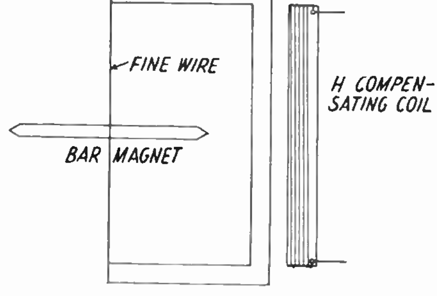

FIG. 10
Use of a compensating coil, with far magnet, to eliminate spurious effects.

circuit is shown in Fig. 11. A rheostat R_1 is provided for adjusting the current through the loop and an ammeter to indicate how much current is required for the compensation. There is also a reversing switch in the circuit for convenience in changing the polarity of the compensating field when that becomes desirable.

Compensation is also required when the energizing current is alternating. If it is not done, the string of the vibration magnetometer will swing in one direction more than in the other. That is, it will be biased.

IMPULSE EXCITATION

A method of locating mineral deposits and electrically conducting bodies underground based on the sudden transmission of an intense current pulse through the ground has been put to test. The current pulse, which may be that of the discharge of a large condenser charged to a high voltage, is impressed on the earth between two metal rods driven into the ground at a suitable distance apart. The ground between the two metal stakes is then explored by means of a receiver which has been designed so that it integrates the current pulse, for example, a ballistic galvanometer. By means of such an instrument, or a similar one, it is an easy matter to measure the energy of the received pulse; for the energy is equal to the time interval during a time T seconds of Ri^2dt, or to I^2RT. In this i is the instantaneous value of the current, R the ground resistance between the two grounded electrodes in the receiving instrument, I is the effective value of the current pulse during the time T. By measuring this energy at many points in the field under similar conditions, it is possible to determine the nature of the soil under the surface, for the presence of any conducting bodies will be indicated by a marked distortion of the current flow lines.

The circuit in Fig. 10 is a suitable arrangement for generating the high current pulses and for impressing them between two points in the ground, marked P and P' and labeled output. Provision is made for impressing either a pure direct current or an alternating current. The choice between the two is made by switch S_5. the two grounded points or the a-c impedance Z, or both. Appropriate instruments are incorporated in the circuit for measuring the currents and voltages required. When either of these The purpose of these is to enable the operator to measure either the d-c resistance R between

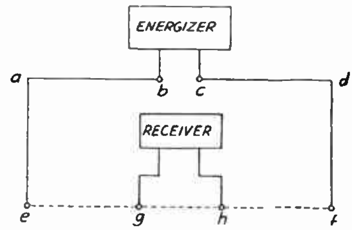

FIG. 12
Sectional view of earth, waves and apparatus.

circuits are to be used, the switches S_3 and S_4 are set so that P and P' are included in the circuit.

The condenser which holds the charge is C. It should have a large value. It is charged through a variable inductance coil L, a variable resistor R_1, and a limiting resistor R_2. The battery E is the charging battery and the milliammeter Ma measures the current. The purpose of L and the variable resistor R_1 is to change the rate of discharge of the condenser and thus to change the shape of the current pulse during the discharge period. The switch connected to R_1 is set at S_1 for charging and at S_2 for discharging. This switch is arranged so that the chargin gand discharging can be done rapidly.

SIMPLIFIED SCHEMATIC

In Fig. 12 is shown a simplified layout of the transmitter and the receiver. Two leads from the energizer, or transmitter, run parallel to *b* and *c* and thence the two wires run in opposite directions to points *a* and *d*. Thence the leads are run to the grounded stakes, here indicated by *e* and *f*. The lines *ae* and *df* are

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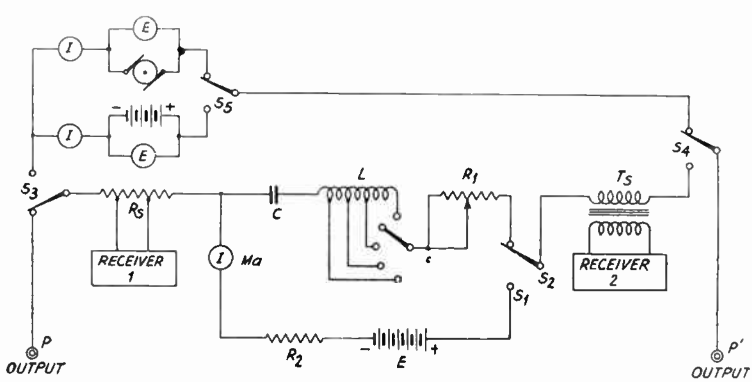

FIG. 11
A circuit for generating high current pulses and impressing them between two points, P and P', in the ground.

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at right angles to the lines *abcd* and *eghf*. The two end lines which appear to be vertical are really lying on the ground.

The receiver is arranged the same as the transmitter but its leads are shorter. This the distance *gh* between the grounded receiver stakes is small compared with the distance *ef* between the grounded transmitter stakes. The midway point between *g* and *h* is also the midway point between *e* and *f*, but the receiver stakes are not always on the line joining the transmitter stakes. They may be on lines parallel with *ef*.

A sectional view of a portion of the earth being studied, together with the arrangement of the transmitter and receiver circuits, is now imagined. Directly under the survey equipment is assumed to be a conducting layer or a metal pipe. The wave lines show the course the current pulses will take. Since the conducting layer or pipe has a much higher electrical conductivity than the surrounding earth, most of the electrical current will flow directly down to the conductor rather than flow through the earth above the conductor. If the earth under the equipment were homogeneous, the current would follow the geometrically shortest path, for this then would also be the electrically shortest path.

METHODS OF DETECTING

In the preceding figures the receiver was connected conductively to ground. But there are other methods in which the effect of any buried conductor may be studied. For example, instead of measuring the current pulses picked up by two grounded electrodes, the electric or the magnetic field may be measured at the observation points. If the electric field is to be measured, a loop is the proper means for getting an indication.

A RECEIVING CIRCUIT

Fig. 13 shows details of a receiving circuit in which the detector is conductively connected to the earth. G is a ballistic galvanometer in series with the two grounded electrodes *g* and *h*. The only essential part in the circuit above ground is the galvanometer. The rest of the ciruit is therefore convenience. Thus there is a condenser C which may be cut into the circuit to block the current in case the potential difference between the grounded electrodes is excessively high. This condenser may be cut into the circuit by opening the switch connected across it. There is also a condenser C_o in shunt with the galvanometer, which may be disconnected by opening a switch. C_o is a shunt to cut down the portion of the current pulses that goes into the galvanometer. A damping resistance may also be connected across the galvanometer, in place of C_o, by means of the switch. This alters the period of swing of the instrument and the instrument and the length of time it swings after it has received a given impulse.

There is also a provision in the circuit for balancing out the effect of stray earth potentials. A low voltage battery **E** is provided for this purpose, together with a potentiometer across it by means of which any desired portion of the battery voltage may be connected in series with the galvanometer. Since the earth potential may be in either direction in respect to the desired potential between *g* and *h*, a reversing switch is inserted in the circuit. The earth potentials are balanced out when, with the switch across C closed, there is no steady deflection in the galvanometer.

DISTINCTIVE FEATURES OF METHODS

The distinguishing features of this method of exploring for buried treasure is the use of a high current pulse of short duration and ballistic instruments for measuring its effect at various points in the area to be prospected for minerals or other conductors. In respect to the method of impressing the signals on the ground this method is similar to other methods employing conductive coupling between the transmitter and the ground. In respect to the layout of the field for observation points, this method is like all other methods, because the points may be laid out either on Cartesian or polar coordinates. The square layout is the simplest to use and for that reason is the one most generally employed.

In order to get very large current pulses into the ground it is necessary not only to have a condenser of very large capacity but also to have a very high voltage for charging it. The condenser, of course, must be able to stand the high voltage used.

The quantity of electricity that can be impressed on a condenser is equal to the product of the capacity and the voltage to which the condenser is charged. Thus if Q is the capacity in coulombs, V the voltage in volts, and C the capacity in farads, we have the relation $Q = CV$. If this quantity is discharged in a time T seconds, at a uniform rate, the electric current is $I = CV/T$. Now suppose that the discharge occurs in a tenth of a second, that

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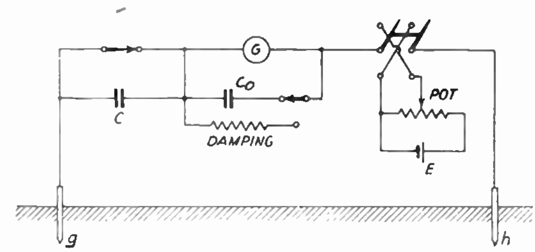
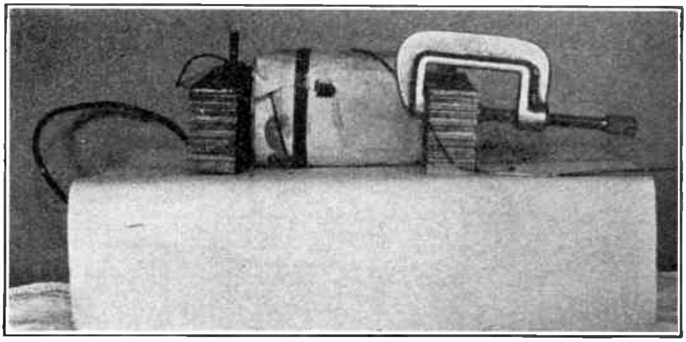


FIG. 13
The detector is conductively coupled to earth. G is a ballistic galvanometer, the only essential part of the circuit above ground.

C Clamp Holds Wire When Winding Halts



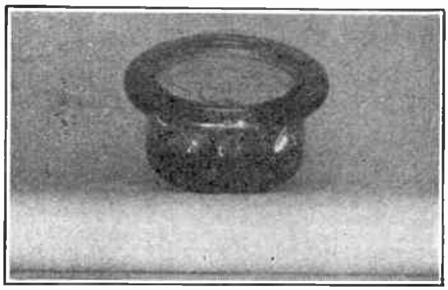
The clamp secures the wire, preventing unraveling, when winding has to be interrupted.

When winding magnet wire on a form, or core, it sometimes happens that an interruption occurs, necessitating some means of keeping the wire from unraveling. This may be accomplished quite easily by means of a small C clamp. During the intermission, the clamp is placed over the wire and form and tightened just enough to prevent the wire from slipping back.

The scheme worked fine in long practice.

Meter Use Retained Though Glass is Off

During the height of an experiment, the experimenter sometimes knocks a meter off the table, accidentally of course, and the glass is broken. This can be remedied with a small piece of cellophane until a new glass can be obtained. A single sheet of cellophane is placed over the rim of the meter and folded back. The cellophane may be held in place with a rubber band, or a piece of string placed underneath the rim. If no damage has been done to the meter other than the broken glass, the instrument may be used with the cellophane with practically the same visibility as with the glass.



Upper part of meter completely wrapped in cellophane enables use with safety to needle though the glass face is missing.

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the voltage is 500 volts, and that the capacity of the condenser is 10 mfd. The mean current during the one-tenth second will then be 50 milliamperes. The maximum current, which occurs at the start of the discharge is many times higher than the mean current.

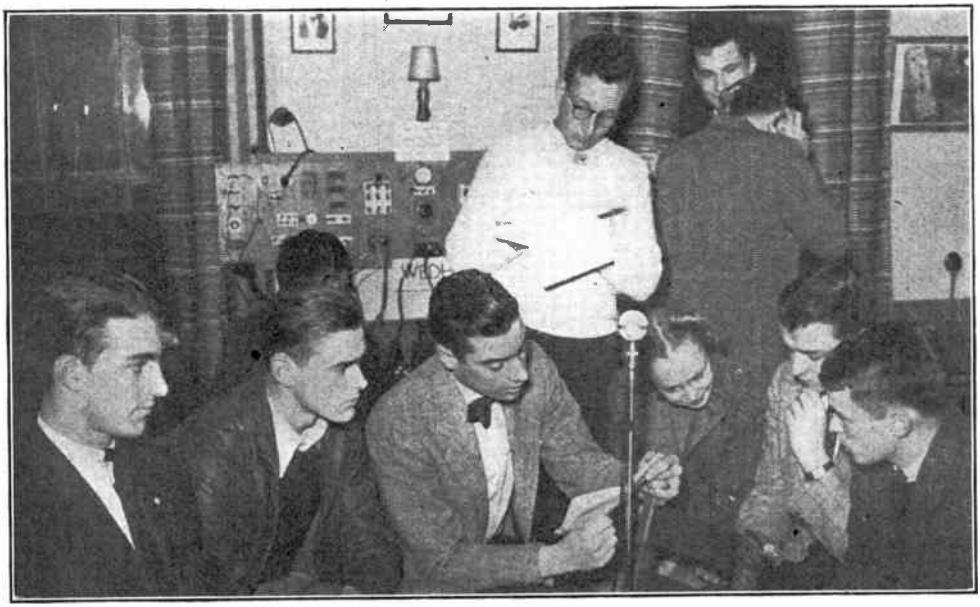
The actual value of a current pulse, and hence of the magnetic field, as received at any observation point depends not only on the discharge current but also on the distribution of the current after it has entered the ground. In the first place the discharge current depends on the resistance in the ground as well as on the resistance of that part of the circuit which is above ground. Since there is no way of changing the resistance in the ground to increase or decrease the current provision is made in the above-ground circuit. About the only way of increasing the pulses for a given condenser is to increase the voltage of the battery used for charging.

Drawings showing the resultant magnetic field usually are based on the presence of a definite conductor in the ground, such as a pipe line, an electrical conductor, or an elongated orebody having a high conductivity. But there are many valuable deposits which are no conductors at all, but rather insulators, and very few natural deposits are elongated like a pipe even if they are conductive. The method may still be used, however, even when the mineral is not a conductor, or when it is not an elongated body. It will work in any case where there is a pronounced inhomogeniety of electrical conductivity. Even if the mineral under ground is a perfect insulator, its presence will disturb the magnetic field set up, and the location and nature of such a body then become a matter of interpreting the field data obtained. It will take experience to draw the right conclusions in some instances, and for that reason the novice had better begin with pipe lines and the like.

While hundreds of patents on geophysical exploration devices have been granted, and the claims in them run into thousands, there is a remarkable uniformity of method. An electromagnetic field is set up in the area to be explored and the disturbance in that field is measured at many points in the area.

Campus Network Blossoms

50 Outlets at Brown University Serve Students



Students at Brown University are shown broadcasting a one-act play in the "main studio," a dormitory room in Slater Hall. In the picture, from left to right, are Robert E. Lord '41, Pittsfield, Mass.; Walter L. Boughton '41, Shaker Heights, O.; John H. Clayton '41, Chicago; Carolyn H. Bradshaw, Pembroke College '41, Pittsburgh, Pa.; Leonard D. LeValley '39, New Bedford, Mass.; and Stephen G. Stone '41, Pleasantville, N. Y. Standing and with the script is William W. Creasey, Jr., of East Orange, N. J.

Providence, R. I.

A campus-wide radio telephone system at Brown University, planned and built entirely by undergraduates, is the result of an idea that two freshmen had a year ago.

Sponsors of the broadcasting system call it the "Brown Network." They plan to put a variety of educational as well as entertainment programs on the wires regularly.

Recent broadcasts included news flashes from the Brown Daily Herald, an organ recital in Sayles Hall by Marcel Dupre, organist of Notre Dame Cathedral in Paris; a one-act play by new members of Sock and Buskin, university dramatic society; a lecture on marriage and two informal talks by members of the faculty.

George Abraham, a freshman from New York, and David W. Borst, a classmate from North Haven, Conn., started the idea with two-way communication with four dormitory neighbors in Brunonia Hall, using a high-frequency generator. Friends in other dormitories were interested and more lines were run, frequency lowered and ordinary radios used as outlets.

The network soon had 42 outlets. Experimental broadcasts of campus news flashes were started. The installation ceremonies for Brown's new president, Dr. Henry M. Wriston, were relayed over the network, which by this time included the infirmary. Recorded music was played on occasional afternoons.

RAPID RISE OF OUTLETS

Technical, managerial and literary boards were organized and now include nearly 40 members. Section managers were appointed to take charge of relay arrangements to the dormitories. Fifty outlets are used now. The sponsors have had requests for close to 100, including fraternity houses and Pembroke College dormitories.

The system has its "main offices and studios" in Abraham's dormitory suite in Slater Hall. Five lines, totalling some 12,000 feet, circle the campus to all residence halls, to Faunce House, student social center, and to Sayles Hall, Brown's chapel. Three fraternities have outlets.

The network has just acquired a portable unit which can be taken to any classroom or lecture hall to pick up discussion meetings or addresses.

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Photographer is Own Model in Action Pictures of Apparatus

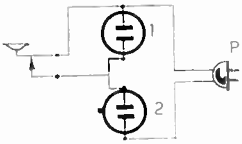

FIG. 1

Diagram of the connections to key and outlets.

Occasionally it is necessary to take a picture of a radio, or piece of test apparatus held in the hands, or perhaps it is necessary to point out a definite part of the apparatus with the finger. The whole operation, modelling and all, may be done very easily by the operator himself by means of a telegraph key and two "outlets."

The key and outlets are mounted on a small wooden base and wired as in Fig. 1. The plug from a low-power lamp, such as a 10 watt lamp, is put into the outlet marked No. 1. The high-power lamp, such as a photoflood, is plugged into No. 2 and the plug P is put into the lighting circuit outlet.

With the key up, or in the open position, the small lamp remains lit, furnishing enough illumination to make arrangements for the pictures. When preparations are completed the key is placed on the floor and tramped upon. This turns off the ten watt lamp and lights the photoflood lamp. At the expiration of the time exposure, the key is released, the photoflood lamp goes out and the dim light goes on until ready for the next picture. The photograph shows how the key and outlets may be mounted on a small piece of wood.

Thus, when taking a picture, the light, rather than the shutter of the camera, is manipulated, which facilitates the operation.

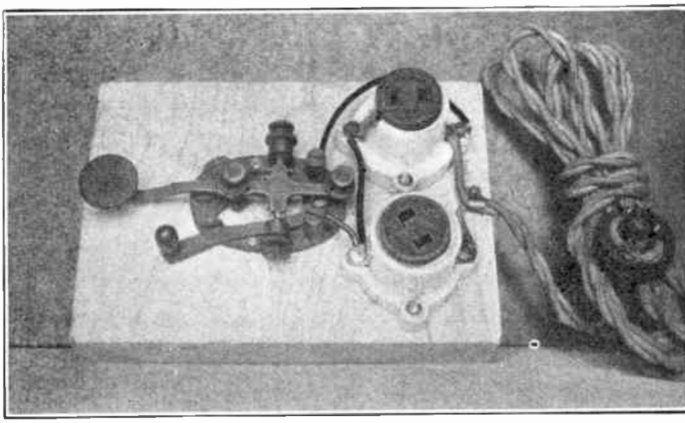

FIG. 2
View of the key and sockets mounted on a baseboard.

(Continued from preceding page)

Further experiments will be tried this year with shortwave broadcasts from the gymnasium and athletic fields to the main amplifying station on the campus, where games can be relayed over the network.

CLASSROOM LECTURES INCLUDED

Educational programs being planned include talks by administrative officers and members of the faculty. Prominent students will be invited to discuss campus affairs. There will be plays, newsflashes, lectures, glee club and orchestra recitals and concerts, programs by the band, debates, and meetings of student governging bodies relayed over the wires.

Prof. Arlan R. Coolidge, chairman of the Department of Music, will be the first member of the faculty to arrange campus broadcasting of his regular classroom lectures. Prof. Samuel J. Berard of the Division of Engineering has an outlet in the mechanical drawing laboratory so that students may hear recorded music over the network during laboratory hours.

Words of Praise

Having read Radio World ever since it was a weekly, I get more valuable information from it than from any other magazine of the trade.

Walter G. Inman,
7327 Jefferson St.,
Kansas City, Mo.

* * *

Radio World is my idea of the best magazine of its kind obtainable.

George Hoskinson,
1196 Bedford St.,
Whitman, Mass.

Detector Becoming Crux of High Fidelity

By Walter G. Wyndham

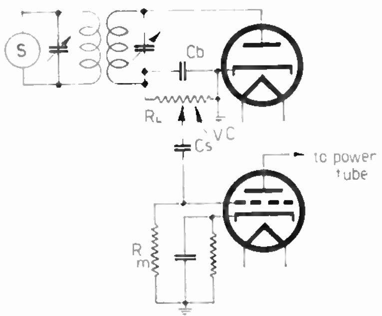

FIG. 1.

The normal diode. It draws current from the amplifier, reduces selectivity, and provides audio voltages, practically without distortion, for percentages of modulation up to 80 only.

ONE of the earliest tube detectors was the diode. Because amplifiers were not sensitive, or tubes and parts to make them sensitive were costly, the diode detector fell into oblivion in receiver use, until automatic volume control became popular, and meanwhile sensitivity of sets could be made anything within reason, at medium cost. The gap was filled by the miscalled power detector, which operated at almost wattless power, and was simply a highly negatively-biased detector, of no-good quality. For when you speak of quality in detection you mean a condition whereby for equal changes of applied signal voltage there is an exactly proportional change in current, for percentage modulation up to 100.

So the diode was hailed as the truly perfect detector, but it got that reputation by comparison, for it was much better than the power detector.

With engineers and, let us trust, the public becoming more and more interested in quality reception, and even high fidelity receivers being purchaseable on the open market, another feat of recent years by set manufacturers, more and more attention was paid to the detector.

SEEKING SOMETHING BETTER

There are weak spots in receivers. The power output stage is one of them, but conditions there have been improved greatly in the past three years. Associated with that end of the receiver are the speaker and baffle, and now there is such quality reproduction, so far as governed by the amplifiers and speakers, that again we are forced to look back into the detector. And we find that it is not all that it should be, yet can be made better, and no doubt receivers will become more and more numerous that offer the best in detection along with the best in amplification and transduction.

When we examine the diode we find to our satisfaction that we have a detector that comes up to requirements as to the current response being proportional to the a-c voltage applied, in other words, we have linearity. This is our maxim, and we stick to it. Linearity for quality! That is the battle cry.

All right. But we get linearity just so far, and no farther. How far? Well, that depends on various factors, but the principle at stake is that we have a detector that may not respond to any modulation, or does not respond faithfully to very high percentages of modulation.

MODULATION FOR INTELLIGENCE

When the broadcasting station puts its wave on the air it sends out the carrier, which the receiver picks up. To convey intelligence, and radio programs come under the heading of intelligence, something has to be done to that carrier wave. In fact, any number of things may be done to it. The amplitude of the wave may be varied according to the amplitude variations of some speech or music put into a microphone, and the frequency of the change of amplitude will correspond to the frequencies of the spoken or played pieces.

The frequency of the wave could be changed, amplitude held constant, the method that National Broadcasting Company is trying out experimentally, because it lends itself to practically static-free transmission and reception on short waves, using a system devised by Maj. Edwin H. Armstrong, who gave us super-regeneration, and possibly regeneration, that is, if the Federal Courts have made a mistake.

Then there are other ways, associated with the two just discussed, but differing so greatly as to rate separate classification. It is possible, for instance, instead of sending both sides of the amplitude-modulated wave, to send only carrier and one sideband, known as unitary-suppressed sideband transmission. In fact, it is possible to suppress the carrier, and send only the two sidebands, or suppress both the carrier and one sideband, and send only the other sideband. Where the carrier-missing principle is invoked, always there must be in the receiver an oscillator exactly at the frequency of the transmitting oscillation, and thus the receiver produces its own carrier, which is modulated by the picked-up single sideband.

But the receivers in use to-day throughout the world respond only to amplitude-modulated carriers, and amplitude modulation is all that concerns the serviceman, except in his oscilloscope work, where he needs frequency modulation of his test oscillator to enable flat-top peaking of intermediate and other channels. That is, the frequency modulator, or wobbler, enables the production of a band of frequencies, and it is necessary to have a band to be able to compare the resonance width of the amplifier. Or, it could be done another way, but the other way is exceedingly tedious to apply, and mistakes in manipulation hard to avoid.

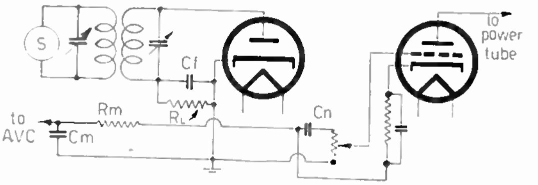

FIG. 2
When a.v.c. is to be obtained also, besides audio, there is more loading, and the ratio of the d-c resistance of the diode load resistor, to the impedance, can never be high enough for good detection of modulation percentages above 80.

THE MAINSTAY

So we have as our mainstay amplitude modulation, and also a plethora of diode detectors, and we want to know what is the matter with the detector that used to be so good? Good is an elastic word. A boy running on the public school or parochial school team may be good as compared with classmates, but let him run against Glenn Cunningham, and then we might want to make modifications. In final comparisons age, condition of service, experience, etc., have no significance. The best is best by test of results, and the diode as we know it is not best.

The limitation of the diode is that we can not get anything out of it without connecting something to it in such a way as to reduce the quality of what we do get.

Looking at Fig. 1, we find the diode at top, with a load resistor R_L across which is a bypass condenser C_b, which removes all the radio frequency, but practically none of the auido frequency. Now, just as a diode circuit, all by itself, that is all right, and if our only object were to measure d.c., and not hear anything, we would put a meter in series with the load resistor, and put a much larger capacity condenser across the entirety (load resistor and meter), so that no audio or modulation or ripple remains, only pure d.c. For such objective, with sufficiently high value load resistor, certainly not less than 50,000 ohms, and preferably not less than 250,000 ohms, we would be attended by excellent success.

TAKING OUT THE AUDIO

Now consider the diode as a detector, meaning a device for eliminating the carrier, but retaining the pulses representative of the audio frequencies that were impressed on the carrier. As said before, we must connect something in parallel with the load resistor. Now, instead of having a load resistor intended only for competing the d-c circuit of the diode, so d.c. can flow through the detector, and for making the diode curvature small compared to the linearity of the load resistor, we have to take out audio frequencies, and do not use the d.c. at all.

REDUCTION OF IMPEDANCE

One way of extracting the a.f. is to have the load resistance composed of the total resistance of a potentiometer, slider of the potentiometer connected through a stopping condenser C_n to the grid of an amplifier or driver tube. If the connection of this second tube is made to a power tube, then the second tube is known as the driver.

Now, the grid circuit of the driver, lower tube in Fig. 1, has to possess d-c continuity, to make the bias applicable, and this is established through the grid resistor R_m. The biasing resistor is in the cathode leg at right.

Assuming the grid circuit alone is an infinite resistance, it has been made finite, equalling the d-c resistance of R_m, but the impedance has been changed by connection to the diode. In what direction? Since it is a case of resistors or impedances in parallel, we have reduced the total impedance.

Because we are alarmed over the diode, and not at all over the driver, we turn to the load resistor that previously was considered only for its d-c effect, and we now find that we must consider its impedance, or a-c effect. While we have not altered the d-c considerations one bit, because the stopping condenser prevents that, we have reduced the audio impedance.

THE IMPOSSIBLE NOT SO EASY

We must now take for granted a mathematical concept of the quality requirement, that for the diode to be capable of 100 per cent modulation handling, without distortion, the impedance of the parallel circuit of the diode load resistor must be equal to the d-c resistance of the load resistor. That is another way of saying that we must not connect anything to the diode in such a way as to bring out any of the audio, for there is no known method of obtaining audio output from such a diode without reducing the impedance.

That is, we are compelled by the requirement of audio extraction to create a condition that makes 100 per cent modulation handling without distortion an impossibility.

The best we can do is compromise, making the load resistor low enough, so the shunting effect in impedance terms of what is connected to it will be small, and yet not make the load resistance so low that there will be great loss of selectivity because of high loading of the i-f amplifier, or departure from linearity because the tube curve has such a high comparative effect on the total current. You see, the diode itself, and alone, has a curvature, and is not

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linear, but only loading seems to make it so. And paralleling impedance for purposes of audio takeoff is more loading, only this type makes for departure from linearity; in other words, to put it bluntly, distortion at high percentages of modulation.

OBTAINING A. V. C.

We can now understand, therefore, that we

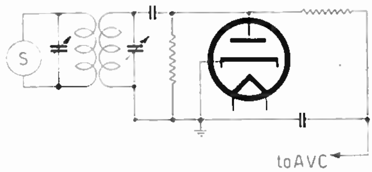

FIG. 3

The condenser-diode offers only a.v.c., no advantages over the other, and no audio output.

have quite a problem on our hands, if we desire to use the normal diode, and get no more from it than the audio pulses, not mentioning automatic volume control.

In Fig. 2 we have the diode again complete so far as its d-c circuit is concerned. The S in a circle, as before, represents a sine-wave input, of the frequency to which the two windings are tuned. R_L is the load resistor, C_f is the bypass condenser, eliminating the i.f. but not a.f.

Now, to obtain output at audio frequencies, and also for automatic volume control purposes, we made two main connections to the diode, instead of only one. In the right-hand direction the audio frequencies charge the stopping condenser C_n, which discharges through the grid load resistor, which is a potentiometer used for volume control. If C_n is assumed to be so large that if the voltage drop across it is negligible, then the potentiometer is across R1. Also R_m, used as a filter resistor in the a-v-c lead, to help keep the audio from modulating the controlled tubes, is across the load diode resistor, while C_m, the filter condenser associated with R_m, contributes a parallel impedance effect, limited by R_m. While some choice exists as to constants, no constants can be chosen that will provide the requirement that the impedance equal the d-c resistance, for any loading reduces the impedance.

HIGH RATIO NEEDED

If the d-c resistance of the circuit is R_{dc} and the impedance is R_{ac}, then the ratio $R_{ac} \div R_{dc}$ must be very high for quality reception, and we can not reasonably make it much higher than would permit distortionless detection of 80 per cent modulated waves.

Well, the question is, what about the other 20 per cent, and is it worthwhile doing anything about?

If you frequently tune in high-class stations that are equipped for 100 per cent modulation for quality reasons, or even low-class stations that use high percentage modulation as a means of reaching out farther, then you will profit by having the same demodulation capabilities in your receiver as the station has in its oscillator. In other words, coming or going, the extra 20 per cent means something, even though 100 per cent modulation does not signify that all audio is always put full blast on the radio wave, but only that it happens occasionally, or frequently, and that the system is *equipped to handle it*. That is, the sending system. The receiving end is up to you. The station can not do any more about your set than you can do about the station.

It may occur to some that a condenser-diode detector may be used, but there is no way to get the full audio out of it, or any audio without depression of tone, and much loss, but it can be used for a.v.c., as shown in Fig. 3. However,

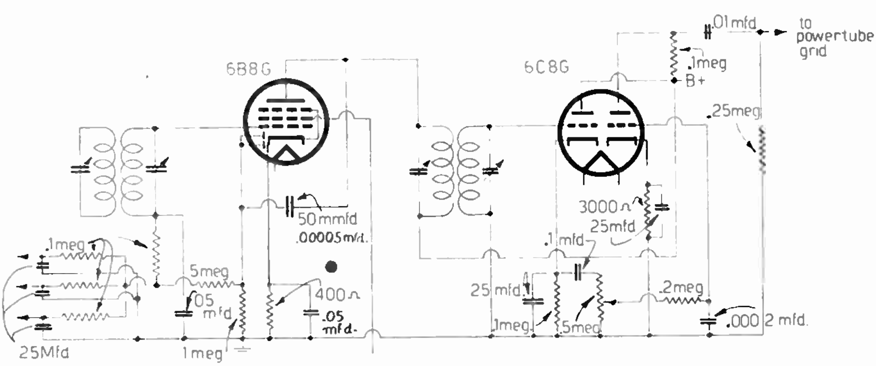

FIG. 4

Here the quality of detection is of the best, as an infinite impedance detector is used, being a triode that has diode characteristics, hence is called an infinite impedance diode. Percentage modulation even to 100 is handled distortionlessly. The a.v.c. voltage is obtained from the diode section of the i-f amplifier, causes small loading, reduces selectivity only a little, but in no way impairs the quality detection. Follow constants carefully.

the other form, or series-connected signal input, permits both audio and a.v.c., so the condenser-diode may be forgotten in this connection.

The solution is to use another detector that also does not amplify, or amplifies so little that it can hardly be measured, and yet which does not have a crooked characteristic but a linear one. Incidentally that type of detector, which is nothing more than a self-biased triode, with plate circuit used for B supply only, and audio drop across the cathode-series resistor, or biasing resistor, affording the audio supply, quite naturally draws no current from the signal source. That is, the i-f transformer secondary, when this type detector is placed across it, is undisturbed, except that a little capacity is added, but as this is in parallel with the tuning capacity, a slight readjustment of the trimmer condenser across this secondary will atone for all. Hence the infinite impedance detector presents to the circuit that feeds it a pure capacity reactance. That's just too fine for words.

Fig. 4 is a diagram of a 6B8G as a combination infinite impedance detector and first audio stage. The constants are those worked out by the engineering staff of Ken-Rad Tube & Lamp Corporation. The 6B8G has its pentode section used for the i-f input, output from the plate circuit as usual for i.f., into the signal detector.

PLAIN DIODE FOR A. V. C.

However, it will be noticed there are two diode plates in the 6B8G, and these are interconnected externally, and supplied through a small condenser from the plate circuit of the tube, so that the rectified voltable is obtainable for a.v.c.

The loading effect is small indeed, the selectivity is reduced less than before, and we are free to proceed to the signal detector at good selectivity, using as detector one section of a twin-diode tube, the 6C8G. This is the infinite impedance diode detector, called diode not because it is a triode but because though a triode it has the linear characteristics of a diode. Only more so.

The circuit is for single-sided amplifier or power tube, as one section of the twin-triode is used as driver. Push-pull is possible, by phase inversion. Any one particularly interested in the push-pull feature may obtain a copy of the diagram by writing to me care of Radio World, 145 West 45th Street, New York, N. Y.

The gain in the audio section, according to Ken-Rad engineers, is approximately 24, in Fig. 4. The circuit, however, does not afford the full possibilities of selectivity that the infinite impedance detector permits, because of the little loading for a-v-c supply purposes. This load across the primary is approximately equal to the parallel resistance of the 500,000 ohms (.5 meg. to left of the diode lead) and the input impedance of the diode. Neglecting the detector efficiency, the input impedance is approximately 1 mik. (diode to ground) divided by 3.

The resistor values should not be exceeded because if made higher may result in so much resistance in the return circuit as to cause blocking.

AVOIDING CUTOFF

ISN'T there some way of adjusting a superheterodyne so that there will be no overload on loud signals? Strong locals play havoc with some supers that have a.v.c If the plate voltage is not fully under control, what would be a good method of assuring that the no-signal bias on the r-f tube was 3 volts?

Fig. 4 on the previous page shows the mixer and r-f stage of a superheterodyne, omits the i-f channel, but shows the input to the diode, and the rectified signal voltages. The bias on the first tube may be made just 3 volts by putting a meter across the cathode circuit self-biasing resistor, and adjusting the screen voltage until the meter reads 3 volts from cathode to B minus. The overload may be corrected by taking off less than the total rectified voltage. Use a rheostat of 250,000 ohms, and adjust it until the strongest local causes no overload. Then remove the rheostat and measure the amount of resistance that was used. Be careful in attempting to follow these directions that you do not measure the unused part of the rheostat but the used part. Then replace with a fixed resistor of equal value.

THIS IS TOO MUCH

Editor Radio World:

I have just recently discovered your excellent magazine, Radio World! I have seen it on the newsstands all the time but didn't realize it was just exactly what I wanted until I looked through one. Since then I have been going through all the old magazine files looking for back numbers. Man, what I've been missing! I have quite a few now.

I read all the complimentary letters from readers which you print, but it seems the writers overlook one feature that would alone set Radio World apart from other magazines. I refer to the manner in which *all* of any one article may be read without those accursed "continued on page 64984," etc. I lack words to tell you what a convenience it is to be able to start at the front page and read clear to the back page without having to skip back and forth. Oh, yes, I certainly do read from front to back, and not miss a thing. And that's another fine point of Radio World—*every article printed is worth reading.* No dead timber to fill space.

Route 3, Snohomish, Wash. L. R. Volz.

RULE FOR LOW A-C VOLTS

In instrument rectifiers, to get lowest voltage range use a highly conductive rectifier tube. Two sections of the 6H6 may be used in parallel. Buck out the idling current with a resistor and 1.5 volt cell across the meter.

The shunting effect of the resistor will be taken into account automatically in the calibration.

Peck's Television News Service Gets Under Way at Dempsey's

Jack Dempsey is shown at a hotel typing the first message to go over the wires in the first commercial installation of the Peck Television News Service. Just behind Dempsey (extreme left) is the inventor, William Hoyt Peck, noted Georgian. The small view shows how the news messages are observed in Dempsey's restaurant.

Commercial television made its bow to the public in New York City recently with the transmission of bulletins from the Hotel Lincoln to receiving equipment installed in Jack Dempsey's Restaurant, about a third of a mile away. The ex-champion himself sent the first message over the new system.

While adapted to use on coaxial cable or radio, the system is not limited to them, but can operate over standard wire lines, as was done during the demonstration.

Representatives of the press gathered in the writing room of the hotel, where they witnessed the television transmission of typed bulletins. The messages, many of them composed by the newspaper men, were typed on a strip of transparent ribbon passing through a special automatic-feed typewriter.

The ribbon, fed through a small transmitting cabinet, was passed through a beam of light which was caused to scan it by means of a Peck lens disc. After passing through the tape, where it was broken up by the typed letters, the light fell upon a photo-electric cell at the top of the transmitter cabinet, thus being converted into electrical impulses which were then amplified and conducted to standard wire lines. The transmitter cabinet is about the size of a four-drawer letter file.

After examining the transmitter, the newspaper men taxied to Dempsey's. There they found a Peck television news service receiver installed. This apparatus is housed in a cabinet seven feet tall, near the top of which is a ground glass screen three feet long by six inches high. The bulletins received by the television process pass across the screen from right to left. They were easily readable in the brightly lighted restaurant.

To test the speed of transmission, one of the reporters went into a telephone booth and phoned a brief message to the operator at the transmitter. Before he had returned from the booth, only a few feet from the receiver, his first words were appearing on the screen.

Reception is accomplished by a simple high-gain amplifier connected to the wire line. The amplifier feeds a Peck light-modulator cell which controls a beam of light passing through it and falling upon a Peck lens disc.

William Hoyt Peck, inventor of the apparatus and president of the Peck Television Corporation, which built both transmitter and receiver, is America's leading proponent of optical mechanical scanning, which he claims is cheaper, more durable and more effective than the better-known cathode ray tube systems. He

(*Continued on following page*)

NBC All Set with Mobile Unit For Televising Outdoor Scenes

America's first mobile television station, to be used in experimental television pick-ups of outdoor news events, was turned over to the National Broadcasting Company in ceremonies in Rockefeller Plaza, New York City.

The new unit, consisting of two large motor vans containing television control apparatus and a micro-wave transmitter, was built by the RCA Manufacturing Company at Camden, N. J. Engineers of the National Broadcasting Company will operate the unit in connection with the present NBC television transmitter atop the Empire State tower. A part of the turnover ceremonies was broadcast during the Magic Key RCA program.

OUTDOOR EVENTS TO BE TELEVISED

Delivery of the NBC mobile television unit presages the most intensive activity in the history of American television. The National Broadcasting Company contemplates the experimental televising of outdoor sports, parades, scheduled news events and other subjects.

After being relayed by micro-wave to the Empire State transmitter, the televised events will be broadcast throughout the Metropolitan area to receivers in the hands of NBC engineers and those built by radio amateurs.

The new mobile unit consists of two motor vans, each the size of a large bus, to be operated by a crew of ten engineers. One van contains complete pick-up apparatus, including cameras, for both picture and accompanying sound. A picture, or "video," transmitter to operate on a frequency of 177,000 kilocycles is mounted in the other. A special directional antenna, to be raised on the scene of operations, is used in connection with the mobile unit. In the Metropolitan area, where the steel framework of many skyscrapers impedes ultra-high frequency transmission, the normal working range of the new unit is expected to be about twenty-five miles.

The van containing the pick-up equipment is the mobile equivalent of a complete television studio. Apparatus in the van, all mounted in racks extending down the center of the vehicle, includes the synchronizing generators and rectifiers for supplying Iconoscope beam voltages, amplifiers for blanking and deflecting potentials and line amplifiers. The principal sound apparatus consists of microphone amplifiers and sound mixing panels.

CAMERAS PICK UP SCENES

The control room is also located in this van. Here, in semi-darkness, engineers are enabled to see the picture as it is actually being transmitted, and also the image being picked up by the second Inconoscope camera preparatory to transmission. Control engineers may switch at will from one camera to the other.

Two Inconoscope cameras, connected with this vehicle by several hundred feet of coaxial cable, are the instruments which pick up the scene being televised. Mounted on tripods, they resemble standard studio cameras, except that they are somewhat smaller and lighter in weight. Engineers check camera focus by looking directly onto the photosensitive plate in the Inconoscope or "electric eye." In studio cameras focus is checked through a separate set of lenses. Among the microphones used in sound pick-up are several parabolic microphones developed in the NBC laboratories.

The second van, connected to the first by 500 feet of coaxial cable, when in operation, contains a complete micro-wave relay transmitter. The principal apparatus here is the radio-frequency unit, generating the carrier wave for picture signals, and modulating apparatus for imposing picture signals on this carrier. Because of the great amount of heat generated by some of the large vacuum tubes used in television, this vehicle contains an air-conditioning unit and a water cooler to maintain tubes at operating temperatures.

(Continued from preceding page)

has been active in television since 1929, prior to which time he was a pioneer in color motion pictures.

The television news service will be commercialized by a group of business men headed by Dailey Paskman, formerly managing director of the Gimbel Brothers radio station, WGBS, and president of the General Broadcasting System which operated the station prior to its sale to newspaper interests. The station now broadcasts under the call letters WINS.

LEASING IS PLANNED

Plans are under way to lease receivers to a number of public and semi-public locations, where bulletins concerning sports, finance, news, etc., will be displayed throughout the day and night. The bulletins will be brief items, both Mr. Peck and Mr. Paskman state, in no way intended to compete with newspapers or news reels. The material will be under the editorial supervision of Robert Eichberg, now of the staff of Gernsback Publications, author of "Radio Stars of Today," and formerly of the New York "Evening World" editorial department.

The New York area will be the first to receive this service, a single transmitter being able to supply any number of receivers irrespective of whether land lines or radio waves are used for carrying transmission. The apparatus has already had exhaustive tests over several miles of standard leased wires, which were found perfectly capable of carrying the image. It is also contemplated, however, to file application for a short-wave radio channel.

A 2-Terminal Oscillator

R-F Amplitude Stability is High in Circuit That Also Simplifies Switching

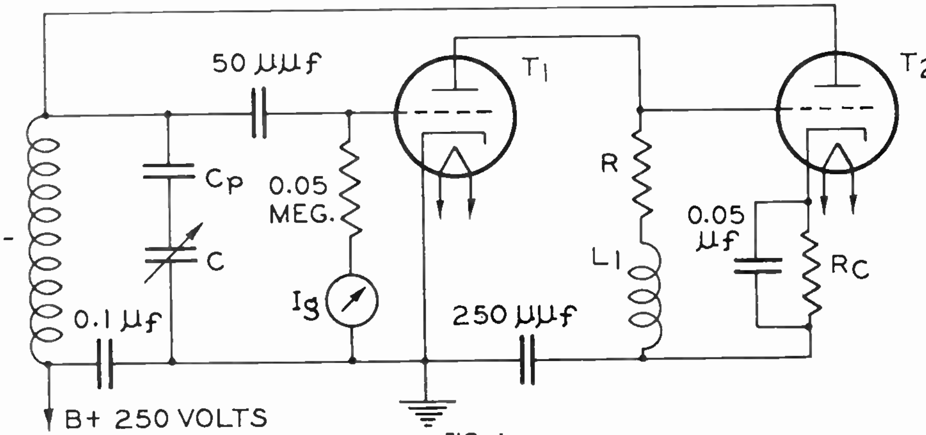

FIG. 1

In this circuit direct coupling is used in a two-terminal oscillator that has high amplitude stability. The meter Ig measures the grid current, which should be steady over the tuning range.

THIS Note describes a simple, reliable, two-terminal r-f oscillator whose output voltage is substantially constant over a reasonable range of frequencies. For a given ratio of maximum-to-minimum tuning capacitance, this oscillator may furnish less output voltage than conventional oscillators, but the ease with which adjustments can be made, the uniformity of the output voltage, and the simplicity of coil design, are desirable features.

Three variations of the circuit are shown in Figs. 1, 2, and 3. In these circuits, the output of T_1 feeds the grid of T_2; the output of T_2 feeds the grid of T_1. Thus, the action of T_2 is analogous to that of the tickler in a conventional tickler-feedback circuit.

Fig. 1 represents a direct-coupled arrangement. In this circuit, signal and bias for T_2 are obtained directly from T_1. Because of the direct coupling, the internal plate resistance of one tube is connected in series with the internal plate resistance of the other; hence, the B supply voltage is divided between T_1 and T_2. In the circuits of Fig. 2 and of Fig. 3 capacity coupling between T_1 and T_2 is used; hence, nearly full B supply voltage is applied to each tube. Fig. 2 differs from Fig. 3 merely in the manner in which B supply voltage is fed to T_2.

EXPERIMENTAL PROCEDURE

In determining the value of R, tune the oscillator to the low-frequency end of the high-frequency band and adjust the value of R for nearly maximum output. Tune the oscillator to the high-frequency end of that band and adjust L_1 for the same output that was obtained at the low-frequency end. Now measure oscillator amplitude over the tuning range of the wave band; a convenient measure of oscillator amplitude is the value of oscillator grid current I_g.

It may be necessary to change these values of R and L_1 to obtain a suitable compromise between desired values of tuning range, oscillator amplitude and uniformity of output. When the values of R and L_1 are determined in this manner they need not be changed when the oscillator is switched to any of the lower frequency bands. In these bands, oscillator amplitude is independent of the value of L_1 and is nearly constant over the tuning range of the band.

For a given amplitude of oscillation the tuning range of this oscillator circuit may be less than that of a conventional feedback circuit because of the high minimum capacitance introduced into the tank circuit by T_2. The shunt-feed circuit of Fig. 3 is suggested as a means of reducing this minimum capacitance. In this circuit, the series combination of C_c and the output capacitance of T_2 is connected across the tank circuit; the entire output capacitance of T_2 is connected across the tank circuit in the series-feed circuit of Fig. 2. A disadvantage of the shunt-feed scheme of Fig. 3 is that the plate voltage of T_2 is reduced by an amount equal to the voltage drop across R_p. Thus, for the same B supply voltage, increased tuning range is obtained at the expense of reduced oscillator voltage.

Typical values of R and L_1 are 200 ohms and 1.5 microhenries, respectively. These values are suggested as guides; final values should be de-

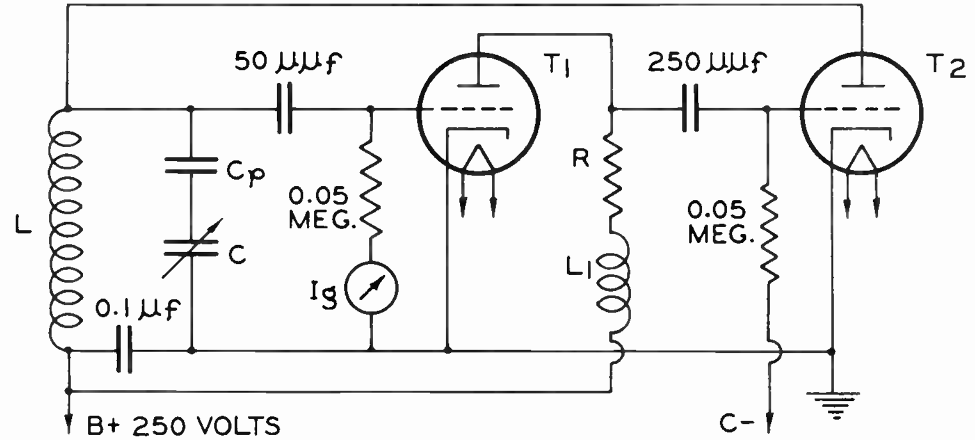

FIG. 2
Capacity coupling is introduced, so that nearly the full B supply voltage acts upon the oscillator, whereas in Fig. 1 that supply voltage is divided between the two tubes.

termined by test. The condensers C_p are used to isolate the high voltage from the tuning condenser C; condenser C_p may be a padding condenser when the oscillator tracks with a signal circuit in a superheterodyne receiver. The bias on the grid of T_2 is used to limit the plate current of T_2 to a safe value. This bias is not required under some conditions of operation.

In a typical setup using the oscillator section of a 6A8 as tube T_1 and a 6J5-G as tube T_2 in the circuit of Fig. 2, a tuning range of 6.4 to 19.7 megacycles (a ratio of 1:3.08) was obtained. The oscillator amplitude throughout this range was approximately 100 microamperes. The coil used in this test had a Q of about 100. When the same equipment was used in the shunt-feed circuit of Fig. 3, a tuning range from 6.5 to 20.7 megacycles (a ratio of 1:3.18) was obtained. The oscillator grid current became approximately 55 microamperes, because of the comparatively low voltage on the plate of T_2.

No specific tube types are recommended for use with this circuit. Twin-triode types may be used in place of the separate tubes shown in Figs. 2 and 3. High output is obtained from tubes having high transconductance (g_m); however, such tubes usually have high capacitances, which curtail the tuning range. For high output, high g_m in one tube is just as effective as high g_m in the other tube, because of the ring arrangement of the circuit.

The two-terminal feature of this oscillator is an important one for applications which do not require the use of padding condensers. In these applications, the two-terminal oscillator simplifies the switching problem.

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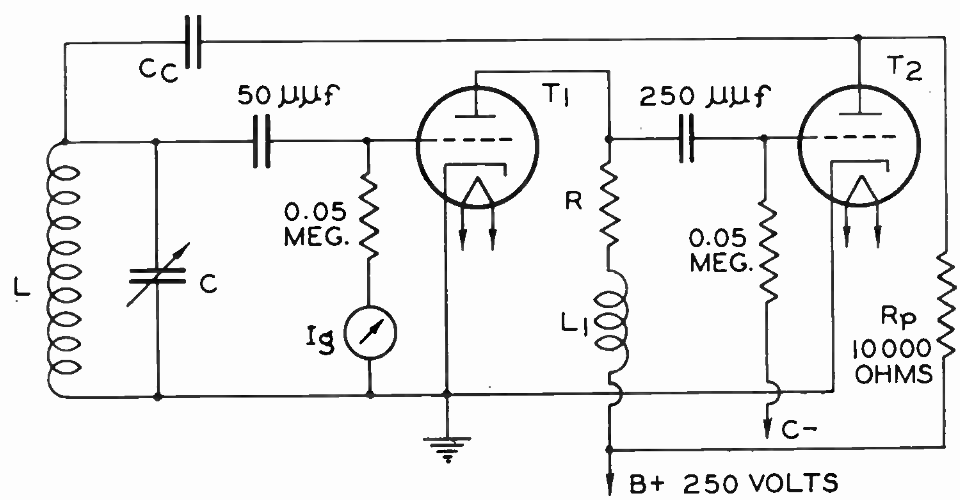


FIG. 3
The minimum capacity normally runs high in Figs. 1 and 2, so a means of increasing the frequency ratio for all bands is provided by this shunt-feld circuit. See text for values of Cc, Cp and Rc in all three diagrams.

6.3-Volt Gas Triode Fits Oscilloscope Work

A new gas-triode was recently announced by RCA Manufacturing Company, Inc. This new tube is designated the 884, available through transmitting-tube distributors.

The 884 is electrically like 885, except for heater rating. The 884 has a 6.3 volt heater which facilitates the use of this tube with other 6.3-volt tubes in the design of sweep-oscillator equipment. It is supplied with a 6-pin, small shell, octal base.

Looking at bottom view of the tube, key toward you, at left of key is pin No. 1, no connection. Going clockwise to No. 2 we find heater, 3 is plate, 4 not present, 5 is grid, 6 not present, 7 heater and 8 cathode.

(TENTATIVE DATA)

Heater Voltage†	6.3	Volts
Heater Current	0.6	Ampere
Direct Interelectrode Capacitances:		
Grid to Plate	3.5	μμf
Grid to Cathode	3.5	μμf
Plate to Cathode	2.5	μμf
Tube Voltage Drop	16 approx.	Volts
Maximum Overall Length	4 1/8"	
Maximum Diameter	1 9/16"	
Bulb	ST-12	
Base	Small Shell Octal 6-Pin	

AS SWEEP-CIRCUIT OSCILLATOR

Plate Voltage (Instantaneous)	300 max.	Volts
Peak Voltage between any two electrodes	350 max.	Volts
Peak Plate Current	300 max.	Milliamperes
Average Plate Current:		
For frequencies below 200 cycles/sec.	3 max.	Milliamperes
For frequencies above 200 cycles/sec.	2 max.	Milliamperes

Grid Resistor—The resistance of the grid resistor should be not less than 1,000 ohms per maximum instantaneous volt applied to the grid. Resistance values in excess of 500,000 ohms may cause circuit instability.

AS GRID-CONTROLLED RECTIFIER

For frequencies below 75 cycles per second

Heater voltage*	6.3	Volts
Peak voltage between any two electrodes	350 max.	Volts
Peak Plate Current	300 max.	Milliamperes
Average Plate current—Averaged over period of not more than 30 seconds	75 max.	Milliamperes

Grid Resistor—The resistance of the grid resistor should be not less than 1,000 ohms per maximum instantaneous volt applied to the grid. Resistance values in excess of 500,000 ohms may cause circuit instability.

*Should be applied for 30 seconds before drawing plate-load current.

†The cathode should preferably be connected directly to the mid-tap of the heater winding. In circuits where the cathode is not connected directly to the heater, the heater may be made negative with respect to the cathode by a potential difference not to exceed 100 volts provided the peak voltage between any electrode and the heater does not exceed 350 volts.

Harmonic

Valuable Crystal

By Wainwr

A TABLE of harmonics and subharmonics, based on fifty fundamental frequencies in the standard broadcast band, was prepared by Frank J. Henry, of Buffalo, N. Y., for checking generator frequencies equal to or lower than the broadcast frequencies, and radio frequencies higher than or equal to the broadcast frequencies.

Where the frequencies are lower than those in the broadcast band they are in columns showing the subharmonic frequency of the broadcast frequency, i.e., as F ÷ n, where F is the broadcast frequency in kilocycles and n is the subharmonic. By multiplying n by the generator frequency that zero beats with the broadcast frequency we obtain the harmonic n of generator frequency f that beats with station frequency F.

Where the frequencies are higher than those in the broadcast band they are represented as nF, where n is the harmonic order, and F is the broadcast frequency in kilocycles.

In each instance the grouping, which is on the following two pages, is separate, low frequencies on the left-hand side of the page, and high frequencies on the right-hand side of the page. This is an extension of some modified tabulations based on frequencies of New York City stations, published several times in these columns in the past few years.

LOW-FREQUENCY CHECKING

In all instances some sort of a detector is necessary. In nearly every instance this will be a receiver. For the low-requency generator checking, or calibration, the receiver is used on the standard broadcast band. That is, a station of known frequency is tuned in, and the generator frequencies will be those that show up in the tabulation, as equalling F ÷ 2, F ÷ 3, etc. This assumes that some general knowledge of the generator frequencies is at

A Comprehensive Tabulation of Harmonics

and Subharmonics of Broadcast Band Frequencies for Generator and Receiver Checking

LOW FREQUENCIES

1/14F	1/13F	1/12F	1/11F	1/10F	1/9F	1/8F	1/7F	1/6F	1/5F	1/4F	1/3F	1/2F	F
39.28	42.3	45.83	50	55	61.1	68.5	78.57	91.66	110	137.5	183.3	275	550
40.71	43.8	47.5	51.81	57	63.33	71.25	81.42	95	114	142.5	190	275	570
42.357	45.385	49.166	53.63	59	65.55	73.75	84.285	98.33	118	147.5	196.66	295	590
42.857	46.153	50	54.54	60	66.66	75	85.71	100	120	150	200	300	600
44.285	47.69	51.66	56.36	62	68.88	77.5	88.571	103.33	124	155	206.66	310	620
45.71	49.230	53.333	58.181	164	71.111	80	91.42	106.66	128	160	213.33	320	640
47.1	50.7	55	60	66	73.33	82.5	94.28	110	132	165	220	330	660
48.57	52.30	56.66	61.81	68	75.55	85	97,142	113.33	136	170	226.66	340	680
50	53.84	58.33	63.63	70	77.77	87.5	100	116.66	140	175	233.33	350	700
50.71	54.61	59.16	64.54	71	78.88	88.7	101.42	118.3	142	177.5	236.6	355	710
51.42	55.38	60	65.45	72	80	90	102.85	120	144	180	240	360	720
52.85	56.92	61.66	67.27	74	82.22	92.5	105.71	123.33	148	185	246.66	370	740
53.57	57.69	62.50	68.18	75	83.33	93.75	107.14	125	150	187.5	250	375	750
54.28	58.46	63.33	69.09	76	84.4	95	108.57	126.6	152	190	255	380	760
55.71	60	65	70.90	78	86.66	97.5	111.42	130	154	195	260	390	780
57.14	61.53	67.66	72.72	80	88.88	100	114.28	133.33	160	200	266.66	400	800
57.85	62.30	67.5	73.63	81	90	101.25	115.7	135	162	202.5	270	405	810
58.57	63.07	68.33	74.54	82	91.11	102.5	117.18	136.66	164	205	273.33	410	820
60	64.61	70	76.36	84	93.33	105	120	140	168	210	280	420	840
61.42	66.15	71.66	78.18	86	95.55	107.5	122.85	143.3	172	215	286.6	430	860
62.85	67.69	73.33	80	88	97.77	110	125.71	146.66	176	220	293.33	440	880
64.28	69.23	75	81.81	90	100	125	128.57	150	180	225	300	450	900
65.71	70.76	76.66	83.63	92	102.22	115	131.42	153,33	184	230	306.66	460	920
67.143	72.308	78.33	85.45	94	104.44	117.5	134.28	156.6	188	235	313.33	470	940
68.57	73.84	80	87.27	96	106.66	120	137.14	160	192	240	320.0	480	960
70	75.38	81.66	89.09	98	108.88	122.5	140	163.33	196	245	328.66	490	980
71.42	76.92	83.33	90.90	100	111.11	125	142.85	166.66	200	250	333.33	500	1000
72.1	77.692	84.167	91.8	101	112.2	126.25	144.28	168.33	202	252.5	536.6	515	1010
72.85	78.46	85	92.72	102	113.33	127.5	145.71	170	204	255	340	510	1020
74.28	80	86.66	94.54	104	115.55	130	148.57	173.33	208	260	346.66	520	1040
75.71	81.53	88.33	96.36	106	117.77	132.5	151.42	173.66	212	265	353.33	530	1060
77.14	83.07	90	98.18	108	120	135	154.28	180	216	270	360	540	1080
78.5	84.6	91.66	100	110	122.2	137.5	157.1	183.3	220	275	366.6	550	1100
80	86.15	93.33	101.818	112	124.44	140	160	186.66	224	280	373.33	560	1120
81.42	87.69	95	103.63	114	126.67	142.5	162.86	190	228	285	380	570	1140
82.14	88.46	95.83	104.54	115	127.77	143.75	164.28	191.66	230	287.5	383.33	575	1150
82.85	89.23	96.66	105.45	116	128.88	145	162.85	193.33	232	290	386.66	580	1160
84.28	90.7	98.3	107.2	118	131.1	147.5	168.5	196.6	236	295	393.3	590	1180
85.71	92.30	100	109.09	120	133.33	150	171.42	200	240	300	400	600	1200
87.142	93.845	101.66	110.90	122	135.55	152.5	174.285	203.33	244	305	407.33	610	1220
88.57	95.384	103.33	112.72	124	137.77	155	177.14	206.66	248	310	413.33	620	1240
89.2	96.1	104.1	113.6	125	138.8	156.2	178.5	208.3	250	312.5	416.6	625	1250
81.142	98.461	106.66	116.36	128	142.22	160	182.857	213.33	256	320	426.66	640	1280
92.85	100.00	108.33	118.18	130	144.44	162.5	185.71	216.66	260	325	433.33	650	1300
93.57	100.76	109.166	119.09	131	145.55	163.75	187.14	218.33	262	327.5	436.66	655	1310
98.57	106.15	115	125.45	138	153.33	172.5	197.12	230	276	345	460	690	1380
100	107.6	116.66	127.27	140	155.55	175	200	233.33	280	350	466.66	700	1400
103.5	111.5	120.8	131.8	145	161.1	181.2	207.1	241.6	290	362.5	483.3	725	1450
105.7	113.84	123.33	135.45	148	164.44	185	211.42	246.66	296	370	493.33	740	1480
107.1	115.3	125	136.3	150	166.6	187.5	214.2	250	300	375	500	750	1500

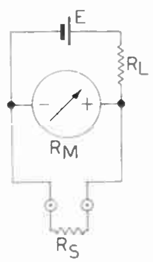
HIGH FREQUENCIES

F	2 F	3 F	4 F	5 F	6 F	7 F	8 F	9 F	10 F	11 F	12 F	13 F	14 F	15 F
550	1100	1650	2200	2750	3300	3850	4400	4950	5500	6050	6600	7150	7700	8250
570	1140	1710	2280	2850	3420	3990	4560	5130	5700	6270	6840	7410	7980	8550
590	1180	1770	2360	2950	3540	4130	4720	5310	5900	6490	7080	7670	8260	8850
600	1200	1800	2400	3000	3600	4200	4800	5400	6000	6600	7200	7800	8400	9000
620	1240	1860	2480	3100	3720	4340	4960	5580	6200	6820	7440	8060	8680	9300
640	1280	1920	2560	3200	3840	4480	5120	5760	6400	7040	7680	8320	8960	9600
660	1320	1980	2640	3300	3960	4620	5280	5940	6600	7260	7920	8580	9240	9900
680	1360	2040	2720	3400	4080	4760	5440	6120	6800	7480	8160	8840	9520	10200
700	1400	2100	2800	3500	4200	4900	5600	6300	7000	7700	8400	9100	9800	10500
710	1420	2130	2840	3550	4260	4970	5680	6390	7100	7810	8520	9230	9940	10650
720	1440	2160	2880	3600	4320	5040	5760	6480	7200	7920	8640	9360	10080	10800
740	1480	2220	2960	3700	4440	5180	5920	6660	7400	8140	8880	9620	10360	11100
750	1500	2250	3000	3750	4500	5250	6000	6750	7500	8250	9000	9750	10500	11250
760	1520	2280	3040	3800	4560	5320	6080	6840	7600	8360	9120	9880	10640	11400
780	1560	2340	3120	3900	4680	5460	6240	7020	7800	8580	9360	10140	10920	11700
800	1600	2400	3200	4000	4800	5600	6400	7200	8000	8800	9600	10400	11200	12000
810	1620	2430	3240	4050	4860	5670	6480	7290	8100	8910	9720	10530	11340	12150
820	1640	2460	3280	4100	4920	5740	6500	7380	8200	9020	9840	10660	11480	12300
840	1680	2520	3360	4200	5040	5880	6720	7560	8400	9240	10080	10920	11760	12600
860	1720	2580	3440	4300	5160	6020	6880	7740	8600	9460	10320	11180	12040	12900
880	1760	2640	3520	4400	5280	6160	7040	7920	8800	9680	10560	11440	12320	13200
900	1800	2700	3600	4500	5400	6300	7200	8100	9000	9900	10800	11700	12600	13500
920	1840	2760	3680	4600	5520	6440	7360	8180	9200	9920	10840	11760	12680	13600
940	1880	2820	3760	4700	5640	6500	7520	8460	9400	10340	11280	12220	13160	14100
960	1920	2880	3840	4800	5760	6720	7680	8640	9600	10560	11520	12480	13440	14400
980	1960	2940	3920	4900	5880	6860	7840	8820	9800	10780	11760	12740	13720	14700
1000	2000	3000	4000	5000	6000	7000	8000	9000	10000	11000	12000	13000	14000	15000
1010	2020	3030	4040	5050	6060	7070	8080	9090	10100	11110	12120	13130	14140	15150
1020	2040	3060	4080	5100	6120	7140	8160	9180	10200	11220	12240	13260	14280	15300
1040	2080	3120	4160	5200	6240	7280	8320	9360	10400	11440	12480	13520	14560	15600
1060	2120	3180	4240	5300	6360	7420	8480	9540	10600	11660	12720	13780	14840	15900
1080	2160	3240	4320	5400	6480	7560	8640	9720	10800	11880	12960	14040	15120	16200
1100	2200	3300	4400	5500	6600	7700	8800	9900	11000	12100	13200	14300	15400	16500
1120	2240	3360	4480	5600	6720	7840	8960	10080	11200	12320	13440	14560	15680	16800
1140	2280	3420	4560	5700	6840	7980	9120	10260	11400	12540	13680	14820	15960	17100
1150	2300	3450	4600	5750	6900	8050	9200	10350	11500	12650	13800	14950	16100	17250
1160	2320	3480	4640	5800	6960	8120	9280	10440	11600	12760	13920	15080	16240	17400
1180	2360	3540	4720	5900	7080	8240	9440	10620	11800	12980	14160	15340	16520	17700
1200	2400	3600	4800	6000	7200	8400	9600	10800	12000	13200	14400	15600	16800	18000
1220	2440	3660	4880	6100	7320	8540	9760	10980	12200	13420	14640	15860	17080	18300
1240	2480	3720	4960	6200	7440	8680	9920	11160	12400	13640	14880	16120	17360	18600
1250	2500	3750	5000	6250	7500	8750	10000	11250	12500	13750	15000	16250	17500	18750
1280	2560	3840	5120	6400	7680	8960	10240	11520	12800	14080	15360	16640	17920	19200
1300	2600	3900	5200	6500	7800	9100	10400	11750	13000	14300	15600	16900	18200	19500
1310	2620	3930	5240	6550	7860	9170	10480	11790	13100	14410	15720	17030	18340	19650
1380	2760	4140	5520	6900	8280	9660	11040	12420	13800	15180	16560	17940	19320	20700
1400	2800	4200	5600	7000	8400	9800	11200	12600	14000	15400	16800	18200	19600	21000
1450	2900	4350	5800	7250	8700	10150	11600	13050	14500	15950	17400	18850	20300	21750
1480	2960	4440	5920	7400	8880	10360	11840	13320	14800	16280	17760	19240	20720	22200
1500	3000	4500	6000	7500	9000	10500	12000	13500	15000	16500	18000	19500	21000	22500

MEASUREMENT DIFFICULTIES SOLVED *for Resistance and A-C Volts*

By H. J. Bernard

SERVICE work requires a handy knowledge of the extension of use of meters, as by increasing ranges, and also the electrical rules affecting such extension. One reason is that, besides the commercially-made instrument that may be used for analyzing, auxiliary equipment comes in handy, some of it has to be constructed for a particular job, and the device is retained



$$R_M = R_S\left[(I_M \div I_0) - 1\right]$$

$$R_S = \frac{R_M}{(I_M \div I_0) - 1}$$

$$N = \frac{R_M}{R_S} + 1$$

$$I_0 = \frac{I_M}{(R_M \div R_S) + 1} = \frac{I_M}{N}$$

FIG. 1

With this circuit the meter resistance R_m may be measured with the aid of a known resistor R_s, or the value of an unknown shunt, R_s, may be determined in terms of the known meter resistance and a current indication, also the extent n to which R_s multiplies the range of the meter, also the current reading that obtains when both R_s and R_m are known.

for its occasional but nevertheless ratable usefulness. Besides, how can one expect to go far in technical attainment without an appreciation of factors that are, after all, basic?

The exposition comes very close to being nothing more than a discussion of Ohm's law. For direct currents and voltages this is true in a very simple way. For alternating-current considerations more factors enter, but they are not beyond ready comprehension.

CURRENT IS THE BASIS

First will be considered the methods of extending the use of a d-c meter, primarily a device for measuring currents, as are all meters we commonly use. There is no essential difference therefore between a current meter and a voltmeter. Both depend on the change of current through the instrument causing a change in needle deflection. In the example of the current-reading meter the calibration is in terms of currents, while the voltmeter represents the case of the current considered in terms of a limiting resistor through which it is passing. Therefore the voltage calibration is the current calibration multiplied by the limiting resistance, since volts equal current times resistance. Does not Ohm's law state that $E = I \times R$, where E is in volts, I is in amperes and R is in ohms?

After we have considered the d-c instruments we shall include the a-c instruments of the rectifier type, which consist of circuits that cause the meter to read the resultant direct current after half-wave or full-wave rectification of the alternating current.

In Fig. 1 we have a simple circuit consisting of a meter that is supposed to be reading full-scale deflection, because a limiting resistor R_L of the right value is inserted in series with a voltage source E. The total resistance in the circuit is equal to the sum of the meter, voltage source (cell) and limiting resistances. This, too, is computable as $R = E \div I$, where again R is in ohms, E in volts and I in amperes.

For most purposes the resistance of both the meter and the voltage source may be neglected, for determining R_L because they are small compared to R_L, assuming that the cell is not near the end of its useful life, and the meter resistance is not substantial. The one milliampere instrument will be given most consideration, because it represents a sensitivity regarded as minimum, and there is a strong trend nowadays to use of meters much more sensitive than that.

HOW CIRCUIT IS COMPLETED

We are not presently concerned with R_L, since it may represent the setting of a 2,000-ohm rheostat, first cautiously put at full resistance before inclusion in the circuit, and then, with 1.5 volts for E, adjusted until there is full-scale deflection. For a 0-1 milliammeter the actual resistance of R_L will be nearly, but not quite, 1,500 ohms, the difference being due to the cumulative resistances of cell and meter itself. Note carefully that the meter itself is in series with the limiting resistance, and the meter has its own resistance due to the resistance of the coil that makes it work. The binding posts are shorted with a wire, or test leads touched, to complete the circuit.

Suppose our first problem is to measure the

Tabulation

Frequency Service

ight Foster

hand. Such would be true, for instance, if one were checking a generator of the commercial type, where the frequencies appear on a direct-reading dial, or at least are obtainable by comparison of dial readings with a curve. Some few generators produce selected frequencies only, and not a continuous variation of frequencies, and as to these the checking would be done the same way, by reference to the table.

If one desires to calibrate his own generator, this may be done by several different approaches. The easiest is to have a known coil that covers the standard broadcast band, and establish the known frequencies by comparison with stations of those frequencies tuned in on the receiver. The generator is loosely coupled to the antenna post of the set, and is adjusted until the beat between the two, the station wave and the generator wave, is zero, or as nearly zero as practical. This may be done by ear, but true zero beat can not be established by ear, except as rare accident; however it isn't necessary. The nearest aural approach to zero suffices.

FREQUENCY RELATIONSHIPS

The whole idea behind the generator checking or calibration is that the generator's frequencies are equal to or lower than the station frequencies, and while the station frequencies are known, the denominator is not known for them, i.e., which harmonic of the generator is influencing the detector. So it was proposed that a coil and condenser of known electrical dimensions be used for the broadcast band, whereupon coils with about one-quarter as many turns will take care of the next band, going to higher frequencies, or on the next lower frequency band, or, four times as many secondary turns for the next lower band.

If sets of coils intended to be used with a particular tuning condenser, such as .00035 mfd., are at hand, for they are commercially obtainable, the approximate frequencies are known for the bands other than the broadcast band which one calibrates anyway. The bands multiply or divide the broadcast frequencies by 3, 9 and 27.

The common harmonic method is a particularly guiding one for those who are "lost" in attempting to identify frequencies. Suppose that responses are heard when generator produces frequencies known to be lower than broadcast frequencies because several responses are heard as one turns the broadcast set over half the dial span. Pick out two stations of known frequency that are receivable, and which have a common subharmonic.

EXAMPLE CITED

The best way to drive home this idea is to cite an example. We are consulting the table at left on next page, marked Low Frequencies. Suppose the frequency of a broadcast station one tunes in is known to be 720 kc. A subharmonic, the eighth ($F \div 8$) equals 90 kc. Now what we are seeking are, (1) another station another subharmonic of which is also 90 kc, and (2) ability to tune in that other station and equal certainty as to its frequency. In large centers of population, where stations are numerous, the common harmonics of locals are sufficiently plentiful for the purpose. In other places, with a very sensitive receiver, the same advantage obtains.

At $F = 1080$ kc we find that, by carrying the eye to the left, we strike 90 kc as the 12th subharmonic ($F \div 12$). Or we look for the 90 and find 1080 at right for F. So if we are in doubt as to whether a particular generator frequency is 90 or something else, we can see whether we get the same beat with 920 kc as we get with 1080 kc, and if so, the unknown is 90 kc, assuming that errors of 100 per cent. are eliminated. That is, the unknown may be 45 kc. But that can be checked, because if the unknown is 90, then starting at 720 kc on the receiver dial, generator zero beating, or nearly so, and left unmolested, as we tune the receiver we obtain at frequencies increasing by 90, or $720 + 90 = 810$ kc, $810 + 90 = 890$ kc, and, again, $810 + 90 = 1080$ kc. We have thus verified the unknown in two directions.

For high frequencies, the generator is at a broadcast frequency, one of the fifty frequencies represented, and the receiver is checked as to its approximately known frequencies, by comparison with the generator beats. The generator need not be molested after a particular known frequency is selected. To calibrate an unknown set, use broadcast frequencies that cause consecutive responses, when $F_x = F_2F_1 \div (F_2 - F_1)$, where Fx is the unknown, F_2 and F_1 the broadcast band frequencies.

It will be noted that the broadcast station frequencies are printed twice, side by side, one set to be read to the left, for low frequency generator work, the other to the right, for high-frequency comparisons (short waves). There are enough frequencies to calibrate a receiver or a generator for all useful bands.

If there are any local stations one wants to use for similar work, and their frequencies and harmonics and subharmonics do not appear in the table, prepare the local station table yourself. Simply divide the station frequencies by numbers from 2 to 14 inclusive, and multiply the same station frequencies by numbers from 2 to 15 inclusive, for the tabulation on the following pages goes to the fourteenth subharmonic and the fifteenth harmonic.

resistance of this coil in the meter. To do this two quantities must be known. Let them be (1) a known resistance R_s in shunt with the meter and (2) the current. It so happens that to find the result conveniently we take two current values,- one of them, however, being full-scale current (say, 1 milliampere), and the other the current to which the first is reduced when we put the known shunt R_s across the meter itself. Naturally the current through the meter will decrease, because the total current flowing is unchanged, or is assumed to remain constant, and now part of it goes through the known shunt, so less passes through the meter.

The assumption that the total drain from the cell, or total circuit current, remains unchanged, is not quite true, because the mere shunting has reduced the series resistance previously mentioned. Now instead of full meter resistance being a part of that total circuit resistance, less than the full meter resistance is present. But if the meter is of low resistance, compared to the limiting resistor R_L, no particular account need be paid to the series resistance effect of the shunt.

STILL GREATER ACCURACY

If for any reason of increased accuracy, with no increased computation, it is practical to use considerably more voltage than 1.5 volts, say, 22.5 volts, and limiting resistance accordingly, say, 20,000 ohms, with a 5,000 ohm rheostat in series, and then adjust for full scale, the change in series resistance due to the meter shunting is entirely negligible. There is now the same absolute change, compared in a total of 22,500 ohms as there was to a total of 1,500 ohms.

The meter resistance is R_m, the shunt resistor is R_s, the full-scale deflection current of the meter is I_m and the observation current (reading taken when R_s is in circuit as shown in Fig. 1), is I_o. We desire to ascertain R_m, the meter resistance. This we do by multiplying the known shunt resistance, R_s, by the factor that caused the reduced reading, and discounting the effect of the meter resistance we are endeavoring to measure. So we have

$$R_m = R_s \left[(I_m \div I_o) - 1 \right] \ldots\ldots (1)$$

The manufacturer of the meter, in his catalogues and elsewhere, discloses the meter resistance, or will supply the information on request, and so one may check on the measurement. The agreement should be fairly close, usually 5 per cent. for high-grade instruments.

We selected two knowns as R_s and the current considerations, but if we do not possess an accurately known resistance we may use a slightly different approach, which, however, requires that we measure a resistor. If a rheostat is placed across the meter when Fig 1 is a closed circuit for full-scale deflection, i.e., R_s is unknown and adjustable, if we turn the knob until the meter reads half scale, then as much current passes through the shunt as through the meter, so the shunt resistance equals the meter resistance. Now we may remove the shunt and measure its resistance on an ohmmeter, or calculate it as will appear, a handy method because we can not subject the meter resistance to ohmmeter measurement with convenience and safety, but can measure the shunt.

$$R_m = R_s \text{ when } I_o = I_m \div 2$$

LOW RESISTANCE MEASUREMENT

Since the meter resistance is information normally at hand, perhaps what we would be much more likely to investigate is the resistance of some unknown external resistor, always bearing in mind that since we are shunting the meter we shall not be able to measure high resistances. For a meter of 30 ohms perhaps 100 ohms would be considered enough for maximum, and for a 50-ohm meter 200 ohms maximum for unknown, or for a 100-ohm meter, maximum unknown resistance of 500 ohms, because of crowding, hence difficulty of good measurement of higher values of unknown.

We can measure the unknown shunt R_s, from knowledge of the meter resistance R_m, current sensitivity of the meter, I_m, and observation reading I_o.

$$R_s = \frac{R_m}{(I_m \div I_o) - 1} \ldots\ldots\ldots\ldots (2)$$

Since in any of these instances the known or unknown shunt resistance will be low, it may be so low that the resistance of the test leads has to be considered. For instance, if a computation is attempted, using test leads of one ohm total resistance (sum of the resistances of the two leads), and we desire to measure an unknown resistor that turns out to be apparently three ohms, we have failed to allow for the one ohm of the leads that contributed an error of 33⅓ per cent. One way around this is to measure the resistance of the test leads, by interconnecting them at two ends, and using the free ends for connection directly across the meter, or binding posts close to the meter. Then from any computation this constant error is deducted, or error eliminated, and for any calibration of the meter scale, or developing a curve, allowance would be made for the test leads' effect.

The effect of the shunt as a multiplier of current is also of interest. In any d-c current meter when we desire to increase the range, i. e., decrease the sensitivity, we put a resistance across the meter to accomplish this. Then, though current through the meter is still never supposed to exceed maximum rating, say, one milliampere, the excess goes through the shunt. What is the new range of the shunted instrument? How many times has the original sensitivity been multiplied?

THE MULTIPLICATION FACTOR

Using n for the number of times, or multiplication factor, with the same symbols as before, R_m for meter resistance, R_s for shunt resistance, we find

$$n = \frac{R_m}{R_s} + 1 \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

We have considered ascertaining the meter resistance, also the resistance of a shunt, and

(Continued on following page)

(Continued from preceding page)

now shall treat the observation current as the unknown.

Using the same symbols as before, we have

$$I_o = \frac{I_m}{(R_m R_s) + 1} = \frac{I_m}{n} \quad ......(4)$$

This formula comes in handy when one wants to adjust a rheostat or an intended fixed shunt

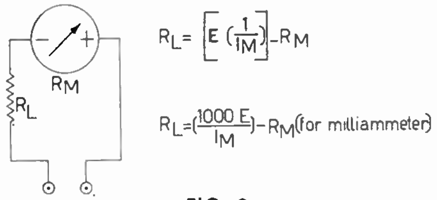


FIG. 2

How to determine the required value of limiting resistor for a meter of known full-scale deflection current, for a given full-scale deflection voltage E.

to a particular resistance value, and therefore watches the meter deflection until the needle reads just what it should. The unknown is therefore really the current, as the resistance in a sense is known, because we know what it should be, and therefore we ascertain the point of current reading at which to stop to adjust to that particular resistance.

Thus we have taken care of measurement of low resistances and of current extension, all by shunting. There is another type shunt, known as a ring shunt, where instead of individual shunts for separate ranges, there is one tapped shunt, and the unknown current is measured by connection to the separate taps. However, though that method serves certain convenient purposes, it is not so suitable for resistance measurement by shunting, as the needle does not return to zero for any save the highest sensitivity range, and besides, the meter can not be used as at its maximum sensitivity, because it is permanently shunted. Also, the ring shunt calculation is not so simple, but any reader interested in the formula may obtain it by writing to the author.

VOLTAGE MEASUREMENT

Now we proceed to the measurement of voltage. We remember that again we are dealing with current, but now that current is passing through a limiting resistor, accurately chosen so that for full-scale current a definite voltage has to be applied, and the meter is calibrated in terms of that full-scale voltage and the lower voltages, which are proportional to the current. For instance, at half maximum current reading (midscale) the voltage is half that of full-scale.

We desire to ascertain what value of limiting resistor R_L is required for a meter of known sensitivity (known full-scale deflection current I_m) and of known internal resistance R_m. Ordinarily the resistance of the meter is small compared to R_L, for high-grade instruments of 0.5 milliampere sensitivity or less. In the following formula E equals the full-scale deflection voltage desired:

$$R_L = (E \frac{1}{I_m}) - R_m \quad .... \quad (5)$$

The numerator is the number one and not the letter eye. See Fig. 2. Assuming that we are

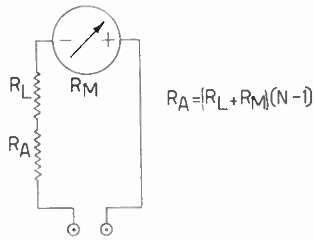


FIG. 3

If, instead of the meter alone, the meter with an existing multiplier, or limiting resistor, has to be considered, then the additional amount of resistance, R_a, may be determined, where n is the number of times the present full-scale deflection voltage is to be multiplied.

dealing with only milliammeters, we may write the formula as

$$R_L = (\frac{1{,}000\,E}{I_m}) - R_m$$

Often the value of additional resistance required for increasing the voltage range is desired, since the voltmeter already covers one range, or more, and the resistance of the "meter" is known. In this sense the built-in limiting resistor that establishes the range that exists is included as resistance of the "meter." So R_L is known, being an internal multiplier, and we treat as the unknown the additional multiplier R_a in Fig 3, whereupon

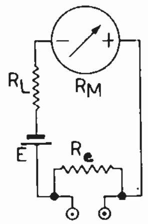
$$R_a = (R_L + R_m)\ (n - 1) \quad ......(6)$$

We therefore have taken into account current and voltage multipliers, also resistors determined by shunting, but not resistors determined by series connection. If, instead of having a series circuit closed, using voltage supply E, limiting resistor L for full-scale deflection, we establish full scale, then have the circuit open, any additional resistance, through which the circuit is closed, and which resistance is the unknown, may be determined. This is the standard omhmeter.

With R_e as the unknown resistor, Fig. 4, the other symbols as before,

$$R_e = \frac{E}{I_o} - (R_L + R_m) \quad ...... \quad (7)$$

The resistance of the cell or battery E has been neglected, as inconsequential, also the meter resistance, as the unknowns to be measured will not be in the very low ohmage range. We have the shunting method for closer readings in those regions, and in fact enablement of much lower resistance measurements than by the normal ohmmeter method, where a sensitive instrument is used. Of course, as the sensitivity of the meter is made less and less, and more current is required for full scale, the voltage supply constant, the limiting resistor becomes proportionately less, and smaller unknowns have a greater influence on the readings, so that finally



$$R_e = \left(\frac{E}{I_0}\right) - (R_L + R_M)$$

$$I_0 = \frac{E}{R_e + R_L + R_M}$$

FIG. 4

The ohmmeter formula is given for unknown external resistor, R_e, which is shown in circuit. The larger R_e, the less the current deflection on the meter R_m. When the external resistor R_e is known, the current indication is obtainable from the second formula from top.

one way yields not much lower resistance reading possibilities than the other, but the shunting methods avoids changing the meter sensitivity, hence makes for simplicity, and besides is satisfactory.

What the current or observation reading will be for any given resistor may be determined in advance:

$$I_o = \frac{E}{R_e + R_L + R_m} \quad \ldots\ldots\ldots\ldots\ldots (8)$$

Thus for d. c. we have given attention to resistance, voltage and current, and we turn to some of the problems relating to a. c.

INSTRUMENT RECTIFIERS

The instrument rectifiers are half-wave or full-wave. If half-wave, they function only during one alternation, or half, of the a-c cycle. If full-wave they function on both alternations. When full-wave rectification is used there is purer d.c., or, less of the a.c. flows through the meter. It is understood that, since the meter is a d-c-measuring device, of the moving-coil type, a.c. will move the needle as much one way as the other, hence there will be no reading for a.c. alone, although considerable a.c. may pass through the meter.

A second classification refers to the type of rectifier. The oxide-copper oxide type rectifier is commonly used, and operates on the principle that dissimilar metals in contact pass much more current in one direction than in the other, therefore rectify. As no heating is at stake, these may be classified as non-thermionic, to distinguish them from the vacuum-tube rectifier, which depends on heat producing an electron source, and which therefore is thermionic.

An alternating current wave is quite different from a d-c potential source. One fact that must be borne in my mind is that in a.c. the current and voltage are ever changing, rising from zero to maximum positive, declining to zero, then descending from zero to maximum negative, and returning to zero. The first half of the wave journey, the ascension from the zero axis and declination to zero, is called the positive alternation and the second, below the axis, the negative alternation. It is assumed that the wave has a sine shape, i.e., there is no harmonic or amplitude distortion.

THE CAUSATION OF RECTIFIERS

A third distinction applying to rectifiers concerns the effect of the a-c wave that influences the rectifier. In Fig. 5, left, we have a copper-oxide rectifier R_r in series with the electromagnetic meter R_m, and a load resistor R_L, and the circuit is completed through the unknown. Therefore since any rectifier must have a continuous path through which the d.c. may flow, this type depends on d-c continuity in the unknown. Actually such continuity may be absent, as where a stopping condenser is at plate of a receiver detector or amplifier tube, and the measurement is attempted between free side of the condenser (terminal other than one going to plate) and ground. Practically no reading obtains. However, this is rather an unusual case, since normally a-c measurements are made in service practice of circuits that have d-c continuity.

Yet one serious factor enters, that the d-c

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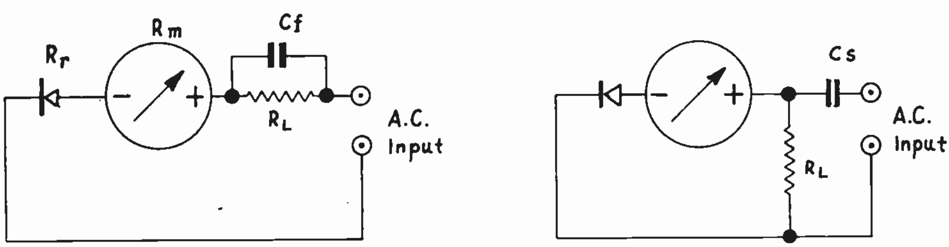

FIG. 5

Two methods of measuring unknown a-c input in terms of the rectified current flowing through the meter. Non-thermionic rectifiers are shown. R_L is the load resistor, R_r the rectifier. At left, the response is according to the average of the a-c input voltage, which is .91 of the deflection that would prevail if d.c. were applied, so filter condenser C_f is included, to bring the reading up. At right, the condenser-diode type rectifier measures the peak of the a-c wave. Stopping condenser C_s must be very large, for wide coverage of frequencies.

(*Continued from preceding page*)
resistance in the unknown circuit must be low, compared to R_L, because both are in series, and the external circuit then adds to the multiplier resistance, or limiting resistance, and affects the accuracy of the reading in inverse proportion to the ratio of the d-c resistance of the external circuit and of R_L.

As to the influence that actuates the rectifier, in the type of circuit at left in Fig. 5, where the load resistance is in series with the unknown, the *average* of the a-c wave is read on the d-c meter. This is even less than the d-c current that would be read if d-c were applied, with positive toward meter plus. The d.c. is 1.1 times the average a.c., or the average a.c. is .91 of the d-c value. It is therefore necessary to provide some compensation, so that the d-c meter will read higher, when a-a.c. is being measured to attain readings that reflect the root-mean-square or the peak values, the only ones of interest.

TWO SOLUTIONS

One solution is to have a different set of load resistors for a.c. than for d.c., but the tendency is to economize on load resistors, making the same ones serve both purposes. In that event a condenser may be put across the load resistor, so that the d-c meter will read up to the required amount. Nearly always the r-m-s values are desired and if there is no specification of type, r-m-s is implied. If it is desired to have the value of the root-mean-square a-c voltage reflected in the reading, the condenser C_f is chosen accordingly, or may be made still larger, and the peak a-c voltage would be reflected.

It is therefore obvious that a rectifier responds to some particular factor of the component of the a-c wave, and yet may be made to read in terms of some other component. The effects may be controlled so that they produce readings as if the causes were the same.

At right in Fig. 5 is shown the basic idea of the condenser-diode rectifier. This is acted upon by the *peak* of the positive alternation, since the rectifier will not function when the plate is negative. During the positive alternation the condenser C_s is charged to the peak voltage, and discharges through the load resistor R_L.

THE CURRENT DRAIN

During the peak, an instantaneous duration, there is d.c. flowing, and because of the inertia of the circuit, or time constant, the d.c. continues to flow until the wave reaches zero. Since there was rectification during the peak, the d-c bias developed, about equal to the peak, and with positive d.c. at cathode and negative at plate, is series-opposing the a.c. So no current flows except during the peak, and of course none flows during the negative alternation. Therefore the condenser-diode type rectifier draws current from the unknown only during the peak, and is an infinite impedance during all the rest of the cycle (both alternations).

The loading effect is therefore at a minimum in point of time. However, the current drawn during the peak may be considerable, yet the drain is of such limited duration that the accuracy of the measurement is not upset.

A point is favor of this type of rectifier is that the d-c path is continuous regardless of the circumstances attending the unknown.

REACTANCE OF CIRCUIT

A fourth basis of comparison between rectifiers applies to reactance. We found that a condenser across load resistor R_L, Fig. 5, left, raised the d.c. flowing through the electromagnetic meter R_m. It did this because R_L no longer was permitted to obstruct the a-c current in the circuit on the basis of only the resistance of R_L, but the condenser permitted some a-c current to detour the resistor, thus bypassing R_L, to an extent proportionate to the capacity of C_f, assuming R_L and frequency constant. So the voltage drop across the parallel circuit R_L, C_f, was made smaller, hence the a-c voltage applied to the rectifier was made higher, and by selecting the right proportion, really capacity of C_f in practice, the meter R_m could be made to read in terms of peak or r.m.s.

By peak value of the wave we mean the voltage (or current) value obtaining at the crest of the wave, the highest voltage of the succession of smoothly changing voltages that a-c develops. It must be borne in mind that a-c voltage is changing, even though statement of the absolute value of the voltage tends to suggest constancy, but we know that constancy refers to a particular point on the slope, i.e., peak or r.m.s.

By r.m.s. we mean that the heating effect of the a-c voltage is exactly the same as the heating effect of a d-c voltage equal to the r.m.s. By measuring the heat generated by a resistor when a certain d-c voltage is applied, and then taking off so much of a-c voltage that the same heating effect is duplicated, we find by a-c measurements that the a-c voltage producing equal heat to d.c. is .707 of the peak. Also we find that the value of this equal-heating-effect a-c voltage is the square root of the sum of the squares of a large number of voltage measurements made along the wave during one cycle, and therefore the known proportion arises. Since the r.m.s. is equal to .707 of the peak and the peak is equal $1 \div .707 = 1.414$ times the r.m.s.

COMPARISONS WITH D.C.

Now we may relate the a-c values more extensively to d.c. We found the heating effect of d.c. equal to the r.m.s of a.c. Also we found that the average, or sum of numerous readings of the changing voltage, divided by the number of readings taken, which the series-load rectifier responded to, was less, or .91 of the r.m.s. Therefore the d.c. is larger than the average, and to bring the average up to r.m.s. multiply by 1.11. Since the peak is 1.41 times the r.m.s., to bring the average up to peak values multiply by $1.11 \times 1.41 = 1.551$. To reduce peaks to d-c values multiply by $1 \div 1.551 = .645$.

That is the situation in regard to an *average* rectifier. Considering, however, a *peak* rectifier.

Since this responds to peaks, the proper load resistor for a given voltage range will give results in peak values, whereas for r.m.s. values the load resistor would be 1.41 times that used when peak volts were to be reflected, because higher resistance reduces the current, and we want to make the meter needle read lower by a definite amount.

Reverting to the average rectifier, and considering the load resistors, these would have to be less than the values computed for d.c., and for reflection of peak volts the peak load resistor would be multiplied by $.91 \times .707 = .64337$.

REACTIVE EFFECTS

These are the circumstances for selection of load resistors, but we have mentioned the fact that the same resistors are often used, and means provided for making such service possible.

Mention was made of the fact that reactance has to be considered. By reactance we mean that the same voltage of different frequencies causes different readings, or the device does not respond uniformly to all frequencies. When we use a condenser across a resistor to reduce the impedance of the load, we introduce capacity, which is sensitive to frequency. That sensitivity is known as capacity reactance, and for a particular frequency, and particular capacity, may be treated as a resistance, for it offers opposition to current flow just the same as does a resistance of equal value. The formula for capacity reactance is $X_c = 1 \div (2\pi fC)$, or using ω, the Greek letter omega, to represent $2\pi f$, we write $X_c = 1 \div (\omega C)$. The capacity reactance therefore is inversely proportionate to frequency, or, the higher the frequency the lower the reactance, and vice versa. Therefore the selection of C_f in the average rectifier is absolutely accurate for only one frequency, for the circuit has become reactive.

The impedance of an a-c circuit is the sum of all the effects that tend to reduce or increase the current flow. Principally reactance and resistance comprise the impedance. So far as practical it is desired to have the sensitivity to frequency as small as possible, that is, the circuit is to have minimum reactance.

Even the non-thermionic rectifiers themselves have some reactance, but frequencies to several thousand cycles may be measured with slight change in current reading, when voltage is held constant, and frequency alone is changed. The compensating condenser we know has reactance. However, if the load resistance R_L is large compared to the capacity reactance in ohms, of C_f, the reactance effect is reduced. Since a low-voltage range is what requires a low value limiting resistor, the rectifier type a-c meters usually have ranges no lower than 5 volts maximum.

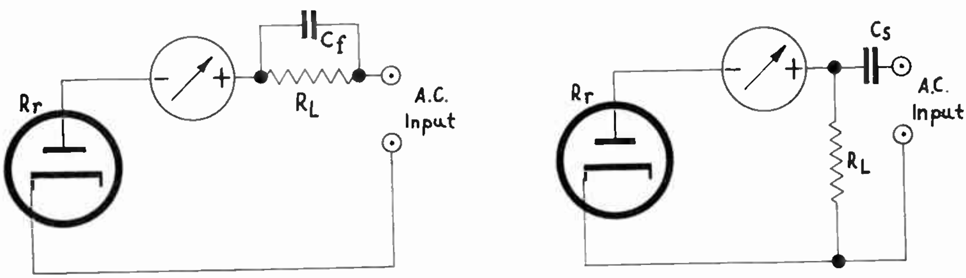

FIG. 6

The "average" rectifier, at left, and the "peak" rectifier at right, substituting vacuum tubes for the non-thermionic rectifiers.

THE LOAD RESISTOR AND C_s

It must not be assumed that the peak type voltmeter is in any way free of the reactance effect. Mere inspection of Fig. 6, right, shows that there is a stopping condenser, C_s. So for a low-voltage range, say 5 volts, for d.c. R_L, using a 0-1 milliammeter, would be 5,000 ohms, but when a.c. is used, 5,000 ohms would be very much too large, because the a-c voltage appears across a series circuit consisting of C_s and R_L. If C_s is 1 mfd., then the capacity reactance at 60 cycles is 2,650 ohms, and R_L would have to be reduced by that amount, becoming $5{,}000 - 2{,}650 = 2{,}350$ ohms for peak readings. Hence the ideal capacity for C_s is infinite. No finite capacity will satisfy all theoretical requirements.

If we have recourse to some percentage accuracy, say, 2%, we may say that for a 5-volt range, using the same load resistor, C_s may be made so large that its capacity reactance is 2% of 5,000 ohms, or 100 ohms. The capacity that has 100 ohms reactance at 60 cycles is 21.5 mfd. The condenser must have an excellent power factor, i.e., the leakage across the condenser must be small, for the greater the leakage the more the circuit tends to behave as an average instead of as a peak rectifier. Any condenser that is chosen for numerous ranges should be of such rating as to withstand the highest voltage of the highest range, because the condenser has to be charged to the full peak voltage, therefore withstands that voltage, before it discharges through the resistor.

So far we have not considered the rectifier as having any resistance, although of course it has some, and it may be considerable. Copper

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oxide rectifiers may have around 5,000 ohms. But it must not be assumed a tube has no resistance, either. Tubes used in instrument rectifiers may have around 2,000 ohms resistance (full-scale deflection of meter).

BRIDGE CIRCUITS

As the voltage ranges increase, the reactive effect of the condensers in either type rectifier, resistance, for zero deflection on meter R_m, then R_t would then equal R_r in both instances, or all four are equal.

At right, Fig. 6, this equality is established by using four rectifiers R_r. The limiting resistance is R_n, in Fig. 6.

The same considerations that apply to non-thermionic rectifiers apply to vacuum tubes, except that the tubes are nonreactive. In Fig. 7 is shown a good position to locate the electro-

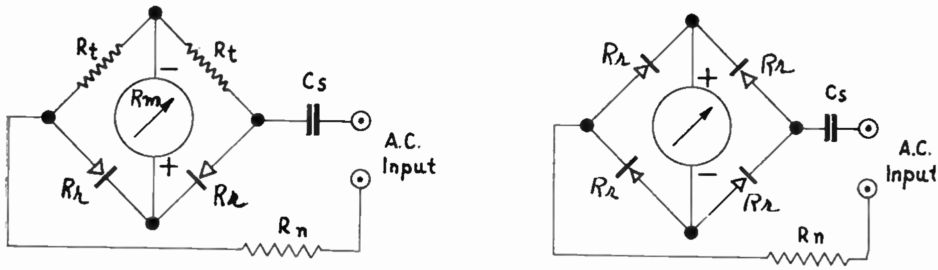

FIG 7

A bridge type rectifier, where two resistors have the same ratio to each other as have the rectifiers R_r to each other, so usually R_t and R_t are equal, and R_r and R_r are equal, but R_r and R_t are not necessarily equal, though they may be. Full-wave rectification obtains. At right the four arms consist of rectifiers.

and the resistance of the rectifier, become of less and less importance, because such a greater percentage of the total drop takes place across the load resistor.

To avoid severe limitation on the lowest voltage range the rectifier is itself sometimes shunted with a resistor, where non-thermionic elements are used, or a bridge circuit is arranged, using full-wave instead of half-wave rectification, with R_r the rectifier, and R_t their respective ratio resistors. The ratio of R_t to R_r on either side, Fig. 6, left, is the same, and since the rectifiers are deemed to be of equal magnetic meter. The average rectifier is at left, the peak rectifier at right. R_L is the load resistor, C_f the filter condenser, and C_s the stopping condenser.

Fig. 8 applies the bridge circuits for full-wave rectification, using two tubes (left) or four tubes (right). The limiting resistor is omitted at left, but included at right as R_n.

DATA ON SWITCHING

The average type rectifier has some points to commend it, principally simplicity of switching. This is shown in Fig. 9, left, where two

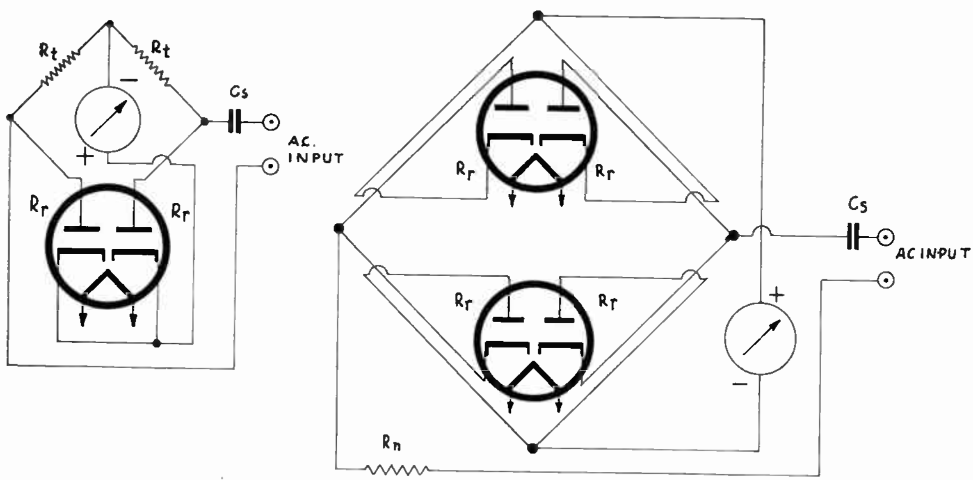

FIG. 8

The bridge type rectifier, at left, using two vacuum tubes, which may be in the same envelope (6H6), and, at right, using four tubes.

passing is coded Cr in previous diagrams. The ac-dc switch, lower center of left-hand diagram, connects to meter minus (Mm) for d.c. and to cathode (k) for a.c. At right, When this d-c voltage, necessary to establish zero potential for the grid, is measured, it is found to be usually around three-quarters of a volt. Therefore we may say that we start

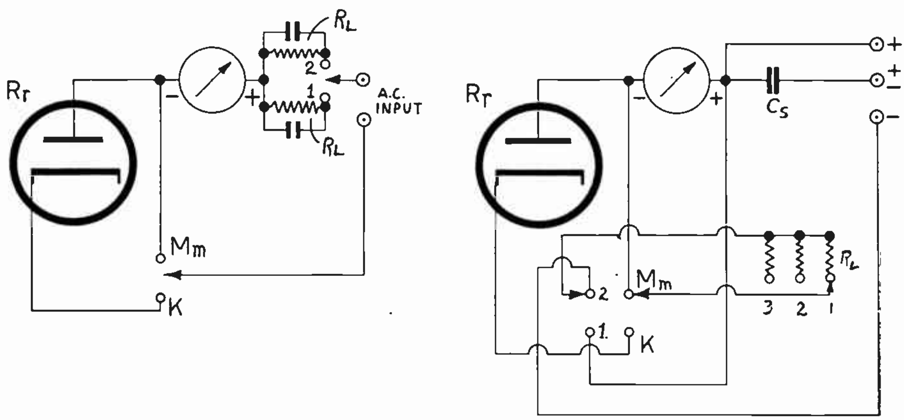

FIG. 9

Switching arrangements. The simplest applies to the "average" rectifier, at left. Two load resistors are shown, both marked R_L. The upper a-c input post picks up position 1 for one range and position 2 for the other range. More ranges may be provided. At right, the "peak" rectifier, requiring also an extra post ( ). Again, C_s must be large. M_m signifies m position of a-c-ac-d-c sw'tch for meter minus (d.c.) and k cathode (a.c.).

voltage ranges are disclosed, numbered 1 and 2. Note that, for use of the same multiplier or load resistors, different condensers are required, one across each resistor. This by-Fig. 9 the different load resistors are selected by R1, numbers 1, 2 and 3 for three ranges, while the ac-dc switch is made two circuit, two position, so that on a-c measurements a condenser-diode rectifier obtains, by picking up positive side of the meter for common end of the chain of load resistors, and selecting the resistors separately for connection to cathode for each range. So position Mm2 is for d.c. and K1 is for a.c.

We have other problems connected with rectifiers. One of them, applicable largely to tubes, is that we should have no current flowing when there is no a-c input to the unknown posts intended for the unknown. Actually there may be d.c. flowing, due to the initial velocity of the electrons. Let us consider this situation on the basis of voltage.

THE ZERO CURRENT START

It is well known that many tubes of the cathode type do produce a current flow at no input, provided d-c continuity exists, which means that in amplifier or detector circuits in which these tubes are present there is a small positive bias on the grid, assuming grid returned to cathode, yet tube hooked up as if for zero bias. Where this trouble exists, the grid, now positive, is made zero by the expedient of introducing a d-c biasing voltage, which is adjusted until the grid is actually zero. An infinite impedance voltmeter across the grid-cathode circuit will enable the measurement.

with a steady handicap of three-quarters volt, and if we had some device with just that voltage, we could insert the device in the circuit, with negative to grid and know we always start from true zero.

Reverting now to a consideration of rectifiers, by which we mean current-drawing devices, we find that for the same reason the same three-quarters volt appears, and so if we inserted the d-c bucking voltage, with negative toward plate and positive to cathode, we would again have a zero current deflection on the simple average or peak a-c voltmeter.

But we can not do that so readily. We must use a 1.5-volt dry cell, but would have to arrange a voltage divider, to be able to tap off the correct voltage, and perhaps, if tubes vary somewhat, as they may, would require a small adjustment from the front panel. But in general a fixed voltage would suffice. The bucking cell would not add to the simplicity of switching, because not only the voltage source but its bleeder network would have to be opened when the voltmeter was turned off, otherwise the cell would be quickly drained. To minimize the drain the bleeder resistors would have to be of high resistance. To minimize the series resistance effect on the load resistor these same resistors would have to be small.

SOLUTIONS FOR IDLING CURRENT

One choice is to use a cold cathode rectifier, and the copper oxide type may be included in this classification, although the terminology usually refers to vacuum tubes of a special type. Anyway, we are concerned primarily with

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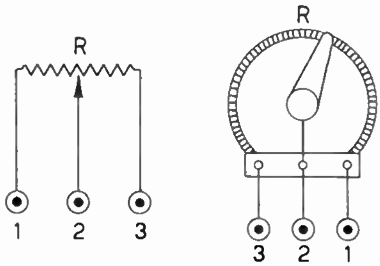
vacuum tubes, wherein the vice resides. We may buck the current from the meter only, by inserting a small dry cell, with limiting resistor not quite large enough, and adjustable resistor safely too large, so that the reverse current causes meter needle to read zero. It is easy to switch this off with a single-circuit switch. But an adjustment has to be made for each range, and for the high voltage ranges no



1 & 2 = Rheostat
1 & 3 = Fixed Resistor
1,2& 3 = Potentiometer

FIG. 10

The potentiometer R is shown at left in wiring diagram form and at right pictorially, with binding posts numbered 1, 2 and 3, and services obtained from connections to these posts. The object is to calibrate the potentiometer as a rheostat, to have known values of resistance at hand, also to enable attainment of proportions of a known voltage connected across posts 1 and 3, when the device serves as a potentiometer. For percentage as R may be 1000 ohms.

bucking is required, so part of the ac-dc switching arrangement would have to include positions for bucking circuit for low a-c ranges and no bucking circuit for high a-c ranges.

Obviously the best solution is to select a tube that when low-resistance loaded does not produce any sensible deflection, but it is impossible to select such tubes, because they do not exist. Manufacturers of tubes should try to make them. Now on a range of 5 volts a-c maximum the idling current in a peak rectifier, using 500 microammeter, ranges from 10 to 100 microamperes, depending on the tube type.

A three-element tube may be used, and, if the grid is left free the idling current will disappear. Plate serves as anode and cathode as cathode. But in that way a very high resistance rectifier is developed. A rheostat of 1.0 meg. may be connected between plate and grid, so no longer is the grid free, but becomes coupled to the plate, the resistance being adjusted until at no a-c input to the posts for the unknown there is just the barest reading, on the lowest-voltage range. Then no adjustment is needed for higher voltage ranges, as the needle will not go below zero.

A fifth comparison of rectifiers is based on linearity. The tube alone affords linear possibilities in rectifier instruments. It is not likely to give linear results on the lowest range, although may come close to doing so. On higher voltage ranges the linearity will be good. By linearity is meant that the rectified current is proportional to the input a-c voltage over the entire scale of the electromagnetic meter.

ADJUNCT TO VOLTAGE TESTS

A wire-wound variable resistor may be calibrated to excellent advantage. The three-terminal type, called potentiometer, is preferable. It permits establishment of proportionate measurements of resistance and voltage and current. It is therefore handy to use a potentiometer of 100 ohms, so that the percentages will be direct-reading, therefore one ohm equals one per cent, five ohms equals five per cent, to 100 ohms equals 100 per cent.

Fig. 10 shows the circuit in wiring diagram and pictorial forms, with three posts numbered 1, 2 and 3. Then the connections are made between 1 and 2, and the input also is to 1 and 2, one has a calibrated rheostat. When the same terminals 1 and 2 are used for test lead connections, but a known oltage is applied between 1 and 3, then the potentiometer serves to do what its name implies it will do, serve as a meter to apportion potentials.

Color code the terminals 1, 2 and 3 and mark the panel for which colors to use to follow a scale you will prepare.

Suppose that one attaches a tube checker type transformer inside a metal box, and brings out the common side of the secondary to one pin jack and the arm of an eleven-position, two single-circuit switch to the other pin jack, slider of switch picking up ten different secondary voltages, and zero voltage (off). If we unite posts 1 and 3 of the potentiometer to the two posts of the transformer output, we may check and calibrate instruments for a-c use and establish any full-scale a-c voltage desired, if need be with the aid of another divider, these full-scale voltages equal to or less than any of the ten voltages obtainable from the secondaries.

THE ADDITIONAL DIVIDER

The extra voltage divider simply consists of another potentiometer, a few hundred ohms being sufficient. Connection of total resistance is made across the a-c voltage source. Since this is too high for full-scale of a meter being checked or calibrated, the 100-ohm "percentage potentiometer" is connected with its total from one end of the second divider to arm of that divider and adjustment made to full scale on meter when the calibrated device is at 100 ohms.

In the tube checker transformer the voltages may not be of exactly the values imprinted, because the load is less than when an "average drain" tube is inserted, and also because the transformer is not of the precision type and does not have "perfect" regulation, but a voltage near enough for all purposes to full-scale intended value may be derived, just so long as full scale is established, by taking the secondary voltage as if it really were what it is supposed to be, and then obtaining the proportion from the calibrated resistor. This proportion

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will enable establishing sufficient points from which one may curve to get intermediate values by extrapolation. Thus one works without known voltage. Then later the full-scale is established by using the right load resistor when the maximum voltage is known. The lesser voltages follow the resistance percentage.

An a-c rectifier type meter is built. The problem is to calibrate it. A-c standards of high accuracy over the full range do not exist in service shops. Precision instruments possess all-over-the-scale accuracy. Ordinary instruments have an accuracy that applies only to full scale. At other settings the accuracy may be less, and except around four-fifths full scale, are almost bound to be less. Therefore the full-scale voltage, if 100 volts, with accuracy 2 per cent. means that for the calibration on the instrument the departure of read voltage from true voltage may be 2 volts anywhere on the scale. At 10 volts read, the true voltage therefore may be 12 volts, an error of about 17 per cent. Readings taken as proposed will correct the error, also.

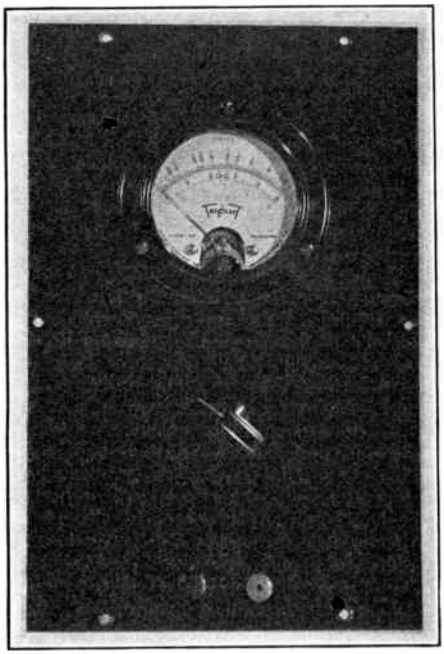

FIG. 11

Front view of the ohmmeter used in calibrating the 100-ohm potentiometer.

KEEPING PER CENT ACCURACY SAME

Now for using a meter for calibrating another meter. A meter accurate to, say 2 per cent, is used at full-scale deflection, or at four-fifth full-scale, and a reading taken. Say this is 5 volts. The potentiometer is at 100 ohms. We desire to know what the needle position should be on the meter for lesser voltages, say, in steps of .5 volt, to the same percentage accuracy at all points taken, not merely the percentage accuracy at full-scale. Therefore we desire to set the calibrated potentiometer so that the changes of its arm position for readings will equal $1 \div (5 \div .5) = 10$ per cent. So we read the needle indication at 100 ohms and at lesser resistance steps equal to 10 per cent. of 100 ohms, or 10 ohms. Hence for 90 ohms we have 4.5 volts, at 80 ohms 4 volts, at 70 ohms, 3.5 volts, etc. A point to watch, however, is that from voltages from zero to one-fifth scale we may desire to take readings at closer steps, say, 2 ohms, or 2 per cent. instead of 10 per cent., because rectifiers are usually most irregular here. If we come to one volt, using 10 ohms, we ascribe .1 volt to each 2 ohms.

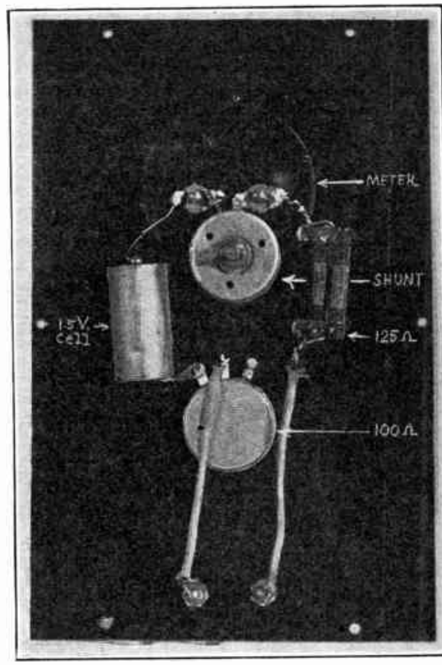

FIG. 12

Rear view of the ohmmeter used for calibrating a 100-ohm potentiometer. The meter and its adjuncts are identified by lettering.

WORKS ON A.C. OR D.C.

Since the potentiometer is accurate, even the test leads having figured in the calibration for the resistance they possess, although one may not know separately what that resistance is, we have accurate ratios. The comparison with the calibrated voltage of other readings on the meter may be made by drawing a curve on which meter reading appears along the base (abscissas) for apparent volts, with true volts along the perpendicular (ordinates). Then when we desire to make any particularly ac-

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curate measurement, we may have recourse to the curve.

The method thus is also applicable to a voltmeter already calibrated, but in which the accuracy is to be improved along the line. The same method applies if the voltmeter is not calibrated for a.c., but only for d.c., since then the d-c values are taken to represent the "apperent a-c voltage," or may be taken simply as so much current, as indicated on the meter scale, while the ordinates refer to the true a-c voltage. Moreover, a d-c instrument may be checked the same way, or calibrated, using instead of the tube checker or other transformer, a d-c potential source. A precaution to take is never to use a high voltage, if the potentiometer is only 100 ohms, as too much current will be drawn, and source and potentiometer imperilled.

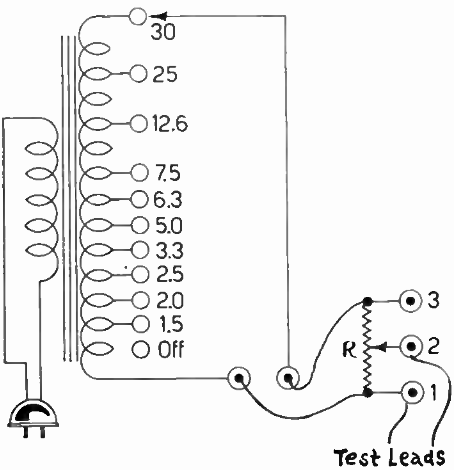

FIG. 13

A power transformer, such as used in tube checkers, fastened inside a box, and provided with a switching arrangement, permits selection of ten secondary voltages, the nominal values of which are imprinted on the diagram. If the calibrated potentiometer is used, connections are as shown, while the test leads go to posts 1 and 2. Thus, besides maximum voltage of any secondary, all intermediate voltages, to zero, are obtainable.

The case just referred to had to do with taking the known accuracy of a particular meter, and applying this same accuracy all along the scale, thus improving greatly the practical accuracy of the meter, and going to hardly any expense to do it.

VOLTAGE NEED NOT BE KNOWN

If one does not have at hand the actual full-scale voltage, it does not matter, so long as a voltage somewhere near it is obtainable. Say the maximum deflection is to represent 5 volts, and we have an assumed 6.3 volts at hand. The potentiometer is used across the 6.3 volts, and the voltage is assumed to be 5 volts, the load resistor made such in the rectifier that full input affords full-scale reading. The proportions are established as before, so that what we really obtain are ratios to full-scale deflection. The ratios are right, although the voltages are not. If the ratios are right the calibration is right, and the desired values may be ascribed, although the test voltage for full-scale is wrong, by assumption, for indeed we do not really know just what the voltage is, only that it is supposed to be 6.3 volts or was intended for tubes having heaters requiring such voltage.

Now all we need do is to obtain an instrument at any later time whereby we may insert the correct multiplier resistor for loading the rectifier, so that at full scale 5 volts is accurately established by having the known meter and the unknown both across the same supply at the same time, and adjusting that supply, using the very same calibrated potentiometer, to bring it down to 5 volts, read perhaps on a borrowed meter, and then inserting the right load resistor for full-scaling. Now our calibration is complete. The necessary precaution is that the voltage source must not be greatly in excess of the intended full-scale reading in volts.

APPORTIONMENT MADE

The 100-ohm potentiometer is put in a box, with pointer long enough to enable a large scale. The calibration may be made by comparison with a good ohmmeter. The universal ac-dc- meter manufactured by Triplett (Model 321 or 521) has a very accurate ohms scale. By using a 1.5 volt dry cell, and shunting the meter (used just as a d-c device) with 10 ohms, limiting resistors 100 ohms fixed and 100 ohms variable, one-third of the scale repre-

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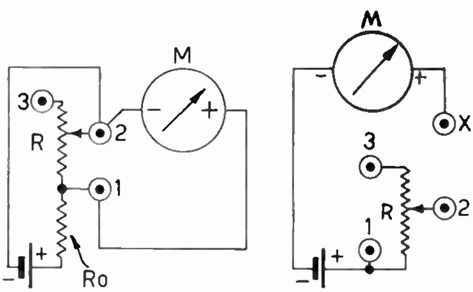


FIG. 14

A limiting resistor Ro may be inserted, so that meter M reads full scale when the arm of R is at post 1, whereupon the meter may be calibrated for resistance readings within the range of R, by noting the reduced deflections for values of R read on the resistance calibration of R. Also, unknown resistances may be inserted between 1 and 2, deflection noted, and unknown removed, and substituted by R, set to provide the same deflection, whereupon the reading on R equals the value of the unknown resistance. At right, R may be used as a limiting resistor, and unknown resistances inserted between post 2 and an extra post, X, for ohmmeter service.

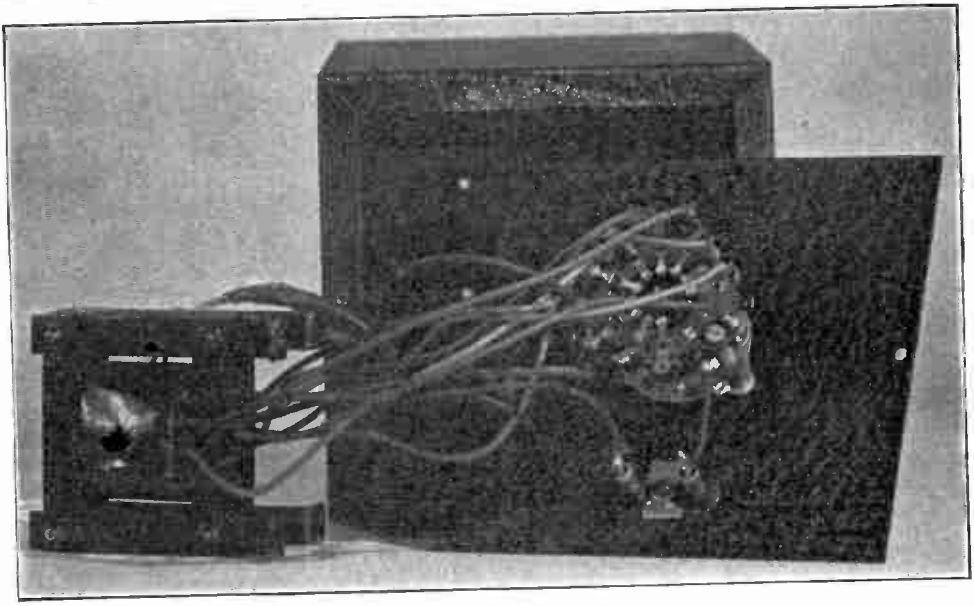
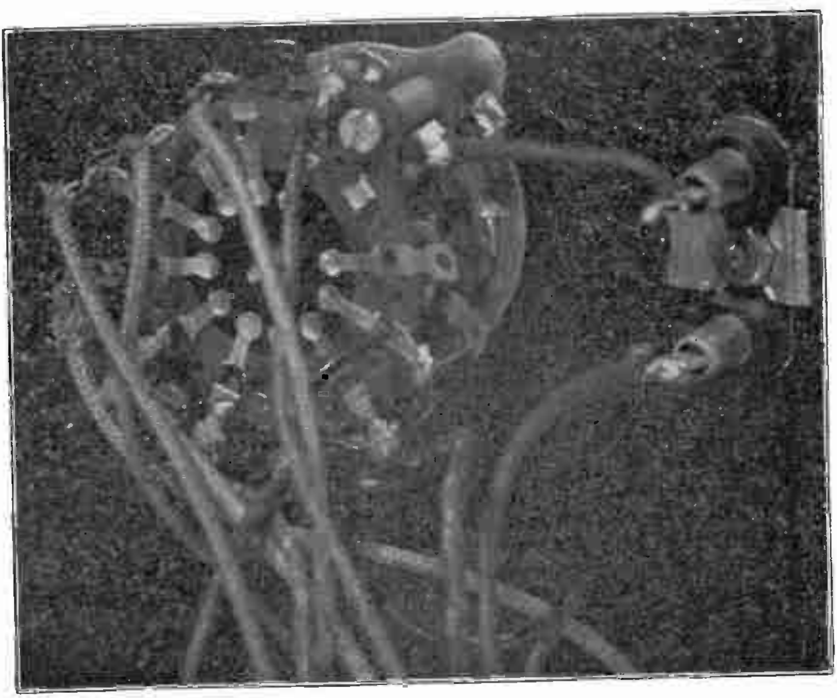


FIG. 15

The transformer leads are wired to the switch, except one to a binding post, with sufficient length provided so that when the transformer is to be mounted inside the cabinet, the panel may be lifted sufficiently to enable tightening the mounting screws. The hole positions are found by using the transformer mounts as template, outside the box, at bottom. The holes are drilled (two of them show in the photograph), then the screw is passed through cabinet and mount, a nut for binding being held in place by holdfast pliers.



The switch is shown actual size in this close-up. Only a single circuit switch is used. The second deck shown near the panel was not connected. The twin output assembly is at right.

FIG. 16

(Continued from page 46)
sents 100 ohms, with 2 ohms separation at lower end. otherwise 5 ohms. That is how an experimental potentiometer was calibrated, and when comparison was made with a $150 ohmmeter, there was no need to apply any correction, as the accuracy already was as high as could be attained due to reading and manipulation limitations on the home-made 100-ohmer.

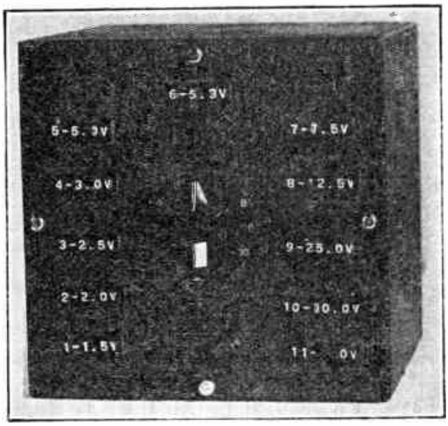


FIG. 17

The 1-11 plate obtained with the switch is used for indicating the positions of taps on the transformer that the switch selects. These numbers are corresponded with numbers put on indicating strips. The voltage lettering was done on a hand punch that embosses on tin ribbon. The letters were made bright by filing. The strips were adhered to the crinkle-finished panel by acetate cement.

The transformer used for boxing was a commercially-obtainable tube checker type with the following code for wire outlets and voltages:

Nominal Volts	*Actual Volts**	*Color Code*
Primary		Gray
Secondary, Common		Red
1.5	1.6	Red, Black Tracer
2.0	2.0	Blue
2.5	2.6	Green
3.3	3.3	Orange
5.0	5.5	Brown
6.3	6.4	Yellow
7.5	7.5	Red, Yellow Tracer
12.5	12.5	Black, Yellow Tracer
25.0	27.0	Black, Green Tracer
30.0	33.0	Black, Solid Wire

**When line voltage was 117.5 volts a.c., and only secondary loads were the 100-ohm potentiometer, with an a-c moving-iron meter of 200 ohms per volt between posts 1 and 2 of Fig. 1.*

USING FIXED STANDARD

If an accurately known resistor is at hand it may be used as a basis of calibration. By substitution its value of resistance is duplicated on the 100-ohmer. Then a small rheostat is duplicated the same way to provide the same resistance. Now you may add the two knowns in series for double the value of either, or parallel them for halving the resistance. A rheostat across the series circuit when set to read for the standard has three times the resistance of the standard, etc. Since the 100-ohmer is such a rheostat, three times standard resistance is attainable. Now duplicate this by substitution and use the same method to get higher and higher resistance until all needs are satisfied. The meter-shunting method itself is applicable, using ohmmeter at full scale, and computing the resistance, but it is always preferable to have at least one standard fixed resistor.

Allied Gives "Antiques" to Science Museum

In the Communications section of Chicago's Museum of Science and Industry is an elaborate exhibit which traces the rise of radio from its earliest days to the present. Among the equipment is a wide range of "ancient" radio material donated by Allied Radio Corporation, of Chicago.

Allied's contributions include a bulky solenoid antenna switch (vintage about 1916), an airplane transmitter-receiver combination with breast-plate microphone, and an emergency "ground radio" transmitter. The ground transmitter was developed about 1916 and was designed to utilize the earth rather than the ether as the medium for transmission of radio signals. The equipment shown was all built for the use of the U. S. Army and Navy during the World War.

Other materials given to the Museum by Allied include a wide range of radio receiving sets and accessories dating back to the earliest days of commercial radio broadcasting.

Renting of Receivers Proves Growing Business

Claiming that renting a radio is the new and inexpensive way to enjoy radio entertainment, and declaring that rented radios are the vogue in Great Britain, a company known as Radio Rentals Pty., Ltd., Sydney, has introduced a service whereby any person desiring a radio set may select a new set, pay an installation fee, and keep the set as long as rent payments are made. The amount of rent depends on the model selected, but the minimum is about 55 cents per week.

If the user should decide to purchase the set, the rental payments already made would be credited against the list price of the set. The company is supplying radios manufactured in Australia by Standard Telephones and Cables, Ltd., whose cheapest set is a 5-tube mantel model listed at about $63.

Two Students Maroon Selves Atop Whiteface in Radio Test

One of the grand sights in the State of New York is to view the surrounding countryside, including Lake Placid, from near the top of Whiteface Mountain, which rises 4,782 feet, and is the highest point in the State. The Adirondacks, Ausable Chasm, Lake Champlain and a wealth of other natural beauties greet the eye.

To get to the top of the mountain you drive your car part way up the Whiteface Mountain Memorial Highway, until you come to the pay station, and get relieved of the cost of about ten gallons of gasoline.

Two students, however, got to the top without paying a cent. They made the slow ascent in an auto, in second speed for safety. They did not have to pay any money. But wait!

POLAR TEMPERATURES

They are making observations in connection with weather forecasting, for they are meteorological students. One is Benjamin Schiffer, of New York University, and the other Idwald Parry, of Rensselaer Polytechnic Institute, Troy. Already they have set themselves up in a stone hut on the summit of the mountain, and have experienced temperatures of 12 to 15 degrees below zero, but as Winter advances it is expected the temperature will drop at times to 50 to 60 degrees below zero.

They are not exactly incommunicado on the lofty peak, for they have telephone communication, in addition to their mainstay, which consists of variegated radio apparatus that they use for reporting to headquarters and for reception. The land wires broke during a cold spell and they are trying to make repairs. They have $500 worth of provisions, a great store of wood, and are all set to spend a purely experimental Winter amid surroundings that free them from distractions and give them the solitude that all true students relish.

The New York State Department of Agriculture is cooperating in the work, and has supplied some of the radio apparatus.

WORK MT. WASHINGTON

By using transmitters on different frequencies the students supply information about pressures and gradients that appear on the aviation weather maps and data issued four times daily, including the reports sent by radio. Two of the receivers the students are operating work the usual short waves, and one of them is a special ultra-frequency receiver. The pioneers on the mountaintop are also equipped to send on any of the frequencies on which they receive, using independent apparatus.

New Hampshire also has a famous mountain, Mt. Washington, loftiest point in the East, atop which is a weather observatory, and the two plucky students get daily weather reports from that source. The effect of atmospheric conditions on transmission on high frequencies is being studied and has been found to be pronounced.

DOG TEAM READY

One of the hopes is that sufficient information will be obtained so that weather predictions may be based on the transmission phenomena on high frequencies.

Meanwhile, nearly 5,000 feet below, the Lake Placid airport has sled and dog team ready, in case any accident or sickness befall the intrepid students. Two doctors and six dogs stand always ready. The doctors know just why. The dogs may have a suspicion.

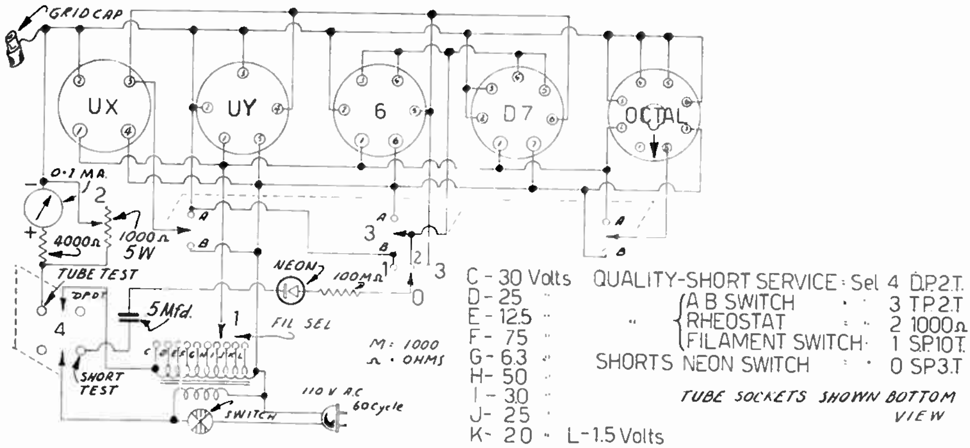
0-1 Meg. Calibrated Unit Made for Bench or Panel

Designed in circular form for either bench use or panel mounting, and continuously variable from 0 to 1.0 megohm with a direct-reading calibrated dial, a Resistance Analyzer and Indicator is announced by the International Resistance Company.

Among its many uses are: voltmeter multiplier; resistance or volume control analyzer for the measurement and determination of resistance values by either substitution or voltage measurement method; determination of the proper control or resistance value for best results in almost any radio circuit; wire wound rheostat or potentiometer (0 to 30,000 ohms); carbon rheostat or potentiometer (0 to 1 megohm); volume or tone control on radio sets; calibrated gain control or attenuator; voltage divider and countless others. A complete instruction manual prepared by IRC engineers and furnished with each instruments gives detailed information as to its use in a wide variety of work.

The Analyzer is controlled by a single knob. Electrically, it consists of two sections, the first comprising a heavy duty, wire wound rheostat type element from 0 to 30,000 ohms. The second section is a specially designed Metallized type resistance similar to that employed in IRC Metallized type Volume Controls. Its range is from 30,000 ohms to 1 megohm.

TUBE CHECKER With 0-1 Milliammeter



The tube checker with sensitive meter.

THE emission type tube checker described in the October and December (1937) issues, using a 5-milliampere Readrite meter, has been adapted for use of a 0-1 milliammeter by R. K. Wheeler. The diagram that includes his provision for the more sensitive meter is given herewith.

There are four sockets used. Reading from left to right these are four-hole (UX), five-hole (UY), six-hole, dual seven-hole and octal. The dual seven-hole socket simply takes care of the medium and small-sized seven-prong tubes, of which the small type tubes are by far the most abundant. The octal takes care of metal tubes, also glass. Bottom view of sockets are shown.

The 0-1 milliammeter has a 4,000-ohm resistor in series with it, and a 1,000-ohm, 5-watt rheostat across it. In general, the tabulation of settings of a linear rheostat of 5,000 ohms will apply, when the values for the large number of tubes listed in the October issue for settings of Selector 2 (the rheostat) are consulted. However, in some instances it may be necessary to shunt the meter additionally with about 1,500 ohms, and this would be done between the minus and plus posts of the meter.

QUESTION OF SHUNTING

Whether the shunting is necessary is decided on the following basis. A tube of known excellent characteristics is taken as the model. The setting is made according to the table published in the October issue. If the meter reads on the Good part of the scale, then everything is all right, but if it reads on the questionable part of the scale (?) then enough shunting, about 1,500 ohms, is introduced to make the tube read Good. The adjustment once made for this purpose and tube applies to all future purposes and tubes.

It is necessary to have a filament transformer that provides the proper voltages. All of the transformer manufacturers who cater to servicemen and amateurs have these transformers, stores stock them, as do the supply houses that servicemen frequently patronize.

The method of using the tube checker, and also other pertinent data, were printed in the October and December issues. In the December issue particularly, a list of questions put by readers was answered, and this contains much information of value particularly to those who are not very familiar with tube checkers, and perhaps will build and use one for the first time.

PERFORMANCE SATISFACTORY

The emission type tube checker is practically standard, and while it does not quite spell perfection, it does give readings of value in nearly all instances, so that its use is to be encouraged from the viewpoint of economy and simplicity.

However, it must be acknowledged that there are better type tube checkers, for instance, the type that determines the worth of a tube by its power output capabilities. Even though the tube is not a power tube, the power output test decides matters, on the operating circumstances of the tube, when a.c. is used as if a signal, just as would happen in a receiver. Such a tube tester is manufactured by Triplett Electrical Instruments Co., Bluffton, O., who supply a circular on it.

RIGHT OR WRONG?

PROPOSITIONS

1 The percentage modulation has nothing to do with the service area of the propagated wave but has only to do with the quality of modulation compared to the quantity of modulation.

2 The triode, quadrode, pentode, etc., are tubes that can be set up in a circuit to produce oscillations, but it is not possible to make a diode oscillate.

3 All forms of distortion met in radio practice can be reduced to an expression that takes in the harmonics of the wave form, therefore there is no distortion without harmonics.

4 A bypass condenser is one used to bypass alterating currents around some resistance or coil, whereas a filter condenser is one that is usually used for aiding in filtering out a particular frequency, which is also a bypassing function, therefore bypass and filter condensers are the same thing.

5 A feedback loop is an inductance consisting of turns of wire wound on a frame and either tapped so that a cathode connection may be made to tap, or having an auxiliary winding, in either instance so that the loop may be used in a feedback circuit.

6 An electrolytic condenser may be tested for capacity by using a low voltage a. c., say, around 5 to 8 volts, but it is preferable to include a d-c polarizing voltage of about one-tenth the formation voltage to the condenser.

7 A good way to calibrate for a. c. is to use a thermo-couple r-f galvanometer, with a limiting resistance, if necessary, and if the resistance is correctly chosen, the instrument, used on accurately known d. c., will read the same as for r. m. s. on a. c., because the thermal element responds to heat, and equal heating is the basis of comparison of d. c. and r. m. s.

ANSWERS

1 Wrong. The percentage modulation has much to do with the service area, since the higher the percentage (assuming 100 per cent. not exceeded), the greater will be the radiated power. If the modulating voltage equals the carrier voltage, hence the total is twice the carrier amplitude, the percentage is 100 and the power output is four times that of the unmodulated carrier.

2 Wrong. It is decidedly possible to make a diode oscillate. One familiar example is the negative resistance diode, such as the mercury rectifier. Besides, special circuits have been devised whereby ordinary diodes can be made to oscillate, too.

3 Wrong. However, the proposition comes close to being true. It is wrong for instance, because fading is a form of distortion, and may be present without any harmonics whatever.

4 Right. There is no real distinction between bypass and filter, as the condenser in either instance shunts the a. c. around some other impedance.

5 Wrong. A feedback loop has nothing whatever to do with a loop antenna, but is a phrase used to designate the path through which the feedback action of any circuit is accomplished, and the path may consist of nothing but capacity and resistance.

6 Right. It is common practice in condenser factories to test the capacity of electrolytics in the way described.

7 Wrong. The proposition assumes that the same scale applicable to use of the thermocouple on d. c. will apply to a. c. The d. c. will flow due to the resistance in the circuit and response will be linear, but on a. c. it will not be linear, the low end being crowded.

The Leak in Its Glory

Its Effects on Oscillator Vital

By H. B. Herman

THERE is more to the grid leak in an oscillator than most persons imagine. How many pay any regard to the fact that the value of the leak affects the input capacity and therefore controls to an extent the tuning range? Is this not something to take advantage of in adjusting a service oscillator to follow a pre-

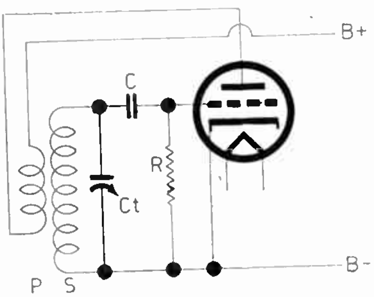


FIG. I
Condenser-diode oscillator works on peaks of the positive alternation. C is the grid condenser, R the grid leak, Ct the tuning condenser, and P and S primary and secondary.

calibrated scale? In fact, other small variations may arise from failure to use the value grid leak that the designer had in his circuit when he calibrated the dial. Or the leak sometimes serves to atone for difference in tubes of the same type.

Superficially the extension of the tuning range, where it seems one already has as much as one will get, as no trimmer is in circuit, depends on the value of the grid blocking condenser. This is a simple example of one capacity in series with another, the tube capacity being one and the grid condenser the other.

RESISTANCE AND RESONANCE

But the value of the grid condenser is usually tremendous compared to the input capacity of the tube, and therefore the loading effect of the grid leak plays its part, and the effect of resistance on tuning or resonance has to be considered. Did you know there are tuning systems that are based only on resistance, that no coils are used, and that the frequencies include the standard broadcast band and even some short waves?

The main effects of the grid leak-condenser combination may be tabulated as follows:

1. Supplying an automatic d-c bias to the oscillator tube, due to the flow of grid current.

2. Reduction of the input capacity of the tube, permitting wider tuning range, or control of establishing the range.

The bias considerations have been discussed in detail in previous articles and need be mentioned here only briefly. The oscillation wave drives the grid positive, and in the condenser-diode circuit (Fig. 1), consisting of grid-to-cathode, grid current develops a polarity opposite to that of the a.c. That is, the grid becomes negative. Therefore at the peak, and only at the positive peak at that, does the grid draw current from the oscillator circuit, or the tube rectify in the grid circuit. Thereafter the grid is maintained negative because the fixed condenser, which has been charged to practically the peak oscillation voltage, discharges through the leak for the remainder of the cycle, even though during the negative alternation there may be no oscillation.

SEPARATION OF COMPONENTS

In the condenser-diode form the a.c. and the d.c. are separated, as the continuity to d.c. is from grid to cathode through the leak. If the grid leak is connected from grid to coil and condenser stator, with grid condenser across the leak (Fig. 2), a different situation obtains, when instead of the peaks the average of the a.c. influences the tube, and the sensitivity of the automatic volume control, for such indeed it is, becomes less. Hence the condenser-diode form is favored, and is represented by leak from grid to cathode directly, fixed condenser leading to the tuning system.

The value of the grid resistor has other effects than tuning range or input capacity control. It is associated with the grid condenser in a circuit that has a time constant of its own. The time constant equals the resistance expressed in megohms multiplied by the capacity expressed in microfarads. Thus, if the resistor is 50,000 ohms, write it as .05 meg., and if the grid condenser is 200 mmfd., write that as .0002 mfd. Then multiplying the two we have a time constant of .00001. The lower the time constant the higher the frequency it represents, i.e., frequency in cycles equals the number one divided by the time constant, or $f = 1 \div K_t$, where f is the frequency in cycles and K_t is the time constant. Hence the frequency in the illustrated case is 100,000 cycles.

CHANGING INPUT CAPACITY

Now, this is not a resonant circuit developed by leak and condenser, but if we assume the leak and condenser produce all the effects, which they do not quite do, as other factors enter, then we have a circuit that, if the grid condenser can not discharge fast enough, will trigger the discharge at the frequency equal to reciprocal of the time constant $(1 \div K_t)$.

Actually, the input capacity of the tube changes, especially as the frequencies to which the oscillator is tuned become high (short waves), and one object of having small values of grid condenser and grid leak is to avoid the super-regenerative effect caused by the introduction of this second frequency of oscillation. By all means the equivalent frequency is kept out of the audio realm, e.g., above 20,000 cycles, but it must be safely kept thereout even as the radio frequencies become very high. The highest radio frequency that the oscillator will tune to is a good one on which to test the grid leak value.

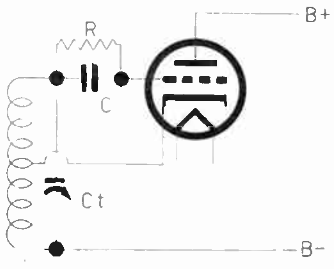


FIG. 2
Another connection for R and C that works well, but does not act as sensitively as Fig. 1.

If the radio frequencies do not exceed 20 megacycles, then the grid leak may be .1 meg. in most oscillators, although for safety .05 meg. is used. The oscillators referred to are those used in service instruments and as local oscillators in superheterodyne receivers.

The usual values in commercial practice for general oscillators are .00025 mfd. (which has been the standard value since the vacuum tube was introduced as an oscillator) and .05 meg.

MUCH INTERDEPENDENCE

It is permissible either to reduce the leak value until no broadness of the emitted wave results, no spurious modulation by super-regeneration, and no otherwise unaccountable tremendous instability.

There is so much interpendence in an oscillator that nothing should be taken for granted as being absolute. For instance, while the grid stopping condenser may be reduced in value to extend the frequency ratio of any and all bands, and also lower the time constant, hence increase the frequency at which super-regeneration would take place, the quantity of oscillation voltage appearing across the grid-cathode circuit is reduced as the grid condenser is reduced. The tuning condenser is not meant, as that does not enter directly into our present discussion.

DISCOVERING BROADNESS

Therefore a compromise has to be struck, which represents a choice of the best oscillation intensity consistent with the largest tuning ratio, provided there is absence of super-regeneration.

The check for super-regeneration may be made by using the output of the oscillator on a receiver. Strike some frequency near the high end (low wave) in the standard broadcast band, tune in the oscillation frequency, and note the dial position, and rock the receiver dial slowly, watching a meter or tuning eye in the set. Switch to the short-wave band, and likewise shift the test oscillator to the frequency for the same dial position on the set. Now if there is super-regeneration there will be either a strongly audible sound, a furious modulation, or, if the auxiliary frequency is beyond audibility, the response will be nearly the same as the receiver dial is moved several degrees, this side and that side, or only one side, depending on how near resonance with

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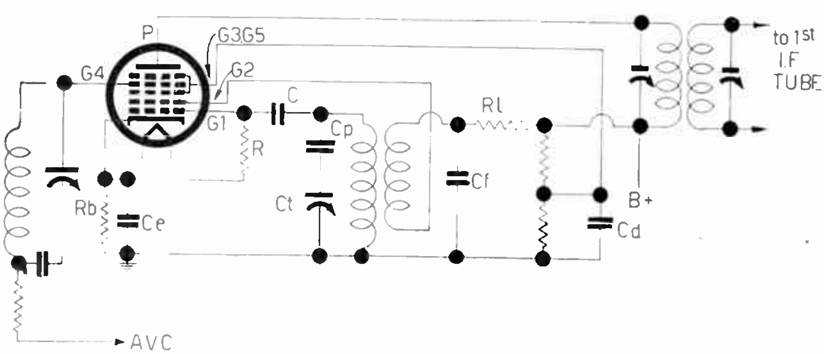

FIG. 3
Circuit for using a pentagrid converter tube. R is the grid leak and C the grid condenser.

(*Continued from preceding page*)

the receiver the oscillator was set when the readjustment was ma le.

FREQUENCY MODULATION

In other words, super-regeneration is a form of frequency modulation, produces a band of frequencies, instead of only a single frequency, and therefore the emission is broad, and the broadness is equal to the width of the ejected band.

Now the question will be asked: If an easy form of frequency modulation is thus present as a vice, why not use it as a virtue in some

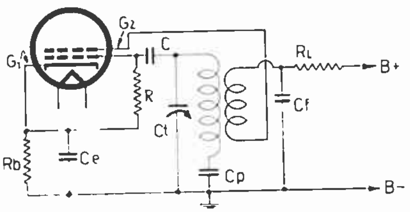

FIG. 4
Cp is the padding condenser, so placed as to simplify switching.

other connection, and have a one-tube frequency modulator, or wobbler, for oscilloscopes? It's a good idea, and has been suggested by H. J. Bernard, with the reservation that it would require development, because along with the frequency modulation there is a great quantity of amplitude modulation, and what is positively needed is frequency modulation only, with amplitude modulation utterly taboo. Otherwise false results would obtain in oscilloscopy. Moreover, their falsity, due to accompanying amplitude modulation, is of a type very hard to discover.

THE PENTAGRID CONVERTER

Figs. 1 and 2 represent the two types of grid leak-condenser circuits discussed, while Fig. 3 is the diagram of a mixer, complete except for the connection of the rotor (frame) of the tuning condenser in the r-f section. However, as a gang condenser is used, grounding of the frame at the oscillator is grounding of the frame for all purposes, and affects the two or three gangs alike, so there is really no omission.

The grids of a pentagrid converter tube are enumerated. No. 1 is the oscillator control grid;; No. 2 the oscillator feedback grid, normally compared in function to that of a plate; No. 3 and No. 5 are two grids tied together inside the tube and constitute the screen; while No. 4 is the r-f injection grid, used for input at the station-frequency level.

Therefore the mixer is a frequency changer, in that the station-carrier frequency is tuned in (G_4), and besides there is a locally-generated oscillation (G_1, G_2) which is mixed in the tube with the other frequency, due to common emission current, so that it is possible to extract any frequency resulting from this mixture. Two possibilities are a frequency equal to the sum of the two and a frequency equal to the difference between the same two. For practical reasons the difference of freaquency is always used, with the oscillator frequency higher than the station-carrier frequency, so the oscillator tuning condenser is readily made to cover as wide a band of frequencies as desired. The difference between the two frequencies is the frequency to which the intermediate channel is tuned.

PADDING THE OSCILLATOR

Not only will the oscillator, if its tuning condenser is equal in capacity to the capacity of the r-f sections, tune to the required ratio of frequencies, but will more than do that, so the ratio has to be reduced. This is normally done by including a padding condenser C_p, which reduces the capacity all along the tuning range of a single band, not only to the required amount, but in such a way that the difference between the two frequencies, the one injected and the one locally generated, remains constant. If it did not remain constant there would be changing intermediate frequencies, with loss of sensitivity and gain, if you can call it gain, of squeals.

It is apparent therefore that poor tracking results in alteration of the intermediate frequency generated, and this is true even though the frequency to which the intermediate channel is tuned remains the same. There is the difference between the deliverance and the acceptance. The pentagrid converter tube does the delivering and th i-f channel the accepting, and what is delivered should be most acceptable, i.e., always the same frequency, and equal to the intermediate amplifier frequency.

The location of the padding condenser as shown in Fig. 3 is the better choice for maximum oscillation voltage, as there is no sacrifice of any of this voltage by the method shown, where C_p is between stator of the oscillator tuning condenser and grid end of secondary.

CONSTANTS FOR FIG. 3

If a single band is to be covered, say the standard broadcast band, then C_p would be left where it is in Fig. 3. However, it is usual to have more than one band, in fact, three bands, and that requires three different padding condensers, one for each band, because as the station-carrier frequencies become higher and higher for the two extra bands, the amount of padidng capacity required becomes greater and greater, since the difference between the two frquencies, station-carrier and local oscillator, becomes smaller. But it is; or should be, always the same difference.

In Fig. 3 the constants are identified as follows, with suggested values for them:

R_b is the biasing resistor of the pentagrid converter tube, and for usual applications may be 250 ohms, although if the oscillation intensity is not abnormal, and more sensitivity is required this resistor may be reduced even as low as 150 ohms. However, any reduction should be accompanied by a test.

TEST WITH CELL

Put a 1.5-volt dry cell in the cathode leg, positive to cathode, negative to ground, instead of the biasing resistor and note the plate current flowing at no signal input, although oscillator is functioning. They remove the cell and institute the smaller biasing resistor, never making it so small that the plate current will read greater than that which obtained when the 1.5-volt cell was tried.

SCREEN VOLTAGE SUPPLY

C_s is the bypass condenser across the biasing resistor and should have a value not less than .1 mfd., and preferably 1.0 mfd.

AVC represents the lead that enables application of automatic volume control, the resistor and condenser serving as a filter to keep the modulation voltage from backing up into the tuner. There would be one such filter for each tube so controlled, and the resistor and capacity values may be .5 meg. and .1 mfd.

C is the grid condenser, and the factors affecting this are the ones that have been covered in the primary discussion. A value of .00025 mfd. suffices.

R is the grid leak, and normally would be .05 meg.

C_p, the padding condenser, should be of mica dielectric, and since the value will be relatively small, this requirement is easy to fulfill. For 175 kc i.f., .00035 mfd. tuning condenser C_t, the value for the standard broadcast band is around .001 mfd., while for i.f. equalling something in the four hundreds of kilocycles, C_p normally would be about .0004 mfd.

C_t is the tuning condenser of the local oscillator, which condenser is padded by C_p.

C_t is a bypass condenser across the supply of B voltage through limiting resistor R_1, which is 20,000 ohms. The condenser should be .05 mfd. The reason for the resistor is to limit the plate voltage on the oscillator.

To obtain the screen voltage from a bleeder it is practical to tap off for the screen at the joint of two 25,000-ohm, 1-watt resistors placed between B plus 250 volts and ground.

SIMPLIFIED SWITCHING

Fig. 4 shows the position of C_p in series with the secondary of the oscillator coil. This is the more usual practice commercially, because switching is simplified.

It can be realized that if padding condensers have to be changed for each band, and the condensers are as located as shown in Fig. 3, a switch circuit has to be devoted to the padding condensers.

To avoid this extra piece of apparatus, or additional deck on an already large enough switch, C_p may be put in series with the coil, so that as the coils are switched the right padding condensers are picked up with them. This becomes possible because the grid leak provides a return circuit (d-c continuity) for the oscillator, and though the location of C_p as in Fig. 4 prevents the coil from having identical return, that makes no important difference.

It is not contended, however, that no difference at all exists. In fact, since now the oscillation voltage is divided across a circuit consisting of a coil and condenser in series, no input to the oscillator is derived from the condenser C_p, but only from the voltage across the coil, hence effective oscillation is weaker. However, with C_t at .00035 mfd. and the pad C_p at about the same value, the voltage is halved, and, with plenty to spare, there is enough input to oscillator for even the standard broadcast band. In fact, this may be a benefit, as overloading due to excessive oscillation is always a possible trouble.

As the higher frequency bands are tuned in, and C_p in series with the coil becomes greater and greater in capacity, the voltage drop across it becomes less and less, the sacrifice less, and practically then the condition approximates that of introducing no difference, so far as effective oscillation intensity is concerned.

PAVES NEW PATH

William Hoyt Peck, president of Television News Service, who recently inaugurated his new invention in New York City, is one of the few exponents of mechanical scanning systems. By developing a special cell, using the Kerr effect, he is able to provide very high degree of illumination very economically. He is an expert on optics.

INSTALLING A SET
Calls for Care and Knowledge

By Herbert E. Hayden

THE installation of a receiver in the home is attended by several problems, although little attention is given to some of them.

The first consideration is to provide a proper antenna. There are numerous special antennas in the market, or kits to enable their erection, and if a particular antenna is recommended by the set manufacturer, it is better practice to follow his advice. It may not be the best practical antenna, but it does represent some engineering, and it is wisdom to take advantage of this asset. Besides, the input connections to the receiver may be such as to require the special type of antenna recommended, for instance, a doublet, which is served by two ungrounded posts, although there is sometimes an extra post for grounding, in case a Marconi antenna is used.

In auto installations, for instance, an attempt is made at impedance matching between antenna and coil. Although the antennas recommended for particular sets by the manufacturers of both sets and antennas may work well, it is far from the truth that enough capacity for pickup is present in all of them. So in a home set, too, although improvements may be introduced later in the antenna installation, the manufacturer's recommendation should get first choice and trial.

INPUT AND SENSITIVITY

One of the familiar facts about modern receivers is that they are often too sensitive, rather than not sensitive enough, so again we are reminded that the antenna has to be considered. The high sensitivity is attended by a hissing sound when no station is tuned in, or a weak one is being received, so if there is no particular antenna for the set, at least one may make a sensible selection of the degree of pickup. This is governed in general by the electrical length of the antenna, which is affected either by the physical length and elevation, or by the amount of series capacity introduced in the antenna lead, assuming the physical length and the elevation are fixed.

Often nothing much can be done about increasing the elevation, since there are antenna poles on roof or elsewhere, or standoff insulators on chimney pots. So if an outdoor aerial is used, its length is fixed more or less by the distance between two poles provided for stretching the wire between them, plus the length of the leadin. Therefore the leadin is a part of the antenna, and must be included as such, with one exception, when a transposed leadin or other transmission line is used.

The difference is that a transmission line, in theory at least, picks up nothing; neither does it transmit. Again less than perfection will be achieved in practice, as the establishment of a perfect transmission line is an engineering feat, if, indeed, it can be accomplished at all.

Of course the transmission line is a factor in connection with receivers that have input arranged to receive them, either two posts free of ground, or, supplied with a transformer in the set, or external to it, to enable proper connection to this line.

WHAT TRANSMISSION LINE DOES

If there is no transmission line, therefore, since the leadin is part of the antenna, a series condenser will affect the aerial as it exists.

Two conditions present themselves. One of them is that due to the great length of the antenna there is insufficient selectivity. The fact that selectivity is reduced by long antennas is due exclusively to the resultant resistance thus introduced.

But we are considering first the reduction of the hiss, and it is obvious that the antenna should be long enough, or high enough, or both, to render the hiss negligible. So when installing a set, adjust the physical length of the antenna so that it is long enough to avoid hiss, but do not have the length so long that selectivity is below requirements.

SELECTIVITY CONSIDERATIONS

What are the selectivity requirements, depends on the selectivity in the rest of the receiver, and also on the location. In general, the more tuned circuits, the greater the selectivity. Intermediate channels are included in the reckoning. Therefore sets having more tubes may be expected to provide greater selectivity. The small sets, especially, of the mantel or armchair type, are the ones that bear close watching, for though they may have excellent selectivity when used with a short piece of wire indoors, serving as aerial, if there is any considerable increase in the input, the loading effect becomes serious, because there is not much selectivity to spare, and to a degree the tracking is upset by the increased antenna capacity. This, however, is adjustable at the antenna coil trimmer in parallel with the first grid circuit. Mistracking might assert itself promptly by the presence of squeals as one tunes the dial through the standard broadcast band, the squeals assumed not having been present before. Remedy is applied by r-f alignment at 1,450 kc.

The quest in radio is always for the happy compromise. Now we must compromise between sufficiency of input to avoid hiss, and limitation of input to avoid undue drop in selectivity. So this is the first test that is to be made by anybody who undertakes to install a receiver.

PRESENCE OF DEAD SPOT

In this connection it is well to remember that small sets in particular are made with the idea of keeping everything at a minimum, barring possibly results, and so the price is low, the size is small, the parts and tubes are few, the power consumed is moderate, and the antenna requirements are barest. This means that the small sets are usually better served by a short indoor intenna than by an electrically large aerial, because the degree of pickup cannot be augmented indefinitely, due to the arrival of the squeal point.

In some exceptional instances the location of the receiver in the home, and the selection of the antenna, go hand in hand, because of shielding effects that in some parts of the house render pickup small, whereas in other parts, even in the same room, pickup may be greater. The facts in each case must be determining. Usually thec ustomer has a choice place to put the set, and there it must go, for the selection will always agree with antenna requirements, unless the single exception intervenes, whereupon the electrical or physical length is increased until pickup is sufficient, without removal of the set to other than the customer's selected location, or, if a dead spot is in fact insurmountable, then the receiver has to be moved to the most favorable position, at least on the same floor as the customer had in mind. Otherwise a more elaborate antenna system, whereby an outdoor wire is strung in some location free of the dead spot effect, is the remedy.

The simple matter of an outlet connection to serve the receiver is often controlling. The installer or the customer will have the idea, quite naturally, that the place to put the set is near some outlet, at least not farther away than the length of the power cord. This convenience should be enjoyed, provided reception is what it should be, but if other considerations require that the set be placed elsewhere, and there is not enough power cord length for the purpose, an extension cord serves the purpose.

WORKS ONE WAY ONLY

In connection with affecting the electrical length of the antenna it should be noted that a series condenser, connected between receiver's antnna post and end of aerial leadin, or end of aerial proper if there is no individual leadin, as when a short stretch is used indoors, behind moulding, or just from receiver to floor, only reduces the electrical length. There is no ready means of increasing it with just a condenser in such a way as not to impair reception on some other frequencies.

The main consideration, from the buyer's viewpoint, is to put the receiver somewhere near enough to the power outlet, and a position deemed to harmonize with the furniture and the rest of the settings of a room. This is quite understandable, and has its points, but there is also the acoustical problem to recognize, and if the fact is called to a customer's attention he might want to consider acoustics.

There is no point in becoming over-technical with a customer, but at least the receiver may be placed in different positions, and an invitation extended to listen carefully, to determine which position produces the best sound. This does not mean the greatest volume of sound, as this may not be expected to differ much, unless dead spot problems arise in connection with the antenna installation.

WHAT'S BEST

A dance orchestra should be tuned in, and if the set has a tone control, that should be adjusted so that there is no control, or minimum control, exercised. That is, the control should be out of circuit, or as nearly so as the set will permit. Then the customer is invited to listen for particular instruments, e.g., bass viol, flute, piccolo, violin. Particularly on the lower and upper registers will there be possibility of quite a difference, with not so much noticeable in between.

However, the final analysis rests with the customer, and the set is for his enjoyment, and what he likes best is best for all hands, except that, if he is married, and his wife is absent at the time, she has the privilege on arriving home of overruling everything, and then that's best for all hands.

Of course, acoustical problems are best considered in regard to receivers of some consequence, as everybody in the industry recognizes that the very small sets, with their baffle limitations and other restrictions due largely to the requirement of keeping within space and price, can not become high fidelity by putting them anywhere in particular.

Yet in recent years improvements in the tone of midget sets has been considerable, as means were found to avoid intense resonance effects that produced over-accentuation in certain frequency regions, and properties of the ear relied on to supply low-note effects from the harmonics of low-frequency notes. Tone chambers of various types have been introduced, so that passable reception is at last possible from these small sets, and to this extent—for small sets costing $20 or more—a little regard to acoustical properties would not be too far-fetched.

IMPROVEMENT VIA GROUND

Nothing has been said about the ground, although a good ground may do a great deal of good. Particularly if there is power line or other such interference, the better the ground connection, the greater the likelihood of reducing this trouble, assuming it is not so serious that this simple remedy can not help noticeably. Ignition noises from buses and even old private cars, also from trolley cars, becomes less, usually, when a good ground is used. A ground clamp is fastened securely to the nearest cold-water pipe, and a wire run the shortest practical distance to the set's ground post.

There is always only one post for the ground, although there may be two posts, or wires, for the antenna. The choice is for long antenna or

(Continued on next page)

(*Continued from preceding page*)
short antenna; in other words, the means of permanently adjusting the input is provided in the receiver, and of course the connection that better serves the purposes of selectivity and absence of hiss is chosen, although even then antenna length adjustment is tried additionally, to determine whether improvement can be effected.

USE STOUT GROUND LEAD

The ground lead is likely to be long, because the cold water pipe will be found in the kitchen, and the receiver may be in the living room, two rooms away. If it is necessary to run a wire this length it should be thick wire, No. 18 or larger diameter (i.e., smaller B. & S. gauge number), and the insulation may be selected so that the wire becomes as obscure as possible, compared to the surrounding furnishings. It must be borne in mind that the longer the ground lead the less it is a ground and the more it becomes a sort of auxiliary antenna, i.e., does not serve the purpose for which it is intended, of providing a highly conductive path for the return of the antenna circuit current, because of reduced potential difference between the two.

If the man about the house is handy, or agreeable to the device, and the installer wants to do the work, a ground wire may be picked up in basement or cellar and brought up through a small hole in the floor. If the installation is in a bedroom, which may be upstairs in a house, the nearest cold water pipe would be in the bathroom, most likely, and the problem then becomes a bit awkward, although the same principles apply.

CUSTOMERS APPRECIATIVE

So antenna, ground and acoustics are the main facts for the installer to bear in mind, and as he pays more and more attention to them, he gains experience which enables him to give good advice to the customer, who usually knows little or nothing about radio, and is appreciative of any suggestions, even if he does not always find it convenient to follow them.

No disheartenment should accompany refusal by the customer to follow the sound advice of the installer, for much is gained at least from the integrity of the suggestions, for the installer is raised immeasurably in the estimation of his customer, and this goodwill is a distinct asset in business.

Patterson Set Now Made by Pierson-DeLance, Inc.

The PR 15 communications receiver production and sale have been taken over by Pierson-De Lance, Inc., 2345 West Washington Boulevard, Los Angeles, Calif., from the Patterson Radio Company.

Karl Pierson, W6BGH, is chief engineer. He designed the PR 15. W. B. Delaplain, sound engineer, is general manager. L. E. Abbott is a member of the firm. The sales manager is Charles Weinberg.

Government Book Simplifies Short Waves

To simplify the somewhat different operations of the short-wave feature of the modern all-wave radio set, as well as to explain in popular language just how the short waves differ from the more familiar broadcast frequencies, the Electrical Division, Bureau of Foreign and Domestic Commerce, has made available "A Guide to Reception of Short-Wave Broadcasting Stations."

The publication was written by Lawrence C. F. Horle in cooperation with the Engineering Division of Radio Manufacturers Association, Inc.

This booklet, the foreword states, provides a simple exposition of the basic phenomena involved in the transmission of short-wave radio signals as used by broadcasting. It will assist the users of short-wave radio receivers to receive such programs as are available with minimum effort and greatest satisfaction and will aid in the avoidance of futile searching for programs not available because of location or other factors.

Since there are available throughout the nation competent radio service experts, it makes no attempt to instruct the user of short-wave radio receivers in the intricacies of the servicing of receivers. And since the design and production of the modern short-wave receivers require the highest type of scientific and engineering skill, it attempts to provide no constructional detail whatsoever except such suggestions as will assist the user in providing himself with a suitable receiving antenna.

By studying the contents of this booklet and following the brief instructions therein the user of the short-wave receiver will assure himself of getting the most out of his receiver and enjoying to the utmost a choice of the world's radio broadcasting.

Meissner Has Innovation In I-F Transformers

A new line of standard i-f double-tuned transformers has recently been placed on the market by the Meissner Mfg. Company. They are known as the Wide Range line. The unusual feature of these transformers is the wide range that the transformers can be tuned to. With only four standard wide-range transformers a serviceman may tune to any i-f required from 121 to 650 kc without skip. They are available in either air core or iron core. Also 1,500 kc and 3,000 kc units are available, these being used mainly by amateurs.

BENDING THE TWIG

Persons who experiment with radio circuits sometimes neglect to encourage young boys in and out of the family to build crystal sets and one-tube battery sets. Offer the parts to son or kid brother, 8 years up, and see what happens.

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. Lee Cooke, 1213 Prince Edward St., Fredericksburg. Va.
Lee V. Douthat, Nauru Island, Central Pacific.
Archie A. Cummings, 46th Squadron, Randolph Field, Texas—radio construction, diagrams of receivers and transmitters, also parts for same.
D. M. Beachy, Yoder, Kansas.
John G. Sanford, Addison, N. Y.
Geo. Saravay, 432 E. 54th St., Brooklyn, N. Y.
H. H. McMasters, Radio Service Co., 4513 North 30th St., Omaha, Nebr.
Nudi Printing Co., Wahoo, Nebr.
James T. Geoin, Adairsville, Ga.
Alfred J. Lawrence, Box 156, Covington, Mich.
C. M. Fennelly.
W. A. Tate, Radio Serviceman, 90 Lenox Street, Uniontown, Penna.
P. Pick, 3120 N. Orchard St., Chicago, Ill.
Donald Meisel, 266 W. Chemung Place, Elmira, N. Y.
C. E. Sager, 5946 Morgan St., Chicago, Ill.
P. Le Fee, 1585 Greenway Avenue, Columbus, Ohio.
M. White, 41 Cochran place, Valley Stream, N. Y.
Geo. E. Metelsky, R.F.D. No. 2, Willimantic, Conn.
Winslow W. Chase, 450 Randolph St., N.W., Washington, D. C.
E. A. Phillips, Box 144, West Point, Miss.
Foster King, Rio Vista. Calif.
Chas. E. Furman, Danbury, Nebr.
Harold Fread, Maplewood, N. J.
Louis Wiech, New Castle, Penna.
R. H. Baldwin, Olean, N. Y.
Donald W. Slattery, Chadron, Nebr.
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Don Blair, Franklin, Penna.
B. E. Wenstrom, Ashtabula, Ohio.
Edwin H. Harrji, Dumont, N. J.
W. W. Brackenridge, Harrison, Ohio.
R. D. Dawson, The Dalles, Oregon.

Triplett Adds 2" and 3" Tubes to List of 'Scopes

The Triplett Electrical Instrument Co. now offers new oscilloscopes with two-inch and three-inch screens, both incorporating the exclusive Triplett turret-tube mounting feature.

This development in tube mounting permits easy adjustment of the tube up or down or to either side, so that the screen is always in direct view of the operator. An adjustable shield enables easy reading in brightest daylight.

These new oscilloscopes meet every requirement for the visual study and adjustment of circuit problems. Linear sweep from 15 to 20,000 cycles.

Model 1690, the 2-inch oscilloscope, is furnished in two case styles—DeLuxe leatherette, or metal, with black wrinkle finish. The 3-inch oscilloscope, slightly larger, is in the metal case only.

DECIBELS FOR THE MASSES

EDITOR RADIO WORLD:

In the December issue you ask "What are decibels, anyway?" The decibel seems to be an elusive quantity to many, no doubt largely because its use is of little value to servicemen and home experimenters.

It seems to be fairly well understood that the decibel is a unit of sound, replacing the older term of T. U. or transmission unit. At the time the writer was employed as field engineer by a prominent theatre sound organization, it was considered that one decibel represents the smallest change of volume or intensity in a *single* tone that the human ear could detect, while for *mixed* tones three decibels were considered the amount of gain or loss necessary to be readily detected. For that reason most of the faders or volume controls in theatre sound work are adjustable in steps of three decibels each.

In theatre sound work the decibel was used mainly in two ways: first, to express gain or loss between two points in a sound system; second, to indicate the level or volume of output. Thus a certain final amplifier had a gain of 20 db, but a level of 36 db. The gain of the amplifier was calculated, of course, from the ratio of the input to the output, while the level was calculated from the ratio between zero level and the output. Zero level is commonly considered as .006 watt, although some engineering organizations use .01 watt, mainly as a convenience in calculation.

As an aid to non-mathematical readers, it can be easily remembered that doubling the power output merely raises the level 3 db, which is not a great increase. This useful bit of information may be of value to many. For instance, it may prevent them tearing down a good 10-watt amplifier to instal new tubes that will give 15 watts, which is hardly enough gain to justify much expense. To increase the amount of volume 100%, it would be necessary to increase power, or watts used, 1,000 times.

For example, if an amplifier is operating at 6 watts output, this is a level of 30 db as compared with zero level. In order to double the amount of sound, 60 db would be required, or an output of 6,000 watts.

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

FADING CURE SOUGHT

WHEN receiving Daventry we sometimes experience serious fading, although usually reception is very good, and about equals that of our local station, as to intensity at least. Can you suggest a remedy?—E. H.

There is no absolute remedy for fading. The cause is deemed to be the arrival of two components of the transmitted wave out of phase. When this opposition is 180 degrees, and assuming the two components are equal in amplitude, then the cancellation is complete, and nothing is heard. The silence interval is usually short. The phase shifts are semi-periodic, therefore waxing and waning are experienced. The simplest approach to a solution is the inclusion of automatic volume control, which tends to keep the output constant, independent of the quantity of input. But this can not be a complete remedy as the input may be zero, due to the phase opposition being complete. When there is less than 180 degrees difference there is less loss of volume, and when there is no difference, the periods of your excellent reception, there is maximum volume. The two wave components are sometimes viewed as consisting of sky wave and ground wave, but for frequencies in the short-wave realm, this may not be true, because the ground wave attenuation is altogether too rapid, or the wave does not travel far. Rather, the sky wave may be split up by refraction or reflection, or influenced by ionization in the upper atmosphere. It therefore arrives in two parts, let us say, and by somewhat different routes, and therefore the fading results.

* * *

SENSITITIVE CHASSIS

WHEN I touch the chassis of my receiver there is a plopping sound in the speaker, and sometimes there is a little static discharge. What may I do to avoid this trouble?—K. E. C.

The reason for this nuisance is that the chassis itself is not grounded. There may be a reason, i.e., the receiver may be of the ac-dc type. A remedy is to insulate the tuning condenser from the chassis, permitting the condenser frame to remain connected to the line, and then freezing chassis for grounding. Or, it is practical to insert a large condenser (.1 mfd.) between chassis and ground post. If there is no such post provide one, and connect the free end of the fixed condenser to it. This is a part remedy, as there still may be a little of the discharge trouble you refer to, because of condenser discharge when you touch the chassis, although the nuisance will be greatly mitigated, compared to what you endure at present.

* * *

GROUND WORKS HARM

WE have a superheterodyne. Why does it play more loudly when we use the aerial alone, and not the ground, than it does with both aerial and ground connected?—D. V.

The return circuit for the antenna current is well established in the receiver without recourse to other grounding, as there is a large capacity effect between power transformer and line, one side of which is grounded, anyway. However, there would not be so great a difference if this alone were the reason, because then there would not be reduction of volume when external ground is used. You will probably find that if the trimmer condenser across the first section of the gang tuning condenser is readjusted when external ground is used, that the volume will come up, for reducing the capacity by means of the trimmer will compensate for the increased capacity resulting from external ground connection. Since you get good reception as it is, there is no particular reason for making the test, but you might be curious enough to try it.

* * *

ACCURACY

IS it a good argument to state that an ohmmeter does not require a greater degree of accuracy than the accuracy to which resistors used in receivers are made?—S. A.

It is not a good argument. Nor is it good in reference to a capacity meter, a voltmeter or a milliammeter. The reason is that, if certain latitude is allowed in parts used in a receiver, say resistors are accurate to only 10 per cent., or voltages or currents held to only 10 per cent. of rated value, the true quantity may be 10 per cent. over or under, a total difference of 20 per cent. for the two permissible extremes, and if the measuring device has the same tolerance, since the errors accumulate, real measurement is not enjoyed. If the ohmmeter, voltmeter or milliammeter is accurate only to 10 per cent., then, it too may be off, not only to the same extent, but rather worse, since the accuracy rating applies to full scale only, and the same absolute voltage or current difference is permitted all along the scale as at full scale, hence the error may be 200 per cent. at some small current or voltage reading. In general,

(Continued on page 62)

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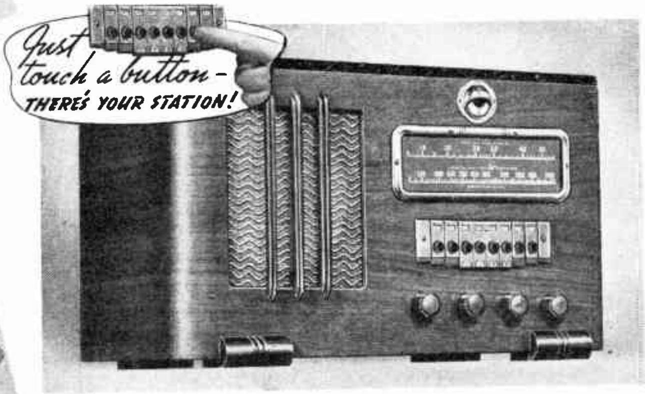

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(*Continued from page* 60)
the meter should be as accurate as possible, and have far more accuracy than that required of the parts being measured, because unless this is true, it will be impossible to determine the accuracy of the resistor with the equipment you have. In other words, to be able to detect departures of 10 per cent. in resistors it is necessary to have a precision ohmmeter, and the same holds for measuring condensers and coils, voltages and currents. No inaccuracy is the theoretical requirement, or, in practice, .5 per cent. would be passable. Hence erroneous meters are impractical, for the meter errors add to the parts errors, and real measurement ceases, and only a system of organized guesswork takes its place.

* * *

NEIGHBORLY DISPUTE

A DISPUTE has arisen between a neighbor and myself (nothing serious, you know) regarding whether what we buy from the electric company for running our receivers is power. We get bills from the company stating that we buy power (i.e., so many kilowatts), the concern itself is known as a power company, and I say we buy power, but my neighbor shakes his head wisely, smiles, and denies that we ever did, will or can buy power. What do you say?—W. D.

We dislike to get mixed up in these neighborhood disputes, but since you have invited us strongly enough, we feel free to state that your neighbor is right. Power is the time rate of energy, where energy may be considered as work done. It is obvious that you do not buy a time rate from the company, therefore what you must be buying is energy. The generators at the power plant produce the energy supplied to you and your neighbor, whereas power is only a way of reckoning the energy.

* * *

TUNING MOTOR HUMS

MY set has a motor for automatic tuning. When I press any one of eleven buttons a local station comes in. However, there is a hum when the motor is operating. During this period, short of course, no station is heard, yet I would like to get rid of the hum.—O. K. L.

The only ready solution is to insert a filter. The position of this filter, and the type to use, will have to be information obtained from the manufacturer of the set. As there are any number of different requirements for the many sets using such a tuning system, we can not give any data that will be strictly applicable to your case. However, if you will send in information of the model number and name of manufacturer of your receiver, we would be glad to obtain the required information and forward it to you.

* * *

EXPERIENCES ECHO

WHAT causes a sort of echo effect when I listen to a chain program on my sensitive superheterodyne?—W. C. S.

This may be due to the same program being on two stations on adjoining channels, some response being obtained in the receiver from both. The time lag difference in the lines used in connection with wire transmission could account for this. However, it has been noticed that in mistracked superheterodynes the trouble is sometimes experienced, whereas a receiver properly tracked, used in the same location, with same antenna, does not cause the trouble. We are at a loss to account for this aspect of the situation.

* * *

INDUCTIVE RESONANCE AVOIDED

WHAT is the object of putting a condenser and resistor in series, across the primary of the output transformer of a receiver (the coil that works into the speaker)?—I. D.

By adjustment of the values it is possible to eradicate the resonance effect of the speaker that is caused by inductive reactance. Thus the output may be fairly even for all frequencies, if other factors permit this. A check may be made by using an output meter and a variable audio-frequency oscillator of constant output. Put in a fixed condenser and vary the resistance, in the series circuit, until the output is flat, or as nearly so as possible, especially a strong peak reduced greatly. The resistance should not be too small, or too much power will be sacrificed. A suggestion combination of trial values consists of .03 mfd. and 4,000 ohms.

* * *

INVERSE FEEDBACK'S VALUE

WHEN inverse feedback is introduced into an audio amplifier, is there much sacrifice of sensitivity, and if so, is that type of a feedback advisable?—W. D.

The loss in sensitivity is rather substantial, but the gain in power output without increase of distortion, i.e., at the same distortion level as for the lower power output, makes the system fully worth while. Whether to include it depends in part on the set, as it is not used in very small receivers, of dubious tone quality and small power capabilities, anyway. But when a receiver is of significant proportions and performance, and power sensitivity is not then a controlling factor, undistorted power output capability becomes ruling, therefore inverse feedback is introduced as a simple means of attaining a desired end.

* * *

VALUE OF ARRESTOR

IS a lighting arrestor effective, or is it something that is theoretically attractive, like the lightning rod, and not of much practical use?—W. S.

The arrestor is effective, and its inclusion is required under the rules of the Board of Fire Underwriters, even though these rules are not observed as much as they should be. The lightning rod also is effective, as representing a conductor that the electric current may find the readiest path to ground, thus avoiding harm. The arrestor is connected between antenna and ground outside the receiver and gap-jumping is relied on for effectiveness of the device.

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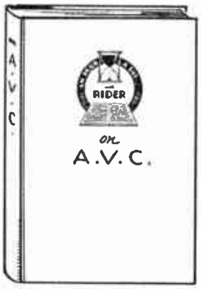

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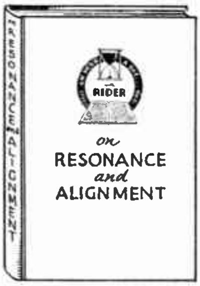

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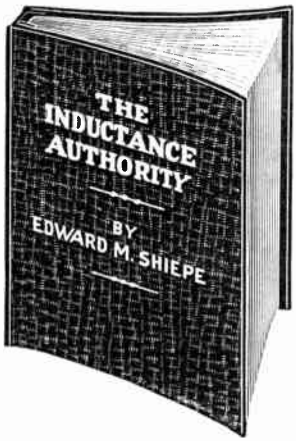

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