RADIO NEWS

Amateurs' Handibook

by the most eminent Radio Experts

Price $1.00

EXPERIMENTER PUBLISHING COMPANY, Inc.
NEW YORK

RADIO NEWS

Amateurs' Handibook

by the most eminent Radio Experts

A Selected Series of
Instructive Articles for
Both The Amateur and Layman

Vol. No. 1

4th Edition (25,000)

Experimenter Publishing Co. Inc. New York

Experimenter Publishing Company, Inc.

New York

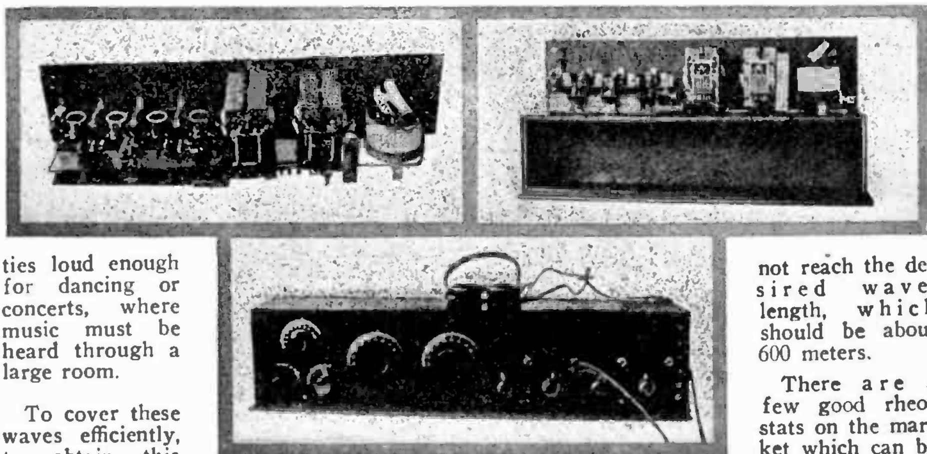
Printed in the United States of America

First Edition, November, 1923
First Reprint, February, 1924
Second Reprint, March, 1924
Third Reprint, May, 1924

A Typical Amateur Receiver

by **F. B. OSTMAN**

After the average amateur has gone through the days of simple crystal sets and one-bulb outfits, he looks forward to having a compact set, efficient on amateur waves and to cover all wave bands, including a few of the higher commercial waves, sufficiently powerful to operate a loud-speaker, or the desire for signal intensities loud enough for dancing or concerts, where music must be heard through a large room.



Top, Back and Front Views of the Amateur Receiver.

To cover these waves efficiently, to obtain this amplification and maintain the original quality of the signal it is necessary to observe a number of precautions in the selection, construction and operation of the apparatus.

Having had a number of years' experience with sets of home-made construction and used some of the best amateur apparatus manufactured, I decided on the construction of a complete receiver and amplifier along my own ideas.

To make a neat appearing set a little thought must be given not only to the appearance and design, but the placing of instruments from a practical standpoint in wiring up.

On the set described the rheostats, inductance switches, coupler dail and binding post are of a similar design, having a sloping knob; this uniformity adds much to the appearance.

A list of material, apparatus and parts used in construction is given at the end of this article.

It is possible, with a little care and workmanship, to make the variocoupler and variometers, but the prices for these well made instruments are low enough, considering the time involved in construction one saves by buying the ready-made instruments. There are a great many variocouplers and variometers on the market to choose from, but those costing a couple of dollars less are worth nothing, as they are poorly designed and constructed and do not reach the desired wave-length, which should be about 600 meters.

There are a few good rheostats on the market which can be bought for a little less than $1 each. When purchasing, one should be able to judge the good and bad points about the apparatus. The same applies to sockets; it is much better to pay 50 cents more than to take some composition thing for $1 which will melt when you solder up your set, if you get the iron within 6" of it.

Use only standard jacks and stay away from the trouble. An extra $1.50 to $2 expended on an amplifying transformer is well worth while, especially if one wants clear undistorted speech and music.

From the largest instrument to the smallest, as found by experience, the little extra money spent for the best apparatus produces results worth many times more than the saving.

No instructions are given as to design, construction and wiring, as builders usually follow ideas of their own on changes in these points.

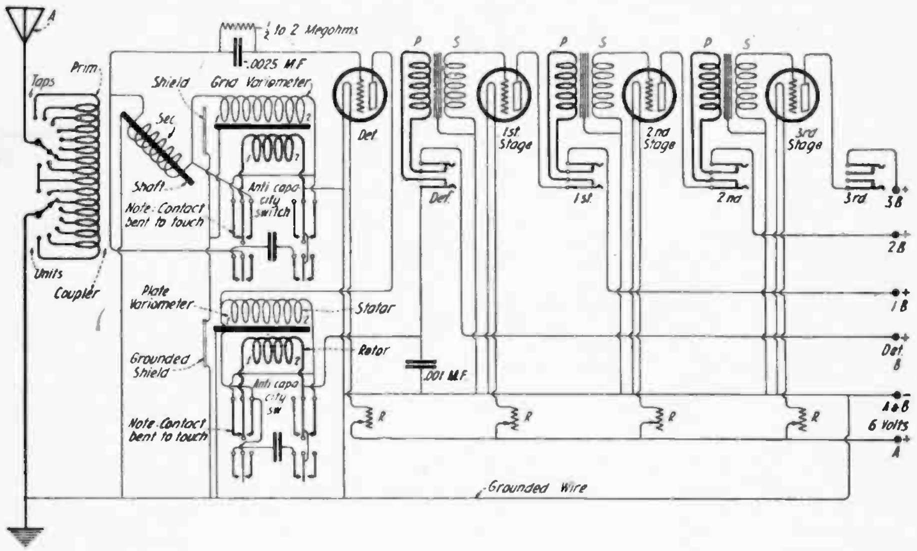
As can be seen in the accompanying photograph two Federal anti-capacity switches mounted on the back of each variometer are used for series parallel connections. (These can be mounted as shown or may be mounted so as to operate from the front of the panel.) Mounting them as shown was done because this secures the shortest length of leads; however, it is necessary to raise one side of the cabinet cover in order to change the switch. This is no trouble because the switch is not used very often, being, in my case, mostly set in the parallel connection for amateur stations.

For short waves, amateur length, the switch handle is thrown to the left as can be seen in the diagram. This connects the coils in parallel, which is ideal for tuning amateur stations. It is particularly desir-

Variometer windings in parallel, wave range 150 to 290 meters.

The switch in natural position, upright, brings the variometer windings back to series connection and this covers a wave band from 180 to 550 meters. It is in this position that the phone stations are best received.

The switch in position to the right, throws the small fixed condenser across secondary and grid variometer. The fixed condenser on the plate variometer is mounted edgewise on the plates 1"x5" separated by a very thin mica washer about the thickness of a piece of tissue paper to give the high capacity desired. The condensers shunted this way enable the grid and plate circuits to tune from 550 to 1,400 meters.



Complete Diagram of the Short and Medium-Wave Receiver with Three-Stage A. F. Amplifier.

able when tuning for C. W. stations, many of which are so sharp they are passed over when tuning with variometer in the usual series connection. The parallel connection allows better tuning on lower waves, which large variometers with series windings can not get down to. The same parallel connection on the plate variometer allows a more gradual control of regeneration.

It will be noted that with a series connection on a grid variometer having sufficient inductance to cover waves up to 600 meters, amateur stations operating on a small band above and around 200 meters would all come in one small section of the dial; this makes tuning very sharp and difficult, while with a parallel connection practically the whole dial is used to cover the same range.

Variometer windings in series, wave range 180 to 550 meters.

A variable condenser is shunted externally across the primary, which is necessary for waves above 750 meters. This is certainly a compact way to double the range of a regenerative receiver with such a simple arrangement and really increases the efficiency of the set, especially on the desired amateur waves because the variometers are working at their maximum efficiency over this certain wave band when coils are in parallel. The resistance of the circuit is reduced. The advantage, however, is purely a practical one, giving much more selective tuning between points on the variometer dial and greater selective control, thereby giving louder signals.

If the signal from the detector is of good quality and loud enough to be heard distinctly in the head-receivers, the chief problem is maintenance of the quality, as it is comparatively simple to obtain the necessary amplification.

Distortion is usually caused by poorly made or constructed amplifying transformers, operation of the amplifier on the tube at the wrong point of its characteristics, or by overloading the tube to the point of saturation.

Two or three amplifier tubes work best in cascade without overloading them. If desiring very strong signals, a small power tube used in the third stage with 250 to 300 volts on the plate, a grid voltage of about 15 to 20 volts negative, which will hold the plate current down to normal, operates the tube upon a straight portion of its characteristic if necessary. This is advised only if using a loud speaker of the Magnavox type.

Using a 2-stage amplifier with a loud speaker, more than sufficient amplification for a living room should be secured.

To further reduce distortion, tube noises, strays, etc., it is well to shield the coupler, grid and plate variometers and also ground the shafts and bearings of these instruments. Grounding the frames of the amplifying transformers and negative side of the "A" battery is also advised especially if the set is to be used for DX amateur work where quiet operation is desired.

In order to produce a combination receiver and amplifier to receive over this band of waves efficiently, operate a loud speaker and give pleasing results on DX amateur work, it is necessary to choose the various parts with care, mount instruments in such a way as to eliminate a criss-cross of wires which produce howling and other noises causing distortion and lessening the whole efficiency of the receiver.

It is well to use Empire tubing throughout when wiring. Black makes a very neat appearance. No. 14 hard drawn copper wire is easy to work with and very neat bus bar wiring may be made. By placing instruments as shown very short and direct leads can be had.

Solder all joints and connections but do not use too much solder as this makes a very sloppy appearance. Much trouble may be caused by using an acid flux, which will ruin the instruments and corrode the wires with which it comes in contact.

A neat cabinet adds much to the appearance of the set; these can be secured from many of the radio stores or concerns which make a specialty of this work.

Buy standard parts, construct and assemble them at home with a little care and workmanship and have the pleasure of seeing your own handiwork in operation.

The photographs show the complete receiver with just the ordinary regenerative receiver controls.

The cabinet is made of 5-ply ½" veneered quartered oak. The cover is in two sections, one opening over the regenerative side, to change the series-parallel switches, the other opening over the amplifier. Covers are set flush with the top of the cabinet and are raised by lifting small nickel insert rings. The hinges are nickel-plated piano hinges,

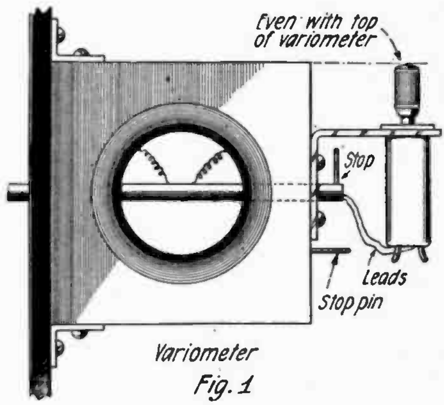


Fig. 1

How the anti-capacity switches are mounted on rear of variometers with small brackets. Mount out far enough to clear leads and stop pin when rotor turns.

which run the length of each cover, making a novel appearance with much rigidness to the cover and finished over in Flemish oak.

By purchasing standard parts, constructing and assembling the set at home, about one-half the price of the set is saved. With a little care and good workmanship a set which will operate as efficiently as the best on the market can be assembled with the satisfaction of seeing your own handiwork in operation.

WAVE-LENGTH RANGES

Grid Switch

To Left short-wave coils parallel	150 to	290 meters
Intermediate coils series....	180 to	550 meters
Right long-wave coils series cond. shunt	400 to	1,400 meters

Plate Switch

To Left short-wave coils parallel	150 to	290 meters
Intermediate coils series....	180 to	550 meters
Right long-wave coil series cond. shunt	400 to	1,400 meters

Plate Switch

Taps 1 units 5	Amateur waves.	
Taps 3 units 5	Phone broadcasts....	360 meters
Taps 4 units 5	....	450 meters
Taps 6 units 5	Commercial	600 meters
Taps 7 units 5	Commercial Bearings	800 meters
Taps 7 units 7	Navy	975 meters

Short Wave

Grid.	Apprx. Wave
60	190 meters
80	200 meters
100	225 meters

INTERMEDIATE

Grid.	Apprx. Wave
70	200 meters
60-80	360 meters
100	600 meters

LONG WAVE

Grid.	Apprx. Wave
40-45	600 meters
75-90	800 meters
90-110	975 meters
135-140	1,200 meters
160-180	1,400 meters

LIST OF MATERIALS

1 Bakelite panel 7"x30"x3-16".
1 Baldwin variocoupler.
2 Baldwin variometers.
1 small dial for coupler.
2 large dials for variometers, Paragon.
4 Fada receiving rheostats.
2 Fada inductance switches with contacts.
4 general radio sockets.
4 Federal Tel. & Tel. double circuit jacks.
3 Federal Tel. & Tel. amplifying transformers.
1 small fixed condenser.
1 Dubilier Grid condenser, .00025 mfd.
1 Marconi Grid leak.
8 binding posts, black hard rubber.
2 Federal No. 1424 anti-capacity switches.
5 lengths black Marconi tubing.
Material for Grid and plate loading condenser.
Bakelite shelf for tubes and transformers.
Cost of nickel plating parts.
Cost of machine bolts, screws, nuts, washers and miscellaneous hardware.
"Cabinet" wood ½" veneered quartered oak, 5-ply
2 nickel plated hinges, each 15" long.
2 nickel plated insert rings.
4 key slip side catches.
Sheet copper for shields.
Wire, solder and miscellaneous material used and construction.

A Radio Flivver

By Stanley Edgar

The expression "Flivver" was applied to a radio receiver, originated in the comparison made between the super-heterodyne and the single-tube super-regenerative receivers by the inventor of both circuits, Major Armstrong, in an address to the Radio Club of America. Major Armstrong reminded his audience that super-regeneration did not supersede all previous methods of reception and that the super-heterodyne, although it required eight or nine tubes to operate it, still remained the most efficient and easiest controlled method of amplifying short wave signals at radio frequency.

In discussing the super-regenerative receiver, however, he explained that the same degree of amplification could be obtained by the latter method with only one or two tubes, although not with the same ease of adjustment. The Super-Heterodyne, then, was the "Rolls-Royce method of reception" while the Super-Regenerator was the "Radio Flivver."

The author has named the set described herewith "The Radio Flivver" because, for its size and cost, it probably accomplishes more than any radio receiver in existence. It is an extreme example of the extraordinary amplification which super-regeneration makes possible with a single vacuum tube and a very small amount of apparatus.

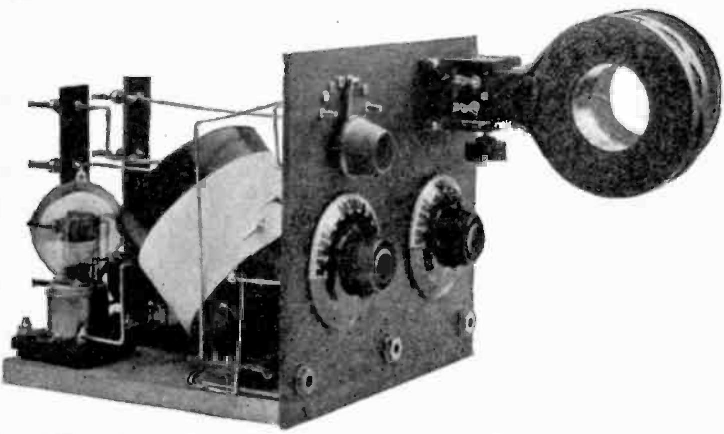


Fig. 1. A Striking View of the Unusual Compactness of the Radio Flivver Set. All the Apparatus Necessary for Operating the Set Is Shown in Fig. 2.

The set is wired as shown in Fig. 3. As indicated in that diagram and in the photographs, it is possible to receive on a loop and operate a loudspeaker by means of this small unit which requires only two vacuum tubes. It is claimed that the signals obtainable are astonishing. From our experience with the set, they are loud enough to be heard several hundred feet from the loudspeaker. It demonstrates in a convincing manner the enormous amplification which super-regeneration produces.

Fig. 2 shows a photograph of all the apparatus required to operate the Radio

Flivver. The loop, batteries and loudspeaker are all placed on a small table and the photograph clearly shows how small the receiver is when compared with the loop, which is three feet square, and the loudspeaker of a well-known type.

The filament rheostats were sacrificed in the Flivver set as they are not absolutely essential, especially with five-watt tubes. Inductive coupling is used between the two honeycomb coils to save the space and cost of the variable condenser and radio frequency choke coil of the capacity coupling system employed in other types of super-regenerators.

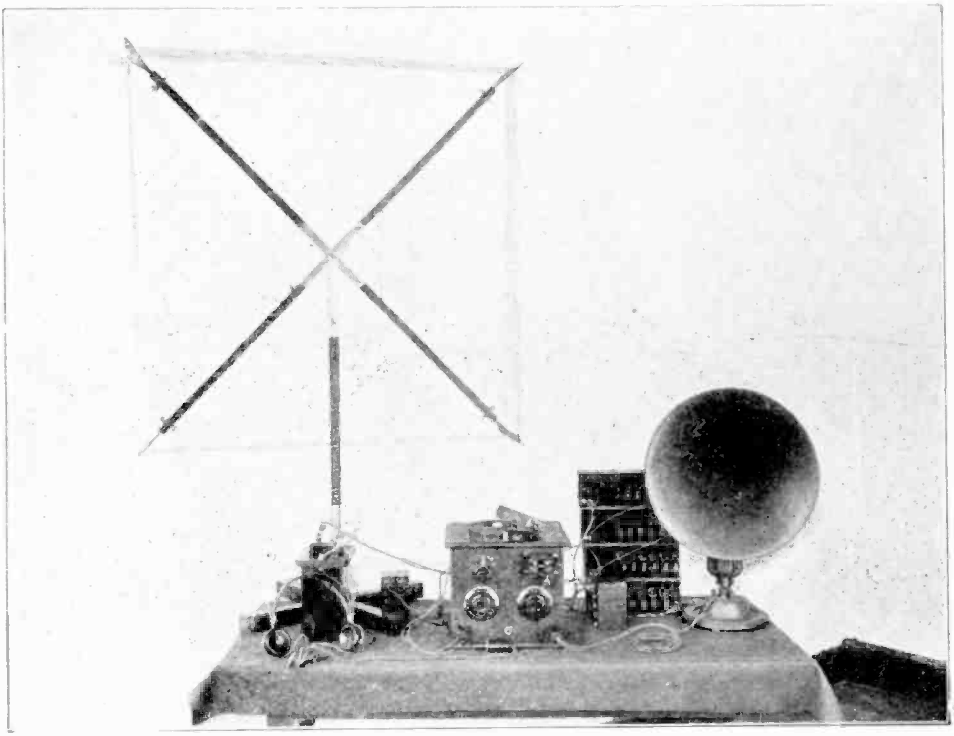


Fig. 2. A Close-up of the Radio Flivver, Indicating Its Extreme Simplicity. The Loop Is Plugged in the Left-Hand Jack and the Loudspeaker in the Right. Telephones May Be plugged in the Center Jack to Cut the Audio Frequency Amplifier Out of the Circuit.

There are only four controls to the set and after two of these have been adjusted for a particular wave-length the amplification is controlled by the coupling between the two honeycomb coils and variation of the condenser across the loop.

In designing this set the object was to produce a super-regenerative receiver which, with one stage of audio-frequency amplification, would operate a loudspeaker with the least possible amount of apparatus in as compact a space as practicable and with the smallest possible number of controls.

To decrease the size of the receiver and reduce to an absolute minimum the number of controls, no filament rheostats were used, a fixed frequency of variation was employed and inductive coupling used between the grid and plate coils of the second feed-back system to produce the low frequency oscillations.

Fig. 1, a photograph of the receiver itself, shows the unusual compactness and simplicity of this remarkable set.

The Circuit

If the wiring diagram of Fig. 3 is studied it will readily be seen that the Radio Flivver set consists of a single-tube super-regenerator with an additional tube for amplifying the output at audio frequency. When the telephones are plugged in the middle double-circuit jack, the audio frequency amplifier is cut out of the circuit.

The system of producing super-regeneration employed in this set has been discussed elsewhere. An ordinary regenerative circuit, with a strong feed-back coupling, is provided with a second feed-back system, represented in Fig. 3 by the coils L3 and L4, each shunted by a condenser. By means of this second feed-back system, self-generated oscillations of any desired frequency are produced in the circuits of the tube.

The alternations of current produced by the oscillations of this second feed-back system introduce variations into the regenerative amplifying system. The plate voltage is increased and decreased at a constant frequency. Similarly, the resistance of the grid circuit of the regenerative system is periodically increased by the grid-filament current which takes place during the positive half of every cycle of the self-generated oscillations. These two variations take place at the same frequency but in proper phase relation.

L3 ..Duo-lateral coil, 1250
L4 ..Duo-lateral coil, 1500
C1 ..Variable condenser, .0005 M. F.
C2 ..Fixed condenser, .002 M. F.
C3 ..Fixed condenser .001 M. F.
C4 ..Fixed condenser, .005 M. F.
C5 ..Fixed condenser, .005 M. F.
R1 R2 ..Two 12,000 ohms non-inductive resistors.
K1 ..Iron core choke coil (.1 Henry)
Tr ..Audio frequency amplifying transformer.
B1 ..Variable grid battery 3 to 15 volts
B2 ..Plate battery, 150 volts
B3 ..Plate battery, 45 volts
B4 ..Grid battery, 22½ volts
B5 ..Filament storage battery, 6 volts
Loop Closed coil aerial
- ..Bakelite panel, 8"x9"

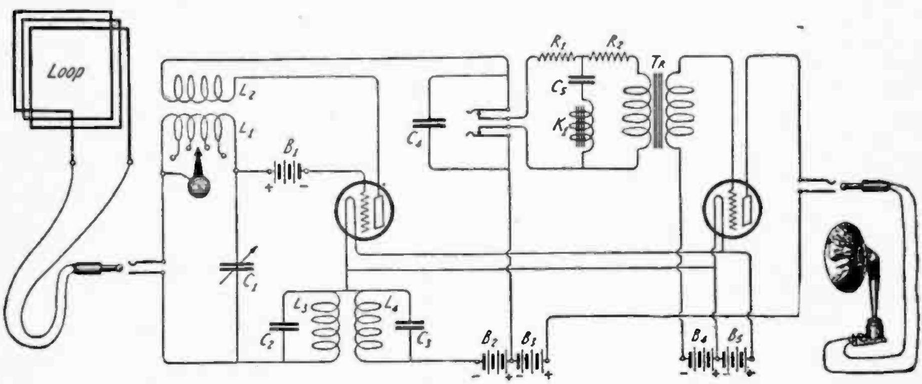


Fig. 3. Hook-up of the Super-Regenerative Set Described Herein. The Second Tube Is That of the Audio Frequency Amplifier. The Grids of Both Tubes Are Impressed with a Negative Potential from "C" Batteries.

The manner in which these variations of the regenerative system produce the enormous amplification of super-regeneration is rather complicated and will not be entered into at this time. The designer of the Radio Flivver set describes the theory of operation in considerable detail. In this explanation, however, it is made evident that this particular type of super-regenerator is only suitable for the reception of radio telephony, spark telegraphy and I. C. W. It is not suitable for the reception of straight C. W. telegraph.

Apparatus Used to Construct the Radio Flivver

The following is a key to the circuit of Fig. 3 and shows all the apparatus used in the construction of this receiver:

Ref. to Fig. 3 Article.
LI ..Vario-coupler Primary (50 turns, tapped every tenth turn)
L2 ..Vario-coupler Secondary (100 turns)

- ..Two bakelite binding-post strips, 7"x 1"
- ..Two open circuit jacks
- ..One double circuit jack
- ..Switch set (switch lever, six contacts and two stops)
- ..Two telephone plugs
- ..Two vacuum tube sockets
- ..Eight binding-posts
- ..Wooden base, 8½"x8"
- ..Duo-lateral coil mounting
- ..Cabinet to enclose receiver
- ..Two dials
- ..Two vacuum tubes
- ..Loudspeaker

Standard materials of the values given above were used by the designer in the construction of this set.

The wiring is shown in detail in Fig 3. The binding-posts, which were employed as the eight terminals of the batteries which appear in this diagram, were attached to two strips at the back of the receiver. These bakelite strips appear in the photograph of Fig. 1.

Method of Operation

In operating the Radio Flivver it was found that five watt tubes gave the best results. With these tubes, 150 to 175 volts were used at the plate battery potential for the regenerative amplifying tube and sufficient voltage added to apply 200 volts to the plate of the audio-frequency amplifying tube in the manner shown in Fig. 3. Six or seven turns on a loop three feet square with ten or twenty active turns in the primary of the vario-coupler were found to be about the correct values for the reception of 360 and 400 meter waves. Close tuning of the loop and grid circuit is obtained with the variable condenser across the grid circuit.

The proper value of grid battery was found to be important. From 6 to 9 volts were used as the potential for the grid battery of the first tube while a 22½ volt biasing battery was employed in the grid circuit of the audio-frequency amplifying tube.

Referring to the photograph of Fig. 1 the upper left hand switch lever short-circuits portions of the primary inductance of the vario-coupler. When the proper adjustment for any wave-length is obtained, it is not necessary to again change the position of this switch.

The dial below the switch controls the rotor of the vario-coupler and therefore controls the feed-back of the regenerative amplifying system.

At the upper right of the panel are the two large duo-lateral coils in their variable mounting. The lower right hand dial controls the condenser across the grid circuit and tunes this circuit to the frequency of the incoming signal.

To the amateur who is learning to operate a receiver of this type, it is suggested that he employ the size of loop and values of batteries given above and proceed as outlined below.

Plug the loop in the left hand jack shown in Fig. 1 and the telephones in the center jack.

Short-circuit all but ten turns of the primary of the vario-coupler with the switch lever.

Loosen the coupling between the duo-lateral coils until they are almost at right angles to each other.

Connect all batteries to the binding posts at the rear. A high pitched continuous whistle should immediately be heard in the phones. If this whistle is not present bring the two duo-lateral coils together and change the value of the grid battery B1 to start the oscillations.

The lower left hand dial, controlling the rotor of the vario-coupler should then be turned until a click and roar are heard in the phones.

Tests should then be made for reception on signals from a near-by station or a wave meter.

Decrease the coupling of the regenerative system with the lower left hand dial. Then turn the right hand dial until the grid circuit is tuned to the frequency of the incoming signals which should be audible in the telephones. Increase the coupling of the regenerative system with the left hand dial until the point of maximum amplification of signals is obtained. Then gradually tighten the coupling between the two duo-lateral coils until a certain point is reached when great amplification takes place. Very careful adjustment of the coupling between the duo-lateral coils and the position of the rotor with the left hand dial should be made simultaneously to find the proper degrees of coupling.

If the telephones are then removed from the center jack and the plug from the loud-speaker inserted in the third jack the signals should roar in with terrific volume. It may be necessary to make minor adjustments to obtain purity of tone.

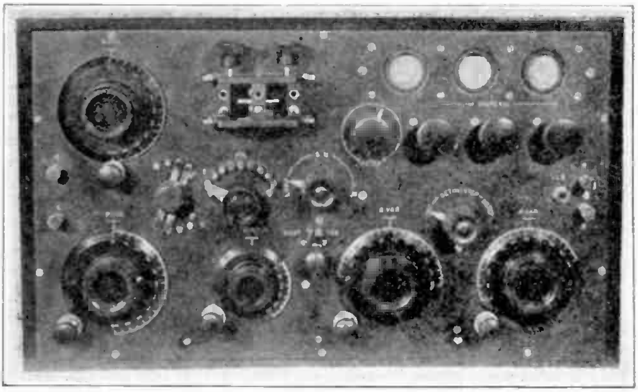
The operation of the Radio Flivver set requires some practice but a little perserverance is well rewarded by the extraordinary amplification it produces.

A Universal Receiver

***By* Louis J. Gallo**

In describing this tuner, it would be well to first mention its possibilities. The knob with pointer marked Loop—S.W.—L.W. is a Storm Lee Multiplex switch and is used to effect the changes made; while at Loop the secondary honeycomb coil must be omitted. This arrangement, together with the Tickler and Short switch makes it posible to use an outside tuner on the same detector and amplifier as the aerial and ground terminals are then connected directly to the Grid and Filament with the two .001 condensers still in the circuit, one across and the other optional, either in series or parallel. These condensers are also automatically put in the primary and secondary of the S.W. and L.W. The other Multiplex switch is connected in the usual manner to the detector and amplifier with the exception of splitting the amplifier "B" batteries, that is, the first tube draws 60 volts while the second 200 volts for consists of the customary variocoupler and two variometers with condensers and the L.W. honeycomb coils.

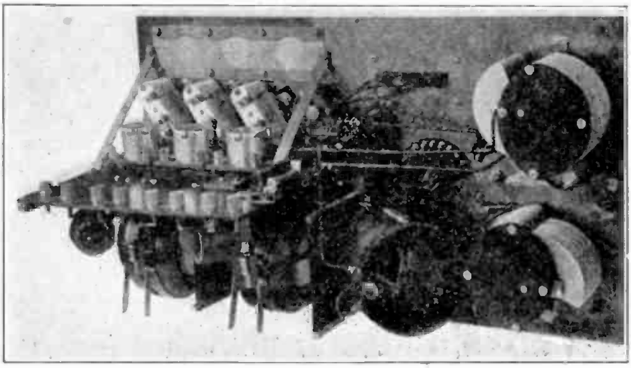
In building a set like this, it is well to use the best material, for, at the most, the cost will not exceed $100 and it is a tuner worth having. Parts required for it are as follows:



Front View of the Universal Receiver.
This Set Will Cover a Wide Band of Wave-lengths, Switches Being Provided for the Necessary Changes.

power; while using a Magnavox, power tubes can be used up to 2.5 amp., as the Bradleystats can take care of this amount of current; also the last socket should have an extra slot cut in it to provide for other tubes. The jack marked L.S. is for input of of Magnavox; when this plug is inserted, the phone terminals are automatically disconnected and the circuit to the fields of the Magnavox closed. This makes a very neat arrangement, as it is impossible to forget the fields all night, and whether the plug is forgotten or not, if the detector bulb is extinguished, so is the field circuit opened. The beauty of this can also be appreciated by tuning in with phones and in one operation put on the loudspeaker. The S.W.

2 .001 V Condensers, Electron Co.
2 Variometers, Remler.
1 Variocoupler, Remler.
1 3-Coil Mount, any make.
3 Sockets, Optional.
3 Rheostats, Bradleystats.
1 Potentiometer, Paragon.
1 Pri. switch with tap.
1 Small switch, Remler.
2 Multiplex switches, Storm Lee.

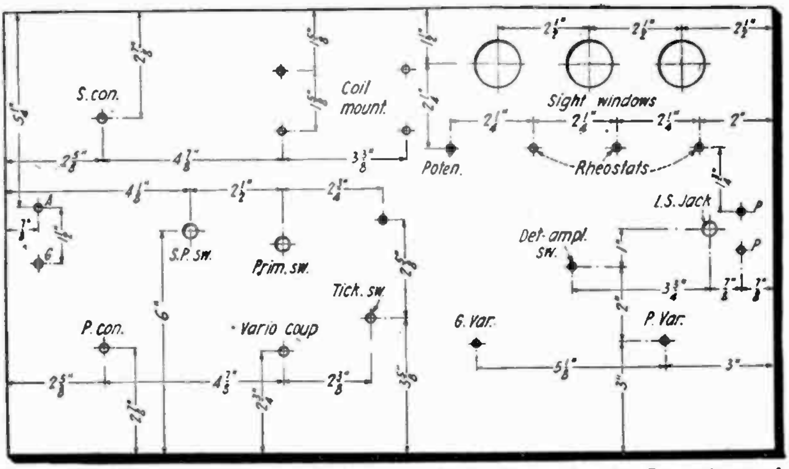


Rear View of the Completed Receiver. A Detector and Two Stages of Audio Frequency Amplification are Employed.

1 Fil. Control jack, Federal.
2 Audio Transformers, Acme unmounted.
1 Grid Leak & Con., optional.
4 4" Dials, Tuska.
1 3" dial, Tuska.
5 Verniers, Arkay.

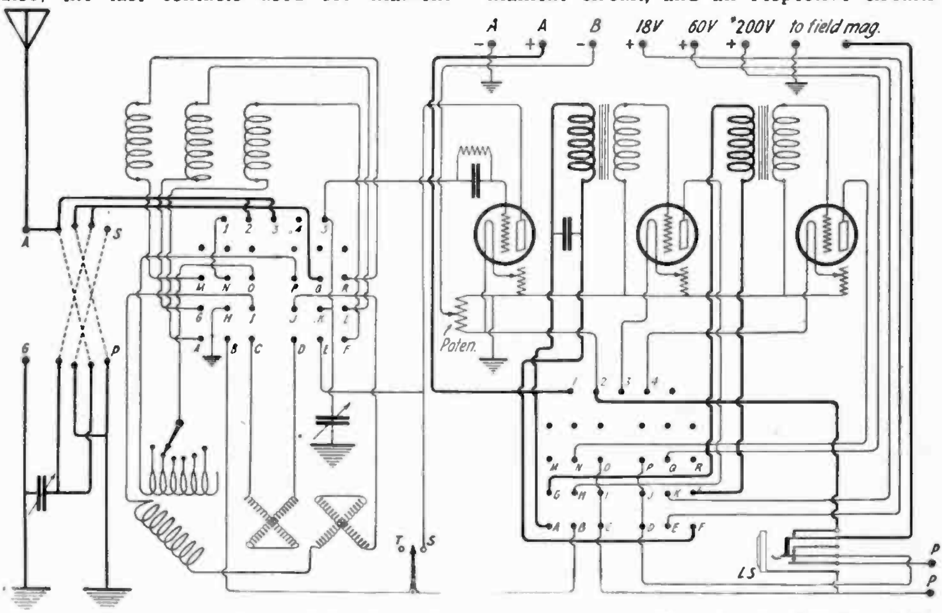
12 Binding posts, optional.
1 pc. ¼" Bakelite 12"x21".
1 pc. ⅛" Bakelite 4½"x9½".
50 Strip .5000 shim brass.
30 ⅜" square brass rod.
Screws, nuts, tubing, etc.
Cabinet.

by purchasing one and studying it a while. The other remains the same, but must be mounted in a slanting position if Bradley-stats are used for minimum of space. The brass shielding is placed over the entire back of the main panel and is put on in the same manner as tinfoil. The reason for



Panel Layout of the Described Set. Details are Clearly Shown for the Convenience of the Prospective Builder.

The multiplex switch for Loop—S.W.—L.W. must first have the cams changed; also, the last contacts used for filament using brass is obvious; it serves as a main bus line carrying the ground and negative filament circuit, and all respective circuits



Complete Circuit of the Universal Receiver. Switching Arrangement Allows for the Selection of the Conventional Three Circuit Tuner or Honeycomb Coils. Detector and Amplifier Are Also Controlled by a Switch Instead of the Usual Jacks.

must be changed, the last one being taken out and advanced one space further than originally. This can be better understood are connected directly and as short as possible to it, it being able to withstand soldering. This is impossible with tinfoil. Lots of wiring is saved by this method and the result is a much neater job. The supports for the cross shielding and sub-panel are made from the 3/8" square brass rod drilled and tapped at one end. The two for the shelving should be 9¼" long, and all should be connected electrically to the main shielding. This sub-panel can be made to any desired dimensions, but should not be more than 9½" long and the outer edge should be screwed to the ends of the supports. Using the material mentioned the dimensions are correct. The sockets are mounted on a cross length of this rod and the transformers are suspended from the bakelite, as far as possible from one another.

On the main panel all exposed screws are flat heads, their respective holes being countersunk carefully and all exposed metal parts are nickelplated, with the exception of the mesh covering sight windows, which is silverplated so as to stay white longer.

For the engraving, as these figures are not standard and as to have them made would be very costly, it is well to make the templates yourself. Procure a quantity of 1-16" annealed brass sheeting, borrow a set of ½" steel dies and a small cold chisel about 3-16" wide and go to it. You may spoil one or two at the beginning, but with very little practice it will be found comparatively easy. When the set is finished some local dealer will let you have the use of his pantograph engraver for a small sum. It should be adjusted to a ratio of 2 to 1 which will leave about a ¼" lettering finished and just right. The usual manner of filling in is then applied and when dry enough, the whole panel is given an oiled and rubbed finish.

In the panel drawing lay-out, there is only shown the shaft holes and main screw holes so as to guide a possible builder, but as he will probably use other makes of instruments, the fitting holes will have to be figured individually. It is advisable to buy all materials before attempting to drill holes, as this enables you to place it more correctly and saves the bother and ugliness of the useless ones.

The cabinet was built of ⅛" oak and stained dark. It was constructed so that the face of the panel fitted flush with the edge of the cabinet, leaving a border around ⅛" oak which gives the set a substantial and commercial appearance. The inner compartment measures 9"x5"x6" and holds a complete set of Giblin Remler Coils.

A Radio Frequency Receiver

By Wayne R. Jamison

To-day radio frequency amplification seems to be one of the greatest steps in the advancing art of radio. It does what was formerly considered impossible, namely it doubles at least the receiving range, improves the quality of speech and music, sharpens tuning, decreases tube noises, and makes the use of a loop aerial practicable.

The set described herewith consists of a two-step radio frequency amplifier, short-wave regenerative receiver and detector. It is the ideal installation for both the concert listener and the "DX" fiend, for it brings in distant stations loudly and clearly and at the same time provides the sharp tuning needed on amateur and broadcasting work, due to the fact that it contains two separate tuners, a combination that will weed out almost any QRM. It may also be used with a loop aerial, and with the additions of a two-stage audio frequency amplifier will furnish sufficient strength of signals to operate a loud speaker.

The list of parts needed are as follows:

1 Bakelite panel 12"x21"x3-16".
1 Bakelite panel 8"x21"x3-16".
1 piece of 3½" tubing, 1-16" wall, 4" long.
½ lb. No. 20 D. C. C. wire.
5 Fada inductance switches.
3 Fada rheostats.
3 R. C. A. tube sockets.
1 Federal anti-capacity switch.
9 Fada binding posts.
2 Atwater-Kent variometers.
1 Atwater-Kent vario-coupler.
8 Nickeled switch stops.
30 Nickeled contact points.
2 Radio Service Laboratory transformers, Type RT-6 and RT-6A.
2 R. C. A. potentiometers,
1 Dubilier grid condenser, .00025 mfd.
2 4" Somerville dials.
1 3¼" Somerville dial.
1 Vernier condenser.
6 ft. spaghetti.
Brass for shielding and angle brass.
Miscellaneous; nuts, bolts, etc.

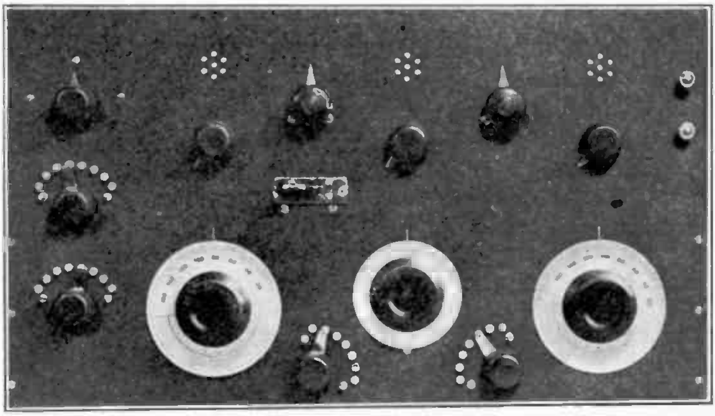
It is not essential that the above-mentioned makes of apparatus be used, but it was found that they worked well together. It has also been suggested that Moorehead tubes be used, but whether they are more efficient in this type of circuit is left to the builder. It was also found that the Radio Service Laboratories transformers were more efficient than the U. V. 1714 shown in the photograph. The hook-up has been drawn to include the first mentioned type, and they should be located at the places indicated by an "x" on the drawing.

It will be noticed that in the layout no exact measurements are given, but merely center lines for the location of parts, as it was thought that other types of apparatus than those mentioned might be used, when specific dimensions would only prove inaccurate and confusing.

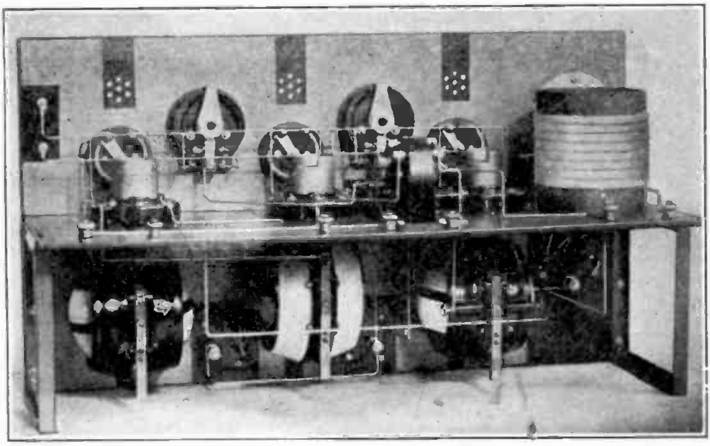
The main panel is divided into two parts by the sub-panel, which is supported on brass frames 5¾" high by 6" deep, made of ½" angle brass, 1-16" thick. These frames are held to the panels with flat head 6-32 machine screws.

On the lower half of the main panel are mounted the two variometers and the coupler, together with the necessary units and multiple switches. The coupler is in the center with the grid variometer to the right and the plate variometer to the left. The right hand switch is multiple, and the left, units; both increasing in value as they are moved down.

Above the sub-panel are the three rheostats, two "A" battery potentiometers and the anti-capacity switch. The first amplifier is to the left, then the second, and the detector is to the right. The right hand potentiometer controls the "B" battery potential and the one to the left acts as a stabilizer. The anti-capacity switch is for throwing in the detector. When thrown to the left, it connects the amplifier in circuit, but when to the right the detector alone is used.



The Two-Stage R. F. Amplifier and Regenerative Receiver.



Rear View of the Shielded Panel and Neat Wiring Arranged for Minimum Stray Capacity.

At the extreme left is the single circuit tuner for tuning the amplifier. At the top is the vernier condenser, below, the units switch, and at the bottom the multiple switch.

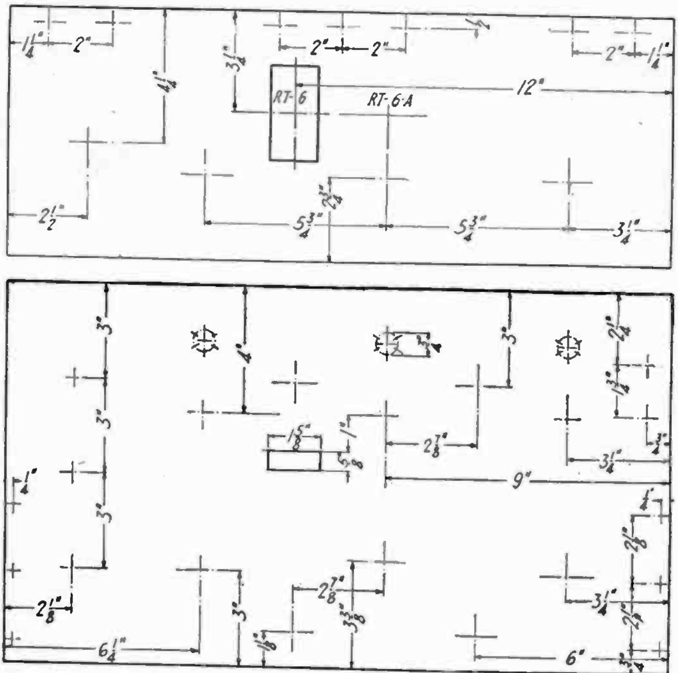
On the sub-base are mounted the three sockets, binding posts, transformers and coil for the single circuit tuner.

Construction

The first step in the construction is to square up all the panels. Then locate the position of all holes with a square and scriber, and fix their position with a center punch. Use a sharp drill, and do not bear too heavily on the work; turn the panel over and drill from the opposite side when the drill begins to come through. The square hole for the anti-capacity switch can be made by first drilling a row of holes around its edge and smoothing off the rough spots with a file.

When both panels have been drilled, give one side of the main panel a good grain, by rubbing it with No. 0 sandpaper and oil, always being careful to make all your motions parallel to one side of the panel. Then wipe off the oil, clean out the holes and polish the panel with a clean cloth.

The next step is to make the coil for the tuner. About 1" from one end of the tubing drill two No. 50 holes about ½" apart. Put the end of the wire down through the one and up through the other, leaving several inches sticking out for making the tap. Wind seven turns and take off a tap, and repeat until seven taps have been made. Then tap every turn for eight turns. Drill two more holes at the end of the winding and thread the wire through them to keep it from loosening. Three-eighths of an inch from the bottom drill three holes, 60 degrees apart, with a No. 27 twist drill. Make three brackets of brass, to the dimensions shown in the drawing, and fasten them to the tube with 6-32 round head screws. You are then ready to assemble the parts.



Layout for the Main and Sub Panels of the Radio Frequency Receiver.

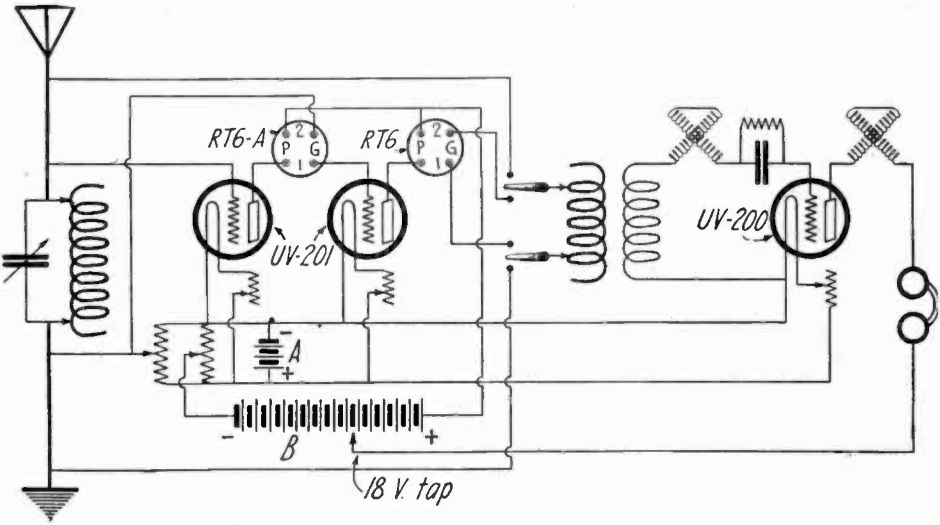
First cut a piece of thin sheet brass the same size as the main panel and cut out carefully around all shafts, bushings and contact points. Do the same for the sub-base, except that it should be 2" narrower than the actual base. When the shielding is in place it should not touch any parts of the electrical circuit.

Then mount the parts with the brass shielding between them and the panel. On the sub-base the brass is placed on the under side. Both panels should be assembled separately, and when mounting the sockets see that the two amplifiers are arranged with the P and G terminals back and the detector with F and P to the rear, as it will simplify the wiring greatly. Fasten the brackets to the panel and slide on the sub-base, fastening it with 6-32 flat head screws.

Wire the vario-coupler primary and the single-circuit coil first, running all wire in spaghetti. Also put on the wire from the secondary of the coupler to the grid variometer, as it is difficult to reach, once the other wiring is in place.

be corrected before a valuable tube is ruined. Test all parts of the circuit to make certain that they do not come in contact with the shielding.

Connect the "A" battery to the posts on the front of the panel, positive at the top



Hook-up of the Radio Frequency Receiver. By Means of Two SPST Switches Only The Regenerative Set May Be Used. The Tubes May Be of any Suitable Make, Such as Radiotron, Cunningham, etc.

and negative at the bottom. On the subbase the two posts behind the coil are for the aerial and ground, the next three for the "B" battery, and the last two for the phones.

All the other wiring should be done with No. 14 tinned copper wire. Wire the "A" battery circuit first, and the remainder may then be put in place. Be careful to keep all grid and plate leads from running parallel as that invites trouble. Speaking in regard to trouble, a few remarks about soldering will not be amiss, as poor connections are one of the greatest causes of the undesirable noises.

See that the parts to be joined are perfectly clean and free from grease, then apply a *very small* amount of non-corrosive paste to both parts. Have the iron hot and *hold it on the joint until the solder flows evenly.* A good joint means good reception and the opposite means equally bad results.

If the builder wishes to improve the appearance of the outfit, he may mount it in a cabinet made of ½" oak. Give the cabinet a good coat of stain and filler, and apply two coats of furniture varnish; allow a day for drying between each. Rub, when dry, with pumice stone and water, rinse, and rub with a rag moistened in linseed oil. Polish with a clean rag and you have a finish that will not finger mark and one that will stand all the abuse you can give it.

Operation

After the set is completed, go carefully over the wiring, so that any mistakes may

Hard tubes should be used for the amplifiers and a soft one for the detector. About 60 volts for the amplifiers and from 18 to 22½ volts for the detector are proper plate voltages.

This set has a number of peculiarities that make it different from the ordinary run of tuners, and while it is not so difficult to operate as the unstable Armstrong circuit, yet good results can be obtained only after you have become thoroughly familiar with its operation.

Using this set in Pittsburgh where operating conditions are very adverse, the following stations were heard:

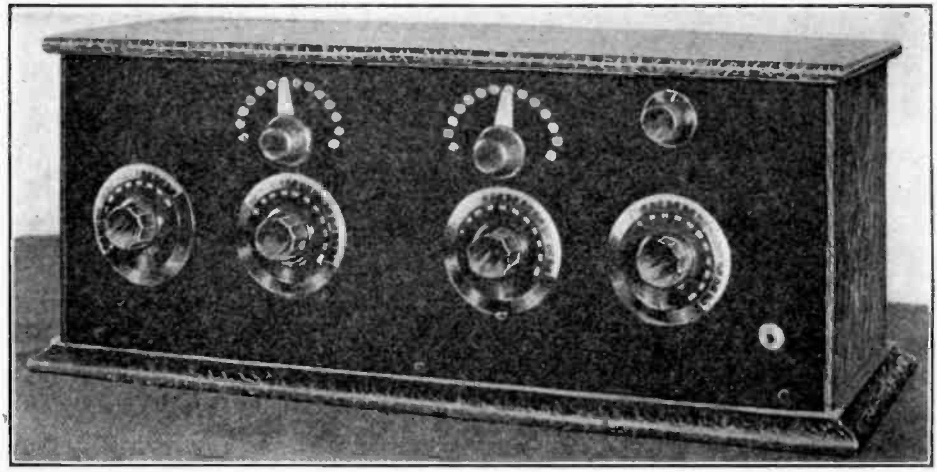
CWX—Havana, Cuba
WKY—Oklahoma City, Okla.
WMAT—Duluth, Minn.
WHB—Kansas City, Mo.
WLAD—Minneapolis, Minn.
WSB—Atlanta, Ga.

and other stations too numerous to mention here. Without exception, these stations came in clearly and distinctly and were not in the least interfered with by local QRM that is usually raging.

A Multi-Range Regenerative Receiver

By **Kenneth Harkness**

In the following description the author has endeavored to explain how to construct a loose coupled receiver of the regenerative type covering wave-lengths from 170 to 3400 meters.



Front View of the Receiver Showing the Neat Arrangement of Controls. All binding Posts Are in the Rear Thereby Eliminating Unsightly and Bothersome Connections in Front.

In the discussion of the respective merits and demerits of direct-coupled and loose-coupled tuners the radio amateurs are divided into two camps. There are those who swear by the former and the others who laud the superiroity of the latter.

There is something to be said for each side. The chief argument in support of the single-circuit tuner is its simplicity of tuning. There is a smaller number of controls which greatly simplifies the operation. It is easier to pick up signals and tune them in to maximum sensitivity.

While the loose-coupled tuner has more controls and is therefore more complicated to tune, the great argument in its favor is the resulting selectivity. It is also claimed that the loose-coupled receiver is less affected by static and atmospheric strays. The reason for these advantages of the loose-coupled tuner is easily understood.

Both the antenna circuit and the secondary circuit are tuned to the incoming signal. Regeneration greatly increases the energy in the secondary circuit and the coupling between the primary and secondary circuits must be made very small to maintain resonance. Therefore, while forced oscillations may be set up in the antenna circuit by passing radio waves of different frequencies, these do not affect the secondary circuit which is tuned to the desired frequency and very loosely coupled to the antenna circuit.

The receiver illustrated in the photographs possesses all the advantages of the standard loose-coupled regenerative receiver with the additional advantage that it is operative over a wave-length range from 170 to 3400 meters. While this feature might result in a loss of efficiency on the short wave-lengths in a receiver of improper design, the manner in which the inductances are wound prevents this loss. To construct this loose-coupled receiver two multi-range couplers are required. The specifications of this type of coupler which greatly simplifies the construction of a short and long wave set are given as follows:

The main inductance is wound in two sections on a bakelite tube 4" in diameter and 6" long. One section is wound single layer for the reception of short waves. The other section is spaced ½" from the short wave portion and consists of a three layer bank wound inductance. It is this method of winding and the spacing between the two sections which prevents loss of efficiency on short waves.

The short wave section is wound with 60 turns tapped every tenth turn and the long wave section is wound with 210 turns tapped every 30th turn. The rotor is wound on a bakelite tube 3" in diameter and 2" long with 46 turns of wire. The rotor revolves inside the short wave portion of the main inductance and the shaft is set at an angle to permit a 180-degree variation of coupling. All windings are made with No. 22 double silk-covered wire.

In the direct-coupled tuner the rotor is used as the "tickler" coil to produce regeneration but in the loose-coupled tuner two couplers are required and the rotor of the first is used to couple the two circuits while the rotor of the second is the "tickler" to produce regeneration.

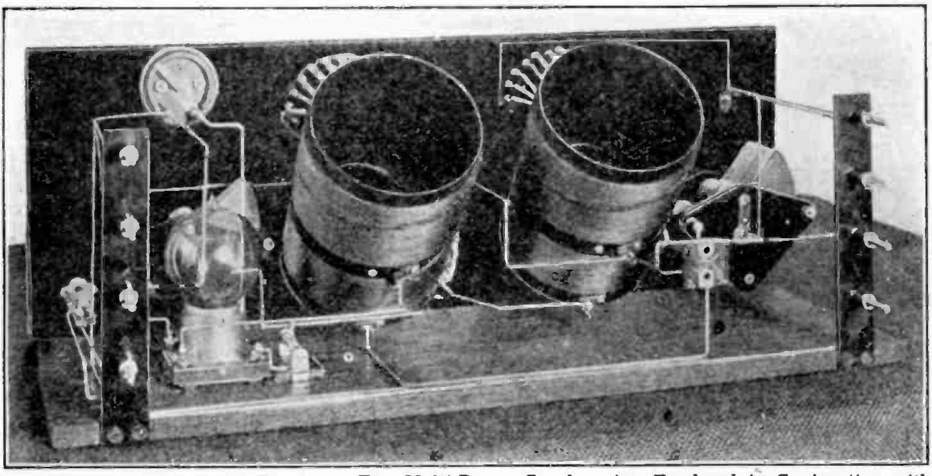
If reference is made to the back view of the completed receiver and to the wiring diagram the method of operation will be clear. The antenna circuit consists of the short and long wave portions of the first coupler with a .001 M. F. variable condenser in series for close tuning. Coarse tuning of the antenna circuit is obtained by short-circuiting portions of the tapped inductance by means of the switch.

Very fine adjustment of the coupling can also be obtained by means of the 180-degree variation. Coarse tuning of the secondary circuit is obtained by short-circuiting portions of the tapped inductance with the second switch and fine tuning by means of a .0005 M. F. variable condenser shunted across the circuit. Regeneration is obtained with the rotor of the second coupler connected in series with the plate circuit of the system.

A loose-coupled multi-range regenerative receiver is somewhat more expensive to construct than the direct-coupled type as it requires more parts but it is our opinion that the resulting selectivity in tuning is worth the additional cost.

The parts required for the construction of this receiver are as follows:

1 Bakelite panel, 21½" x 8" x 3/16".
1 Wooden base, 21" x 7½" x ⅛".
2 Bakelite terminal strips, 7" x 1" x ⅛".
2 Multi-Range Couplers.
2 Switch sets (including 2 switch levers. 24 switch points and 4 switch stops).
1 Variable condenser (.001 M.F.)
1 Variable condenser (.0005 M.F.)
1 Filament Rheostat.
1 Vacuum tube socket.
1 grid condenser (.0005 M.F.)
1 grid leak (2 megohms).
1 Phone condenser (.002 M.F.)
1 Double-circuit phone jack.
8 Binding-posts.
4 Dials.
1 Cabinet.



Rear View of the Complete Receiver. Two Multi-Range Couplers Are Employed in Conjunction with the Necessary Condensers. Note the Neat Appearance by the Bus Bar Wiring.

The secondary circuit consists of the short and long wave portions of the second coil in series with the rotor of the first coil. Coupling between the two circuits is obtained with this rotor and the coupling can be maintained at a very low value.

Assembling the Receiver

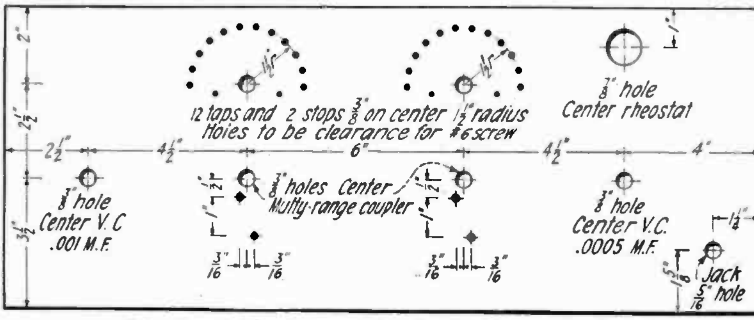
The photograph of the back of the receiver and the plan of the front panel clearly show the method of constructing this set with the foreging parts.

In the plan of the front panel we have indicated only the center holes of the apparatus as the positions of the mounting screws vary in different types of apparatus.

The front pannel can easily be drilled by the constructor himself with a hand-drill the cabinet and the binding-post tops are screwed down on wires connecting to the batteries.

Notes on Wiring

With the apparatus all assembled the wiring is completed as shown in the diagram.



Layout and Measurements for the Drilling of the Panel

and finished with sand-paper and oil. The two multi-range couplers should then be screwed in the positions indicated in the photographs and the wiring between the taps on the couplers and the switch points completed. This should be done with flexible wire covered with tubing. The wiring to the switch points should be made so that when each switch lever is on the first stop both inductances are completely short-circuited. In this manner, as the switch levers are turned to the right the value of inductance in the circuit and correspondingly the wave-length increases. The first few stops of the inductance switches will therefore control the shorter wave-lengths and these points should be wired to the short-wave portions of the inductances. The short-circuiting wire from the center of the switch lever to the last switch point should be of "Litz" to permit the switch to revolve.

With the wiring from the couplers to the switch points completed, the two variable condensers, the rheostat and the phone jack should be secured to the front panel as shown and the front panel screwed to the wooden base. The tube socket and grid condenser should then be screwed to the base as indicated.

The binding post strips are each drilled for four binding-posts equally spaced and two counter-sunk holes are drilled at the end for screwing them to the base. The terminals are made up of stock parts. The screw is an 8-32 measuring 1⅛" in length. Over each screw is slipped a fibre spacer ½" long, which is tightened down with a nickel-plated 8-32 tapped spacer. The screws project through holes in the back of

Referring to the back view photograph, the four terminals at the right-hand side are connected, from top to bottom, to the aerial, ground, negative and positive of the plate battery respectively. The four terminals at the left, from top to bottom, are for the output (two terminals) the negative and positive of the filament battery respectively. The two output terminals are connected to the center-points of the double-circuit jack. By connecting the terminals in this manner an audio-frequency amplifier can easily be added to the receiver as the four terminals are in the proper position for connecting to it.

In wiring to the rotors of the couplers it is necessary to connect the wires in the proper direction as, with the 180-degree type of coupler, revolving the rotor does not reverse the direction of current through the rotor. If the plate current does not pass through the rotor of the second coupler in the proper direction, it will be impossible to obtain oscillation. If there is any uncertainty as to the proper method fo wiring the rotor the constructor should make these leads with temporary wiring and test for oscillation. If oscillation is not obtained in one direction the two leads to the rotor should be reversed.

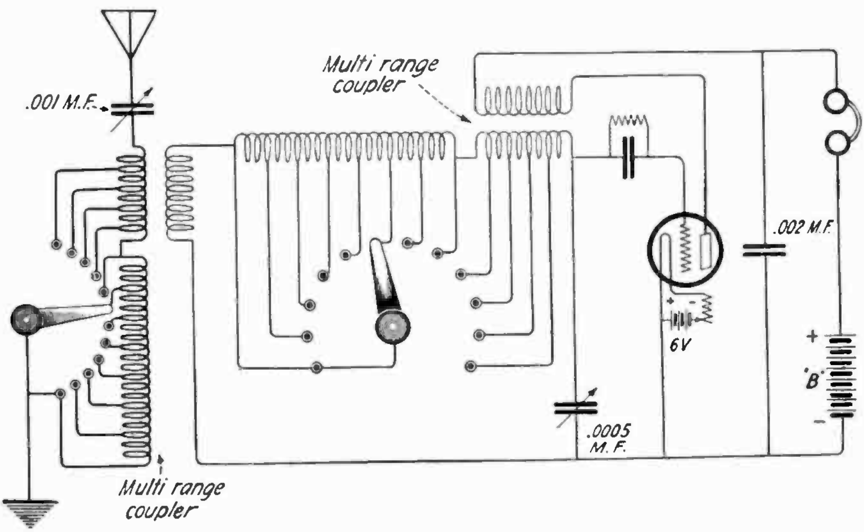
The wiring should be made with hard-drawn copper wire. The buss-bar method is the simplest and most efficient. It is not necessary to use insulation if tinned wire is employed. All joints should be carefully soldered.

Method of Operation

The operation of this receiver is somewhat more complicated than the direct-coupled type but can easily be mastered. It should be remembered that there are two separate circuits to be tuned to the incoming signal, the antenna circuit and the secondary circuit.

Referring to the front view of the receiver, the antenna circuit is tuned by means of the first inductance switch and the dial at the extreme left which controls the condenser in series with the antenna circuit. The secondary circuit is tuned with the second inductance switch and the dial at the extreme right controlling the condenser across the secondary circuit. The left-hand center dial varies the coupling between the primary and secondary circuits while the right-hand center dial controls regeneration or produces oscillation.

maximum position and the rotor of the second coupler turned until the circuits commence to oscillate. The extreme left and extreme right dials should then be revolved simultaneously until the heterodyne whistle of the transmitting station is heard. The "tickler" should then be decreased until the circuits stop oscillating. If finer adjustments are then made with both tuning condensers and the tickler the signals will be loud and clear. In most cases it will be unnecessary to make further adjustments but if interference is present the circuits can be made more selective by reducing the coupling between the primary and secondary circuits with the left-hand center dial. As the coupling is reduced



Circuit Diagram of the Described Set. By the Use of Two Couplers Flexibility of Control Is Accomplished, While Regeneration Is Obtained by the Usual Tickler Method.

To pick up a signal or while "standing by" the coupling between the primary and secondary circuits should be at maximum and the two circuits tuned to the approximate wave-length to be received. After a signal is picked up and it is desired to exclude other stations which may be interfering the coupling should be decreased and corresponding adjustments made of the two circuits.

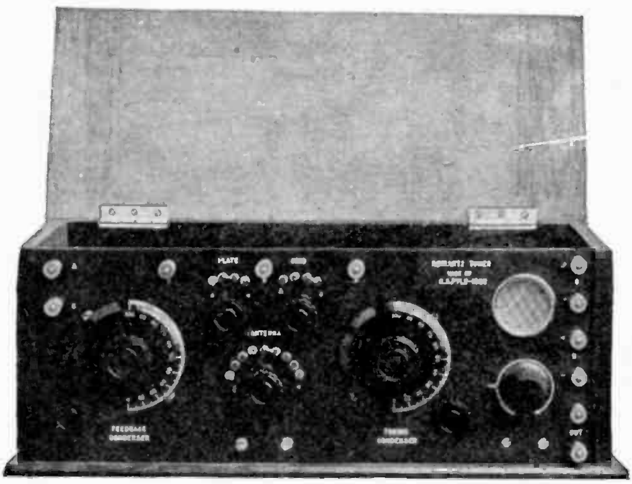
For example, to pick up a broadcasting station on 360 meters the two inductance switches should be turned to the fourth or fifth stops, the coupling dial turned to the further tuning of both circuits with the two condensers and adjustment of the tickler coil will be necessary until a degree of coupling is obtained when the interfering signal is excluded and the desired signal properly tuned. A record can be kept of the best positions of all the tuning elements for particular stations and these stations can then be easily tuned in at any time.

In concluding, the writer wishes to record the unusual qualifications of a Western Electric VT2 tube as a detector and oscillator in a circuit of this type. It functions extraordinarily well with a plate voltage of from 45 to 75 volts.

A Reinartz Set

By Howard S. Pyle

Much has been written relative to the development in tuning arrangements known as the Reinartz tuner, named for its originator, Mr. John L. Reinartz of South Manchester, Conn. This appears to be the long looked for tuner for relay stations and traffic work, involving but a single tuning control and a number of other desirable features.



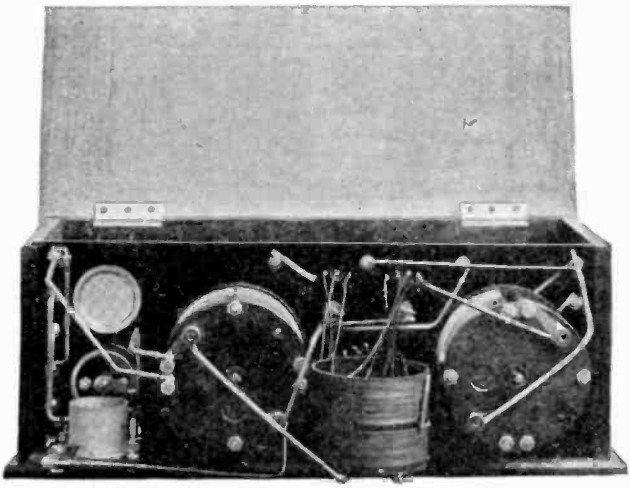
Panel Layout of the Reinartz Tuner.

We will not enter into a discussion of its theory herewith, this having been very thoroughly treated of late in the various publications. It is the author's purpose, however, to describe briefly the construction and specifications of an efficient Reinartz tuner which will give very satisfactory results. The drawing of the panel face, being made to scale, the various dimensions may be had by using the dividers. A panel having a length of 15⅜" and a height of 5¾" was chosen, this being a stock size, and a well finished walnut cabinet being available to accommodate that size panel. Obviously, any size panel may be used, but this size was found to be admirably adapted to the purpose.

A departure from the usual Reinartz design is incorporated herewith, in the use of a single layer coil in preference to the spider-web type. The single layer is considerably easier to wind and to mount and was found to give equal results to the spider-web. This one coil constitutes the only inductance in the circuit and contains two separate windings: one an antenna inductance and the other serving as the plate inductance. Part of the main antenna coil is used as the grid coil also.

A formica tube, 3" in diameter and 2½" long serves as the winding form. For best efficiency, a winding of stranded wire, or "Litz" is recommended. A very excellent wire for this purpose is the type known by the code name HABITUAL, manufactured by the Belden people or Radio Specialty Co.'s No. 323 Litz Wire. Starting at the bottom of the tube, a ¼" space is left and the end of the wire is passed through a small hole and secured. Forty-five turns are then wound, a tap being taken at the 15th and 30th. This leaves two ends and two taps when completed. The finishing end is secured in the same fashion as the starting end, and another small hole is made through the tube, ¼" above the END of the first winding. The antenna inductance is then wound on, consisting of 40 turns with taps taken at the 2nd, 4th, 5th, 6th, 7th, 8th, 9th, 10th, 26th, 33rd, and 40th turns. With the exception of the 10th tap, these are all soldered progressively to the switch marked "ANTENNA" in the illustrations, and which controls the antenna inductance in circuit, and to the grid switch as shown. The 10th tap is carried to the ground post of the set. It will be noted that the last switch point on the various to combine the two. It also allows of greater portability and presents a neater appearance.

In connecting the various elements, No. 12 or No. 14 bus wire should be used, and



Rear View of the Panel Showing the Arrangement of the Apparatus. Instead of the Usual Spider-Web Coil, a Single Layer Inductance is Employed.

switches is connected to one of the three binding posts marked "1, 2, 3" at the top of the panel. This is a recent refinement of Mr. Reinartz and permits of an external coil being used if a greater wave range is desirable.

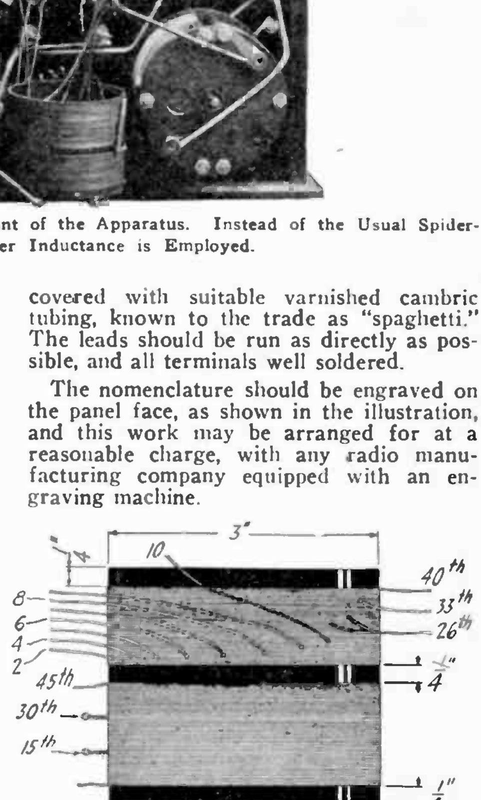
Oscillations, and regeneration to a certain extent, are controlled in this tuner through the variable capacity marked, "FEED-BACK CONDENSER." This adjustment is not critical. All tuning is accomplished with the capacity labelled "TUNING CONDENSER" and which will be found to be very sharp. Likewise the grid and plate switches will be found to be important initial adjustments. However, once the three switches are set at the point giving maximum response to the desired signals, it will seldom be necessary to change their position when tuning, it being necessary only to move the tuning condenser throughout its arc. Of course any great wave change requires a suitable readjustment of the inductance switches.

While a vernier attachment on the feed-back condenser is not really necessary, it is almost imperative that the tuning condenser be provided with a suitable vernier for proper operation. The writer uses the reducing-gear type of vernier adjustment with entirely satisfactory results.

The vacuum tube is incorporated in the tuner unit, as it has always been considered desirable from the standpoint of efficiency

covered with suitable varnished cambric tubing, known to the trade as "spaghetti." The leads should be run as directly as possible, and all terminals well soldered.

The nomenclature should be engraved on the panel face, as shown in the illustration, and this work may be arranged for at a reasonable charge, with any radio manufacturing company equipped with an engraving machine.



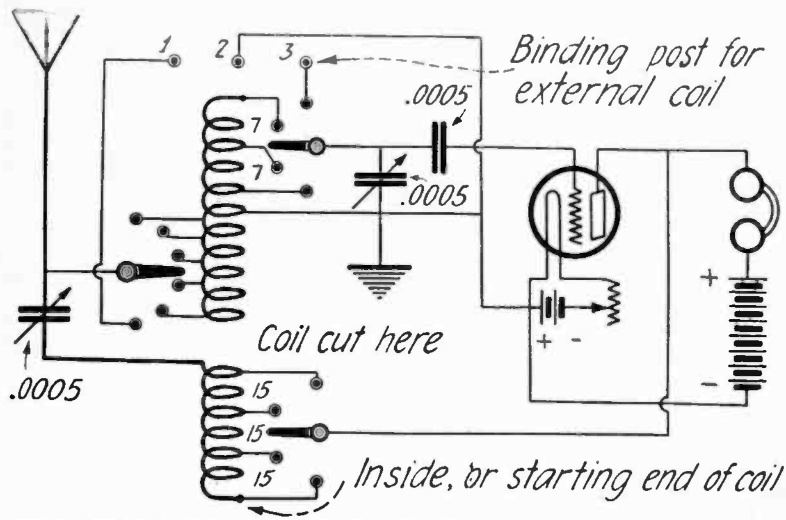
Details for Winding the Inductance Used in the Set. This is Easier to Wind Than the Spider-Web Type.

For those who wish to follow the writer's design and produce a duplicate instrument the following specifications are given:

Panel—Hard Rubber, 16⅜" x 5¼".
Cabinet—Walnut, hinged cover.
Condensers—Vernier type .0005 Mfd
Switches—Self Cleaning—one inc radius.

Switch points—Optional.
Binding posts—Optional.
Dials—Optional.
Rheostat—SHRAMCO.
Socket—With built-in grid leak.
Bezel—ERLA
Grid Condenser—Dubilier Micadon, .0005 Mfd.
Stopping condenser—Dubilier Micadon, .001 Mfd.

Nothing exceptional can be claimed for this tuner in the reception of radiophone signals nor those from spark stations, although the writer's experiments would tend to indicate that the results were at least equal to those obtainable with other types of apparatus. It is in the reception of C.W. signals that a Reinartz tuner stands prominently at the head of all other known types. The ease with which the elusive whistles are picked up and HELD, and the lack of body capacity when tuning, are remarkable, and in addition to these good points, the signal strength is a marked improvement over the more familiar regenerative circuits.



The Reinartz Circuit Which is Widely Used at the Present Time. Both Capacity and Inductive Feed-Back are Employed.

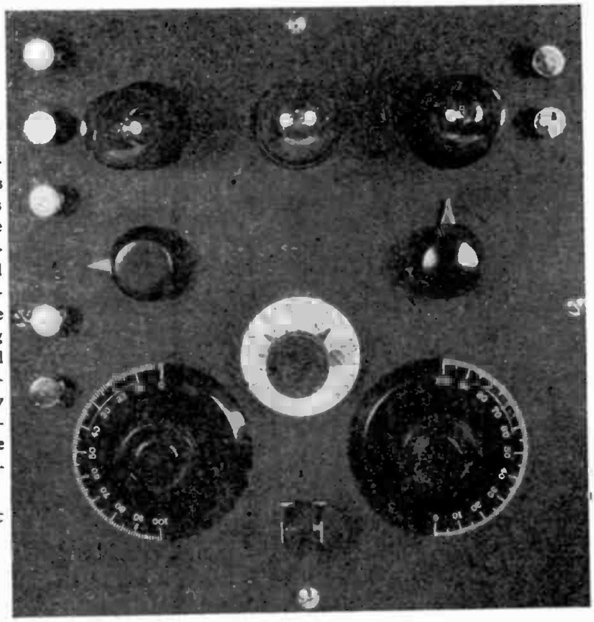
A Three Tube Reflex Receiver

By J. R. Balsley

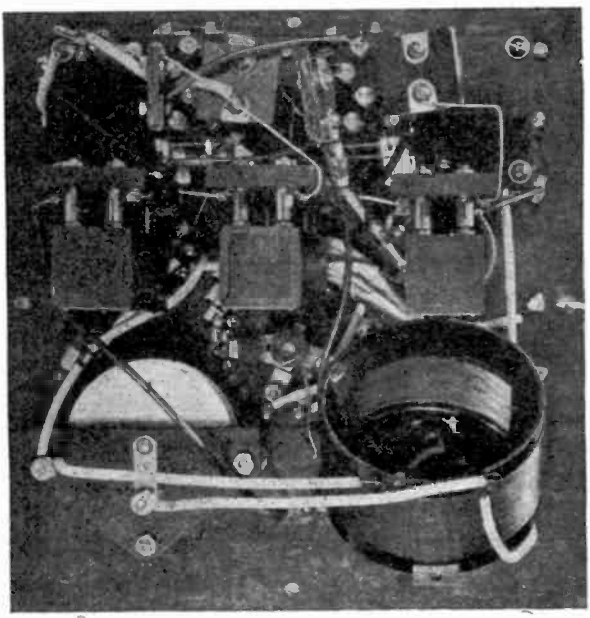
The Reflex circuit, although well known by this time, is not extensively used. The average person has fought shy of this latest development probably due to the lack of practical information covering the characteristics, design and operation of this combination. The author who has built a number of these sets and has obtained gratifying results, feels that a description of his present receiver would not be out of place.

Referring to the photographs, the set is of the horizontal type, that is, the panel is parellel to its setting instead of perpendicular as is usually the case. The dial on the right controls a variable condenser and the left one, the variocoupler. The "Gold Grain" detector is mounted between them. The double knob in the center of the panel controls the single and multiple turn taps of the 180° variocoupler. The knob directly above the condenser dial is that of the potentiometer and the other knob, the rheostat. The panel is 10½" by 12" and requires a cabinet 6¾" deep.

In constructing this set, a piece of hard wood ½" thick was used as the panel in which the holes for the tubes were drilled on 2⅝" centers, the holes themselves being 1½" in diameter. Three Atwater-Kent

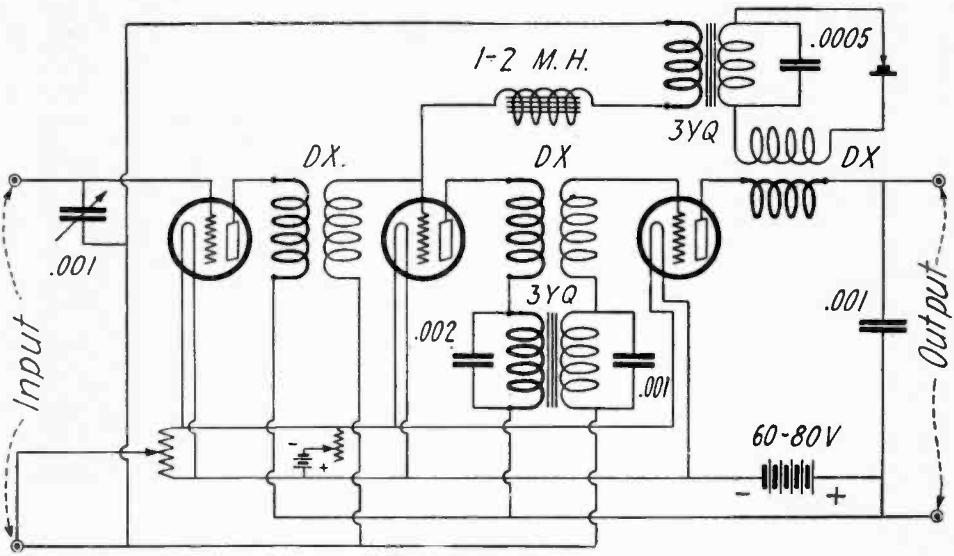


A Top View of the Three-Tube Reflex Receiver Described In This Article. A Gold Grain Detector Is Mounted Between the Two Large Dials. The Dial on the Right Controls the Variable Condenser and the One on the Left, the Variocoupler. The Double Knob in the Center Is a Back Panel Switching Device Controlling the Single and Multiple Turn Taps of the Vario-Coupler. The Other Knobs Directly Above the Condenser and Variocoupler Dials Are Those of the Potentiometer and Rheostat Respectively.



An Inside View of the Outfit. As Will Be Seen, the Main Tuning Units Consist of a Variable Condenser and a Variocoupler. The Radio Frequency Transformers Are Mounted Directly Behind These Units. The Three Vacuum Tube Sockets Are So Arranged That Their Necks Come Up Through Holes Made In the Panel and Supported In The Back By Means of a Strip of Bakelite. The Transformers Are Also Mounted on This Strip By Fastening Them Securely to the Edge With Screws.

sockets are supported by a strip of bakelite 2½" by 8¼" by ¼". This serves as a shelf which is shielded from the bottom of the panel by wood screws and brass tubing for spacers. Two 3YQ audio transformers are fastened to the bottom of this shelf and tube. This was found necessary to keep the radio frequency currents from leaking through the audio frequency transformer and between parallel wiring. A rheostat for the control of the filament current is not absolutely necessary since the tubes



The Three-Tube Reflex Circuit As Employed With This Receiver. A Radio Frequency Choke Is Connected In Series With the Secondary of the First Audio Frequency Transformer.

the DX transformer mountings are screwed into tap holes on the edge of the shelf, as shown in the rear view of the set. In coupling the radio and audio frequency transformers so close together, the necessity for shields was obviated by grounding the frames of the audio transformers. WD-11 tubes can be used with the set if desired, although the use of either A.P. or Radiotron tubes will give greater volume. The hook-up of this set is shown in Fig. 1. It will be noted that a choke coil is placed in the grid circuit of the second must be heated to the maximum allowable for the best results. With A.P. tubes greater amplification is obtained with about 100 volts on the plates. With this receiver, I have heard on the loud speaker in Philadelphia a total of 74 broadcasting stations from Havana to Montreal and Toronto including Dallas and Fort Worth, Texas, and Denver, Colorado. This set was designed for use with a loop aerial although an out-door antenna can be used if desired. In this case it is best to use a variocoupler and a condenser in series with the antenna.

A One Tube Super-Regenerative Receiver

By John T. Norton

The use of the super-regenerative circuits has greatly increased the amplifying power and sensitivity of the vacuum tube, and has made possible a really practical receiver employing a small loop aerial and a single vacuum tube. Such a set has been constructed by the writer and has given very gratifying results.

The arrangement of circuits is shown in the diagrams. Fig. 1 is a simplified equivalent circuit, and Fig. 2 is the complete wiring diagram of the set. It will be noticed that the arrangement is very similar to one of the common types of regenerative circuit employing variometer tuning in the plate circuit. The only change is the omission of the grid condenser and leak and the addition of the oscillator coils. These coils make it possible for the tube and its circuits to oscillate at the comparatively low variation frequency which is characteristic of the super-regenerative circuits. This frequency is of the order of 10,000 cycles per second, and the circuit oscillates very readily. The constants of the various component parts of the set are given on the diagram.

The set was designed for experimental purposes, and for this reason, the leads to the various instruments were brought out to a terminal board on the back, so that different connections could be made without changing the permanent wiring of the set. The frame was made of half-inch brass angle, and to this was fastened a quarter-inch bakelite panel the size of which was 11" x 13". The panel was rubbed to a dull finish, and marked with white drawing ink. All of the instruments, with the exception of the oscillator coils and the tube socket, were mounted on the panel. The voltmeter was arranged so that the switch immediately below it connected it to either the filament or the plate of the tube, the plate connection including a multiplier which multiplied the scale reading by ten. The jacks at the bottom of the panel allowed the use of three pairs of telephones in either series or parallel. The photographs show the arrangement very clearly.

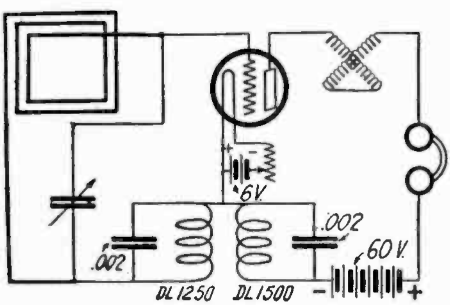
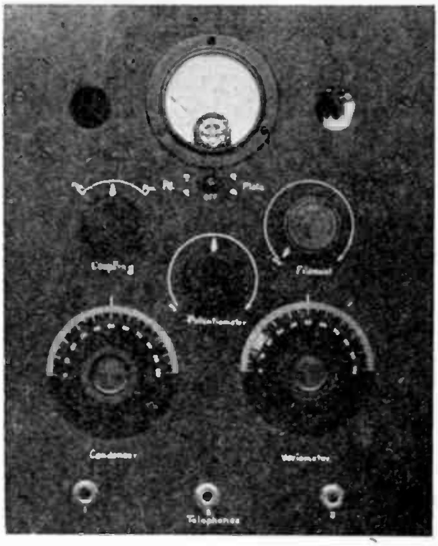


Diagram of the Circuit Employed.

The variable condenser used with the set was designed by the writer. It consisted of two plates, one of tinfoil, and the other of mercury, separated by a dielectric of thin sheet mica. The mercury was the only moving part of the condenser, and it gave very satisfactory service. The loop aerial was square three feet on a side, and was wound with 10 turns of No. 18 wire spaced ½" apart. Taps were taken at every turn from the third to the tenth and connected to an eight-point switch in the center of the loop, and from this a pair of twisted leads ran to the set.

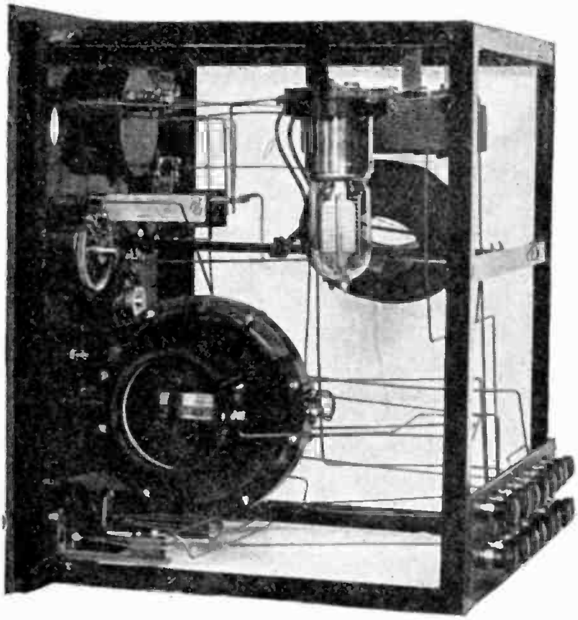
In the operation of this receiver, a plate voltage of between 60 and 70 has been found most satisfactory for both telephone and continuous wave reception. A "C" or grid battery of 4.5 volts may be used, but



Front View of the One Tube Super-Regenerative Receiver. This Set Incorporated the Use of a Potentiometer Which, However, Is Not Necessary.

it does not seem to improve the results. A radiotron U. V.-201 tube was very successful in this set, but a Western Electric V. T.-1 gave the best results. The tuning of this set is no more difficult, and is almost identical to that of the well-known regenerative receiver. The tube should be lighted to its normal brilliancy and the oscillator coupling set at a maximum. The note of the variation frequency should now be heard loudly in the telephones. If not, the connections to one of the oscillator coils should be reversed. With the tube oscillating strongly at the variation frequency, decrease the coupling slowly until a loud click is heard, but the variation frequency note is still audible. The set is now oscillating at both radio and variation frequency, and is tuned in the ordinary manner with the variable condenser, variometer and filament rheostat. The variation frequency note is heard at all times during reception. If the oscillation coupling is decreased too far, the variation frequency oscillations will cease, and the set operate as a plain regenerative receiver.

The set has been in operation in Boston, Mass., for about two months, and the results obtained have been very gratifying. On broadcasting wave-lengths, WOC, Davenport, Iowa, (1,150 miles) has been heard several times. KYW and WDAP in Chicago (980 miles) have been heard quite often, and KDKA in Pittsburgh (550 miles) comes in very regularly. Reception from local stations is of sufficient strength to



Rear View of the Receiver. The Leads from all the Instruments Connect to Separate Binding Posts so That Different Circuits May Be Tried. Note the Downward Suspension of the Tube Socket.

operate a loudspeaker in excellent shape. The receiver seems at its best in the reception of continuous wave signals. On 200

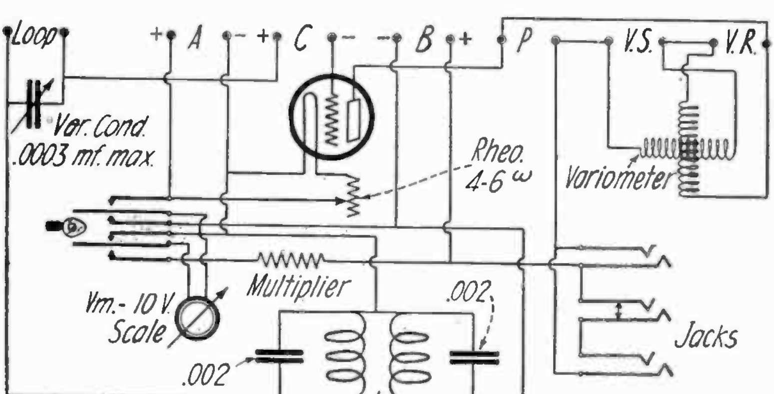


Fig. 2

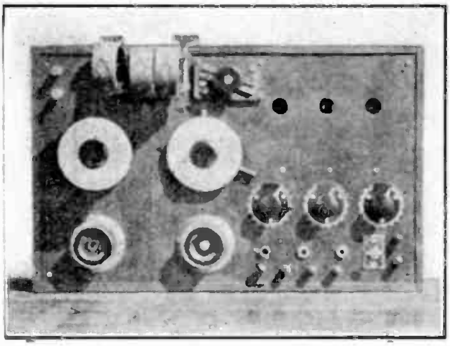
Complete Wiring Diagram of the Connections of the Set.

meters during the trans-Atlantic tests, over 200 amateur stations in every district except the sixth and seventh were copied. Several Canadian amateurs were also copied. 9CM and 9DQ in Wisconsin were the farthest, about 1,200 miles. The set is practically worthless for the reception of spark signals because the spark tone is destroyed to such an extent that the signals are almost unreadable. It seems as if a receiver of this type with a loop aerial approximating the proportions of an outdoor antenna would be of great value to the amateur in handling long distance traffic.

A Honeycomb Coil Receiver

By H. V. Houyoux

After considerable experimenting, extending over for almost a year with different receivers such as the vario-coupler and variometer types, single circuit tuners, etc., I finally decided to return to the honeycomb as being most efficient for all wave-lengths from 150 to 25,000 meters.



Front View of the Completed Honeycomb Coil Receiver.

The receiver described below has been operated under all conditions and has proven exceptionally efficient, being less subject to static interference than any other tuner on the market. It has been found, on test, to be much superior both in electrical sensitiveness and mechanical adjustment to anything previously tried. Its ease and simplicity of operation and its extreme sensitiveness to slight variations of coupling, together with the great gains in signal strength resulting therefrom, should be greatly appreciated.

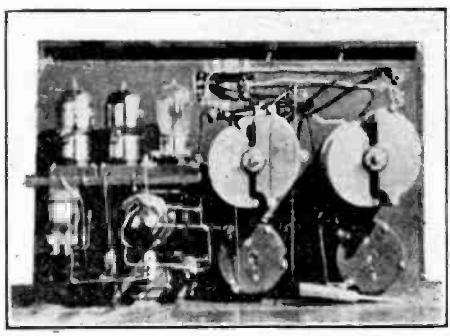
Owing to its sharp tuning qualities, local interference can be easily eliminated. In addition to its quality of causing the detector to oscillate on all wave-lengths with minimum manipulation of units, it is compactly built, small in size, considering the fact that every unit, including the two-stage amplifier, is contained in one cabinet and mounted on the same panel. The only external accessories being the "A" and "B" batteries, making the complete outfit easily portable.

The location where this receiver is used is directly over an immense deposit of zinc and magnetic iron ore, which might or might not interfere with long range receiving. However, in view of this, among hundreds of C.W. and spark stations which have been copied from Europe, South America, Canada and on the Pacific coast, the following telephone broadcasting sta tions have come in QSA enough to entertain several hundred people assembled in our school auditorium: NOF, Anacostia, D. C.; WBZ, Springfield, Mass.; KYW, Chicago, Ill.; KDKA, Pittsburgh, Pa.; WGY, Schenectady, N. Y.; WMH, Cincinnati, Ohio; WWJ, Detroit, Mich.; 9XM, WHA, University of Wisconsin, Madison, Wis.; WOH, Indianapolis, Ind.; WBT, Southern Radio Corp., North Carolina; CKCE, Ontario, Canada.

It must be realized that some of these stations are more than 1,800 miles distant, which is quite a record for two stages of amplification.

I wish to emphasize the fact that these stations were all received loudly enough to fill the school auditorium so no one had any difficulty in hearing and understanding.

Public demonstrations, to give the public a general idea of the possibilities of radiophone broadcasting, have been held, using a Magnavox in place of the phones. In these cases, 112 volts were used on the plates of the amplifier tubes, although 90 volts brought in music and speech clearly and loudly enough to be heard and understood distinctly in any part of the auditorium, which is 100′ x 150′.



Back View of the Completed Receiver With the Location of Apparatus Clearly Shown. Variable Grid and Phone Condensers Are Used on This Set.

Description and method of tuning of the set follows:

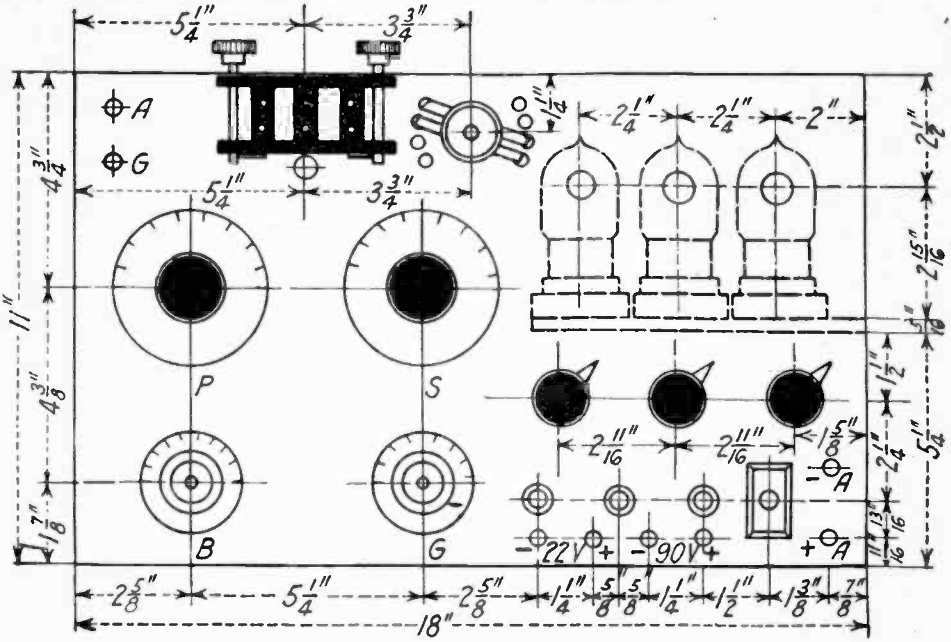
The antenna used is a single wire, seven-strand copper 225′ long, 55′ high with an 8″ cage lead-in composed of 6 wires. The cage lead-in is not essential, but I found that signals came in a little better with it.

Panel—¼″x11″x18″, bakelite or formica.

Shelf for tube sockets and transformers

5/16"x4⅝"x7½". The tubular grid leak is also mounted on this shelf back of the detector socket. Transformers are hung from the bottom of the shelf 3½" from the center of one to the other. The first stage uses an R.C. of A.U.V. 712, the second is a Federal, mounted so the core is at right angles to the first transformer.

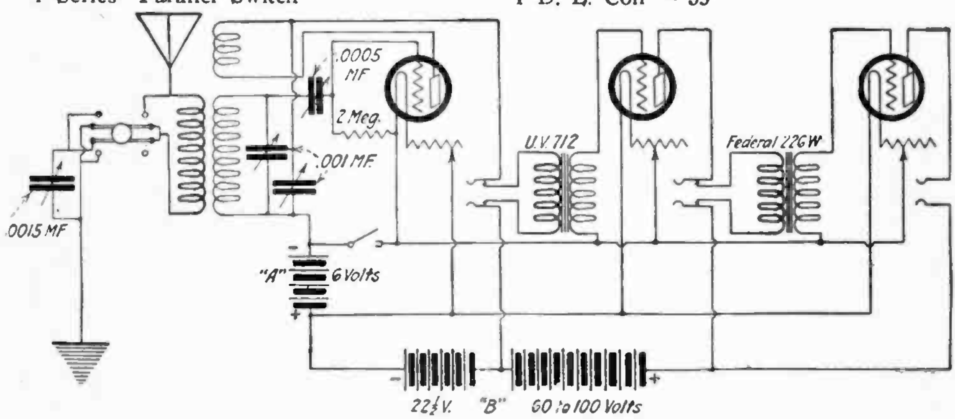
1 Bridging Condenser, .001 Mfd.
3 Murdock Sockets
1 Tubular Grid Leak and Base
8 Binding Posts
1 U. V. 712 Transformer
1 Federal 226 W. Transformer
3 Rheostats
3 Telephone Jacks



Dimensions for the Panel Layout.

The remainder of the set can be assembled by referring to the drawings.

List of units:
1 Geared Three Coil Mounting
1 Series—Parallel Switch
1 "A" Battery Switch
1 U. V. 200
2 U. V. 201's
2 D. L. Coils— 25
1 D. L. Coil — 35



Hook-Up of the Honeycomb Coil Receiver.

1 Primary Condenser, .0015 Mfd.
1 Secondary Condenser, .001 Mfd.
1 Grid Condenser, .0005 Mfd.
1 D. L. Coil — 50
1 D. L. Coil — 75
2 D. L. Coils—150

With these coils, stations up to 3,000 meters may be heard. For longer wavelengths, other coils must be used, from 250 to 1,500.

Cabinet is made of black walnut, inside dimensions 6" deep by 11" high by 18" long.

In tuning for broadcasting stations from 250 to 450 meters, use D. L. 25 primary, 50 secondary, 35 tickler. The tickler is closely coupled to secondary, and tuning is done with primary coil and secondary condenser. After becoming accustomed to the set, all tuning up to 1,000 meters can be accomplished with secondary condenser. For stations below 250 meters, tune with tickler coil and primary condenser. Secondary condenser should be set at zero.

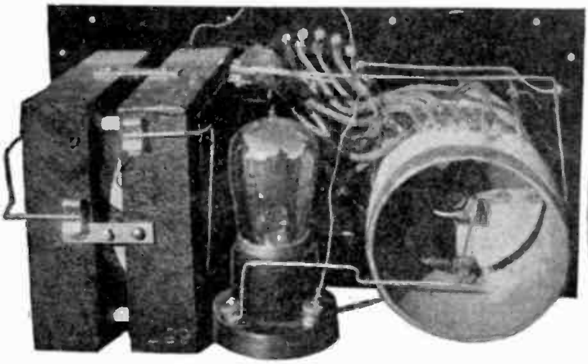
Grid and bridging condensers are all in except when tuning for long distance, in which case, adjustment is necessary.

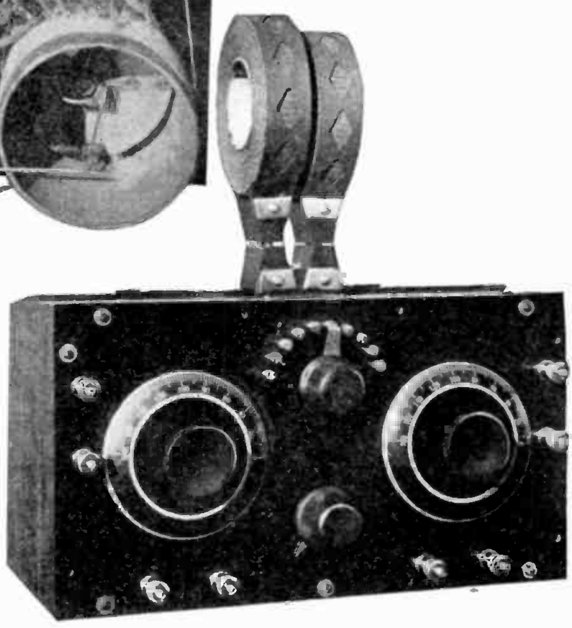
These directions may not apply to all locations or antennæ, but are correct where an antenna of the length given is used.

A Compact Super-Regenerative Set

By Rual C. Jones

The description herewith gives an idea for the construction of a single tube super-regenerative receiving set which has proved an advantage in the reception of amateur

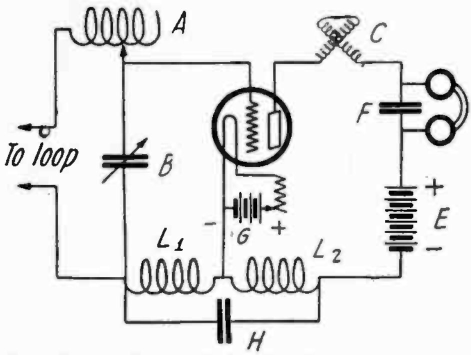




Two Views of the Compact Super-Regenerator. This Set Employs a Plate Variometer and a Tapped Inductance in Series with a Loop Aerial. The Photo Above Shows the Arrangement of the Apparatus Which Takes Up a Minimum Amount of Space. To the Right Will Be Seen the Front View. Note that the Honeycomb Coils Are Mounted on Top of the Cabinet.

and broadcasting stations. This set tunes a great deal easier than a single circuit regenerative receiver and the signals come in as loud and clear as an ordinary receiver using an aerial and ground and two stages of amplification.

The loop employed with this set is 2½' square with approximately 13 turns of wire on its frame. Referring to the diagram, A, is an inductance on a card-board tube 3½" in diameter wound with 45 turns of No. 22 D.C.C. wire tapped every five turns. This inductance is not necessary if the loop has the proper length of wire wound on it. L^1 and L^2 are honeycomb coils of 1,500 and 1,250 turns respectively. After the set is wired, the terminals of the coils may have to be reversed before the set will work properly, these coils are mounted stationary with a coupling of about ½" between them.



The Circuit Employed in the Compact Super-Regenerative Set.

B—.001 mfd Variable Condenser (Brilliantone Radio Products Co., N. Y.)
C—Variometer (Brillantone Radio Products Co., N. Y.)
D—U. V. 201 Amplifying tube and socket.
E—45-volt "B" battery (Eveready.)
F—.001 mfd fixed phone condenser (Radisco.)
G—6-volt storage battery.
H—.004 mfd fixed phone condenser (Radisco.)

To tune this set, turn on the rheostat until the filament burns brightly. Place the rotor windings of the variometer at right angles to the stator windings and turn the condenser, B, until the plates are nearly out, or to a point where a hissing sound is heard. After a station is heard, it can be cleared up with the variometer and by slightly moving the condenser, B. If the loop is set in the right direction, the station usually bursts in clearly and loudly by only varying the condenser, B.

The photographs show clearly the construction of the set and the arrangement of the apparatus. The panel is of hard rubber measuring 6"x12". From my home in Carter, Oklahoma, I receive radiophone programs from all stations such as Detroit, Chicago, St. Louis, Atlanta, Ga., Los Angeles, Calif., and San Antonio, Texas, employing the 2½' loop aerial as described. The simplicity of control makes this set ideal for the reception of amateur C.W. stations on 200 meters.

An Efficient Receiving Set

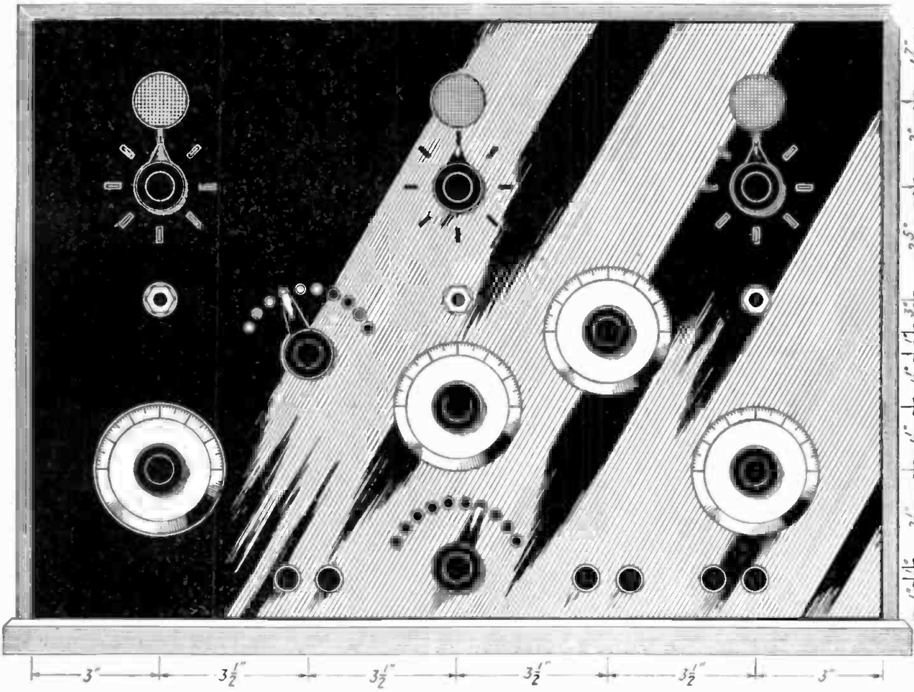
By Paul G. Watson

The receiving set described here was designed to meet the requirements of a store, where the loudest possible signals could be had with the apparatus taking up as little room as possible. There are numerious other designs of sets containing the tuner, detector and amplifier in one cabinet, most of which are great long cabinets, measuring up to 40" in length. The set described here was designed to be placed on the top of a roll-top desk, and could not, therefore, take up very mush space. The space required for this set is about 10" by 20", with a height of 16", the extra height making up for the short length.

The circuit of the tuner element is given in this book under the title "An Efficient Amateur Receiving Circuit," and is also included in the diagram. The spacing of the various pieces on the panel is shown in the detail drawing of the panel.

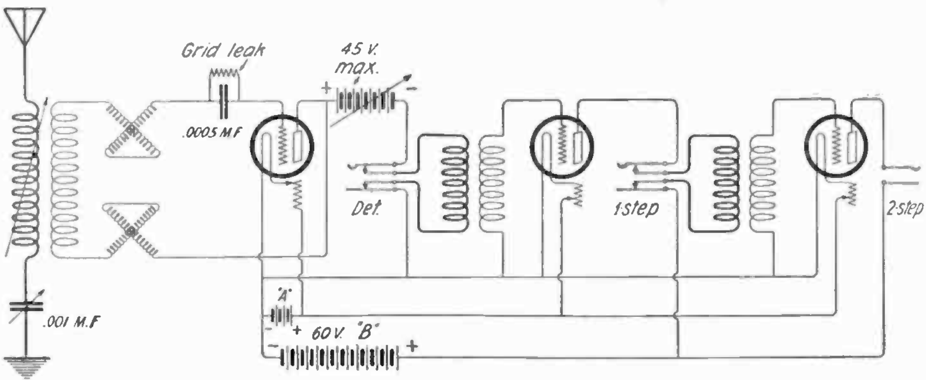
The variometers and variocoupler used in this set are the "Simplex" type, selected for their high efficiency and selectivity of tuning. The necessity for a good contact to the moving elements cannot be exaggerated, and is well taken care of in this type of apparatus. No sounds are heard in the phones when tuning with these variometers, as there are no brushes to cause them. In wiring the coupler primary, only the large steps are used, the short wave condenser will handle the close variation of the primary more efficiently than the single taps. The short wave condenser is a 43-plate condenser, of .001 Mfd. capacity. The proper use of the condenser and taps will give a very closely tuned circuit.

The only variable elements in the secondary circuit are the variometers. The grid variometer should have shielding placed on the back of the panel and connected to the ground terminal of the tuner. This shielding is nothing more than a piece of tinfoil about seven inches square, fastened to the back of the panel with shellac, and insulated from the variometers. This shielding will remove the capacity effect of the hand while tuning. The grid condenser is a fixed one of .0005 Mfd. and a grid leak is shunted across it. The "B" or plate battery for the detector is a battery having variable voltage. Variation is made by the upper switch on the panel. In connecting the points of this switch only alternative points should be used, thus avoiding a short circuit of sections of the battery as the lever passes from one contact to the next. The detector tube used in this set



Layout of Front Panel with Distance of Holes to be Drilled.

was a pre-war "Audiotron" and required a maxamum voltage of 45; if the "Radiotron" UV 200 is used, a 22 volt maximum is sufficient. The rheostats used were the "Paragon" type, and give a close, smooth regulation of filament current. The three tubes are connected in parallel in the filament circuit, and are brought to two binding posts on the face of the panel where the storage battery is connected. Extreme care should be used to have soldered connections throughout the set, so that no noise can come from the poor connections and joints in the connecting wires. "Federal" jacks were used in the detector and amplifier circuits, as they give good tight contact when the plug is removed. Poor contact in the jacks will give an unlimited amount



The Hook-Up of the Three Tube Receiving Set.

of trouble, and cannot be overlooked as a point where trouble can start. Two double circuit jacks and one single circuit jack are needed, the single circuit being used in the last step of the amplifier. In soldering the connections on the lugs of the jacks, care should be taken to keep the soldering paste out of the insulation.

Two transformers are required for this amplifier, since it has two stages of audio frequency amplification. "General Radio" transformers were used in this case and worked extremely well. Howling is eliminated completely by mounting the transformers as far apart as possible and at right angles to each other. In connecting the transformers of any make, care should be used to see that the out turn of the secondary is connected to the grid terminal of the tube. Three "General Radio" sockets were used in this set, the contacts being secure and the ability to resist the action of heat being the points considered in the selection.

The manner in which the "B" or plate batteries are connected is one taken from several types of commercial apparatus. "Fahnenstock" spring binding posts are used to connect all the plate batteries. The two large size posts on the one variometer are the terminals for the amplifier plate battery. The opposite variometer has one spring binding post of the detector plate battery. The five small spring posts placed along the edge of the upper board are the connections for the tips of the variable battery which has been mentioned previously. This method of connecting both batteries assures a firm contact at all times, and removes the possibility of noise from this source.

All wiring in the set is to be done with No. 14 bare wire, using spaghetti insulation when necessary. The use of wire as large as this may seem unnecessary to the layman, but it can be pointed out, as examples of this point, that all commercial and military apparatus is thus wired, and again a comparison of the tuner wired with small wire and then re-wired with the larger, will convince the experimenter of the necessity of the large wire. The possibility of short circuit is lessened by the fact that No. 14 wire is stiff enough to remain in position when once placed.

The lower board or base of this tuner is about 19" long. On it are mounted all the parts of the tuner, the panel being fastened to the front edge with flat head wood screws. The width of the board can be varied; the one used in this set was 8" wide, and gave room along the back to place the blocks of "B" batteries. The upper board is about 4" wide, and mounts about 5" from the top of the panel. All the parts of the detector and amplifier are on this board. Like the base board, it is mounted with flat headed wood screws running through the panel.

A loud speaker was made to work with this set. A type "C" Baldwin phone was mounted on the end of a large "Morning Glory" or "Edison" horn. By keeping the rubber tube between the receiver case and the metal of the horn, much of the "grind" was eliminated. This loud speaker reproduced signals very clearly, and with volume sufficient to be heard a city block.

A case was made to contain this receiver, and was finished to match the woodwork of the office where the set was to be used. If the set is intended for exhibition purposes, or for selling similar parts of apparatus, a glass back should be placed in the apparatus.

A Super-Sensitive Receiver

By E. M. Lerchen

For all-around amateur, broadcasting and ship reception, the receiving set described will be found entirely suitable.

The circuit is so arranged that only three controls are necessary, regeneration being freely obtained over the entire range.

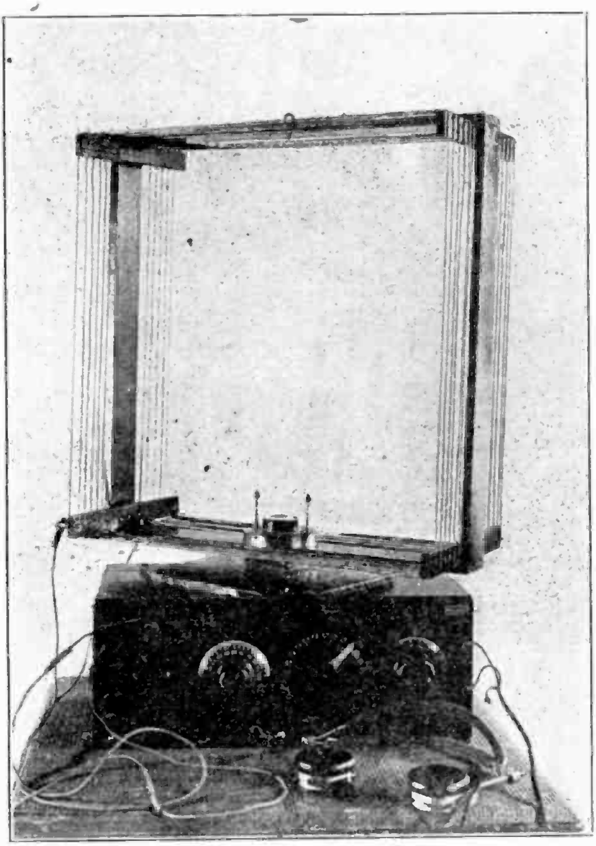
Distances up to 600 miles have been covered, using this receiver in conjunction with an indoor aerial 12' long. With a very small loop wound on a form 18" square, broadcasting stations ten miles distant have been heard on detector tube alone. Loop reception is made quite feasible if a good ground connection is employed in the regular manner.

This set is very selective and should appeal mostly to amateurs who have been bothered with interference. In constructing this receiver the following material will be necessary:

1 43-plate variable condenser.
1 switch.
8 contact points.
2 spider-web coil forms.
1 tube, 4" diameter, 7" long.
1 lb. No. 24 D.C.C. wire.
1 ball rotor.
1 detector or amplifying tube.
1 storage battery.
1 "B" battery.
1 headset.
Wire, bakelite, panel, dials, screws, etc.

Wind each spider-web coil with 20 turns; The forms for these coils may be made from stiff schellacked cardboard or heavy sheet celluloid. The wire may be given a light coat of thin shellac to prevent absorption of moisture. It would be well to provide two binding posts on each coil so that they may be changed if desired. No. 24 D.C.C. wire is used, as it is generally in stock at dealers and possesses most of the requisite qualities for efficient reception.

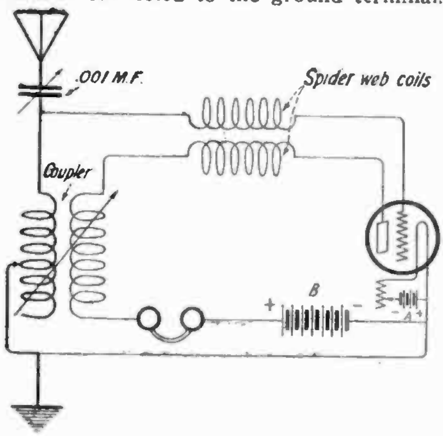
The spider-web coils are separated 4" and placed parallel to each other. Square-tinned wire should be used for connections and if maximum results are desired all joints should be soldered. To make the connections more readily understood, the following directions may be of aid: The "P" post on the vacuum tube socket is con-



View of the Complete Receiver and Loop With Which Remarkable Results Have Been Obtained.

The primary of the coupler is wound with 80 turns or No. 24 wire tapped every 10 turns. Taps should be soldered. The rotoı is wound with 40 turns of the same sized wire, and 20 turns are wound on each half. On both of these coils a light coat of shellac may be spread. The method of coupling the rotor to the outer form should be similar to standard practice. Pigtail flexible leads must be employed to make positive contact to the rotor. A dial and knob will be required on this shaft to control the movement. A 180° dial should be used.

nected to one terminal of one spider-web coil. From the other terminal of the same coil connection is made to one rotor lead. From the other rotor lead to the phone, from the phone to the positive side of the "B" battery and from the negative (-) side of the "B" battery to the ground connection. From the aerial to one connection on the variable condenser, from the other variable condenser terminals two leads are brought, one to the remaining spider-web coil, through the spider-web coil to the "G" terminal of the tube socket. The other lead is brought to the start of the outer winding on the coupler. (The rotor ball should be located at this end of the form.) The switch blade is connected to the ground terminal.



The Hook-Up of the Super-Sensitive Receiver Which Employs the Double Feed-Back Circuit.

The filament circuit is quite simple, the rheostat, "A" battery and filament being in series. Connection is made to the positive side of the "A" battery from the ground terminal. After the set is in operation, it would be well to try reversing the leads to one of the spider-web coils. The connection which gives the maximum results should be employed.

The operation of this receiver is very simple. Wave-length variation is had by adjusting the series variable condenser and the inductance switch. Regeneration may be controlled by varying the coupling of the rotor.

In selecting apparatus, it would be well to bear in mind that the best material, even though it should be more or less expensive, will give the best results over an indefinite period of time.

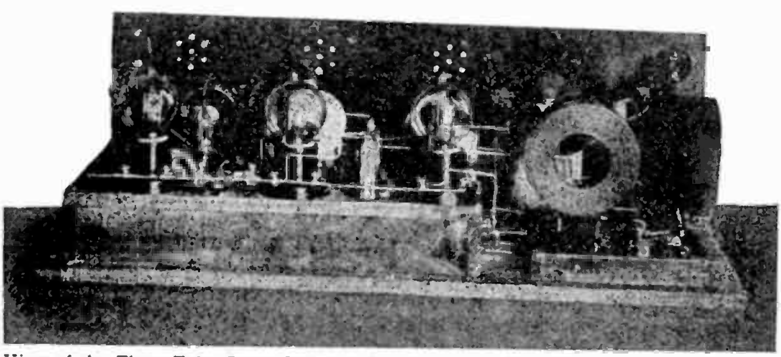
Either a hard or soft tube will give satisfaction in this circuit. The regular detector tube is to be preferred. No grid condenser is necessary, although one may be inserted for trial. The apparatus should be mounted on a bakelite panel, set in a suitable cabinet. It would be well to shield the panel to eliminate body capacity effects.

This receiver will function from the lowest amateur wave, 150 meters, to the short wave limit at 800 meters. The results obtained with a good 100′ aerial (outdoor) will well repay the constructor for the time, energy and money invested.

An Armstrong Super-Regenerative Receiver

By W. Harper, Jr.

This remarkable principle of radio reception and amplification has probably created more discussion than any other since the advent of popular broadcasting; and it has been rather strange to me that a greater use has not been made of it among the amateurs, and that such a receiver has not as yet appeared on the market. After my own personal experience with all the other standard systems, I unhesitatingly say that, especially for city use, and also for the country, when one considers the Summer static difficulties, it is the real Rolls Royce of receivers.



A Rear View of the Three-Tube Super-Regenerative Receiver. Note That the Large Honeycomb Coils Are Mounted at Right Angles to Each Other.

Now it may be that on account of its radical departure, in principle, from the straight regenerative system that one attempting to wire up such a set for the first time may encounter a great many discouraging troubles until the new principle has really been mastered. At least, this was my own experience and it was only after several months of very persistent effort that some of the mysteries dissolved into very simple facts. And even then, I confess, it was quite some time before I really began to appreciate this wonderful circuit and could use it to somewhere near its full capacity.

In principle its range is unlimited as well as its amplification and it is solely temporarily restricted by the quality of tubes employed, the receiving phones and artificial local conditions, as all of these details will be subject to marked improvement in a short time.

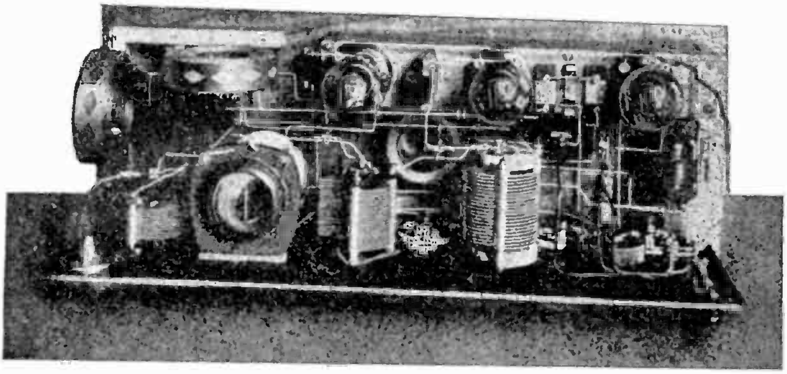
It looks as though at last the human mind is at the threshold of touching upon the infinite.

To one who is contemplating experimenting with such a receiver I would say by all means do it, although so many have not been successful. Because, if the following instructions are carefully noted, it is really quite simple after all, as is the case with nearly every big thing worth while.

Contrary to the idea that it is critical and hard to tune I unhesitatingly state that the set here pictured and described is quicker and easier to operate than the most approved conventional phonograph and I don't mean just on local stations either, but from New York, tuning in KDKA and WGY.

It is the ideal receiver for the good little wife to use during some of those boresome lonely hours when friend husband is away at the office and she hasn't much patience to turn up a lot of rheostats and fish about with several dials.

In the case of a well designed "Super" all that is necessary is to push a button which lights the tubes, and if there is any thing on at the station at which the one tuning condenser is set, you have it right away, full volume and quality with no critical rheostat adjustment or tickler setting to improve it or hold on to. And by tuning the one dial throughout its range, you will know whether anything else is doing between here and the Mississippi River. You see, there is the absence of the old idea of tuning the primary and then trying to coax in the signal with regeneration at each step in tuning.



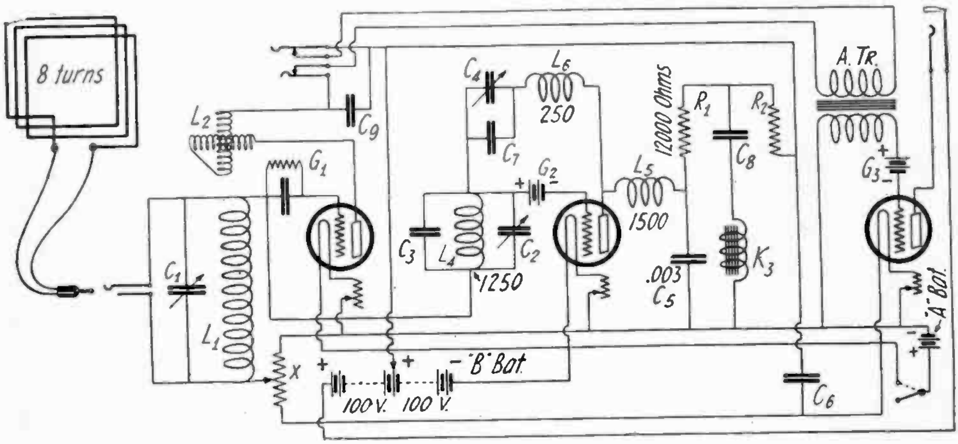
Another View of the Armstrong Super-Regenerative Receiver. The Tubes From Left To Right Are, Detector and Regenerator, Oscillator, and Amplifier.

As to volume and quality, the old style regenerative fan has a most pleasant surprise in store for him. There is not a loud speaker on the market that can take care of all that three V.T.-2 tubes can put into it. The amplification is fautless, so far as the work of the circuit goes.

A few moments ago, while writing this, I walked across the room and pressed the button without even looking at the receiver. and at the same moment I was searching my mind for a clear way to word the idea of its new simplicity, and until I returned to my desk I had not realized that I was listening to the overture at the Capital theatre and after a moment's thought decided it was too loud so the only adjustment made was to tone it down a little; quite a new complaint for a radio receiver.

There are some essentials to bear in mind regarding the assembling of the "Super." In the first place it should be placed in a cabinet not less than 24" by 8", inside measurements. The best of materials must be employed and the three variable condensers must be separated from the tubes as far as kept well separated. The inductance coils possible, and the tubes so placed that their respective plates shield each other.

It is also necessary that the primary winding is in the same direction as that on the stator of the variometer above it. This variometer should be of a type of least distributed capacity effect and there should be 58 turns of wire on its 2½" diameter rotor, with a respective number of turns on its stator.



The Circuit Diagram of the Super-Regenerator. The Variometer L2 Is In Inductive Relation To Coil L1.

Be sure that the tuning condenser is shunted between the loop and the primary coil. Use V.T.-2 tubes as I have found that very few of the U.V.201's are hard enough. However, I believe that the new 201-A should work nicely.

When you first try your "Super," set the variometer at full inductance and if there is no sound, reverse the leads to its terminal connections. Also turn the rheostat of the middle or oscillating tube on full and after the detector of the first tube is up, reduce the current on the oscillating tube until just above the point where it roars. (Quite the reverse of the case of the plain regenerative set).

The phone plug in the first jack which is using the first two tubes only will give all the sound a pair of head phones will stand; do not put them on the last tube if they are good phones. The first dial on the panel from the left controls the tuning by means of a .0005 mfd. condenser. The second controls the amount of regeneration, and on distant stations will cut out interference. The third is on a .001 mfd. variable condenser which controls the two grid oscillations aind requires very little adjustment for local work; set it about half way in. The fourth is also a .001 mfd. variable condenser, and for all local work leave it at zero, but for distance and great volume turn in. The condenser controls the plate oscillations and upon it depends the absence of oscillating noises in the phone; the less condenser used the quieter it will be. It should also be noted that these last two variable condensers are merely the variable part of the whole condenser capacity used.

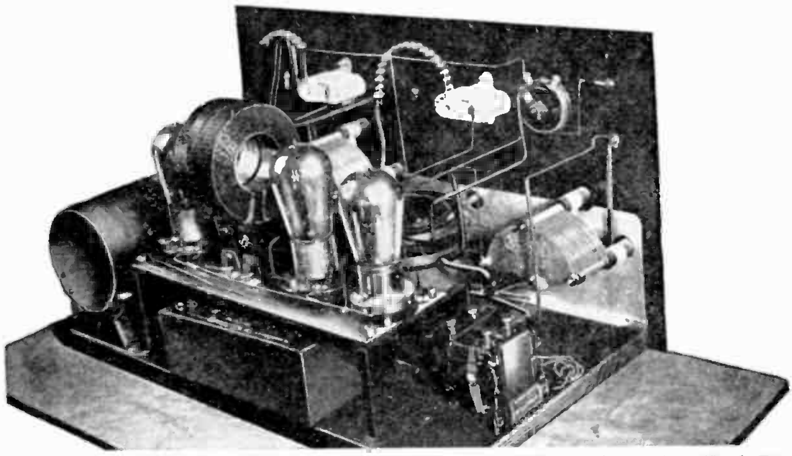
In constructing this set I would also advise that the various parts be placed exactly as shown and the wiring followed likewise.

The grid batteries are necessary and the one on the third tube should be at least 22 volts. These batteries are small and must be placed as near the tube as possible. Up to 300 volts may be used on the plate of last tube, if more grid battery is also used.

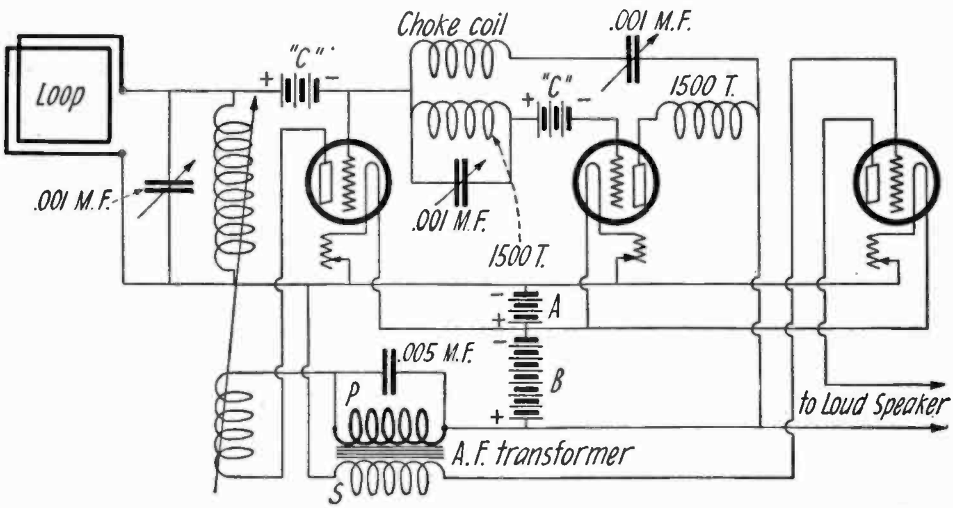
A Well Designed Super-Regenerator

By **H. L. Hodson**

The accompanying diagram of the wiring connections, photographs of the set and detailed data are self explanatory of a super-regenerative receiver.



A Rear View of the Super-Regenerative Receiver. Radiotron UV-202 Tubes Are Used Throughout.



A Complete Circuit Diagram of the Receiver Shown Above. This is the Conventional Armstrong Three-Tube Super-Regenerative Hook-up. The First Tube is Employed as the Detector and Regenerator; the Second Tube is the Oscillator, and the Third Tube is Employed for Audio Frequency Amplification.

A loop aerial used in conjunction with this set is wound with 7-strand No. 22 twisted wire, 12 turns separated ½" on a 3½' square. An aerial 150' long of No. 14 wire, which is connected to the top binding post of the loop, and enables reception over a radius of about 1,000 miles, this distance increased by 150 miles as the operator learns to handle the set.

One stage of audio frenquency is added, so as to be able to use a loud speaker and it is this set that this writing pertains to, as the 3-tube set is just an enlargement of the 2-tube set.

Description of Apparatus

Following is a description of parts of the set: One variocoupler of special design, consisting of tubing 4" high and 4" in diameter, with a regenerator inductance coil at the bottom consisting of 35 turns of No. 22 D.C.C. wire; at the top a stator winding of 26 turns of No. 30 D.C.C. on each half and the rotor which is 3" in diameter and 1½" long is wound with 26 turns of No. 30 D.C.C. wire. All this is mounted on a 4½"x4½"x⅞" wood block and shellacked. The air choke coil is wound on a tube of 5" diameter and 8" long and supported by blocks cut to fit under each end and shellacked and is wound with No. 28 enameled wire of 400 turns, as described above.

3—Cotoco .001 M.F. variable condensers.

1—.005 fixed condenser.

2—Bradleystat filament controls.

1—Vernier filament control.

1—Dayton audio frequency amplifying transformer.

3—Power tube sockets.

3—Radiotron U.V.-202 tubes.

1—Bakelite panel 3/16"x12"x21".

2—"C" batteries 0 to 12 volts.

1—"B" battery 100 to 200 volts.

4—3" dials.

2—Contact arms, 1½" radius.

30—Contact points.

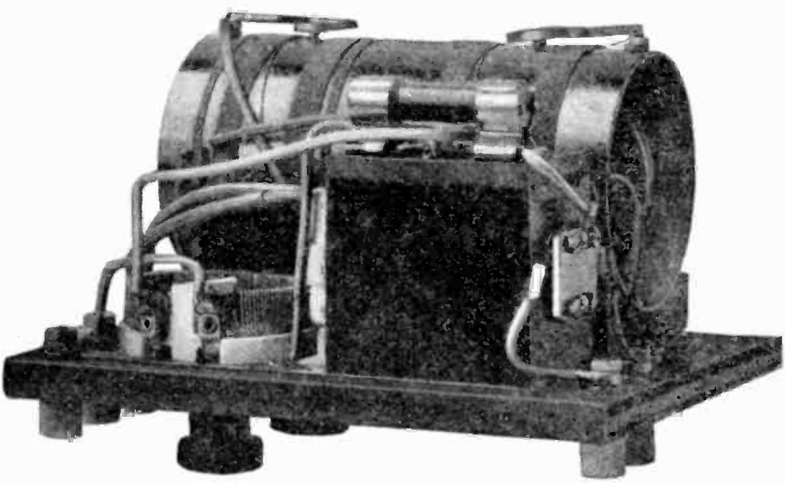
6—Terminals for loop and battery connections, all mounted on and to the panel and wood base. (I used a bench mounting for the tubes, sockets and honeycomb coils.)

2—1500-turn honeycomb coils manufactured by the Coto Coil Co. I experienced some trouble when I first built my set, due to bad material which I had to replace, as one tube was broken down between the grid and filament, one fixed condenser shorted and a screw with the threads stripped on a coil support. When I was sure of the wiring and material, I was still unable to tune in, but I kept trying for several evenings and first heard KSD and from then my list grew and is still growing and so does my "company" when I am home. I am now using a Western Electric loud speaker.

How to Make a Portable Receiver

***By* W. B. Hodgson**

The circuit described herewith has one or two peculiarities which I am sure account for the remarkable records this set has employed in only two sets on the market today, one the Aeriola, Sr., the other the Colin B. Kennedy apparatus. This feature



The Portable Receiving Set. Simplicity in Design and Construction Has Not Been Overlooked.

made in long distance reception. The method of securing regeneration by means of both a tuned and tickler plate circuit is gives the strong oscillation produced by means of tickler feed back together with the very gradual control of regeneration and oscillation common to any variometer tuned plate circuit. Another unique feature is the fixed antenna circuit condenser. As we all know, the usual single circuit receiver employs a fixed inductance or one variable in steps in series with a variable capacity to resonate the antenna circuit. It is every bit as efficient to have a fixed capacity and a continuously variable inductance, and this is the method employed.

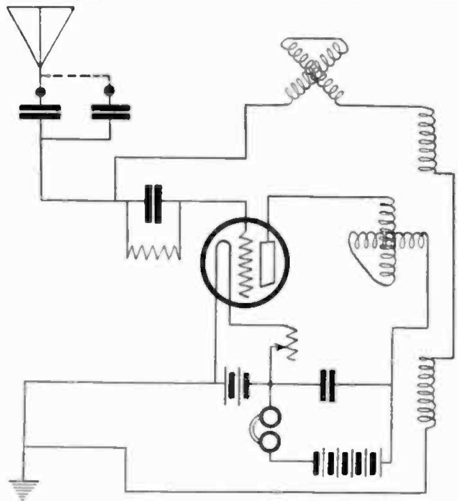
Let us now proceed with the actual constructional details. As this set is operated with the controls in a horizontal position, as the British build their sets, and the great majority here prefer a vertical panel, a few changes will be made in order to adapt the instruments to panel mounting. The parts needed are as follows:

1 piece of bakelite tubing 3½" in diameter by 6" long with a wall 1/16" to 1/32" in thickness.
2 pieces of bakelite tubing 2¼" diameter by 1⅝" long.
¼ lb. of No. 24 D.C.C. magnet wire.
3 type 601 micadons having the following capacity: .0001, .00025 and .002 microfarads respectively.
1 type 600 Dubilier condenser, capacity .00025 MF.
1 megohm Radio Corp. grid leak.
1 socket for the WD-11 or UV-199 tube (there are several good ones on the market and either the Atwater Kent, NaAld, General Radio or R. C. A. will do nicely).
1 rheostat.
A vernier is hardly necessary and is not recommended, as this tube is not critical.

This completes all parts necessary except panel binding posts, spaghetti and dials. Complete parts without tube should not cost over eight dollars.

Draw a line down one side of the 6" tube parallel with the center line and on this line measure in 1 7/16" from each end and drill a 5/16" or ⅜" hole. Directly opposite these holes in the opposite wall of the tube drill a 3/16" hole. The larger hole is on the side of the tube next to the panel and is large enough to allow the shaft and an insulated flexible lead to pass through together without binding. At both ends of a line drawn through the centers of the 3/16" holes drill a small hole, the proper size for a small machine screw. Put these two screws through the holes from the inside and hold them in place with a nut. We are now ready to start winding.

Hold the tube horizontally in the hands and fasten the end of the No. 24 wire under the screw at the left hand end and wind so that the winding progresses toward the right. Furthermore, the direction of rotation of the winding should be such that the spool of wire is passed away from you as the wire passes under the tube and comes toward you as the wire is brought over the top. This small detail is important in order that the inductance of the tickler winding may assist and not oppose the plate variometer. When the wire is fastened under the screw head it is brought straight in for about ½" before the winding is started.



The Circuit of the Westinghouse Aeriola, Sr., Which is Employed in the Above Receiver Because of Its Operating Efficiency. All of the Stationary Coils Are Wound on the Same Form.

Just 16 turns are put on and then a space of ¾" is left and the winding again continued for another 16 turns. The width of these two windings is about ⅜" each and they constitute the stator of the tuning variometer. The wire may be stiffened and held securely in place as it is wound, by painting it with liquid bakelite. If this cannot be obtained water glass will do, but is not quite as efficient. The winding is now continued after a space of 1⅜" is left and six turns wound on. At the end of these six turns a very small hole is drilled in the tube and after about 6' of wire is unreeled from the spool it is broken and the end passed down through the hole and pulled through until all slack is taken up. Just 2" further along on the tube and about ⅝" from the right hand end of the tube, a similar hole is drilled and the wire passed back through the tube and six more turns put on.

The Winding

Two small holes about ¼" apart are drilled close up at the end of this winding and the wire threaded through once or twice to keep it from unwinding. A lead about 6" long should be left and this is later soldered to the shield behind the panel. In the 2" empty space between the two coils of six turns each is wound the stator of the plate variometer exactly similar in every respect to the stator of the antenna circuit variometer. Be careful to keep to the same direction of rotation as before. The start of this winding is made at the back of the tube so that connection may be made to the rotor by means of a pigtail to the end of the metal shaft of the rotor. The other end of the stator winding is fastened in place with a piece of oiled cambric covered with the varnish and held under the windings. A 6" lead is left at this end, a piece of spaghetti is slipped over this and connection is later made to the plate connection on the socket.

The two rotors are next taken in hand and wound exactly alike. Commencing about 1/16" from the edge 20 turns are put on. A ¾" space is left, and another 20 turns wound on, and the end fastened by threading through two small holes, as described before.

A 6" piece of flexible insulated conductor as small as can be had is soldered to the end of the winding on the inside of the rotor and passed out through a small hole drilled about ¼" away from the hole for the front shaft. After the rotors are set in position inside the tube, this lead is brought out through the shaft hole in the stator which was drilled 3/16" or ⅜" for this purpose. This lead goes to one of the phone binding posts on the panel after the parts are all assembled. This, of course, applies only to the rotor of the plate variometer. The lead from the other rotor is brought out to one side of the antenna series condenser. The other ends of the rotor windings are soldered to the rear shafts which are made of 3/16" brass rod fastened securely into the rotors by means of small brackets on the inside. After the rotors are slipped into place a pigtail is soldered onto the end of these shafts and fastened under the screw heads which were placed in the large tube at the start. There should now be a total of four leads coming from the assembled unit as follows:

1. A flexible lead coming through the front shaft hole in the antenna circuit variometer which, as may be seen from the winding diagram, goes to the condenser.

2. A flexible lead through the shaft hole of the plate variometer which goes to one of the phone binding posts.

3. A lead from the end of the tickler winding. This is soldered to the shield after the tube has been fastened to the panel by a bracket at either end.

4. And lastly a lead from the stator of the plate variometer which goes to the plate of the tube.

This practically completes all constructional work and the set can now be assembled.

The tube is mounted vertically behind the left-hand side of the panel with the antenna variometer at the top. To the right of the tube at the bottom on a line with the plate variometer is placed the rheostat. Above the rheostat is the tube socket. The wiring of the set is a simple matter and should preferably be of the busbar type. By consulting the wiring diagram any details which have not been made quite clear should be easily seen.

A Practical Receiver

By A. W. Lambert, Jr.

The accompanying illustrations show how any amateur or novice, with the aid of very few tools and little constructive ability can construct a complete receiver of the good old variometer type. And he will find that it not only works as well as the most expensive similar outfit that money can buy, but that it will grace the operating table at any station and be a source of pride to the builder.

Although this tuner and detector unit is a complete receiver, the set is designed as the first unit of a series of units. It can be simply and quickly connected to an external detector and amplifier, of audio or radio frequency design.

Fig. 1 shows the receiver in its cabinet. Used as shown, with but a single detector tube, the writer, at Arcadia, Mo., one hundred miles south of St. Louis, listened to the St. Louis Municipal Opera as broadcasted by KSD, hearing the lines and music far better than could the audience in the seventy-five cent seats at the theatre itself. With external detector and two stages of amplification we let her run at home and listened to the entire programs of *Sari*, *Yeoman of the Guard*, *Spring Maid* and other delightful renditions.

In the middle of summer, while at Arcadia (which is close to the lead belt section of Missouri, and also surrounded by hills) with the receiver shown in Fig 1. we heard broadcasts from Madison, Wis.; Detroit, Mich.; Memphis, Tenn.; St. Louis, Mo.; Indianapolis, Ind.; Kansas City, Mo.; and Atlanta, Georgia; to say nothing of numerous distant amateurs and 600 meter stations sending in code.

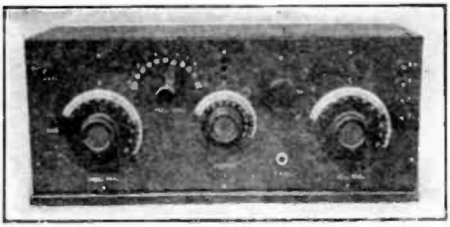


Fig. 1. Front View of the Regenerative Receiver.

The following materials were used in this receiver. Standard apparatus of other makes than those named can no doubt be substituted with equally good results.

1 Cabinet, oak, mission finish.
1 Hard Rubber 7"x18"x3/16" (New U. S. Rubber Co.) Material for radio panels.
2 *Heard Co. Variometers.
1 ‡Heard Co. Variocoupler.

*Wound with 56 turns No. 20 D. C. C. on Stator and Rotor.
‡Primary consisting of 50 turns No. 22 D. C. C. tapped every 5 turns. Rotor ball wound with 36 turns same wire.

1 Oz. tinfoil.
12 Feet spaghetti.
20 Feet No. 14 aerial wire.
10 Feet No. 20 D. C. C. (used scrap).
5 Feet flexible lamp cord (used scrap).
1 Wood board 2"x14"x½".
4 Cigar-box wood spacers 1"x3½".
1 piece brown wrapping paper.
½ pint orange shellac.
3 dozen ½" No. 4 R. H. brass woodscrews.
1 dozen No. 6 brass washers.
2 only 2" No. 6 flathead wood screw.
8 only 1" No. 8 flathead woodscrews.

* Binding-posts have 1" No. 8-32 machine-screws with brass base-lug and thumb nuts tapped clear through. This makes it unnecessary to fit binding-posts to any special panel thickness, and leaves plenty of room for heavy interunit connections.

It is readily seen that should the builder of this set desire to economize he can make his own cabinet, wind his own variometers and variocoupler, use less expensive dials, etc.

The tools necessary to construct this unit are found in nearly every amateur workshop or can be purchased at any hardware store for very little. About the only tools used by the writer were: 1 hand-drill and drills, small soldering iron, ten cents worth of solder, ten cents worth of paste, pliers, hammer and screw-driver. The entire set was constructed on the back porch of a summer home, using the dining-room table (between meals) for a work bench.

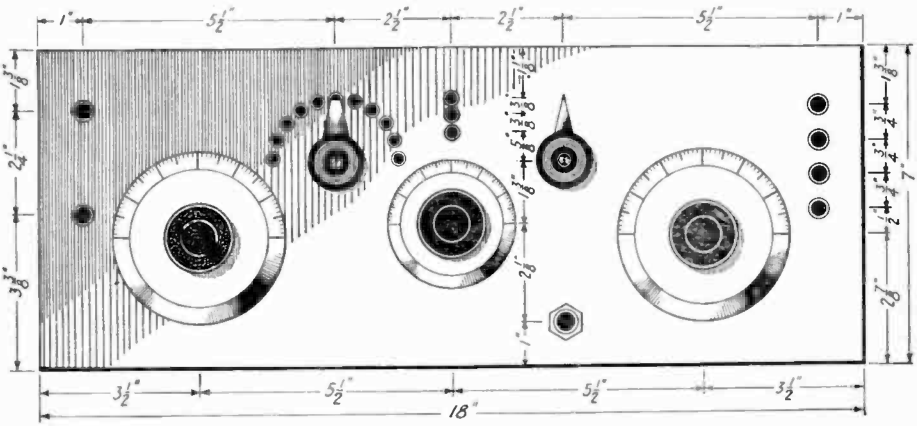


Fig. 2

Front of the Panel with All the Distances Between Holes for the Apparatus Illustrated.

1 Kellogg Vacuum Tube socket.
1 Cutler-Hammer filament rheostat.
1 No. 131 Frost Jack.
2 4" bakelite dials.
1 3" bakelite dial.
1 1½" radius switch lever.
11 Contact points.
1 Gridleak and Condenser.
10 *Binding-posts.

We will now describe the assembly, step by step.

First Step, Panel Preparation

(1) Lay out the panel as shown in Fig. 2. It is best to lay out this design on a piece of paper. The paper pattern may then be on the panel front and the various holes marked with a center-punch.

The layout given shows dimensions for the instruments used in the set built by the writer. If other makes are used, although the panel layout is practically the same, the various holes should be checked and placed in proper position.

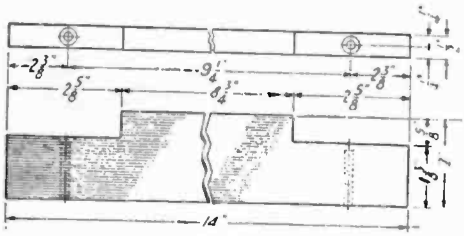


Fig. 3

Dimensions of the Back Support Which Holds the V. T. Socket Are Given in This Diagram.

Holes for the screws that are to attach the panel to the cabinet are not shown. In any case it is best to wait until mounting the panel before locating these.

(2) Drill the holes. Take care to see that you do not drill a small hole-mark for a ¼" shaft by mistake. The writer prefers to drill the *large* holes first, and before drilling each hole he checks and rechecks the same.

(3) Ream out the shaft holes slightly larger than the relative shafts. This allows for any slight irregularity in drilling holes for the attachment screws and keeps the shafts from binding.

(4) Countersink all holes for flathead attachment screws.

(5) Engrave the panel. If bakelite is used, it is best to have a professional engraver do the job. However, if hard rubber or black fibre is used the letters may be stamped in.

The panel shown in the photographs was a hard rubber panel. The letters were stamped in with a set of steel dies borrowed for the occasion. (Ordinary printers' type has also been used with fair success. Good sharply cut block letters should be used, however, as such type is rather soft.)

(6) Give the back of the panel and also one side of a sheet of tinfoil a good coat of shellac and let dry. In shellacking the panel be sure to hold face up. This will prevent the shellac from running through the holes onto the face.

(7) When the above coats are dry, reshellac the panel and tinfoil. Wait until the second coat has become gummy. Then stick the tinfoil on the back of the panel and let dry. (If desired, copper-sheet may be used in place of the tinfoil, but it is harder to work.)

(8) After giving the tinfoil shield a little time to set, take a sharp knife and cut away the shielding from about the shaft-holes, switchpoints, binding-posts, etc. However, the shield should not be removed from around the ground connection binding-post hole.

(9) When the tinfoil shielding has had time to set firmly in place, give it one or two coats of shellac and stick a sheet of brown wrapping paper over it. This protects the shielding and acts as an insulator to prevent accidental grounds. It should also be given an outside coat of shellac.

The panel should then be put away for at least 24 hours to dry.

(10) Punch out the holes through the paper. This is done quickly and easily with a red-hot ice-pick.

The panel is now ready for the mounting of the instruments.

Second Step, Mounting the Instruments

Fig. 4 shows the panel assembly; all the instruments are mounted either directly or indirectly to the panel. This makes the entire assembly a *unit* which may be removed at will from the cabinet and turned in any position for soldering or repairing.

The use of the brace across the back of the variometers is a novel wrinkle, which the writer believes to be the best mounting method for such an outfit ever tried. Besides providing a convenient mount for the tube-socket, it aids greatly in securing rigidity. It serves as a convenient support for long bits of wiring and makes a convenient place to put the "sub-terminals" for the "A" and "B" battery connections.

The photos show the method of mounting. However, the writer recommends the following procedure:

(1) Mount the switchlever and each switchpoint fully before proceeding to the next; this gives plenty of room for the pliers in tightening the nuts. (Two little stops should be cut from a strip of brass or tin for the two end points.)

(2) In mounting the variometers, secure them to the panel with four 1" No. 8 flathead wood screws. The front of the variometers should be spaced away from the panel about ⅛" to prevent accidental grounding to the panel. Two wood-spacers 1"x3½", of cigar-box or other thin wood, shellacked, should be employed. Care should be taken to drill holes to pass the 1" assembly screws.

(3) Mount the variocoupler.

(4) Mount the filament rheostat. If Cutler-Hammer is used, it is best to mount with the terminals *down*.

(5) Mount jack.

(6) Mount binding-posts.

(7) Mount the wood brace that serves also as a socket mount. The dimensions of this piece are shown in Fig. 3. This brace should be mounted ½" above the variometer base and care should be exercised to

see that it is mounted *square*. Use 2" No. 6 flathead wood screws and take care they do not penetrate the stator windings.

Now test for accidental *panel grounds*. If none are discovered, the unit is mounted and all ready for the wiring.

Third Step, Wiring

The hook-up used in this set is shown in Fig. 4.

Fig. 5 shows the wiring. The circuit is the good old standard two-variometer circuit. The diagram of connections shows the proper order in which to make the connections if convenience in soldering is desired The "inside" and "close-to-the-panel" connections are made first. The arrowheads show the beginning and end of each wire. Using the pictured view in Fig. 5 and taking a little care in making right-angle bends and using straight wire will produce a remarkably neat and workmanship looking outfit.

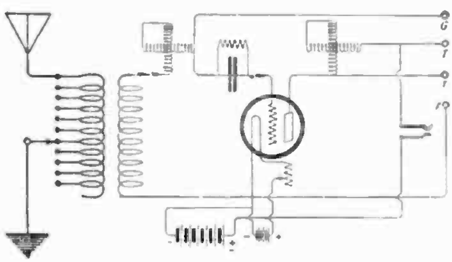


Fig. 4. Wiring Diagram of This Short-Wave Receiver. The Same Tuner Can Be Used With Another Detector.

Connections to taps should be made of No. 20 bare or D. C. C. All others should be made of No. 14 bare copper wire or larger. Connections should be covered with spaghetti, which should also be used to cover any wires which are in danger of touching others.

When the connections shown in Fig. 4 are completed, they should be tested for misconnections. If none are found, the unit is ready to be placed in its cabinet.

Fourth Step, Placing in Cabinet

The cabinet shown in Fig. 6 was made of ⅜" oak, with mission finish, measuring 7"x18" by 8½" deep.

"A" and "B" batteries are connected to binding posts at the *rear* of the cabinet. Their location is shown in Fig. 6.

Fig. 6 gives the dimensions and layout. You will notice that the cabinet is of the flush panel type. Only the over-all and a few odd dimensions are given.

The binding posts for "A" and "B" should be connected to the sub-terminals on the socket-mount board by one-foot lengths of lamp cord. This makes it easy to remove

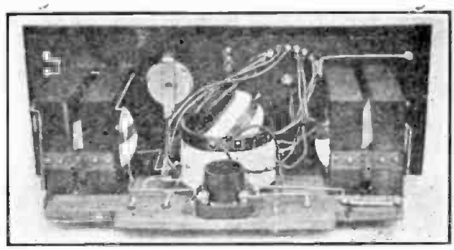


Fig. 5. A Full Back View of the Finished Receiver Which Clearly Shows the Wiring.

the wired tuner-detector unit from the cabinet, to get at any part of the set. As soon as the "A" and "B" connections mentioned are made, the unit should be placed in the cabinet and the screws that hold it in place put in. The letters should then be whitened The writer used white shoe-polish and a steel pen. This fills in the indented letters and soon dries.

The dials should be put on last, and when they are in place it is only necessary to connect the antenna and ground wires and attach the batteries, when the outfit is ready for work.

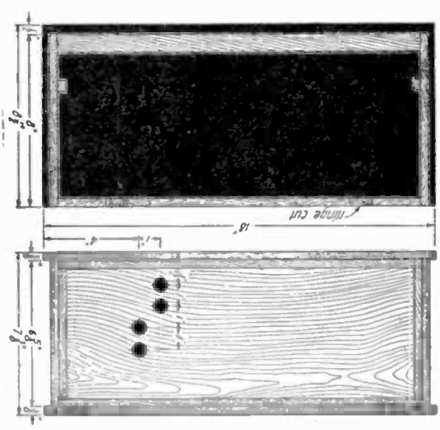


Fig. 6. Dimensions and Details of the Cabinet Which Encloses the Receiver Are Given Here.

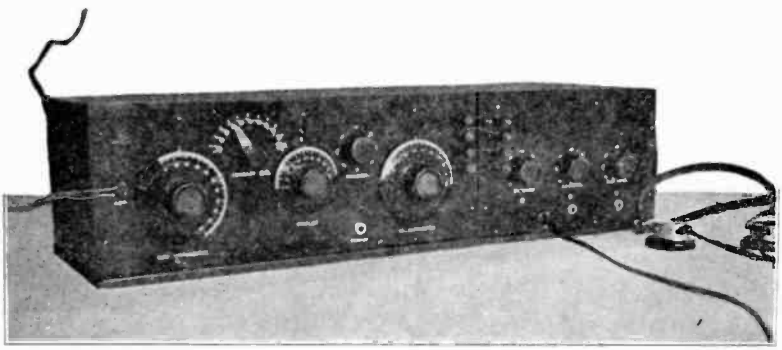
The four binding-posts *G*, *T*, *T*, *F* enable an external detector to be connected. The next article will describe a detector and two-step audio frequency amplifier unit that matches up with this one.

A Detector-Amplifier Unit

By **A. W. Lambert, Jr.**

The description of the detector-amplifier unit as an addition to the standard regenerative set has been one of the amateur's singular requests. The writer has therefore given an explanation of a simply constructed unit that is suited to almost any type of tuner.

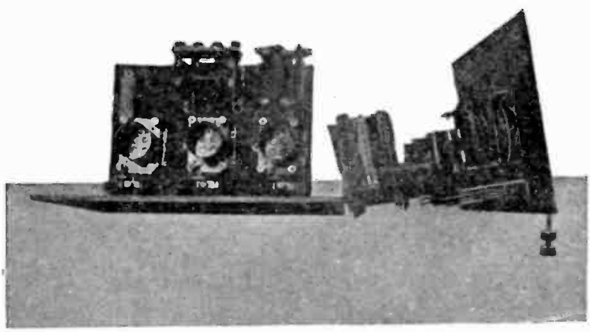
short bits of wire to hook together the two units. These connections are made in front because with them so placed it is easy to disconnect the short-wave set and hook on another tuner at will. The battery connections are all in the rear.



The Detector-Amplifier Unit Connected to the Receiver Described in this Book.

However, this unit was especially designed to be used in conjunction with the set described in this book under the title, "A Practical Receiver."

To some it might seem unnecessary to include another detector. However, the added cost of duplicating the detector socket, rheostat and one or two other items is



Interior View of the Detector-Amplifier Unit Showing the Arrangement of the Parts.

A view of the two units (the regenerator and the herein described detector-amplifier unit) is shown in an accompanying photograph. The smaller cabinet on the right contains a detector and two stages of audio frequency amplification. The binding-posts for connecting the detector-amplifier unit to the tuner are on the left of its panel, matched to the four relative binding-posts marked G. T. T. and F. on the original. This makes it necessary to employ only four

small compared with the great convenience of having a detector-amplifier unit that will function with any other tuner the builder may want to work with it. The writer is now using such a unit and is continually changing it from his short-wave set to a honeycomb outfit so as to get Arlington and the long waves. Of course it is not necessary to employ two detector tubes.

The first operation to begin constructing the unit is to mount the instruments "laboratory fashion." Place them on a board in any convenient manner. Connect them up in any old way to begin with,—and make them work. In this way you will become accustomed to the way different things act.

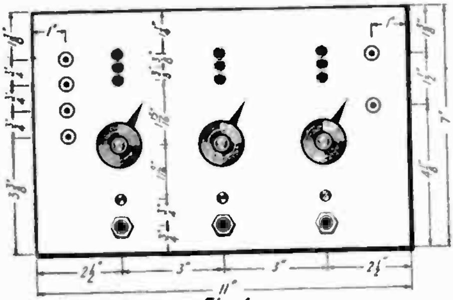


Fig. 1

Dimensions for the Layout of the Panel.

After this so called "undress rehearsal" a neat job resulting in a cabinet receiver is a mere second step. The arrangement and dimensions herein given are merely suggestions. The dimensions may have to be changed slightly if apparatus of different makes than those listed by the writer are used. However, by following the details carefully the constructor is sure to come across useful little kinks that may be employed with benefit.

MATERIAL NEEDED

1 Cabinet, oak, mission finish, 7"x11".
1 Hard rubber panel.
3 Vacuum tube sockets.
3 No. 131 Frost jacks.
*2 Amplifying transformers.
**3 Cutler-Hammer filament rheostats.
1 Grid condenser and leak (home-made)
***11 Binding-posts.
1 Oz. tinfoil.
1 Wood board, 8½"x6"x½".
12 Ft. spaghetti.
20 Ft. No. 14 aerial wire.
3 Doz. ½" No. 4 round-head brass woodscrews.
1 Doz. ¾" No. 6 round-head woodscrews.
1 Doz. No. 6 brass washers.
3 2" No. 6 flat-head woodscrews.
8 1" No. 8-32 round-head brass machine screws.
8 No. 8-32 hexagon brass nuts.
6 Small two-cell flashlight batteries.

*Any good amplifying transformer may be used.
**It is recommended that the vernier type of rheostat be purchased for the detector tube.
***The writer used binding-posts having a 1" No. 8-32 machine screw with brass base-lug and thumb-nut tapped clear through. This makes it unnecessary to fit the binding-post to any special panel thickness, and leaves plenty of room for heavy inter-unit connections.

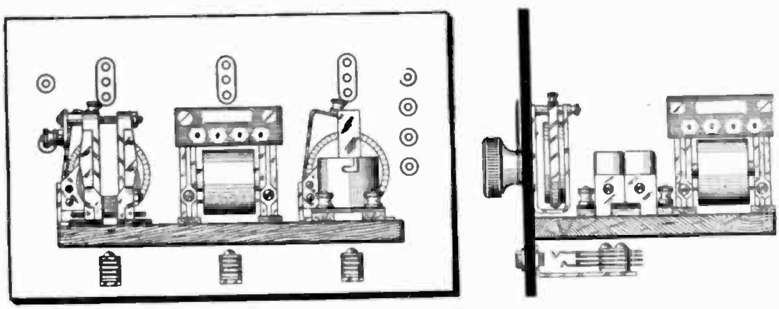


Fig. 2

Perspective Drawing of the Unit. The Sockets and Transformers Are Mounted on a Shelf, a Most Convenient Method.

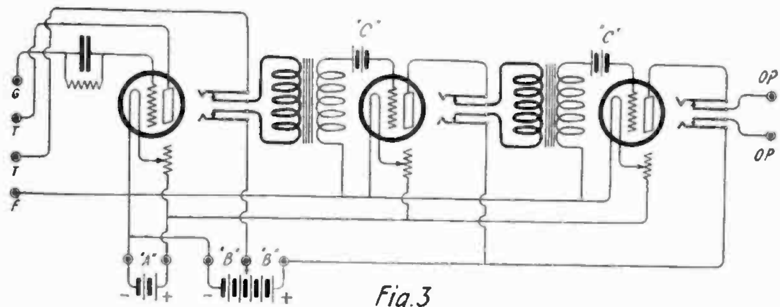
The following materials are necessary for the construction of the unit. Standard apparatus of other makes may be used if desired; only care must be taken, as mentioned above, to see that they fit in place properly. The unit is completely panel-mounted, which makes it easy to remove the "works" from the cabinet for alteration or repair.

Should the builder desire to economize, he can build his own cabinet. Dimensions for it will be seen in Fig 4.

Fig 1 shows the layout of the panel. This layout should be copied on a sheet of paper, full size, and this paper used as a pattern to locate the holes.

The four binding-posts on the left should be marked G, T, T, and F. The two binding posts on the right should be marked OP (referring to output). And under each rheostat knob mark respectively the words Detector, 1st Step and 2nd Step. Name plates like these may be purchased from radio dealers and attached to the panel with small escutcheon pins. A series of arrow heads are stamped at intervals around each rheostat knob as a position indicator for the pointer. A close scrutiny of the photograph will show this marking.

If everything is laid out as indicated, it will be found that ample clearance for the tips of the vacuum tube (if Radiotrons or Cunninghams are used) is provided for. However, if any slight changes are made this should be made sure of, and in case



Complete Circuit Diagram of the Detector-Amplifier Unit. "C" Batteries Are Used in the Grid Circuit of the Amplifier Tubes.

there is not enough clearance, holes should be bored in the lid of the cabinet to permit its being closed.

After all the instruments are mounted, as shown in Fig. 2, the unit is ready for wiring, but before doing this the whole should be carefully tested for accidental grounds to the shielding. This is the time to make certain that no such grounds occur. An accidental ground discovered and remedied at this stage of the construction may save hours of hunting and repairing later.

A battery and buzzer or a battery and flashlight should be used to do this testing. One wire from the tester should be held in firm contact with the tinfoil shielding and the other brushed against all the other instruments in turn. Also ascertain that each instrument is electrically insulated from other instruments.

When sure that no accidental grounds exist, the unit is ready for wiring.

The hook-up for this unit is shown diagramatically in Fig 3. This is a standard detector two-step audio frequency amplifier circuit.

The attention to the builder is directed to the two batteries in the grid leads of the amplifier tubes (marked "C"). These batteries are seldom used and may not be necessary; nevertheless their use will probably improve the amplification of the tubes considerably. Provision should be made for inserting these batteries after the unit is complete. They may be placed in the cabinet. The proper voltage will have to be ascertained by trial. This will probably be found to be somewhere between four and eight volts. As the "C" battery supplies practically no current, small two-cell flashlight batteries of ten-cent store variety may be used. They will last indefinitely.

Although shielding is not essential it is a good precaution to take and inexpensive in the end. It is advisable to shield the inside of the entire detector-amplifier cabinet. Heavy tinfoil is stuck in place with shellac, and a layer of brown wrapping paper smoothed on over this. This shielding should then be grounded. Although not shown herewith, an additional binding-post in electrical contact with the shieding may be put on the back, in a position so as not to interfere with the battery connections. This post may then be connected with a short length of wire to the regular *ground* connection.

Fig. 2 shows the back and side views of the panel assembly. No dimensions are given as the instruments should be mounted according to the make used. It will be seen from this sketch how the unit system of mounting all instruments to the panel is accomplished.

The only item of importance not shown in detail with dimensions, is the socket-transformer shelf. This is only a board measuring 8½"x6"x½". It should be a piece of well dried wood, shellacked, and held in position by the three 2" No. 6 flat-head woodscrews. The holes in the panel should be countersunk for these three screws. The position of these screws is clearly shown in the side view of Fig. 2.

It is suggested that the instruments be mounted in the following order:

(1) Mount the rheostats.
(2) Mount the jacks.
(3) Mount the binding-posts.
(4) Mount the wooden shelf (countersink screwheads.)
(5) Mount the tube-sockets (keep the *G* and *P* to the rear.)
(6) Mount the transformers (at right angles as shown.)

G, T, T and F in Fig 3, as mentioned before, refer respectively to Grid, Tickler and Filament connections. The binding-posts marked OP are "Output" posts. Connections to a loud speaker may be made here, or another step of amplification added if one might be desired.

The "A" battery terminals are shown at A and the "B" battery terminals shown at B. Any 6-volt storage battery may be used as an "A" battery; however, as three amperes are drawn when Radiotrons are used, the battery for such tubes should be of 60 ampere-hours capacity or larger, to obviate too frequent charging. If peanut tubes or other low voltage tubes are to be used, care should be taken to have the proper "A" battery and to place sufficient resistance in the circuit to prevent burning out the filament. For "B" battery a 45-volt battery with a tap at 22½ volts, or two small 22½-volt "B" batteries may be used.

The battery binding-posts are shown schematically in Fig. 3 in vertical rows, as they are shown in the cabinet plan in Fig. 4. With this scheme of battery binding-post arrangement it will be found easy to make all battery connections. Beginning at the top we have respectively: (1) Positive terminal of plate battery: (2) Terminal for 22½ detector plate voltage tap; (3) Negative terminal of plate battery; and below and in a line to one side; (4) Positive terminal of storage battery; (5) Negative terminal of storage battery. This gives us a simple rule to follow when hooking on batteries; namely, high voltage at top—low voltage at bottom, positive at top—negative at bottom.

To facilitate panel removal, five screws with brass washers should be put in the rear edge of the socket shelf-board and the "A" and "B" connections as shown in Fig. 3 made to them. These "sub-terminals" should be connected to the binding posts on the back of the cabinet with 12" lengths of flexible lampcord.

All wiring should be made with No. 14 bare copper wire, and the liberal use of spaghetti for insulation is encouraged.

It is recommended that a beginner make the connections as best he can and not try to make too neat a job until he becomes more familiar with the action of such a combination of apparatus. For a "professional" job, the wiring should be properly right-angled and should hug the instruments as closely as practicable. A glance at Fig. 2 will show a clear space from back to panel. If the wiring is made to hug the instruments and the panel, shields may later be placed between each amplifier step to further increase the efficiency of the unit.

The wiring of this detector-amplifier unit is a rather complicated affair and great care should be taken to make all connections as short and direct as possible. If the builder will make a light pencil sketch of the diagram of connections, and go over each connection heavily as soon as it is made, he should be able to complete the job without trouble.

When the hook-up is complete; TEST, TEST, TEST!

Make sure that there *are* connections where they should be, and that there *are not* any cross connections or short circuits where there should be insulation. And *above all* make sure that no "B" battery voltage gets into the "A" battery circuit. Whatever you do, *do not put the tubes in place with "B" batteries connected until you know that everything is right.* It might cost about $18 in real money to replace the tubes.

The cabinet shown in Fig. 4 may be made of ⅜" oak, mission finish, measuring 7"x 11" by 8½" deep.

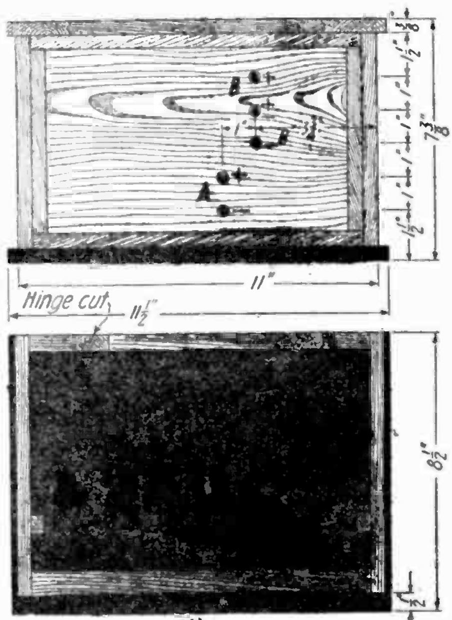


Fig. 4

Constructional Details of the Cabinet.

When all is ready the panel assembly should be placed half-way in the cabinet and the flexible leads from the "A" and "B" battery sub-terminals soldered to the proper binding posts on the back. Then push the panel assembly in place and fasten the panel to the cabinet with ¾" round-head (preferable nickel finish) woodscrews. To avoid confusion the holes for these screws were not shown in the panel layout; but a close look at the photograph of the unit will show the location.

The lettering on the panel should now be filled in with white shoe-polish, and the binding posts on the rear of the cabinet should be marked for identification.

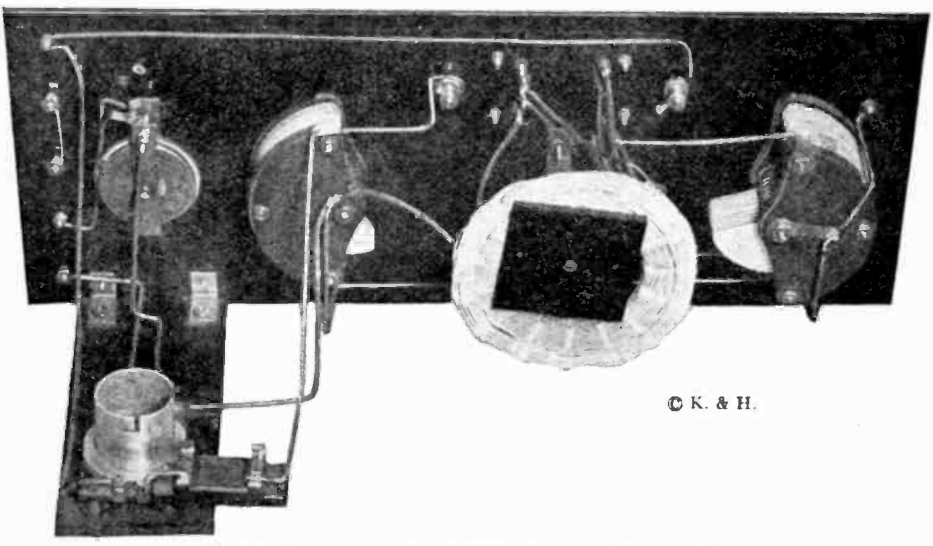
A final test should now be made to make sure that the filaments of the expensive vacuum tubes will not be burned out when the "B" batteries are connected. Put the bulbs in place but *do not connect the "B" batteries*. Now connect the storage battery (six volts) across the "B" battery terminals. The bulbs should *not* light. If they do, something is wrong and the fault must be rectified. If the bulbs remain dark, it is a sign that it is safe to connect the "B" batteries to the unit. The "A" battery should then be connected in its proper place, and if the rheostats work properly and the bulbs light the unit is ready for action. To connect to a tuner it is only necessary to make the G, T, T and F connections with four pieces of wire.

The Unit used in conjunction with a regenerative tuner is shown ready for business in the photograph. If the work is carefully done it makes a combination that any amateur may be proud to display to his friends.

Modern Hook-Ups for the Amateur

The Reinartz Receiver

The Reinartz receiver has become very popular because of the simplicity of its construction and the excellent results that can be obtained. It is well suited for the reception of both broadcasting stations and spiderweb coil in the photograph, condenser 5 being to the left. Both of these condensers have a capacity of approximately .0005 MF. each (23 plates). The switch-arms 2 and 3 are used in conjunction with condenser 1, for tuning, while switch-arm 4 and condenser 5 control the regeneration;



© K. & H.

Fig. 2. Hook-up for the Reinartz Receiver Shown in Fig 1.

amateur stations, and has in some instances been able to receive from very distant points. A photograph of a well constructed Reinartz receiver is shown in Fig. 1, with the corresponding wiring diagram in Fig. 2. As may be seen, the main instruments are two variable condensers and a spiderweb coil. The variable condenser marked 1 in the diagram is the one to the right of the 6 is a standard .00025 MF. condenser and a 1-megohm grid leak. In the photograph this is shown attached directly to the tube socket. The spiderweb inductance is, really, two distinct coils on one form. The first coil has 45 turns, taps being connected to the points of switch 4, from 0, 15th, 30th and 45th turns. The second coil has 40 turns. Take taps off at 2, 4, 6, 7, 8, 9, 10 and 11 turns and connect them to switch 2. Taps for the points of switch 3 are taken off at the 26th, 33d and 40th turns. If a WD-11 tube is used, a dry cell should be connected to the "A" battery posts instead of a 6-volt storage battery.

coils having the proper number of turns. The radio frequency amplifiers may be cut in or out of the circuit by the manipulation of switches S2 and S3, the amplifiers being cut out when both switches are placed on points D, and cut into the circuit when the

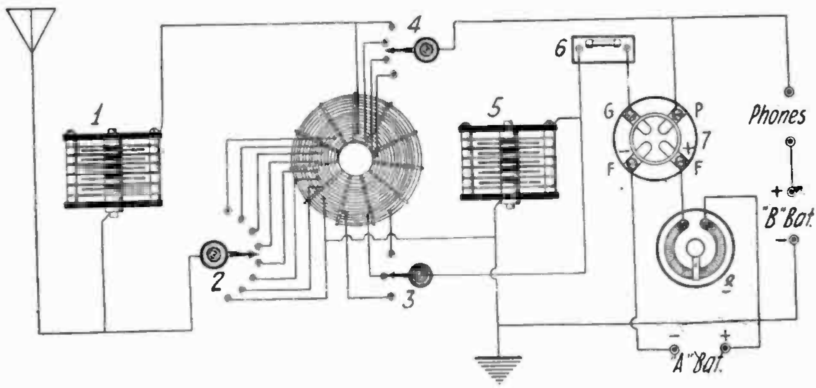


Fig. 2. Hook-up for the Receiver Shown in Fig. 1.

The Flewelling Receiver

A one-tube Flewelling set can deliver enough volume to nicely work a loudspeaker. When properly operated, it is capable of long-distance reception. A well designed Flewelling set is shown in Fig. 3, with its wiring diagram in Fig. 4. The two honeycomb coils 1 and 2 are mounted on the front of the panel. These are of 50 and 75 turns, respectively. The variable condenser 3 is one with 43 plates and a combined vernier; 4 is a .00025 MF. grid condenser, and 5 is a variable grid leak, having a comparatively low minimum resistance. The three condensers 7 are each of .006 MF. capacity. The set shown in the photograph uses three banks of condensers, each bank consisting of three fixed condensers of .002 MF. capacity, thus making a total of .006 MF. in each of the three banks. The grid leak 6 need not be of the variable type. This set works best when using a VT-1, VT-2, UV-201, C-301, UV-201A or C-301A and a "B" battery of from 45 to 100 volts.

It is necessary that the best quality of apparatus be used in this receiver or the results obtained will be poor.

A Long Distance Receiver

One can receive from great distances with a receiver of the type shown in Figs. 5 and 6. It consists of two stages of radio frequency amplification, detector and two stages of audio frequency amplification. Tuning is accomplished by the use of honeycomb coils and variable condensers. It is possible to cover any band of wavelengths desired by plugging in honeycomb

switches are thrown to points R. The honeycomb coil marked T is employed for regeneration. The variable condenser marked PC is used for tuning the primary circuit, and may be placed in series, or parallel with the honyecomb coil P, by means of the switch S1. The same switch is used to cut this variable condenser out of the circuit. The variable condenser SC is connected across honeycomb coil S, and is used for tuning the secondary circuit. These condensers each have 43 plates. The potentiometer should have a range of resistance from 200 to 400 ohms. The honeycomb coils do not show up in the photograph. They are plugged in to a three-coil mounting, which is attached to the front of the panel.

A Four-Tube Reflex Receiver

The Reflex Receiver might well be called a double-duty outfit, for the tubes do just this. A four-tube reflex set is shown in the photo of Fig. 7, its corresponding hook-up being in Fig. 8. The first three tubes are used for five stages of amplification, three of radio frequency and two of audio frequency. The last tube acts as the detector, and is used in conjunction with the usual grid leak and condenser. The two variable condensers provide the means for tuning. One is connected in series with the primary coil of the variocoupler, and the other is in shunt with the secondary coil. In the photograph, the radio frequency transformers are seen mounted at right angles to the vacuum tube shelf. The two audio frequency transformers are mounted on the base, between the two variable condensers. The small square fixed condensers show up clearly. Their values are given in the circuit diagram of Fig. 8. A loop aerial can be used to advantage with this receiver, if desired. It should be connected to the points marked "A" and "B." The variocoupler, of course, should be disconnected, when the loop is in use.

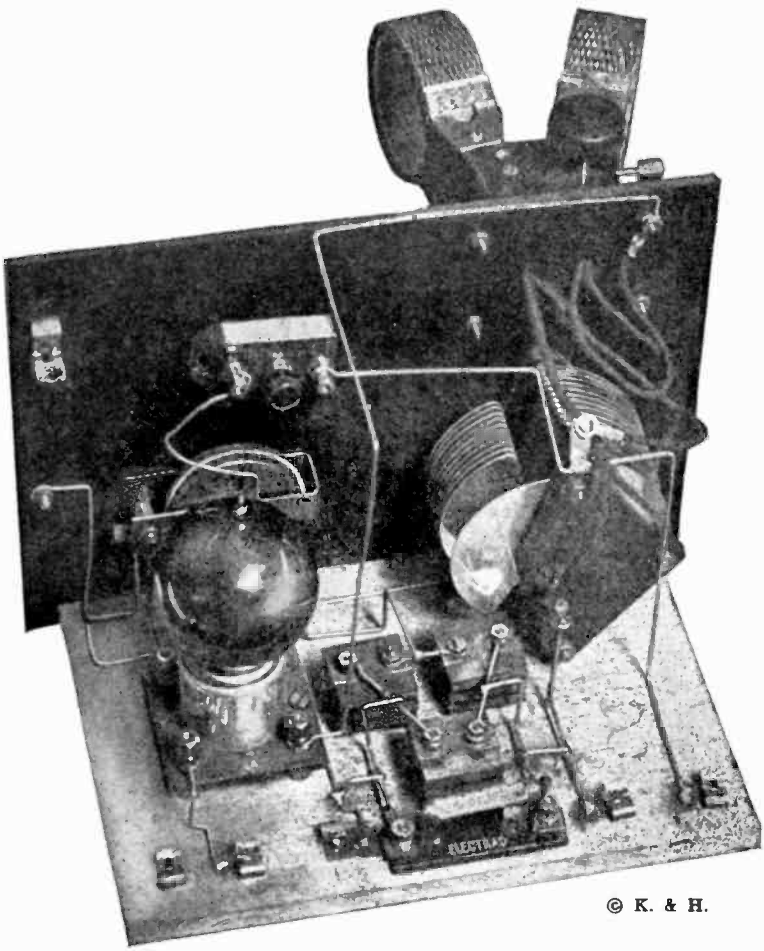


Fig. 3. A Photograph of a Flewelling Receiver. The Apparatus is Well Arranged, Allowing for Short Connections.

Super-Heterodyne Receiver

The most sensitive type of receiver known today is the Super-Heterodyne. The front and rear views of such a set are shown in Figs. 9 and 10. This set employs 10 vacuum tubes, one of which is used as an oscillator, two as detectors, five as radio frequency amplifiers, and two as audio frequency amplifiers. The corresponding hook-up of this receiver is shown in Fig. 11. Although only seven tubes are shown as being used, this number is really satisfactory for all purposes, there being three stages of radio frequency amplification and one stage of audio frequency. The radio frequency transformers (11) are the type having an iron core and designed for operation on a wave-length of 5000 meters. The audio frequency transformers (13) can be of any standard make. Variable condensers (8 and 9) have a capacity of .001 MF., while the honeycomb coils (10) each have 250 turns. The potentiometer (12) has a variation of resistance of from zero to 400 ohms and is used for stablizing the action of the radio frequency amplifiers. If more stages of radio frequency are desired, they should be connected into the circuit in the same manner as the three shown.

In the circuit shown below, 1, 2 and 3 constitute the aerial circuit which is tuned in the usual way. If a loop is used instead of the aerial it takes the place of the secondary of the variocoupler. The oscillator circuit 5 is made of a tube 3" in diameter, wound with 40 turns of No. 20 D.C.C. wire, with a tap at the 20th turn. On the same tube and about 2" from the first coil are wound 8 turns of the same wire, connected in series with the secondary of the variocoupler.

Although the tuning of such a receiver may seem difficult at first, it is not, in fact, more complicated than that of an ordinary three-circuit regenerative receiver. When a loop aerial is used there are only two controls, the tuning of the loop and the oscillator by means of the variable condensers.

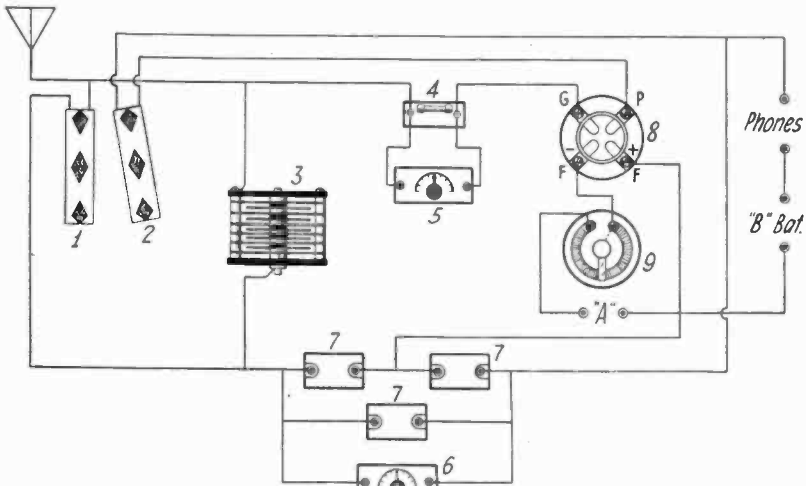


Fig. 4. The Wiring Diagram of the Flewelling Set. No Ground Connection is Used in This Circuit.

A Tuned Radio Frequency Amplifier

It is the desire of the average owner of a radio receiving set to be able to pick up the distant broadcasting stations, as well as the local ones. If this can be satisfactorily accomplished, there is the advantage of a wide selection of broadcast programs, any of which can be received at will. Again, there is that unexplainable itch for distance that makes such a set desirable.

In order to receive in a reliable manner programs from stations at some distance, it is necessary to use radio frequency amplification in conjunction with a receiving set. Although the transformer coupled type of radio frequency amplifier is excellent, the type referred to as a tuned impedance ampli-

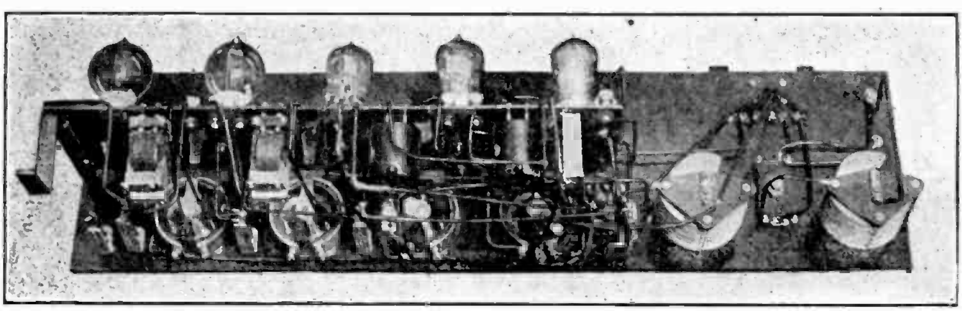


Fig. 5. A Sensitive Receiver, Built For Both Distance and Volume. It Employs Two Stages of Radio Frequency Amplification, a Detector and Two Stages of Audio Frequency Amplification. The Potentiometer is Mounted to the Right of the Three Filament Rheostats.

fier is superior. Where but one stage of radio frequency amplification is to be used, it is advisable to employ this type, as a ployed in such a receiver. Very good results can be obtained with but two tubes, utilizing one as a radio frequency amplifier,

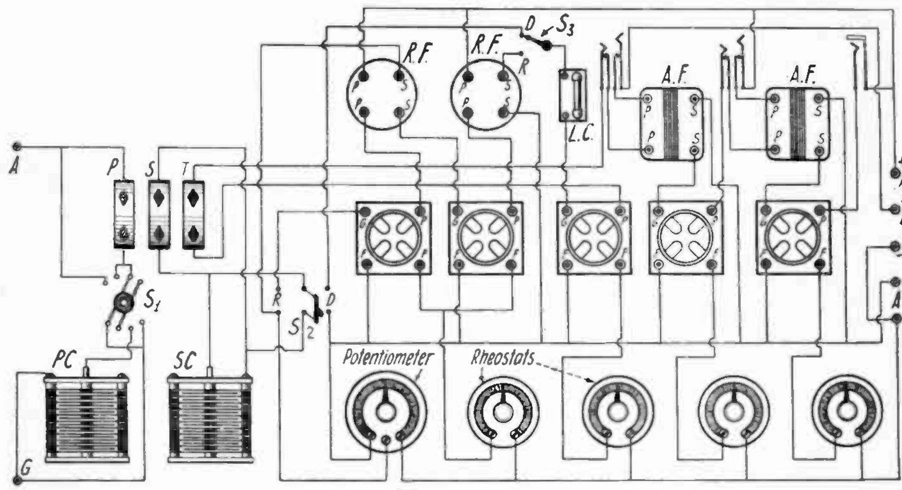


Fig. 6. The Circuit For the Receiving Set Shown in Fig. 5. Although a Rheostat is Shown For the Filament of Each Tube, the Pair of Radio Frequency Tubes and the Pair of Audio Frequency Tubes Can Each Be Controlled By One Rheostat.

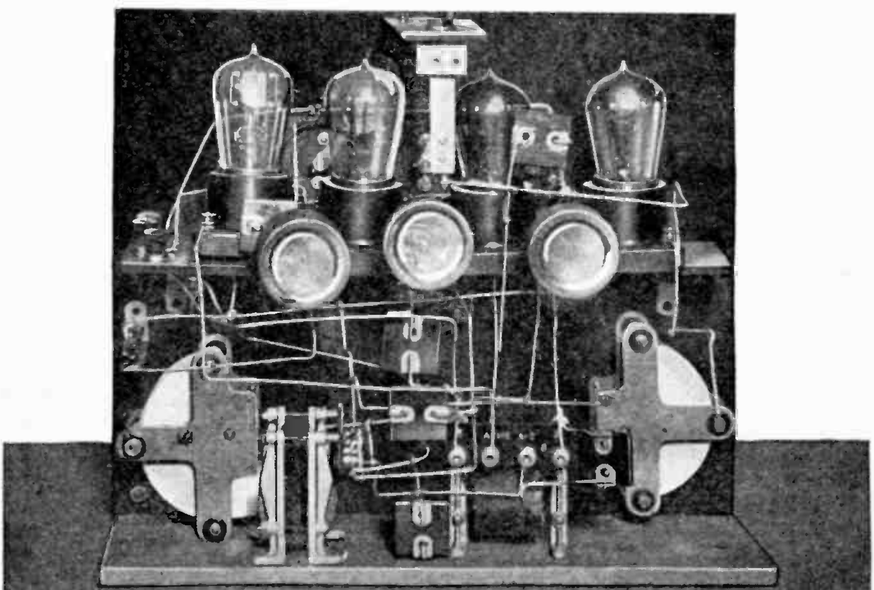


Fig. 7. A Four-Tube Reflex Receiver That Furnishes Three Stages of Radio Frequency Amplification and Two Stages of Audio Frequency Amplification. The Tube on the Extreme Left is Employed As a Detector. The Small Square Fixed Condensers Are Used to By-Pass the Radio Frequency Currents. Great Distances Can Be Covered With a Receiver of This Type, Using a Loop Aerial.

greater distance can be covered. The WD-11 and UV-199 tubes are very good radio frequency amplifiers, and can be well em- and giving all the possibilities of distant reception.

This set is easily built, all of the parts being standard. The necessary apparatus required, with their corresponding numbers in the diagram, Fig. 13, are as follows:

(2)-(3). Variocoupler; (4)-(7). Two 23 Plate Variable Condensers, (.0005 MF.) of the same make; (5)-(9). Two vacuum Tubes; (6). DL-35 Honeycomb Coil; (8). Fixed Grid Condenser, (.00025 MF.); (10). Head-Phones; (11)-(15). Two Filament Rheostats; (12). Two 22½ Volt "B" Batteries; (13). 1-Megohm Grid Leak; (14). 200-400 Ohm Potentiometer; (16). Two or more dry cells depending upon the tube used.

Referring to the diagram of Fig. 13, the tube (5) is the radio frequency amplifier, and the tube (9) is the detector. Coils (6) and condenser (7) compose the tuned impedance with which amplification is obtained. The layout of this receiving set is shown in Fig.12. The apparatus is placed to correspond with the circuit of Fig. 13, i. e., everything is set in the most convenient position for the allowance of short, direct wiring. Where it is possible, the same position of apparatus should be followed when mounting it on a panel. The DL-35 honeycomb coil may be replaced with a single-layer coil, if so desired. In such a case, the coil should be wound on a tube having the same diameter as the secondary coil of the variocoupler, but with about 10 turns of

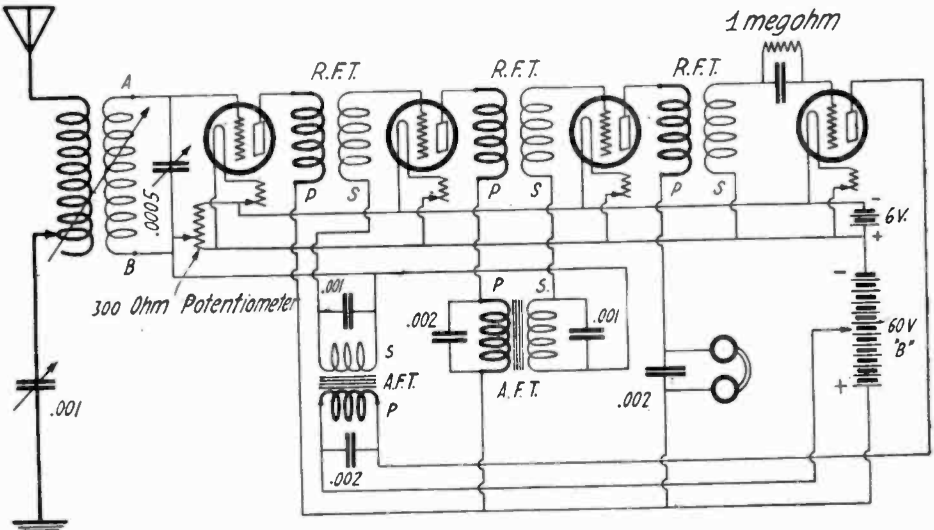


Fig. 8. The Circuit of the Four-Tube Reflex Receiver, a Photo of Which Appears on the Opposite Page. A Loop Aerial Can Be Used To Advantage With This Circuit. Its Terminals Should Be Connected to the Points Marked A and B, and the Secondary of the Variocoupler Disconnected.

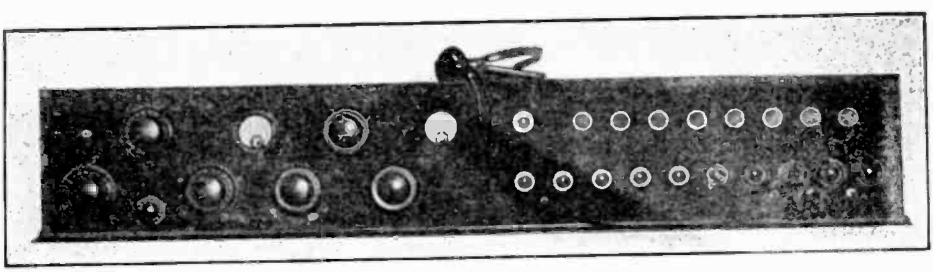


Fig. 9. A Front View of the Super-Heterodyne Receiver. The Main Tuning Controls Are Situated Along the Lower Part of the Panel, So As To Be Within Easy Reach.

© K. & H.

wire less. In other words, this coil should be identical with the secondary coil of the variocoupler used, except for the number of turns.

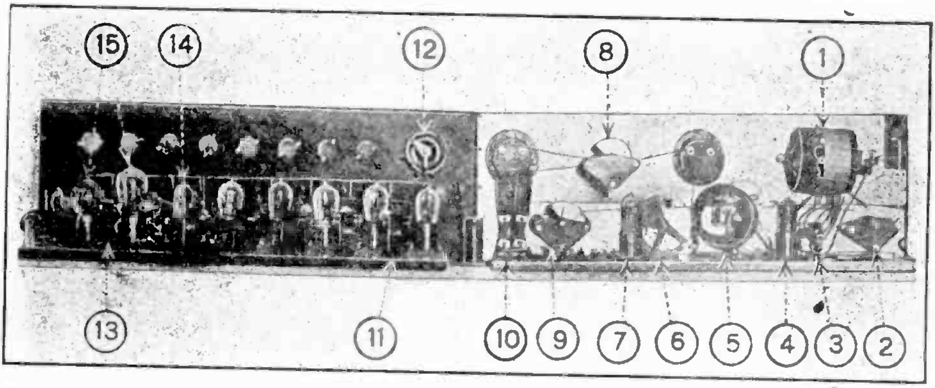


Fig. 10. A Rear View of the Ten-Tube Super-Heterodyne Receiver. There Are Five Stages of Radio Frequency Amplification and Two Stages of Audio Frequency Amplification Employed in This Set. Mr. Mayo Has Succeeded in Picking up 2LO, London, As Well As Numerous Stations On the West Coast of the United States.

Referring again to the circuit-diagram of Fig. 13, note that the grid leak 13 is connected directly to the positive side of the filament, instead of crossing the grid condenser, as is usually the case. Be sure to connect it as shown.

adjusting the secondary circuit with the variable condenser (4). Continue this operation until a station is picked up. Find the best contact point for the switch arm in the primary circuit. Then, by the simultaneous adjustment of condensers (4) and (7), complete the process of tuning. This last operation is usually rather critical, especially the adjustment of condenser (7), wherein a slight movement of the dial is sufficient to obliterate the signals.

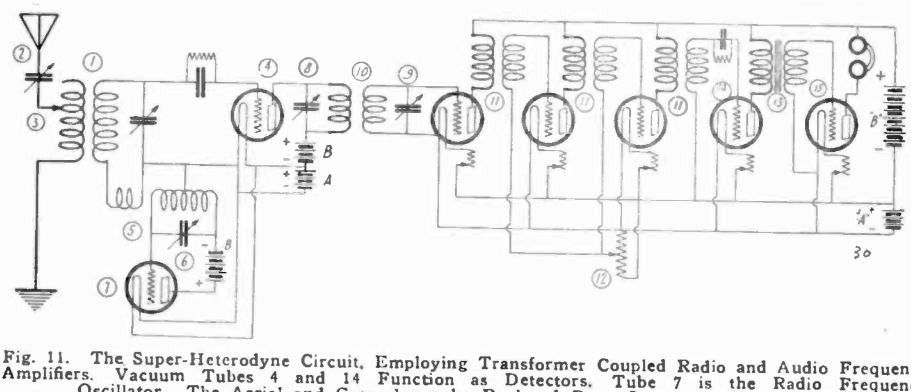


Fig. 11. The Super-Heterodyne Circuit, Employing Transformer Coupled Radio and Audio Frequency Amplifiers. Vacuum Tubes 4 and 14 Function as Detectors. Tube 7 is the Radio Frequency Oscillator. The Aerial and Ground can be Replaced By a Loop Aerial, If Desired.

In regard to the operation of this set: The temperature of the filament of the first audio amplifying tube is not critical. That of the second, or detector tube, however, may require a fine rheostat adjustment. As a first operation, light the two tubes by means of their respective rheostats. The knobs of the rheostats should be turned towards the right until the filaments of both tubes burn a dull red. With the secondary of the variocoupler placed at about the angle shown in the photograph, start tuning the set by adjusting the primary circuit with the switch arm and, at the same time,

For the reception of long-distance stations, all of the tuning is accomplished by the two variable condensers. For example, if a distant station, which transmits on 360 meters, is desired, the primary switch arm should be placed on the point that was previously found best for reception on this wave-length. The secondary variable condenser (4) is then adjusted to a point where nearby 360-meter stations can be heard. Then, by a very slow simultaneous adjustment of the two variable condensers, all of the waves close to 360 meters are explored, until the desired station is picked up. It is advisable to equip these condensers with Vernier knobs, or purchase variable condensers that have a Vernier condenser included. It is well, for future reference, to copy the scale-readings on the dials of the two variable condensers, where certain stations are received best, as well as the number of the switch-point that gives best results for that wave-length.

During the process of tuning, the operation of the set is apt to become unstable. This is denoted by a sudden plucking noise in the head phones, after which reception is completely spoiled. This unbalanced state is normalized by the use of a stabelizer, which, in reality, is a potentiometer; it is shown in both illustrations, under (14). When the set becomes unstable, as described, this stableizer knob should be turned to the right, or to the left, until a position is found where normal operation of the receiver is restored. It is advisable to adjust this control each time a station is tuned in.

Standard tubes may be used with this set, if desired, providing standard tube sockets are used and a 6-volt storage battery is provided for the filament supply, instead of the two dry cells. In such a case, the first tube should be a UV-201, a C-301, or a VT-1; while the second or detector tube can be a UV-200, C-300, VT-1, VT-2, or any other type of 6-volt detector tube.

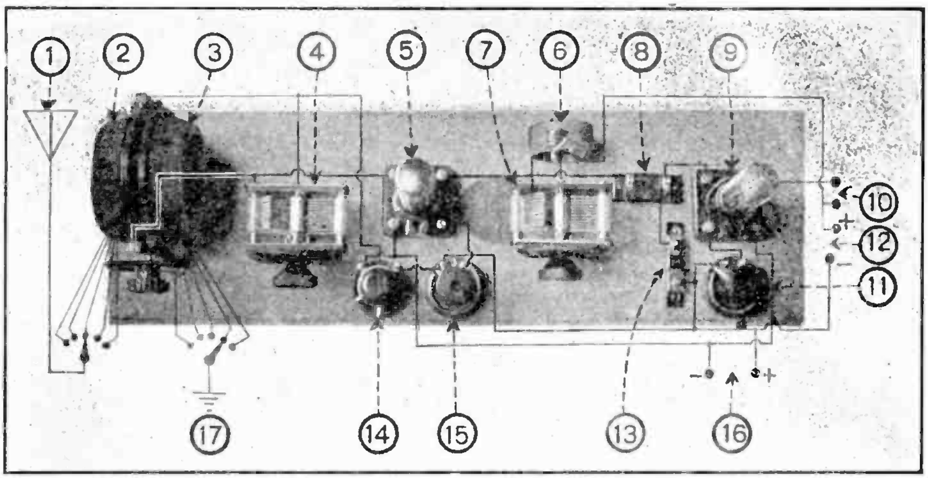


Fig. 12. Layout and Connections of the Apparatus Composing the "Tuned Radio Frequency Amplifier and Receiver." The First Vacuum Tube is the Radio Frequency Amplifier, the Second Being the Detector. Quite Some Distance Can Be Covered With a Set of This Type. Any Standard Make of Apparatus Can Be Used.

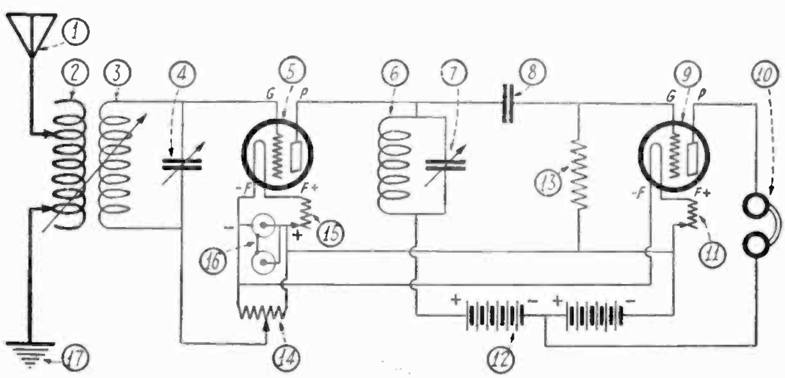


Fig. 13. Wiring Diagram of the Tuned Impedance Radio Frequency Amplifier and Receiver. Dry Cells 16 Are Replaced With a 6-Volt Storage Battery, If a 6-Volt Tube Is To Be Used.

Dual Amplification Circuits

By John Scott-Taggart

It must not be imagined that the crystal detector is obsolete. It will acquire even greater importance when a thoroughly reliable pattern is evolved, that is, one which will not require constant resetting; claims have already in fact been made for such a detector.

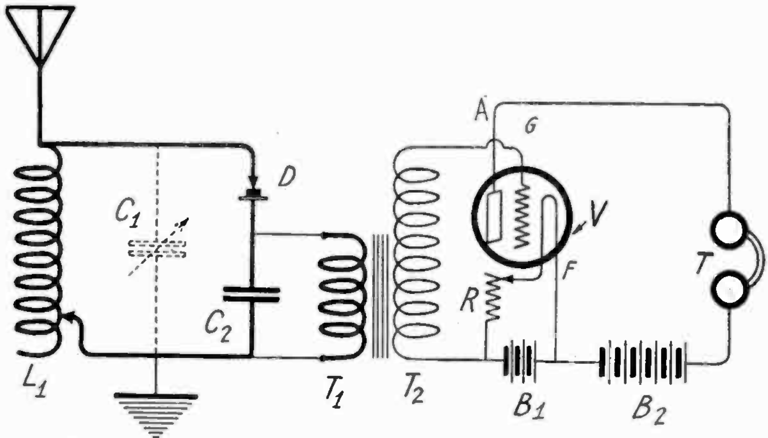


Fig. 1. An Ordinary Crystal Circuit With the Addition of a One-Stage Audio Frequency Amplifier.

The circuits given below not only use crystal detectors in combination with valves, but use the valve in a dual capacity—namely, as a low-frequency amplifier and as a means of either introducing reaction into a circuit or of actually amplifying the high-frequency currents.

Improving the Single-Valve Circuit

Fig. 1 shows what is probably the best single-valve circuit of a straight-forward type permissible for the reception of broadcasting. In some cases, the valve is better

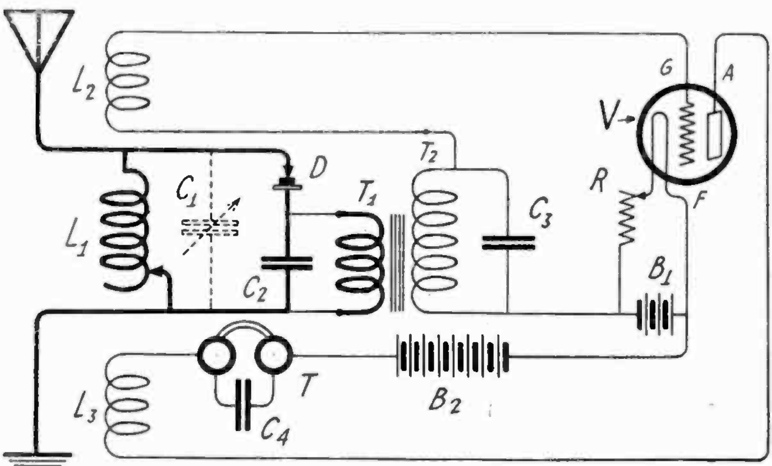


Fig. 2. The Circuit of Fig. 1 Is Greatly Improved By Introducing Regeneration, As Shown.

used as a high-frequency amplifier, but there is little to choose between the two classes of circuits. It is proposed to improve the efficiency of this circuit by introducing reaction into the aerial circuit. secondary T_2 should be shunted by a condenser C_2 having a capacity of not less than 0.001 MF. In the anode or plate circuit of the valve is included another coil L_2, which is connected in series with the telephones T,

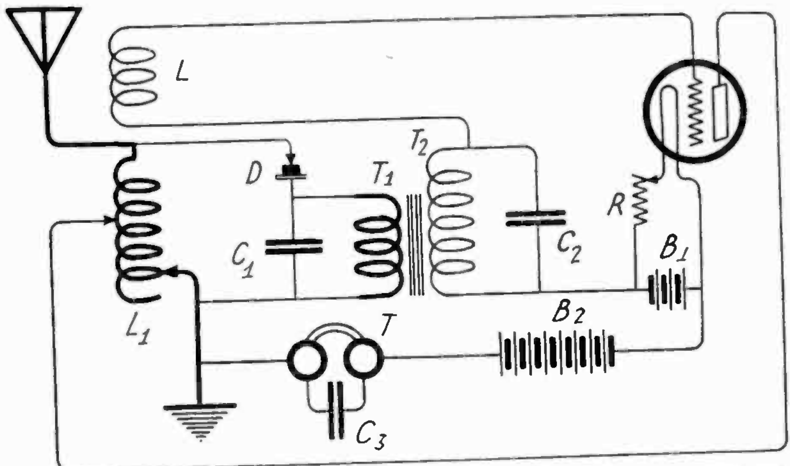


Fig. 3. A Crystal Circuit of the New Type, In Which Two Inductances Are Used.

As Fig. 1 stands, there is no reaction effect in the aerial circuit, which, therefore, considerably damps down the incoming signals, which for the moment we may assume are due to raido telephony. I introduce reaction into the aerial circuit by using the which now require to be shunted by a condenser C_4, also having a capacity of not less than 0.001 MF.

When honeycomb or similar coils are used, the aerial coil L_1 may be in the middle and the other two coils arranged one on

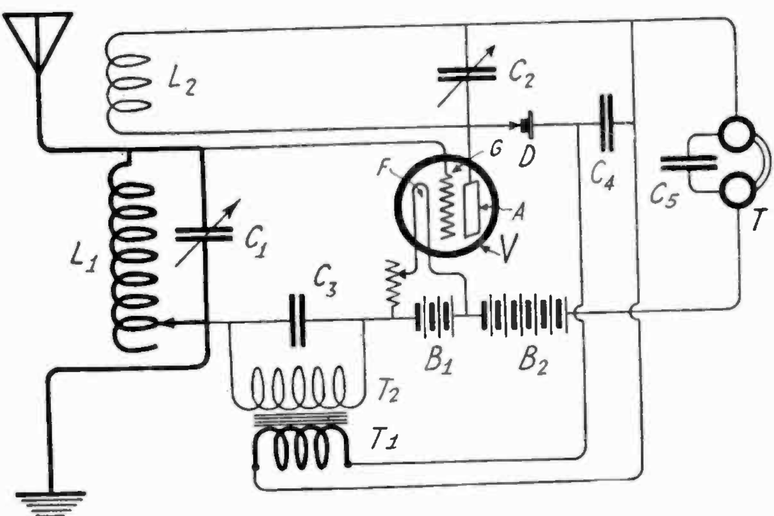


Fig. 4. A Shunt Amplification Circuit, Which Has Recently Proved Very Effective.

valve in an additional capacity. An inductance coil L_1 (Fig 2) is now included in the grid circuit of the valve V, this coil being in series with the secondary T_2 of a step-up transformer T_1 T_2. The each side, the two couplings being variable. The size of the coils L_1 and L_2 is important, and the best values must be found by experiment. The circuit is adjusted by coupling L_2 tightly to L_1 and varying the coupling between L_2 and L_1. The reverse procedure might be adopted. If both coils are tightly coupled to L_1, the valve will oscillate of its own accord and continuous wave signals may be received; on the other hand, when spark or telephony signals are to be received, the coupling is such as to obtain the critical reaction effect which gives the loudest signals.

Fig. 4 shows a circuit in which the crystal detector D and the primary T_1 of a step-up transformer T_1 and T_2 are connected across the anode oscillatory circuit L_2 C_2 of a three-electrode valve V. The coupling between L_2 and L_1 is adjusted as before to obtain the reaction effect. The secondary T_2 of the transformer T_1 T_2 is shunted by a condenser C_3; the condensers C_3 and C

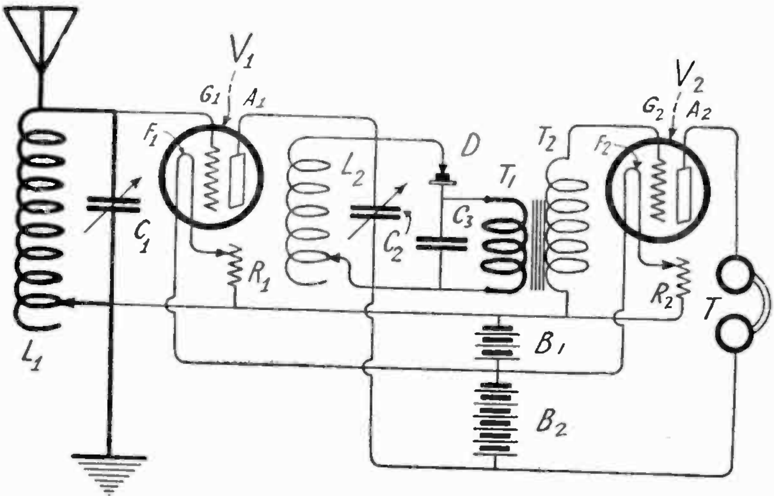


Fig. 5. A Two-Tube Circuit, In Which Radio and Audio Frequency Amplification Is Accomplished. A Crystal Is Used For Rectification.

In order to make sure that the reaction effect is being obtained, the leads to one or other of the coils L_2 and L_3 should be reversed. As one of these coils is made to approach L_1 the signal strength should increase considerably.

Another Single-Valve Circuit

Fig. 3 shows another valve circuit in which only two coils are employed. The aerial coil L_1 may conveniently be a two-slider inductance. The lower slider is for the purpose of adjusting wave-length and the top slider is for adjusting the degree of reaction introduced into the aerial circuit.

Fig. 3 is, in principle, very similar to Fig. 2, but this time the anode circuit of the valve is directly coupled to the aerial circuit, the anode current flowing through a portion of the inductance L_1 and then through the telephones T and the high-tension battery B_2, and so back to the filament. The coupling between L_2 and L_1 is adjusted to obtain the desired reaction effect. The circuit might be adapted to a circuit using an inductance tuned by means of a variable condenser, in which case a fixed tapping might be taken from a point on the inductance coil or even from the top of the coil.

may both have a capacity of about 0.002 MF. The valve V is acting not only as a high-frequency reaction amplifier, but also as a low-frequency amplifier, the telephone receivers T being included in the anode circuit of the valve.

Two-Valve Circuit

It is probably when we consider a two-valve circuit, that most readers will be specially interested, as these circuits may be employed for broadcast reception as there is no reaction on the aerial circuit. Fig. 5 shows the ordinary straight-forward and quite effective circuit in which the first valve acts as a high-frequency amplifier, the high-frequency oscillations in the circuit L_2 C_2 being rectified by the crystal detector D, and the low-frequency resulting current being amplified by the second valve V_2.

I have greatly improved the results obtainable with such a circuit by introducing reaction into the oscillatory circuit L_2 C_2, which is shunted by the crystal detector. The obvious way of introducing reaction into this circuit would be to couple the inductance L_2 to the inductance L_1 in the aerial circuit. As this is forbidden in

England when receiving broadcasting, I introduce the reaction by means of the second valve, which is acting as the low-frequency amplifier.

Fig. 6 shows a method of doing this. A fixed inductance coil L_3 is included in the grid circuit in series with the secondary T_2, which supplies the low-frequency potentials to be amplified. In the anode circuit of the valve V_2 is an inductance coil L_4 which is coupled the right way round to L_2. In the anode circuit will also be found the telephones T shunted by a by-path condenser C_5.

When the coils L_3 and L_4 are only very loosely coupled to L_2, the circuit is, in effect, the same as Fig. 5. As we approach the two coils towards the inductance L_2, the signal strength increases greatly. The fact that a reaction effect is being got out of the second valve does not appear to impair its effectiveness as a low-frequency amplifier.

Another Circuit

Fig. 7 shows another circuit in which the now well-known tuned anode circuit with reaction is employed. The circuit L_1 C_1 containing the amplified oscillations of the incoming frequency, is connected across grid and filament of the condenser C_2 being connected for the purpose of preventing the high voltage of the battery B_2 being communicated to the grid of V_2. A grid leak R_1 is connected between grid and the negative side of the filament accumulator B_1. In the anode circuit of the valve V_2 is a tuned circuit L_3 C_4, which is also tuned to the incoming frequency.

Across the circuit L_3 C_4 is connected the crystal detector D and the primary T_1 of a step-up transformer T_1 T_2. The usual by-path condensers C_5 and C_6 are provided in the position shown. The telephone receivers may be connected either in the position shown between the bottom of L_3 and the positive side of B_2 or between the anode of the first valve and the junction point J. The telephones and telephone condenser are shown in dotted lines. By connecting them in this position certain complications which are liable to occur may be avoided, but, on the other hand, certain disadvantages attend its use in this part of the circuit. If connected next to the high-tension battery B_2, it is important to see that the condenser C_3 is of small capacity.

This circuit is operated by tuning all the three tuned circuits to the incoming wavelength, the brightness of the two filaments not being excessive, as otherwise self-oscillation may be set up. Unless there is sufficient natural reaction between the circuits, the inductance L_3 may be gradually brought up to the inductance L_1 until the maximum signal strength is obtained, all the circuits being readjusted whenever the reaction is varied. Both valves are now acting as high-frequency amplifiers, and the first valve is, in addition, acting as a low-frequency amplifier.

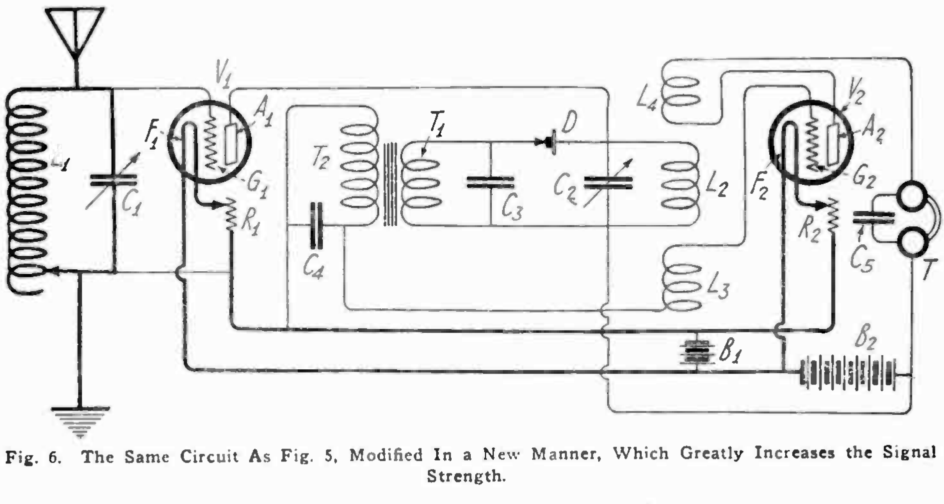


Fig. 6. The Same Circuit As Fig. 5, Modified In a New Manner, Which Greatly Increases the Signal Strength.

Any of these circuits may be extended by the addition of an extra one or two valves in accordance with the well-known principles. A point worth noting is that when reaction is being introduced into an oscillation circuit associated with the crystal detector, as in the case of Fig. 6, it is not necessary to use the first low-frequency amplifying valve as the valve for introducing reaction. The coils L_3 and L_4 in Fig. 6 might equally well be connected in, respectively, the grid and plate circuit of any subsequent low-frequency amplifying valve provided any transformer windings or telephones in series with the coils are shunted by by-path condensers for allowing the high-frequency currents to flow readily through them. Considerable development work is still possible with these circuits and modifications of them, and experimenters will find here an interesting field of work.

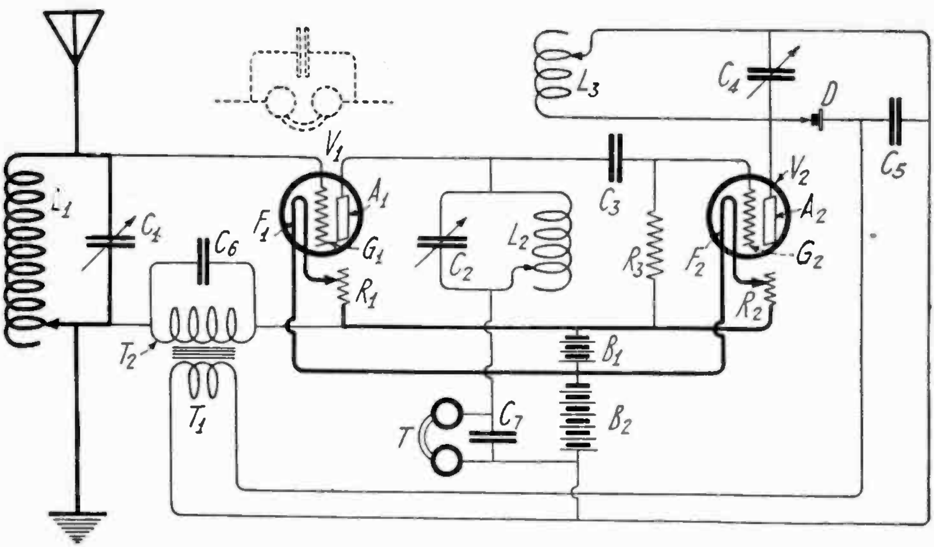


Fig. 7. A Somewhat Complicated Circuit Which Involves Two Radio Frequency Stages, Crystal Rectification and One Stage of Audio Frequency Amplification.

A Simple Reflex Circuit

By Clyde J. Fitch

A reflex circuit that is especially adapted for broadcast reception is shown in the illustration. This circuit is much simpler than the regular reflex circuit in that it uses less equipment to attain practically the same amplification and in addition is easier to tune. The results obtained from this circuit were made possible by simply combining the regenerative property of a vacuum tube with the detecting property of a sensitive crystal, and then using the same vacuum tube for a one-step audio-frequency amplifier. This circuit has been thoroughly tested and has given excellent results.

Almost any simple one-tube radio receiving set can easily be converted into this simple reflex set by merely adding an audio-frequency amplifying transformer and a crystal detector and making a few minor changes. Much louder signals will be the result, and the additional expense is well worth while. To convert the simple one-tube receiving set into the standard reflex set, a radio-frequency amplifying transformer and a potentiometer will be required in addition to the above equipment; therefore, this simple reflex set is less expensive and easier to construct, and consequently represents a gain in efficiency.

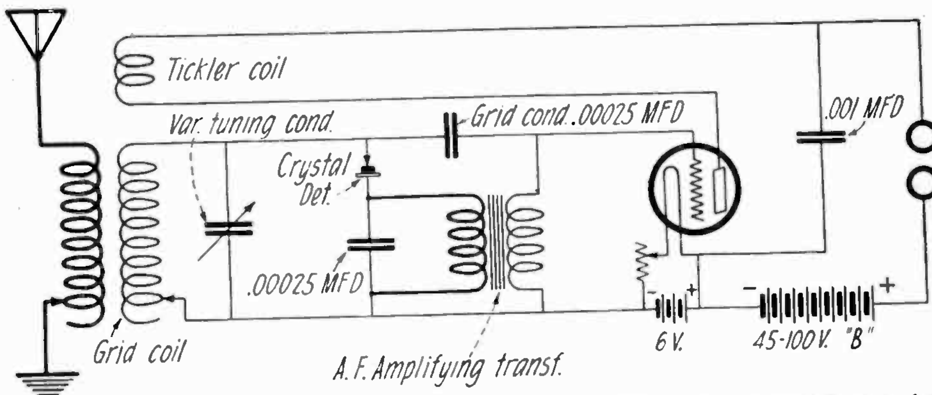
The diagram gives practically all of the information required to connect the apparatus. It may be well to mention here that better results are obtained with a double circuit tuner as shown than with a single circuit tuner, due to the fact that the addition of a crystal detector introduces resistance into the circuit, and this resistance tends to decrease the selectivity and thereby makes it difficult or practically impossible to tune out the unwanted stations and still retain the wanted station. As the crystal detector circuit absorbs much of the radio-frequency energy, it is necessary to use a tickler coil that is capable of very close coupling to the grid coil, for which honeycomb or spider web coils may be used.

Various types of audio-frequency transformers were tried in this circuit, and all types gave excellent results, although the high ratio transformers, some as high as 10 to 1, seemed to give the best results. Different types of crystal detectors were used, and all proved successful; also different values of fixed condensers were tried, but the values indicated in the diagram gave the best results.

Tuning is accomplished by first tuning in the station with the crystal detector disconnected, thus putting the audio-frequency transformer out of use, except for the fact that the secondary of the transformer is used for a grid leak resistance. Many crystal detectors may be disconnected by simply removing the cat whisker from the crystal. Now the station may be tuned in, the circuit being the same as a single tube regenerative circuit. After tuning in the station to its maximum intensity with the tickler coil placed as close as possible to the grid coil without generating oscillations in frequency energy, where it is amplified by the vacuum tube and made audible in the phones or loudspeaker. The stations will then be received much louder. In other words, this circuit is equivalent in results to a one-tube regenerative circuit with a one-stage audio frequency amplifier, except that a sensitive crystal is used in place of a vacuum tube for detecting purposes. For DX or loop reception it will be no better than the above set.

As every increase of the received energy builds up a negative charge on the grid, the amplifying transformer should be connected so that it will also impress a negative potential on the grid at the same time. The correct connection is determined by reversing the primary or secondary leads of the transformer and noting which connection gives the best results.

One convenient feature about this circuit is the ease in which comparisons may be made. By removing the crystal, we have a simple one-tube regenerative set. By removing the grid condenser and connecting in the crystal, we have a crystal detector and one-stage audio-frequency amplifier.



The Circuit of the Reflex Receiver Developed by the Author of This Article. A good Portion of the Radio Frequency Current Passes the Crystal Detector and is Impressed on the Grid of the Vacuum Tube, Eventually Being Fed Back to the Crystal by the Tickler Coil, Rectified, and Then Amplified At Audio Frequency.

the circuit, the crystal detector may be connected, and if adjusted on a sensitive spot, the station will be nearly as loud as before. As the crystal detector circuit absorbs some of the radio-frequency energy from the grid circuit, it will be necessary to move the tickler coil up closer to the grid coil before the tube starts to generate oscillations again. A slight readjustment of the tuning condenser will be necessary after moving the tickler coil. Obviously, more energy is fed back from the plate circuit of the tube to the grid circuit with the closer coupling, and more energy is absorbed in the crystal detector circuit where it is rectified and passed on through the amplifying transformer and impressed on the grid and filament of the tube in the form of audio-

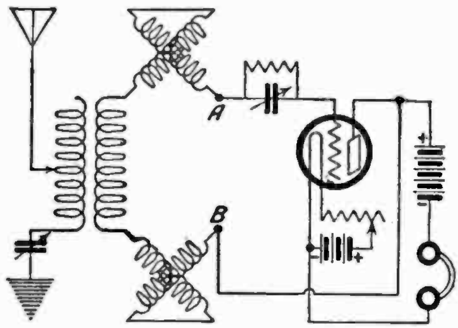
By connecting in both crystal and grid condenser we have the combination audio and regenerative amplifier.

One phenomenon observed was that when the tickler coil was brought too close to the grid coil, both radio and audio-frequency oscillations were generated in the circuits, the audio-frequency component manifesting itself by a loud howl in the phones. It is interesting to note that when the instruments are adjusted so that the set is just on the verge of howling, it is possible to tune the set to spark or C. W. telegraphy so that every time the telegraph code comes in, the set howls at great intensity. When so adjusted, some of the weakest signals are received with a deafening roar.

An Efficient Amateur Receiving Circuit

By **Paul G. Watson**

In the accompanying diagram is shown a circuit which is a little different from the ordinary amateur regenerative circuits. The writer had considerable trouble with howling and grinding when using the standard



This Circuit Has Been Found to be More Flexible Than the Conventional Regenerative Circuit Using Two Variometers and One Variocoupler.

regenerative and similar circuits on certain adjustments, so he started to experiment to find a way to eliminate a portion, at least, of this noise. This circuit practically eliminates the howls and other noises when the proper adjustments have been made. The customary regenerative distortion is present in this circuit as in all similar circuits, but it was found that in many cases it can be eliminated, partially at least, so that sparks and radiophone signals are clarified considerably.

One great advantage, in using this circuit is the flexibility of tuning. It has repeatedly proved itself to be equally efficient on 200 and on 600 meters. The writer is fully aware of the loss in efficiency of sets tuning over wide ranges, but it has been found by actual comparison with commercial and amateur apparatus, that there is no loss on either wave length; this is a very decided advantage.

The tuner itself is an ordinary regenerative set, consisting of two variometers and a variocoupler of standard design. In picking the variometers and coupler, attention should be paid to the size of the wire in the windings, as well as to the clearance. The wire should be of fairly large size, with a small amount of clearance between the rotary and stationary elements.

It will be found that shielding the panel with copper foil will remove the capacity effect of the hands, as the tuning is done. The shield should be connected to the ground terminal of the panel.

The short-wave condenser is .001 mfd. capacity, rotary variable. An arm was soldered to the shaft of the moving plates, so that it automatically short circuited at a point just beyond the 180 degree adjustment. A contact should be arranged on the stationary element to receive this arm. A crude way to get this effect is to bend a corner of one of the rotary plates so it bears heavily on the stationary ones. As previously mentioned, this is a crude method, and apt to give trouble.

The circuit is shown complete in the diagram. It will be noticed that the variable grid condenser is of much importance in tuning, and eliminating the local noises common in regenerative tuners.

A "soft" tube was used, a pre-war "Audotron" and fine results, on all wavelengths up to 700 meters, were obtained. The circuit has been in use for some time in many amateur stations, copying after the original, and is giving them complete satisfaction on both C.W. and spark. It oscillates readily, making it desirable. Fine regeneration is obtained as the point of oscillation is approached.

A Long Distance Hook-Up

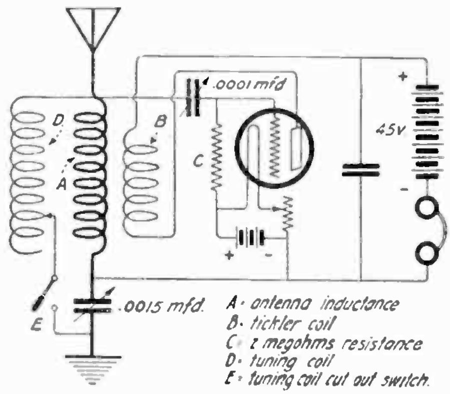
By **William Bessey**

For the benefit of the amateur who is trying to cover a good distance with one vacuum tube and a medium sized aerial, I will describe my hook-up and a few experiments that I have tried with it. The diagram shows my hook-up. A is the antenna inductance and B, the tickler coil. I use honeycomb coils for both A and B. C is a resistance of two megohms. A lower resistance than one megohm gives poor results. D is a tuning coil which aids in tuning in small wave-lengths and which is also a great help in tuning wireless telephone. I use a variable grid condenser. This is not absolutely necessary, but I advise it for sharp and close tuning. A Marconi vacuum tube is used with four dry cells in series for filament lighting.

Using honeycomb coils—L750 for antenna inductance and L400 for tickler, I can hear —Balboa, C. Z., NBA; Charleston, S. C., NAO; Guantanamo, Cuba, NAW; Sayville, L. I., NDD; Bermuda, W. I., BZR; Demerara, British Guiana, BZL; and San Diego, Cal., NPL. All come in plain and readable. Using L400 as antenna inductance and L200 as tickler I can hear Washington, Key West and New Orleans. Then by switching in the tuning coil I can hear wireless telephone concerts.

By cutting out the ground and aerial and by touching the ground and aerial connections lightly with my hand I can read Sayville, L. I.

I have a small loop aerial one foot square wound with about 600 feet of No. 35 silk covered wire which I can switch in at will, in the place of or with the large aerial. Using it alone I have heard several stations which were quite faint although readable. When listening to wireless telephone I tune in without it and then with it. I find that it makes the telephone louder and plainer. On the other hand when receiving spark stations, if I switch in this small aerial, it makes the signals fainter.



A Good All-around Hook-up.

With an aerial of No. 20 copper wire, eighty feet long and ten feet high I can hear NAA almost as clearly as with my large five-wire aerial which is one hundred feet long and thirty feet high. A one-step amplifier would make it possible to hear European stations.

A Receiver Using Rectified A. C. Supply

By Francis J. Andrews

This circuit is designed for the full wave rectification of the usual alternating current with which homes are supplied.

The plate current for the detector tube is supplied by two 2-element rectifying tubes.

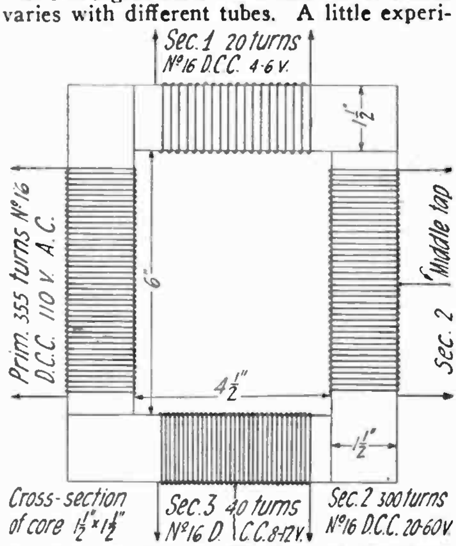
A step down transformer supplies the necessary voltages for these tubes and the filament of the detector tube.

The filament of the detector tube is shunted by a rheostat R-2 with a resistance of 20 ohms. By varying the slider, the characteristic hum of the alternating current will be reduced to a minimum.

The condenser C-5 is of rather large capacity; between two to six mfd. It is a good idea to have this condenser variable, that is, tapped.

L-1 and L-2 are the primary and secondary of the usual vario-coupler; L-2 is used as a tuning inductance with the variable condenser C-1. The secondary of the variocoupler, L-2, is used as a tickler coil to provide regeneration. C-3 is a grid condenser of approximately .00025 mfd. capacity. C-2 is the second variable condenser to provide fine tuning of the coil L-1.

R-3 is a grid leak. The value of this leak varies with different tubes. A little experi-

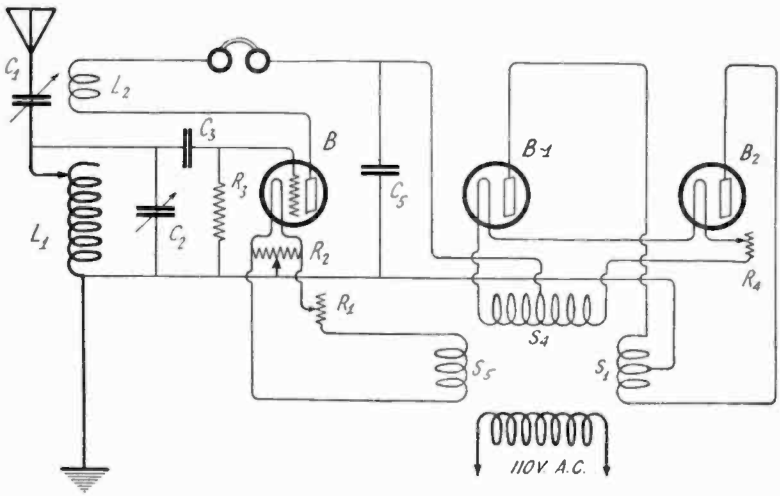


Specifications For the Windings of the Transformer Used With the Receiver.

menting is necessary to obtain the right values.

R-1 is a small rheostat for the control of the filament current of the detector tube. One with about four ohms resistance will be satisfactory. The rectifier bulbs, B-1 and B-2, are of the usual two-element type; Kenotrons are excellent for this circuit.

Following are the parts and material necessary for the construction of this set:
1 vario-coupler
2 variable condensers, .001 mfd.
2 variable condensers, .002 mfd.
1 grid leak and mounting



This Circuit is Designed For the Full Wave Rectification of the Usual Alternating Current With Which Homes Are Supplied. The Usual "A" and "B" Batteries Are Unnecessary.

R-4 is a small rheostat to control the filament current of the rectifier tubes. Its resistance should be about 10 or 12 ohms.

Now for the transformer:

The secondary supplies two voltages; 6 volts and 60 volts. There are two 6-volt secondaries, one for lighting the filament of the detector tube and the other for lighting the filaments of the rectifiers. By studying the diagram, the construction of this transformer will be readily understood.

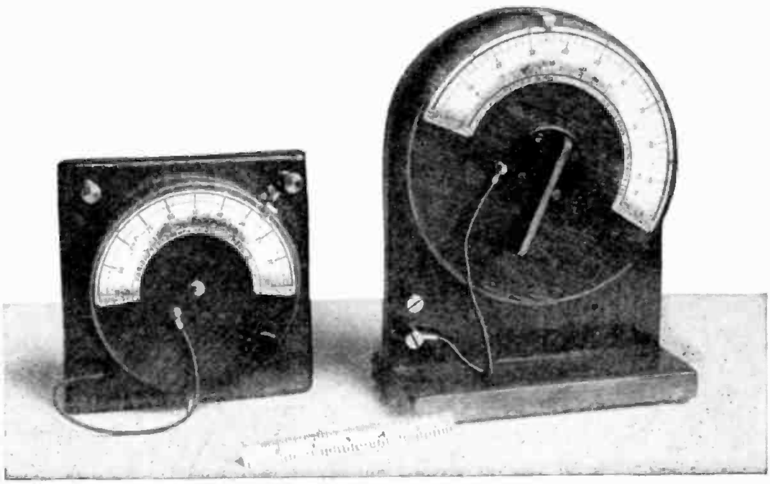
1 detector tube
1 tube receptacle
1 20-ohm rheostat
3 2-mfd. condensers
1 rheostat, 4 ohms
2 rectifying tubes
2 tube receptacles
1 rheostat, 10 ohms
4 pounds No. 16 D.C.C. wire
Magnet iron for core of transformer
Taps, switches, etc.

How to Make D-Shaped Variometers

***By* D. R. Clemons**

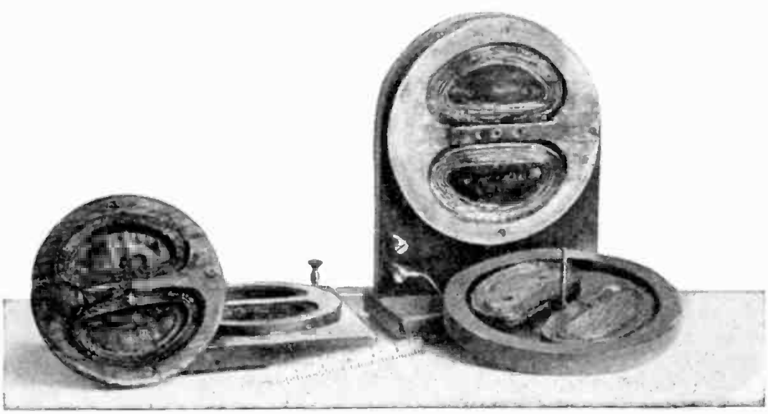
A magnetic field is established about a wire carrying an electric current. This field may be considered as an accumulation of magnetic energy extending into considerable space, and formed of rotational lines or strands enclosing and revolving about the axis of the wire. Ampere's right-hand-rule showing the direction of field rotation about a wire may be applied by grasping a wire with the right hand; the thumb pointing the direction of current, the four fingers then show the direction of field motion. Fig 1A is an imaginary sketch of a field's position about a wire carrying a current away from—and B the current moving toward—the observer, thus following the rule.

When current begins moving in a wire, a field moves outward as the current increases, or returns with decreasing current, but it assumes a fixed position and strength after the current becomes constant. Hence, magnetic flux changes with the current producing it. If a wire is long and straight the field is distributed through a considerable volume of space, but if a wire were bent into a circular ring, then all of the lines produced must pass through a much smaller area; hence, in a loop of wire, lines enter and depart from a space enclosed by a winding giving a definite direction of field projection establishing its magnetic poles. Fig. 1 shows how space enclosed by a loop is threaded by a downward propagation of enclosed space is threaded by one field—a results of the several turns contributing. Now, if two coils are related with each field projected in the same direction, the fields will again interlink and increase the field, as shown in Fig. 2; but if the two equal fields are opposed, they will not unite, Fig. 2A.



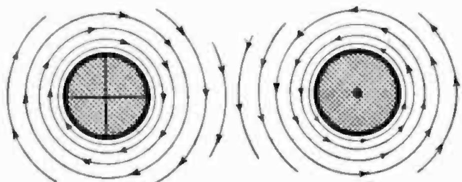
Two Views of Completed D-Shaped Variometers. The Large Wooden Discs Containing the Graduated Scales Also Support the Movable Windings of the Instruments.

each line. If two parallel conductors carry currents in the same direction, their respective fields rotate in a common direction also; and if both wires are far apart, the fields remain quite separate, but as the wires become more closely related the fields interlink, until they may finally enclose both wires as one field. Thus, if several turns are wound into a compact coil, Fig. 2D, the



The Same Variometers As They Appear Unassembled. The Stationary and Movable Coils Are Revealed, Furnishing a Good Idea As To the Method of Their Construction.

The field about a current-carrying conductor opposes an increase of current, and later, prolongs or retards the time during which the current is decreasing. A field does not instantly establish itself in the magnetic circuit but requires appreciable time for its outward movement to its final position. Now, if a current is passed through a coil of several turns, the field, due to each turn, on moving outward to establish the resultant field, cuts through the turns of the coil, and in doing so generates in them a voltage opposing that potential which established the current. Thus, as the current rises, the increasing flux in radial motion generates a counter E.M.F. that tends to oppose an increase of current.



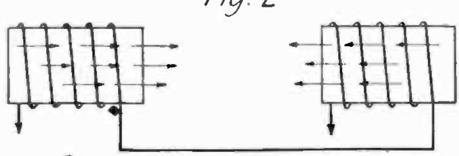
-A- Fig. 1 -B-

"A" Is An Imaginary Sketch of a Field's Position About a Wire Carrying a Current Away From the Observer, While That of "B" is Moving Towards the Observer.

If the current is decreasing in a circuit, the flux returning to the circuit moves through the turns in an opposite direction and the induced potential, being in the same direction as the current, tends to prolong the time interval during which the current moves, i. e., increases the period. This effect of a field upon such an electric circuit is called "self induction." Since this is evidently a counter voltage related to a circuit, the coefficient of self inductance is expressed in a unit called the Henry. A coil has one henry of self inductance; if, when the current through it is changing at the rate of one ampere per second, the induced counter E.M.F. is one volt. Since

D E

Fig. 2



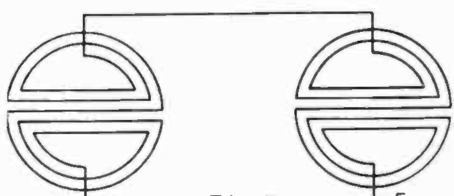
D Fig. 2-a E

In Fig. 2 the Fields of the Two Series Coils Are Assisting Each Other, While In Fig. 2-a They Are Opposing Each Other.

the flux in air-cored coils used in radio work varies directly with the current, the coefficient of self inductance is a constant independent of the current, but dependent upon geometrical dimensions of the winding shape, turns, etc.

If two inductances are placed with their fields interlinking, as in Fig. 2, the flux of each coil induces a counter E.M.F. in itself, and also induces a counter E.M.F. in the neighboring coil; so if two inductances are placed close, with fields interlinking, the total counter voltage in the entire circuit will be the two self-inducted voltages plus an additional voltage in each coil caused by the adjacent coil's field. Hence, if the coils are very close together the inductance will be much greater than the sum of the two inductances; and, if the coils are moved apart, less interlinkage is effective and additional counter voltages decrease until, finally, if both fields do not interlink at all, the inductance of the circuit becomes a sum of both self inductances. This action of one part of magnetic circuit upon another part is called "mutual inductance," which is positive if the resultant inductance is greater than the sum, and is negative if less than the sum of the two inductances.

When two coils are placed with fields opposing, flux from one coil extends



D Fig. 3 E

Methods of Connecting Up the Stationery and Movable Coils of the Variometer Described. It Will Be Noted That They Are Both Wound In the Same Direction.

through the adjacent coil and induces a potential in the *same* direction as the impressed potential. Thus a counter E.M.F., due to self induction, is decreased by the induced voltage through mutual induction, and since this resultant is much less than the inductance before the coils were reversed. Mutual inductance is negative. Mutual inductance evidently varies with the relationship of the fields, being positive for additive fields; zero when the fields do not interlink, and negative when fields are opposed. So an effective inductance changes as the relative position of coils are altered.

Now, in radio-frequency circuits combinations of inductance and capacity are used. Inductance tends to prolong the time interval during which currents flow, but condensers act oppositely, tending to lead the current. If a condenser and inductance are in series, there is one alternating current frequency at which these two opposite effects neutralize admitting currents of that frequency. This is the tuned frequency or wave-length at which a circuit responds. Changing the inductance varies the period of a circuit; likewise, capacity may be varied for tuning. In many types of equipment both capacity and inductance are varied, and where capacity may be inherent as in the vacuum tube, the circuit is tunable by employing variable inductances called variable "inductors" or variometers. Best known types of variometers operate as previously described, two windings being in close relationship, one, generally a ball, is turned about for variation of the mutual inductance. Ball type variometers have the following characteristics: Movable inductance is of 220 microhenries, stationary winding 230 microhenries. When placed at right angles, the mutual inductance is zero and in the inductance of the arrangement is 450 microhenries. By opposing the fields, a negative mutual inductance obtains 50 microhenries, and reversing the ball increases the inductance to 960 microhenries. Thus, values between 49 and 961 microhenries are obtainable by turning the ball.

Variometers, popular in radio today, are suitable for short-wave tuning; however, variable inductors may also be made large to serve for long wave-length reception. A type of variometer suitable for short and very long wave work is illustrated. This principle has long been employed in foreign equipment and is also manufactured in America as a precision instrument. The windings are mounted in a flat plane, as shown in Fig. 3. All coils are placed in pairs connected so that their electric rotation is opposite; i. e. adjacent polarities are opposite, so a field of force extends upward through one coil and downward through the adjacent coil. If another similar set of coils is placed over these with interlinking fields, the flux passes through all four coils. By revolving one set of coils through 180 degrees, opposing fields establish a condition of minimum inductance.

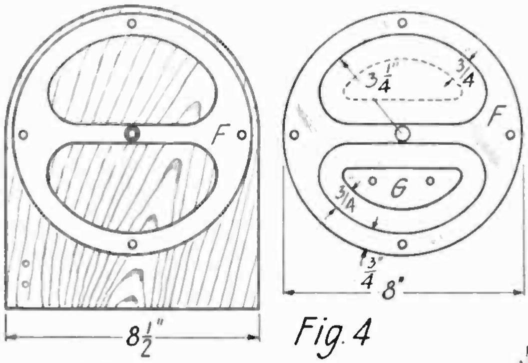


Fig. 4

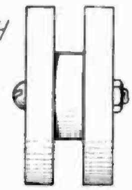


Fig. 5

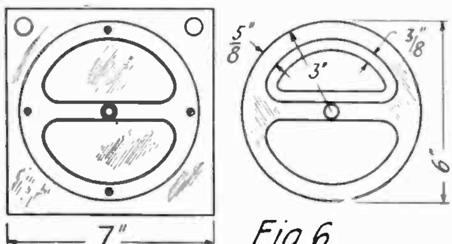


Fig. 6

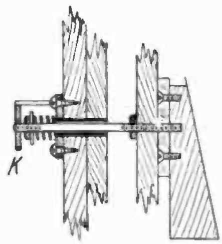


Fig. 7

Constructional Data For Making the Stationary and Movable Forms of the Variometer. These Are Made of Well Seasoned Hard Wood. Fig. 7 Shows the Arrangement of the Shaft.

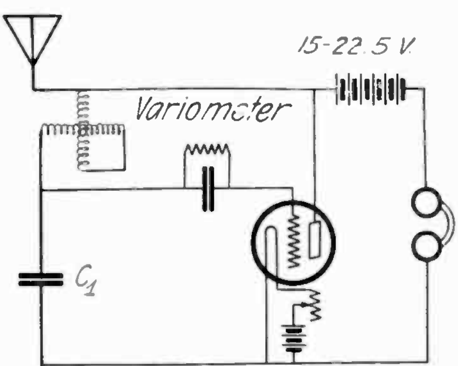


Fig. 8

Suggested Circuit For Use With the D-Shaped Variometer. This Is An Adaptation of the Colpitts Oscillator Circuit.

The larger variometer was prepared for laboratory work and long-wave reception.

The smaller instrument was designed for use on short wave-lengths such as broadcast receiving, the electrical values being similar to the small ball-type variometers of the better types.

The large variometer is mounted upon a neat base and support sketched in Fig. 4. All windings are form-wound for mounting in openings cut in a ⅜" thick wooden disc mounted as shown in Figs. 4 and 6. Three large discs 8" in diameter are cut from ⅜" cypress, using a scroll saw. Openings for the coils are scrolled out, after which the parts are attached by a good glue and screws. Pieces removed from the discs are later used as end pieces of a winding form H in Fig. 5. Four wooden cores G in Fig. 4 are cut as shown, allowing a winding depth of ¾". Four coils are then carefully layer-wound, filling up the form. About 1¼ pounds of No. 22 double cotton wire allow about 200 turns in each winding. These coils should be as nearly alike as possible and are secured by attaching their wooden cores to the discs by small brass screws, after which they are heavily varnished. A special bushing of brass and bakelite handle are made up as sketched in Fig. 7, where K is a bronze spiral for perfect contact with the moving shaft, which forms one terminal of moving coils.

The small horizontally mounted variometer is similarly made. Here each coil has 36 turns of No. 22 double cotton wound to a depth of ⅜", and is simply forced into place and varnished. The form used for these coils is comprised of the parts cut from the discs, as before. The illustrations should be quite clear as details appear there in photographs and sketches showing dimensions. Each form-wound coil of the larger instrument is 5 millihenries; inductance of the instrument is 5.98 to 36.8 henries maximum. The smaller instrument's value varies almost linearly and by designing the micro-henries, each coil 130 micro-henries with 275 micro-henries for each pair or couple. Inductance in both instruments varies almost linearly and by designing the coils for that condition, a straight line variation is obtainable.

Fig. 8 shows a method of using the single large variometer in conjunction with a vacuum tube for long-wave reception. C1 may be a fixed or variable condenser of 0.001 or 0.002 mfds, the arrangements forming the assential parts of a Colpitts oscillator responding to stations transmitting on wave-lengths between 4,000 and 18,000 meters by adjusting the rotary coils.

Regenerative Tuners to R. F. Amplifiers

By Chas G. Kahant

Tuners more sesitive than the standard single tube regenerative sets are needed for two general purposes; one, to increase the range for long distance reception and, second, to enable the use of small outside aerials, inside aerials or indoor loops for strong reception of local broadcasting stations. It is the purpose of this article to describe a simple way of attaining this sensitivity by adding but one tube to the set.

There are, of course, several ways of increasing sensitivity and for most people the selection becomes a question of which gives the most amplification per tube consistent with ease of control and freedom from foreign noises. The superregenerative circuit gives tremendous amplification per tube, but for the layman at least is difficult to adjust and is accompanied by quite a variety of high pitched notes which are difficult to eliminate. Radio frequency amplification using one of the several makes of radio frequency transformers on the market is easier to handle and is effective if one knows what makes of such transformers have the proper electrical characteristics for best reception on broadcasting wave-lengths. Usually, however, two stages of it are necessary to show an improvement in sensitivity over a good regenerative tuner.

A very efficient method of R.F. amplification which has been utilized lately by several manufacturers of prominence is the so-called tuned plate circuit, in which the plate circuit of the amplifier tube is adjusted to resonance to the particular wave-length being received. This tuned plate circuit is then coupled loosely with the tuned grid circuit of the next amplifier tube or with that of the detector tube as the case may be. Standard variometers alone or inductances shunted with variable condensers are used in place of the commercial R. F. transformers.

This last named method is so sensitive that but one stage of it is needed for all ordinary purposes. On a recent test in daytime it was found that this one stage brought in quite loudly a distant station that was only faintly audible with a regenerative tuner carefully adjusted. At night-time this one stage used with a short outside aerial enabled the reception on a loud speaker of stations over a thousand miles distant. One stage of audio frequency was employed between the detector and the loud speaker.

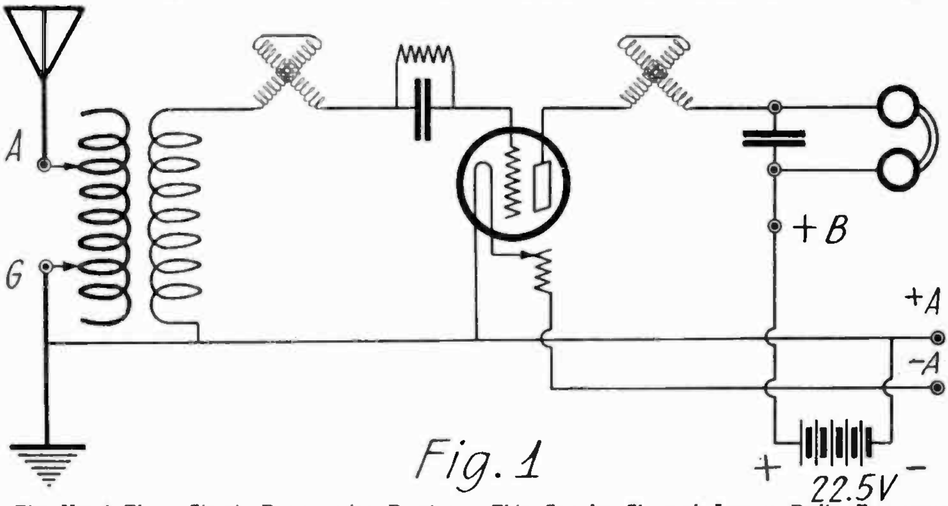


Fig. 1

The Usual Three Circuit Regenerative Receiver. This Can be Changed Into a Radio Frequency Amplifier as Shown Below.

A very good feature of this R. F. amplifier is that there is no distortion or howling when adjusted for maximum signal strength. In adjusting the controls, signal strength increases up to the point where sustained oscillations start as evidenced by a single sharp click in the telephones, unaccompanied by any other audible noises or whistles whatsoever.

One stage of tuned R. F. amplification can be added very readily to most regenerative tuners, particularly those of the double tuned circuit type. Referring to Fig 1, we have the conventional wiring diagram for one incorporating a variocoupler and two variometers. Fig. 2 shows the same circuit with one stage of tuned impedance R. F. aplification added. The grid condenser in Fig. 1 is short-circuited or removed and the socket in Fig 1 becomes the amplifier tube socket in Fig 2, where a second socket and rheostat are added for the detector tube. The by-pass condenser in Fig. 1 should be disconnected or removed. If removed it can be used in the plate circuit of the detector in Fig 2. A potentiometer is installed as shown to control the voltage on the grid of the amplifier tube. Three new binding-posts will be required, two for the new "output" and one for the positive "B" battery connection to the detector. The two original output posts are shorted and the two original "B" battery posts connected to the amplifier plate battery which should be about 90 volts for best results. A UV-201 tube serves very well in the amplifier and any good detector tube can be used in the second socket.

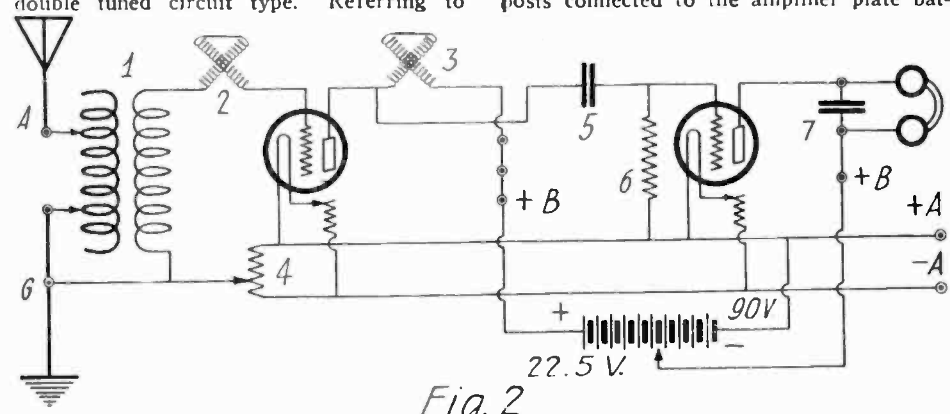


Fig. 2

This Shows the Necessary Changes in the Circuit of Fig. 1 to Transform it into an R. F. Amplifier.

The coupling between the amplifier and the detector circuits is accomplished by one manufacturer by using two separate inductances inductively coupled, each with a variable condenser. A much simpler scheme which is just as effective is that shown in Fig. 2, where but one inductance is used. feet total length. It can be either indoors or outdoors, but naturally the latter would usually be better.

When a loop is used it can be connected to advantage in series with the grid variometer as shown by the dotted lines in Fig. 4. The aerial condenser is then not needed,

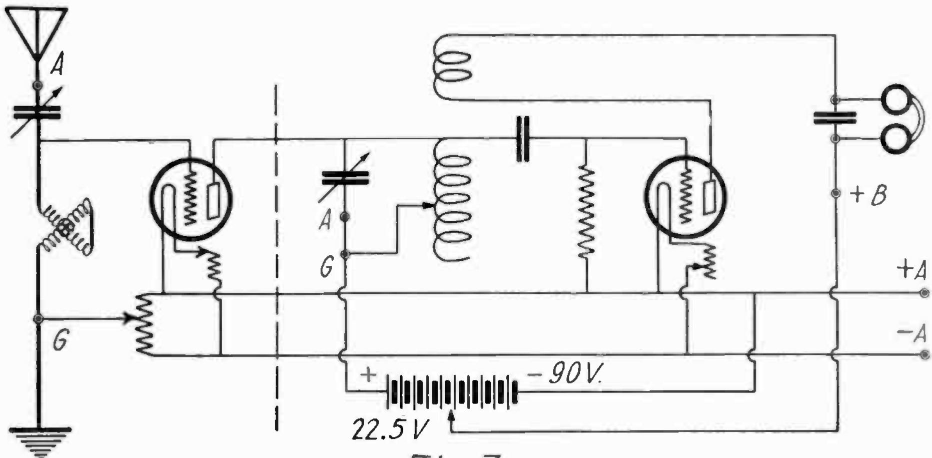


Fig. 3

Simple Tuned Circuit Regenerative Receiver With One Stage of Tuned Impedance Radio Frequency Amplification Added to Left of Dotted Line.

The grid condenser in the detector circuit is very small and should be preferably between .00005 and .0001 mf. The value of the grid leak is on the order of one megohm and the leak should be connected as per Fig. 2.

It was found feasible in the case of a Grebe type CR-8 tuner to install the extra parts in the cabinet with the new rheostat, potentiometer and binding-posts mounted at the right-hand end of the panel.

Where a single tuned circuit tuner is involved it will probably be necessary to mount separately the apparatus to the left of the dotted line in Fig. 3. Note carefully that the "ground" post of the tuner is to be connected to the positive side of the amplifier "B" battery so that the connections in the tuner between the "ground" post and the rest of the interior wiring must be broken except for the lead running to the inductance. The "aerial" and "ground" posts are then connected together so as to put the variable condenser in parallel with the inductance. The grid lead is changed so that one end is connected to one of the "A" battery wires. The inductance in the amplifier is a standard variometer and the variable condenser in the aerial circuit is about .0003 mf. total capacity with vernier.

If the aerial is connected to the set through a variable condenser as shown in Figs. 3 and 4, it is recommended that the aerial be a single straight wire not over 75 tuning being accomplished by the grid variometer. Using a loop consisting of five turns of No. 18 bell wire tacked to the inside of a closet door it was found that a broadcasting station fifteen miles away could be heard quite loudly when the door was pointed in the proper direction. The loop was about two feet wide by six high.

While a variometer can be put, if desired, in the plate circuit of the detector tube, the writer can find no advantage in doing so as the same increase in signal strength can be obtained by adjusting the potentiometer.

A very pleasing characteristic of this circuit which will be noted as soon as it is tried is the absence of distortion, even with the potentiometer set for strongest signals. If any of the controls are set beyond that point, there is a sharp click heard after which nothing is heard at all until the control involved is brought back to its proper position. This action is quite different from that of a regenerative receiver where considerable distortion is produced when the regenerative effect is used beyond a certain point to say nothing of the many varied squeals with which we are all so familiar.

In tuning this R. F. amplifier it is best to work *up* on the grid variometer, but from a high point *down* on the plate variometer or the plate variable condenser as the case may be. It is also suggested the potentiometer arm be set initially near the postive post and then gradually turned towards the negative until the point of best reception is found, keeping in mind that each new setting of the potentiometer will usually necessitate slight readjustments of the variometers.

It is interesting to note that the addition of a by-pass condenser across the amplifier "B" battery seems to decrease strength of signals instead of increasing it as might be expected. Similarly a by-pass between the potentiometer arm and one of the "A" battery wires gave poor results.

For broadcasting reception the writer believes that this system of R. F. amplification is the best so far developed because for one stage it requires no more tuning controls than a regenerative tuner while the sensitivity is increased many times. Frequently when used with an outside aerial the signals from broadcasting stations within a radius of ten to fifteen miles are loud enough to work a loud speaker direct from the detector.

Supplementing the above WD-11 tubes do not perform well as radio frequency amplifiers in this circuit. The new UV-201-A tubes are better, but not quite as good, apparently, as the regular storage battery tubes for this purpose.

could probably be used instead. In using honeycomb coils or the equivalent, it is interesting to note that if these are plugged into a two coil mounting, the potentiometer may be omitted if desired and control of amplification is then secured by varying the position of the coils relative to each other. In this case the lead which ordinarily connects to the potentiometer lever is attached to the positive "A" battery lead.

The coupling between the aerial and the R. F. amplifier circuits and between the latter and the detector circuit must be rather loose for best results. The coupling between the R. F. amplifier and the detector is controlled by the capacity of the grid condenser, hence the desirability of keeping the condenser to a low value. If a seven plate variable condenser is substituted the best value can readily be ascertained. The coupling between the aerial and the R. F. amplifier is most easily controlled where inductive coupling is employed as in Fig. 2. The best coupling value in this case will usually be found where the coils are almost at right angles to each other, particularly if the aerial is of fair size. The single tuned arrangement shown in Fig. 3 is not adapted so well for obtain-

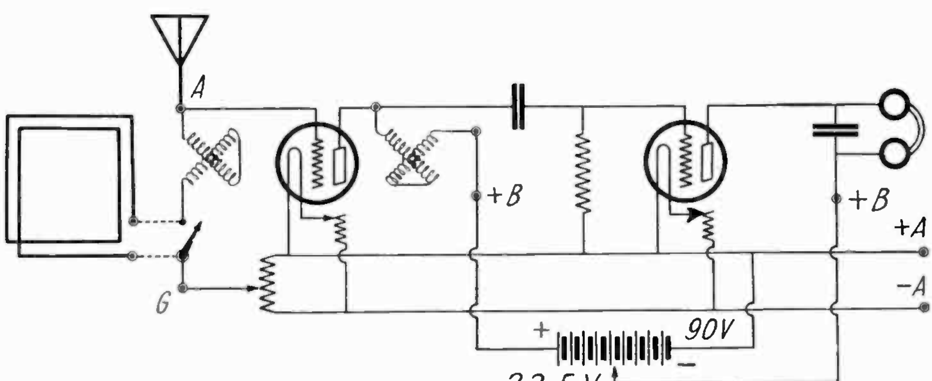


Fig. 4

Simple Hook-up of Radio Frequency Amplifier and Detector for Use With Short Inside Aerial or With a Loop.

As to using honeycomb coil inductances instead of variometers for 360 and 400 meters, it was found by the writer that a 75-turn coil with about ten turns removed was satisfactory in the plate circuit when shunted by a seven or thirteen plate condenser. The inductance used in the grid circuit was a 75-turn coil with four taps brought out, but standard coils without taps

ing loose coupling and that is the reason why this scheme cannot be used successfully except with small aerials. With the latter, however, suitable variation of coupling is brought about by increasing the value of the inductance with consequent decrease of the series condenser setting for a given wave-length, until the best combination is found.

Head Sets

By **Jesse Marsten**

For some time since the advent of radio broadcasting, there have come into being almost one hundred different manufacturers of radio head-sets, and as is to be expected, some are good and some not so good.

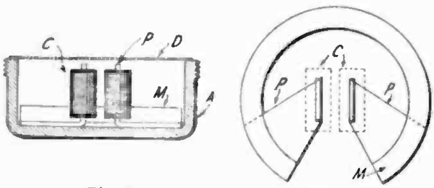


Fig. 1 Fig. 1a

The Internal Construction of the Receiver is Shown in Fig. 1 and Fig. 1a.

The internal construction of most of the head sets, with exception of a few minor mechanical design modifications, are alike. They are all rated by their ohmage, 2,000 or 3,000, or whatever the case may be, from which very little can be told as to the quality of the phones.

Before this period there was just a handful of reputable head set manufacturers and their claims could be relied upon. In that stage of development of the radio art when only crystal sets were in vogue and radio communication had to be maintained between stations, good head sets were a necessity. Good head sets were, therefore, produced. But with the advent of the boom and the appearance of carloads of miscellaneous junk on the market, many head set manufacturers were content to put their O. K. on telephones which gave a loud signal when tested in back of a regenerative receiver with a two-stage amplifier a couple of miles away from a powerful broadcasting station. It is not surprising, therefore, that bad head sets were produced, since even bad telephones will give a fair signal under such conditions.

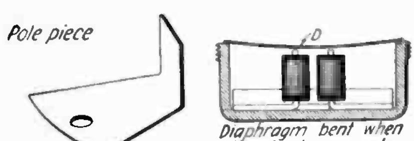


Fig. 1b Fig. 2

Design of the Soft Iron Pole Piece. Fig. 2 Designates the Influence on the Diaphragm When a Current Traverses the Magnet Coils.

It is safe to say that a number of the new makers of head sets are not really familiar with the theory and design of telephones, in fact had never before manufactured telephone equipment requiring electrical design. They were perhaps good tool and die makers. They had presses which were standing idle. Coil winding machines were easy to make. Steel, wire, fibre, etc., were procurable. There was an unprecedented demand for head sets; hence they made telephones. It is as though one who had the tools for, and experience in, slaughtering cattle, felt himself qualified to perform surgical operations on human beings.

A good deal of what passes for radio and electrical design is very often nothing more than small mechanical changes or variations in standard approved apparatus. Illustrations of this contention are so numerous

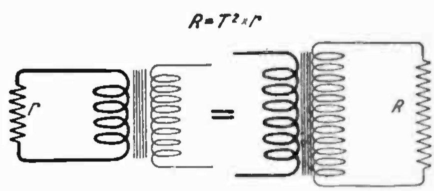


Fig. 3

A Resistance in the Low Tension Winding of the Transformer Is Equivalent to the Same Resistance Multiplied by the Square of the Transformer Ratio When Transferred.

and obvious to one familiar with radio apparatus that mentioin of this is almost unnecessary. Thus a new headband for telephone or a novel method of connecting the telephone cords to the magnet coil windings will be heralded as a great "radio improvement," and will be talked up by the manufacturer of the head set to the exclusion of such prime essentials as the sensitivity of the telephones. It is amusing to listen to the average salesman tell his selling points —how wonderfully light this headband is, how well the ear caps fit the ear, how beautiful the head set looks, the highly polished nickel plated metalware—and then gloss over or forget entirely such trivial matters as the sensitivity and performance of the phone.

Those experienced in radio are able to separate the chaff from the wheat, but the average lay enthusiast is not, and so is often taken in by such talk as given above.

It might, therefore, be timely to give here in a brief and limited way an outline of the simple theory of the telephone receiver to show what factors determine its sensitivity to explain wherein lies the significance of the resistance of the phones; to discuss design features of the head set and what goes to make a good head set.

attracting it to the pole pieces. In this condition the diaphragm is, therefore, slightly bent as in Fig. 2, (usually called "dished" position). When a current flows through the coils a magnetic field is set up, due to this current. When the current flows through the coils in one direction its magnatic field adds to the field of the magnet

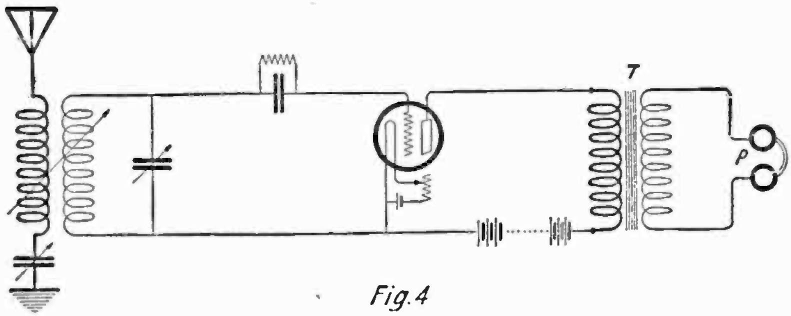


Fig. 4

A Vacuum Tube Receiving Circuit Incorporating a Step-Down Transformer in Conjunction With a Pair of Low Resistance Phones as Described in this Article.

MM and hence the diaphragm is attracted with a greater force than originally. When the current reverses its direction through the coils, its magnetic field opposes that due to the magnet MM, and hence the diaphragm is attracted with less force than originally which is equivalent to a repulsion from its original position. Furthermore, the amount of this attraction or repulsion depends upon the strength of the current flowing through the coils. In this way a to and fro vibratory motion is imparted to the diaphragm, this vibratory motion being in harmony with the variations of the current flowing through the coils. But the variations in the current are simply electrical reproductions of the transmitted sound, be it signal or speech. Hence the vibratory motion of the diaphragm will result in the reproduction of the original sound.

The theory and operation of the radio head set is the same as that of the telephone receiver used in wire telephony. The construction is somewhat different from that used in telephone booths and desk stand telephones, but is practically the same as the one used by the central station operator. Fig. 1 shows schematically the construction (internal) of the average telephone receiver. The container is generally of the so-called watchcase type, that is, a shallow cup made of moulded insulation or of such non-magnetic metal as aluminum. Fastened to the base of the container is a permanent magnet MM—shown in detail in Fig. 1 (a)—this is usually circular in shape. To each pole of this permanent magnet there is attachel a soft iron pole shoe, the general design of which is shown in Fig. 1 (b). Due to the magnetic influence of the permanent magnet MM the pole shoes PP are also magnetized, one pole shoe being a North Pole, the other a South Pole. Around these poles pieces are wound the receiver magnet coils CC. These are generally wound on a bobbin first, and then slipped over the pole pieces. Resting on the top of the watch case container and just over the pole pieces is the telephone diaphragm D, which is generally of soft iron or tin, shellacked on one side and enameled on the other. The internal parts are then completely enclosed by means of the ear cap E which screws onto the containing case.

The action of the telephone receiver may be simply explained as follows: When there is no current flowing through the magnet coils CC, the magnets MM exert a certain force upon the diaphragm D, thus

The amplitude, through which the diaphragm vibrates, determines the loudness of the signal; the greater the amplitude the louder is the signal. As implied in the previous paragraph this amplitude depends upon the force with which the diaphragm is attracted to the magnet pole pieces. Without going into the mathematics of the problem, we may say that analysis shows that this force depends directly upon two factors: one, the strength of the permanent magnets MM; and two, the strength of the magnetic field created by the current flowing through the coils CC.

1. Strength of permanent magnets. The sensitivity of the telephones increases with the strength of the magnets MM. Hence magnets are made as strong as possible. There is a limit, however, to the extent to which magnets may be magnetized, exactly

as there is a limit to which a steel spring may be stretched. The value of the maximum strength to which a magnet may be magnetized depends upon the kind of steel used in the magnet. Certain steels permit only a low magnetization, while others permit of a high magnetization. The best kind of steel to employ in the case of telephone receivers is either chrome steel, or tungsten steel, and of the two tungsten steel is the better. In view of the fact that the sensitivity of the telephones depends upon the strength of the magnets, it is obvious that it is extremely important the the magnets should not weaken with age. There are some magnets that, originally strongly magnetized, gradually lose their magnetism and weaken with age. The writer knows some telephones now on the market which are in this class. Steels, such as chrome and tungsten, retain their magnetism, but even these will not, unless they are properly treated before being magnetized. They have to be passed through a hardening and ageing process in order that they retain their magnetism. One of the important qualifications of the good telephone is, therefore, that the proper steel must be used and that its magnetism must be retained over long periods of time.

2. Strength of magnetic field created by the current in the telephone coils CC. This is the second factor on which the sensitivity of the telephones depends. The strength of the magnetic field due to the current is dependent upon two factors; one, the value of the current, and two, the number of turns in the coils. That is, it is proportional to the so-called "ampere-turns," which is the product of current by turns. If we call the magnetic field due to the current, F; the current, c; the number of turns in the coil, n; then

$$F = K\ c\ n$$

where k is a factor of proportionality and is constant for each magnet. From this we see that the larger the current and number of turns are made the greater will be the magnetic field and hence also the sensitivity of the telephones. However, in practice the value of the telephone current is usually very small. This is due to the fact that the energy received by the receiving antenna is usually microscopic, if this term may be used and furthermore the resistance of the detector, be it crystal or tube, is usually very great. Hence the telephone current is small. Therefore in order to make up for the small current it is necessary to use a very large number of turns on the coils in order to increase the sensitivity of the telephones. The amount of space available in which to wind the magnet coils is extremely small. Hence, in order to get a large number of turns in a coil it is necessary to use extremely fine wire. As a result a coil having a large number of turns say between 3,000 and 5,000 and wound with the wire generally used, say No. 40 to No. 44 will naturally have a very high resistance.

From this it should be clear that the high resistance of telephones is due to the necessity of getting a very large number of turns of fine wire in limited space. Therefore, stating that telephones have a high resistance, say 2,000 or 3,000 ohms, in itself means very little. What counts is the number of turns in the coils. It should be emphasized that resistance figures mean little, for telephones may be wound with resistance wire to give a very high resistance, but the number of turns would not be there, and inefficiency would result. Such phones, it appears, have been set loose on the market by unscrupulous makers. The phone should be wound with copper wire only.

Some telephones are today being sold for radio purposes which have very low resistances, say between 80 ohms and 350 ohms. Such phones, if used in the generally known circuits, will be found to be almost useless. Their sensitivity for radio purposes is too low, for the reason that these low resistance phones have not enough turns on their coils, and since the received current is small the ampere-turns are too small to produce any appreciable effect on the telephones. These phones would be suitable if the received current were very large, for then the small number of turns would be compensated for by the excess current. But, inasmuch as the current received is generally small, such phones are unsuitable for radio.

However it is possible to adapt these low resistance telephones for radio purposes by means of suitable telephone transformers. This adaptation is made possible by the application of a certain principle in the theory of transformers. This principle is briefly this: A resistance in the low tension winding of the transformer is equivalent to the same resistance multiplied by the square of the transformer ratio when tranferred to the high tension winding. Thus in Fig. 3, if r is a resistance in the low tension side, and T is the transformer ration, then the equivalent resistance in the high tension winding would be given by R

$$R = T^2\ r$$

The application of this principle to the use of low resistance telephones in radio is shown in Fig. 4. T is a telephone transformer whose high tension side is connected in the place where the telephones are ordinarily connected, right after the detector. P is a pair of low resistance telephones having a resistance of, say 100 ohms, and is connected in the low tension side of the transformer. Suppose the transformer has a ratio of 5 to 1, then the 100 ohms phones in the low tension side of the transformer are equivalent to

$$100 \times (5)^2 = 2{,}500 \text{ ohms}$$

when transferred into the high tension side. In other words, by means of the transformer we are able to transform the low resistance phones in the low tension side of a pair of high resistance phones in the high tension side. Thus with the transformer the low resistance phones should have the same effect as a high resistance telephone without transformer. Experiment shows this to be true.

In general, however, it is preferable to buy the high resistance phones, for the low resistance ones cost almost as much as the high, and besides, there is the added cost of the telephone transformer, and unless one has some skill and experience, best results are liable not be obtained.

The properties of the pole pieces PP (Fig. b) are different from those of the permanent magnet MM. The pole pieces should be made of very soft iron, so-called Swedish iron. This Swedish iron is so soft that it can be peeled with a knife, with ease. Unlike the permanent magnet steel which should retain its magnetism under all circumstances, this soft iron has the property of easily losing its magnetism, and of being easily magnetized. This is essential in order that the magnetic field set up in the pole pieces by the current should be able to follow without lag the variations in the telephone current.

The diaphragm is generally made of iron or tin plate and is usually enameled and shellacked to avoid rusting. The uncoated diaphragm is about 0.007 inch thick, and the coated diaphragm is about 0.009 inch. This diaphragm is placed over the faces of the pole pieces, the clearance being about 0.002 inch between diaphragm and pole pieces. In constructing the phones, the pole pieces are not to the exact size to secure this clearance. The procedure in securing this clearance is to assemble the pole pieces and then grind down the faces of the pole pieces until this required clearance is obtained. It is very important that the clearance be obtained. Some phones are so poorly constructed that the clearance is so large the diaphragm is hardly affected by the current flowing through the phones. In purchasing phones, this point should be well looked into. It sometimes occurs that the diaphragm is not too far from but too close to the pole pieces and is not released at all, so that no response is given by the phones.

Other details of the design of the telephones, such as the design of the head band, ear caps, phone cords, etc., are small matters compared to the design of the magnets and coils as outlined above. The cords should, of course, be long enough to allow the wearer of the phones to move around comfortably, the head band should be light and should not become entagled with the hair; the mechanical design of the ear caps and head band should be such as to prevent outside noises from reaching the ear. These details are the so-called common sense details, but in the purchase of the phones the electrical features must be stressed and looked into most carefully, for what ultimately counts in your radio set is not whether the head band is made of music wire or plain copper wire, but whether you can hear signals on your phones.

Reducing Interference With Single Circuit Sets

By P. H. Russell

Long into the silent nights, the home radio man can be found trying his luck in getting that distant station.

If he is like most of us who are beginners, he has a single circuit turner hooked up regenerative with a tickler for a plate feed back or may have a variometer in the plate circuit. In either case the scheme hereafter shown will be of service.

His single tuned combined grid and antenna circuit has been letting in interfering howls and whistles of stations near and far and he has, as did the writer, wished that he had constructed or acquired a coupled tuner.

Let the single circuit man then wind up another antenna coil having an appropriate number of turns, say 30 to 40 on a 4" tube tapped every 10 turns if he wishes. Then make another coil which will rotate inside the other and in some convenient manner mount it, bringing out leads through the shaft or with flexible wire. This coil should have not more than 20 to 30 turns at most or it may be found that the main tuner will not tune down because usually as much inductance as possible is put on for the sake of efficiency. If the main tuner has taps, this is less important. Then try results. Hook the leads from the rotating coupling coil to the antenna and ground connections on the tuner and hook the ends of the tuning coil with a variable condenser if used, in series or parallel as may be found best, to the antenna and ground leads. Then tune in and the results

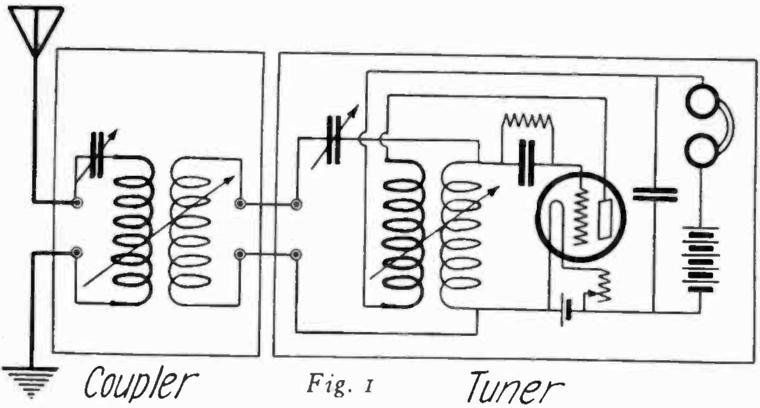


Fig. 1

A Single Circuit Tuner, Showing How the Coupler is Connected.

may prove surprising. The typical single circuit hook-up is shown in Fig. 1, with the coupler above suggested hooked on. It will be seen that the result is practically a coupled circuit with a tuned grid having a variable condenser in series with a grid loading coil. For reasonable comfort in tuning, a vernier condenser on the main tuner is necessary, as tuning is very sharp on the grid, especially with loose coupling. The antenna circuit tunes very broadly.

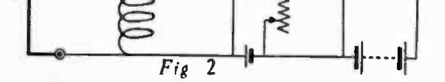


Fig 2

Another Arrangement For Eliminating Interference.

Body capacity will be found to be very slight if (as in the writer's intrument) spider web coils are used. For the coupler described he uses an 18-turn spider web coil on a 5" frame for a coupler with a 60-turn spider web on a 5" frame in the antenna circuit. The main tuner is a 60-turn spider web with a 60-turn tickler wound on thin celluloid frames; all are 5" in diameter. If a thicker medium is used for the tickler frame more turns than 60 will be needed for proper regeneration, as the thin medium seems to give closer coupling and greater inductance.

A word as to results may not be amiss. The writer lives in Central Alberta, Canada. The nearest stations have respectively 2,000 watts and 1,500 watts input. They are distant about 75 miles and can be heard over about 30 degrees on a .001 condenser in the single circuit tuner loud enough to interfere badly with the faint distant stations. They have been heard all over the United States and in Hawaii. Now using the above coupler, Los Angeles, KHJ; KGW at Portland, KYW at Chicago, KSD at St. Louis, WOC at Davenport and numerous others including the Star Telegram at Fort Worth, the Journal at Atlanta, Sweeney School at Kansas City, can all be sorted out easily and brought in through the crashing of the local stations. All this is on two stages, A. F., without any R. F. to increase the selectivity.

It will be seen that by the addition of a simple switching scheme this arrangement may be used for a standby broad tuner to find out what is going on, and with a throw of the switch the coupler can be cut in and fine tuning done.

Now another simple scheme, which increases selectivity greatly, but not so much as the coupler system. This arrangement operates to cut down quite bad static to a low rumble which is much less difficult to work through than if it is not used. Shunt a .0005 variable condenser around the antenna and ground connections, with the tuning condenser in series on the antenna side of the tuning coil and use no ground connection. The above arrangement shown in Fig. 2 results in a very slight loss in signal strength, an improvement in the quality of the signals received, which more than makes up for the loss in strength, much easier tuning on either condenser.

and noticeable decrease in static noises. It may be that local conditions have something to do with this hook-up working so well, but it is simple and easy to try and if no success results, no harm is done. The writer has received too loud for comfort, with two stages of A. F., stations well over 2,000 miles distant. If they were any farther away they would need to be out in the Atlantic as New York, Philadelphia, Anacostia, and Atlanta are about as far as one can reach on dry land from Central Alberta.

Using this latter hook-up, a curious condition will be found, however. It will be obvious that none of the instruments are at ground potential, as there is no ground connection. Consequently, when the operator has his telephones clamped on, he is in effect part of the instrument. Therefore, if other telephones are in use and after tuning is done, they are put on by other listeners, a pronounced detuning will be found, as the other listeners then become part of the instrument, as is the operator, and the capacity characteristics are changed. Therefore, tuning must be done with all the telephones that are to be used on the heads of the listeners.

It will be found then that there is practically no body capacity in the operator for the same reason given above, that he is in fact part of the instrument. This arrangement can be used sometimes without a series condenser. Simply put the tuning condenser in parallel with the antenna coil.

Broadcast Receiving and Receivers

By John F. Bront

Broadcast receiving stations issue many complaints from the deep chests of irate listeners the the "rockcrusher" across the way, or the naval station further along, breaks up the concerts and makes the news and weather reports a mass of hieroglyphics. Much of the entailed fault lies within the receiver in use and not at the door of the rockcrusher. There are in some cases sound basis for complaint. Nevertheless the QRM can be often traced directly to the inefficiency and lack of selectivity of the receiver. The fault lies chiefly in the design and probably not to any inherent incapability of the listener.

Many broadcast listeners do not take into account that radio receivers in general are not designed to be heard all over the room. In commercial work especially, the radio operator has trained himself, as is proper, to receive signals when his receiver is adjusted close to such a point that the signals approach unit audibility. If insistence was made that received signals were as loud a

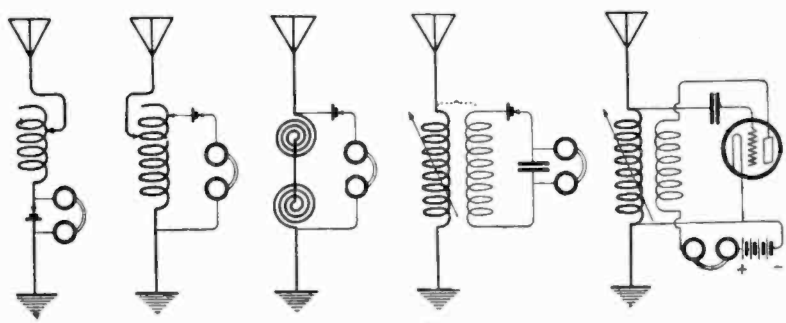


Fig. 1

Fig. 1. "Rock Crusher" Receptors, the Seat of Unsatisfactory Receiving.

possible, only a few stations could work at one time, which would slow up communication and impede progress. The same applies vitally in the receiving of concerts and other broadcasts from local stations by the novice or the advanced radio experimenter. In efficient receiving of radio signals, where a number of stations are working simultaneously, the circuits must be very loosely coupled and exactly tuned to avoid interference and static surges as far as is possible. With loose coupling is entailed a falling off in audibility. The average broadcast listener does not desire this. He wants his signals loud enough to be well received, so that possibly others may listen within a room. However, loud signals and avoidance of interference are generally incompatible. There is only one resort in general: selective tuning with amplification, if an out door aerial is employed.

It must be kept in mind that in a two circuit tuner, the signals are loudest when the incoming energy is equally divided between the primary and the secondary. That entails proper coupling and exact tuning. In tuning, the capacitive and the inductive effects of the circuits are so varied as to bring the effective reactance to a minimum for the frequency of the desired wave. The circuits then respond most efficiently to the signals desired. However, this latter may be of low amplitude and the reactance of the circuit may be less for a signal from a nearby high power station, sending out great energy at another frequency, than for the weaker signal which is the one desired. This condition entails QRM and will bring the broadcast signal back into the phones and if the rockcrusher again is in evidence, the coupling must be further reduced and maybe further amplification added. This process may have to be repeated alternately until the rockcrusher is finally eliminated and the additional amplification brings out the audibility of the desired signals to the desired point.

An honest critical survey of the receiving apparatus by the user may surprise him in the inefficiency of his own receiver. It is the case in many instances that the receiver itself is at fault. Take for instance the naval stations. Their transmitting decrement is limited by law as are all other stations at .2. The navy regulations further limit the decrement to .15. If the 400 meter receiver cannot tune a station out, the decrement of which lies in this quantity, there is generally something lacking in that receiver or in its manipulation.

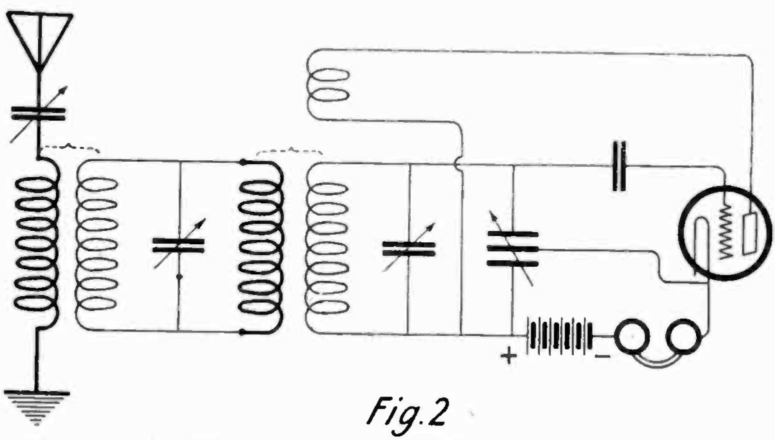


Fig.2

Fig. 2. A Selective Receiver With Intermediate Circuit Which Gives a Sharper Tuning and Prevents Radiation from the Set.

generally emphatic comment on the inhumanity and the downright cussedness of the rockcrushers. The damping of the nearby high power station may be very low and its operation according to law and Mr. Hoyle, yet there is interference.

One thing must be done. The coupling must be loosened at the receiver and brought to a point where the rockcrusher is excluded, if this is possible, which is not always the case when the audibility of the desired signal has been reduced by the loosening of the coupling to a point where it is just audible. Further loosening of the coupling may drive out the unwanted signals completely, but it defeats the desires of the broadcast receiver because the broadcasted matter is inaudible. In this case the only resort is amplification, which

In regard to many receiving circuits, they are not stiffened sufficiently to be at all selective. In some instances the actual decrement of the receiving set is so large as to retard proper selectivity, although the apparatus in general as far as the actual circuits employed are concerned, is efficient otherwise. In this regard, just for comparison imagine the difference in decrement between the "plain aerial" (phones and detector in series with antenna) and an aerial circuit composed of a high grade condenser and Litzendraht cable, with the phones in a secondary circuit. The first is of very high resistance (therefore decrement, within limits) with the crystal and phones which may amount to thousands of ohms. The tuning is very broad and any surge of energy either from static or from a multitudinous scattering of nearby stations will come rollicking down the antenna and through the phones in a mad bedlam.

In a proper oscillating circuit, there is a distinct limit which the resistance must not exceed. If the resistance is greater than twice the square root of the inductance in henries divided by the capacity in farads, there will be no oscillations. The point is this: the closer the constants of the circuit come to the limits imposed by the above formula, the lesser will be the efficiency of the tuning abilities of the receiver. One might go over a receiver and find surprisingly manifest evidence that wear and tear rough usage, corrosion of joints, improper conductors and atmospheric effects bid well to bring the constants of the receiver down to a point where the resisted traverse of oscillations is becoming more and more detrimental to the tuning qualities, the receiving abilities, and the general usefulness of the receiver as a whole. Improper circuits are the main offenders. Probably next comes wrong conductors. Then bad joints, especially those soldered with acid preparations to clean the soldered parts of all oxides.

The resistance of bad joints and improper conductors is often serious. Increase in the decrement is unavoidable if the latter is large. Only when the circuits have a decrement of .2 or less is the tuning ability satisfactory. This allows about 15 oscillations before the amplitude has fallen 10 per cent of the original amplitude.

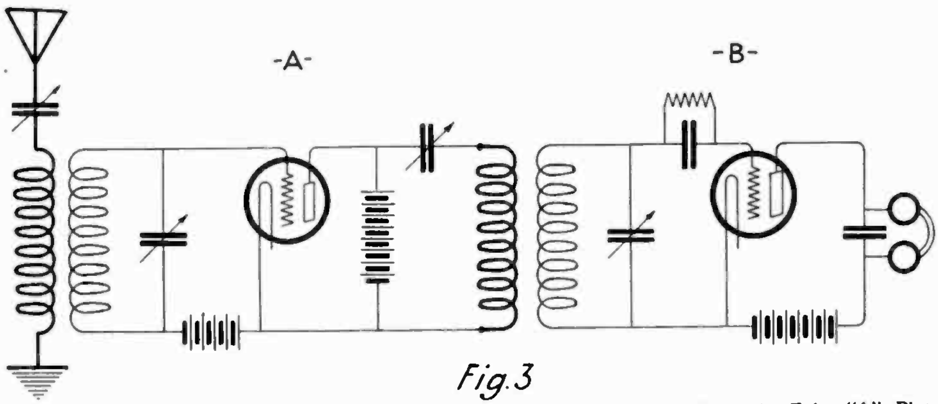
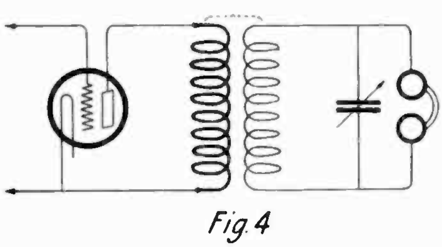
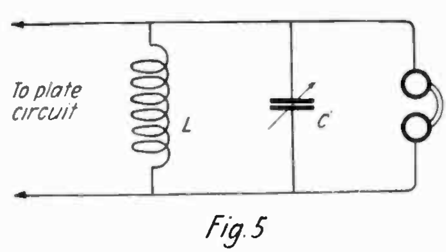


Fig. 3. A Circuit For Selecting Desired A. C. Component of Desired Signal in Tube "A" Plate Circuit and Amplifying as Well as Detecting in "B."



Selection by an Auxiliary Circuit.

The resistance of conductors is often unnoticed and unexpected. It is established that the effective resistance of a conductor traversed by high frequencies depends upon the frequency, therefore the wavelength. The resistance to a longer wave is generally less for a given conductor than that for a shorter wave, because of the difference in the frequency. High frequency currents mainly travel on the surface. In order for them to reach below the surface time must be allowed. It is manifest that in a circuit, say receiving a 300 meter wave, the actual sinking of the energy below the surface is small in amount or effect but in receiving a lower frequency, corresponding to a longer wave, there is more time allowed for the current to sink below the surface and enlist the further conductivity of the inner particles of the conductor. For instance at a frequency of 1,000,000 cycles (300 meters) the current may only traverse



Note Selector for Heterodyned Signals.

the conductor below the surface to an extent of .0025 inch. At a lower frequency the depth reached is greater due to the time element.

The above may seem hairsplitting but for best results it is not. If we do not properly take into account the actual agents which bar our receiver from selectivity and low damping we may as well go back to the coherer and popoff's lightning rod. If nothing better, we may be able to ascertain that in most cases QRM and extraordinarily unnecessary and constant static interferences are in part due to the inefficiency of our receivers rather than to the contrary.

The way the situation now stands in the radio field is this: Congestion is rampant. Interference is great. Stations are numerous and their sparks and sustained waves are intermingled, blanketing, interfering, heterodyning, and often powerful. There is no happy medium in receiving, especially with the use of an out-door aerial. The way is pointed exclusively to loop and other directional receiving antennae.

However, for those who insist on the outdoor antennae, the above points have been reviewed, as they have been lately many times over.

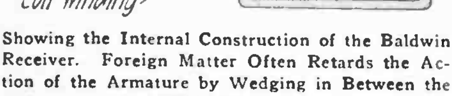
When the old rockcrusher across the way comes roaring in like a ton of lead pigs, go over your receiver on a critical and conscientious survey and try to discover if your receiver is correct. The results may be surprising.

Hints on Loud Speaker Unit Operation

***By* J. E. Frisbee**

The radio enthusiast of today is not satisfied until his single bulb set has grown to two stages, and until he is the proud possessor of some form of loud speaking horn. Although we all hope to some day own a horn of the Magnavox or Western Electric type, the intermediate step usually is the adapting of a Baldwin receiver to some form of horn.

The Baldwin receiver is extremely delicate and very sensitive to the electrical impulses passing through its coils, and for this reason extreme care should be taken



Showing the Internal Construction of the Baldwin Receiver. Foreign Matter Often Retards the Action of the Armature by Wedging in Between the Pole Pieces.

in its use. Under no circumstances should a pair of these phones be allowed to drop on the floor, as the armature spring or the mica diaphragm is easily broken. It is well to remember that if you are located over 100 miles from a broadcasting station of any power, that it will be necessary to have two stages of amplification to make this type of a receiver an every day success.

When using a regular Baldwin phone with considerable amount of volume it is sometimes noticed that the receiver when forced beyond a certain point rattles or "chatters" and distorts the voice or music. This can be corrected by detuning the receiver, but at a corresponding reduction in signal strength. A close examination of the receiver construction will show that the entire pole pieces, armature and diaphragm are fastened to an aluminum sub-diaphragm, and do not in any part touch the sides or bottom of the receiver case. When signals above a certain strength are passed through the receiver the mechanical energy becomes so great that the entire pole pieces and aluminum diaphragm are set into vibration, and in this way either counteract the movement of the mica diaphragm or causes it to rattle.

Between the pole pieces and the bottom of the receiver case is a space of about ⅛". If this space is filled with cloth or felt so as to stop the vibration of the unit as a whole, the problem of the "chatter" has been solved and it will be possible to obtain far greater strength of signal with perfect reproduction even if used on three stages. Cut several pieces of felt or cloth 1⅞" long and place them in the bottom of the receiver. The layers should only be built up until on placing the unit in the case, the mica and aluminum diaphragms will barely rest on the case edge, as they would normally. The idea, is as may be readily seen, to prevent abnormal virbations of the entire unit but not to interfer with any weak impulse transmitted to the mica diaphragm proper.

If a receiver of this type is working satisfactorily it is well to let well enough alone and not examine the interior. If, however, any trouble develops take the unit out very carefully and hold it in a very good light. You will notice that the armature is suspended by a very small spring about the diameter of a common pin, between or rather inside the energizing coil. The clearance between the armature and the inside of the coil frame which is an associate part of the two pole pieces is very small. In several cases an iron filing or chip has found its way into the telephone case, and attracted by the magnets has worked its way between the armature and the pole piece and interfered with its movement. This fault can be corrected very easily by cutting a piece of paper 3/16" wide and an inch or two long. With this as sort of a cleaner, work it back and forth on each side of the armature until in a very strong light you are unable to see any projections on its surface. Foreign particles of this sort will cut down the signal strength and in a few cases have made the unit inoperative.

With a perfect reproducing unit the signals may not be satisfactory if the operator abuses his tubes and the operation of his set. If you are located very close to a broadcasting station you will of course not be troubled with weak signals, and there will not be the temptation to get as near the oscillation point—which means distortion—as there would be with weaker signals. In general, if you obtain good, clear music or voice in your detector tube circuit with a headset, you will obtain the same clear signals in your two stage output to your loud speaker.

Amateur Reception on Honeycomb Coils

By **J. P. Jessup**

Very little is said concerning honeycomb coils for 200-meter reception. A number of amateurs, who never took the time to learn to use honeycombs, have discarded them and invested their money in expensive regenerative sets.

Now, in the first place, one thing that will surely kill 200-meter signals is capacity between the secondary leads. It does not make much difference for higher waves, but for amateur reception, capacity between secondary leads is to be avoided. Another thing of great importance is the length of the lead from the grid of detector to grid condenser. This must be as *short* as possible. Get the grid condenser as close to the detector as possible; also, a short connection between grid condenser and secondary is advisable.

With regard to tuning for long distance work, loose coupling is essential. If the tickler coil is set so that the bulb does not oscillate, but is close to the oscillating point, and the primary is pulled away from the secondary, the further you move the primary from the secondary, the more sensitive the detector becomes. Moving the primary out brings the set up to the oscillating point gradually, makes it very sensitive and cuts out nearby QRM to a great extent. It decreases the strength of stations within a hundred miles and increases the strength of those 500 miles and more away. This is considering honey combs in connection with a two-stage amplifier. By setting the tickler at different distances from secondary, you can cause the bulb to start oscillating at any desired point on the secondary condenser scale. Suppose you have the tickler about ½ in. from the secondary and the primary about 2 in. from the secondary, there will then be a definite place on the scale where the bulb starts to oscillate. Call this place 40° on the scale. From 35° to 40° will be very sensitive to spark signals and from 38° to 40° will be supersensitive. If you have a vernier condenser across the secondary condenser, set the latter at 38° and the vernier at 0°, then tune on the vernier and you will find it very sensitive. The sensitiveness increases as you approach the oscillating point and far distant stations will be considerably amplified.

If you have not a vernier condenser, just tune carefully on the secondary condenser from 38° to 40°. A slight loosening of the coupling between the secondary and tickler will increase the region that signals can be heard in *lower* on the scale. Thus it would permit tuning from 30° to 40° and cover a wider band of wavelengths, although not quite so sensitive. The oscillating point can be made to occur at 35° or 21° or 50°, or anywhere, just as the distance of the tickler is varied. The closer the tickler, the lower on the scale it will be. The primary condenser is set in one place and left there; this place can be determined by experiment and depends on the aerial, primary, etc. My aeriel is large and I need an L25 as primary with a 43-plate condenser set at 180°. Sometimes the bulb oscillates best with a series condenser and sometimes with none at all. At any rate, once it is set, leave it in one place and do your tuning on the secondary condenser.

Now, as to C.W. (amateur) reception. Both your primary and tickler coils will require closer coupling with the secondary. The tickler needs to vary from directly against the secondary to ¼ in. away. The primary needs about 1 in. separation from secondary and generally can stay in one place. For example, say the bulb oscillates at 40° and you have been getting spark stations from 30° to 40°, and you wish to tune in C.W.: Set the primary at about 1 in. from the secondary, the tickler about ¼ in. out, and tune from 40° to 90° for C.W. Ordinary C.W. stations with 200-meter licenses will be found up as high as 280 meters. You can leave the tickler stationary and just tune on the secondary condenser if you wish. However, a slight variation of tickler, after the C.W. has been tuned, will usually increase the strength. For phone stations the tickler will have to be pulled away from the secondary until the bulb almost stops oscillating and close coupling of the primary and secondary is necessary.

A Portable Wavemeter

A wavemeter is a device for measuring the frequency or the length of radio waves. Radio waves always travel with the same velocity, and if the frequency is known the wave-length is also known.

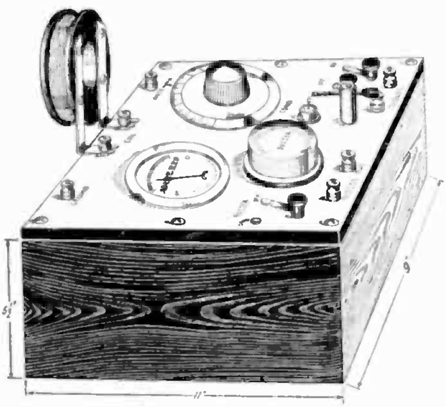


Figure 1

Appearance of Completed Short Wave Wavemeter as Described.

Resonance is a most fundamental phenomenon of radio. When the inductance and capacity of a circuit, on which an alternating electromotive force is impressed, are adjusted so that the impedance of the circuit is a minimum and the current flowing in the circuit is a maximum, the circuit is said to be in resonance. For information regarding resonance and the measurement of wave-length, reference may be made to "The Principles Underlying Radio Communication," Signal Corps Radio Communication pamphlet No. 40, and to Bureau of Standards Circular No. 74. These publications may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C.

Amateur radio stations in the United States are at present required by law, when transmitting, to use wave-lengths not exceeding 200 meters, and it is, therefore, important that amateur operators should have a wavemeter available so that they may adjust their transmitting sets to comply with the law, and it is necessary that this wavemeter should be adapted to measure short wave-lengths such as 200 meters. Other comparatively short wave-lengths, such as 360 and 485 meters, are now used for radio telephone broadcasting, and it is important to have a wavemeter which can measure these wave-lengths. The Radio Telephony Conference, which met in Washington in February, 1922, recommended narrow bands of waves for particular services, some bands being only 10 meters wide. Stations which must work within such narrow bands must be provided with well-designed wavemeters if they are to comply with the requirements of the law. The design of a portable short-wave wavemeter is therefore a matter of importance. It is the purpose of this article to point out the most important considerations in the design of such a wavemeter, and to describe the construction of a wavemeter suitable for the measurement of frequencies from about 3,000 kilocycles per second to 530 kilocycles per second (wave-lengths from 100 to 570 meters).

The parts of a wavemeter are, usually, a variable condenser, a fixed inductance coil, and a device to indicate current flow. The condenser will first be considered.

It will be well at the start to eliminate certain large classes of condensers whose construction makes them unfit for use in wavemeter circuits. Variable condensers employing other dielectrics than air, and condensers whose capacities are varied by a screw to change the distance between plates, however serviceable they may be for furnishing a variable capacity, will not in general retain their calibration and are, therefore, untrustworthy for use in a wavemeter. This elimination leaves only air condensers whose capacity is varied by changing the overlapping area of parallel plates—the usual type of variable condenser. All condensers of this type can by no means be used in wavemeters. A condenser to be used in a wavemeter should have fairly heavy plates rigidly held together with ample tie rods and nuts, spacing washers of large diameter and sufficient thickness, adequate conical bearings, and, preferably, unimpeded rotation through 360 degrees of arc. Particulars in which variable condensers commonly fail to meet these and other requirements are: too thin plates, spring-supported bearings, extremely close spacing of plates, vertical or lateral play of the shaft in its bearings, contacts made by brushes wiping on movable parts, stops which in arresting the rotating plates shift them out of line, shifting scales or indices, and faulty workmanship which allows short-circuiting of the condenser at some settings. In general, anything that allows a capacity change without a change in scale reading or a change in reading without a capacity change destroys the usefulness of a condenser for wavemeter purposes. Some method of shielding is desirable to eliminate any change of condenser capacity owing to movements of surrounding bodies. The shield usually is a grounded metal case placed around the condenser.

The first requirement, which has to do with the range of wave frequencies, will first be considered. It is well to restrict the part of the condenser scale used for frequency measurements to the sector between 15 deg. and 170 deg. on a scale graduated in degrees, or between the eighth division and ninety-fifth division on a scale graduated in hundredths. Since the capacity at 170 deg. or 95 hundredths will almost always be more than six times the capacity at 15 deg. or 8 hundredths, the frequency obtained with any one coil at the lower end of this region will be not less than about two and one-half times the frequency obtained with the same coil at the upper end. This will make it possible with one coil to cover the range from 3,000 to 1,200 kilocycles per second (100 to 250 meters) and with a second coil to cover the range from 1,330 to 530 kilocycles per second (from 225 to 570 meters).

The following table gives the number of turns required for two single-layer inductance coils which will cover approximately the stated ranges with each of the maximum capacities indicated in the table. It will be noted that the size of the wire and the spacing between turns are not specified. The inductance is nearly independent of the size of wire used, and the spacing is controlled by the number of turns and the length of the inductance coil, both of which

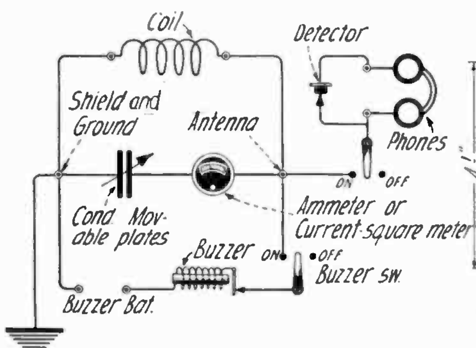


Figure 2

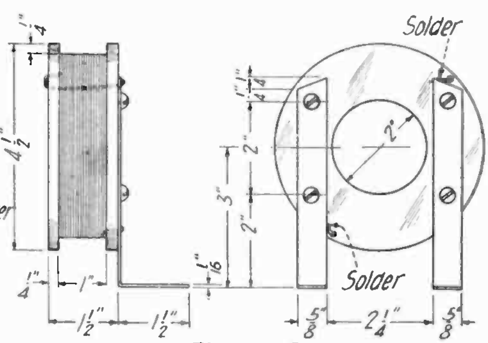


Figure 3

Fig. 2. Circuit Diagram of the Wavemeter. Fig. 3. Detailed Design and Dimensions of the Inductance Coil.

The inductance coils will next be discussed. The requirements of a wavemeter coil are: (1) that its inductance be such that with the condenser used the desired range of wave frequency can be covered; (2) that its effective resistance and effective capacity be low; (3) that its inductance, resistance and capacity all be constant.

are given. The length of the coil, as indicated, is the length of the actual winding, not the length of the supporting core.

Single-Layer Inductance Coils for Portable Wavemeter

Coil 1, Range 3,000-1,200 kilocycles per second (100-25 meters); Diameter, 10 cm. (4 inches); length of winding, 2.5 cm. (1 inch).

Maximum capacity of Condenser	Number of Turns
0.0005 microfarad	16
0.0007 microfarad	11
0.0010 microfarad	11

Coil 2, Range, 1,330-530 kilocycles per second (225-570 meters); Diameter, 10 cm. (4 inches); length of winding, 5 cm. (2 inches).

Maximum capacity of Condenser	Number of Turns
0.0005 microfarad	42
0.0007 microfarad	35
0.0010 microfarad	30

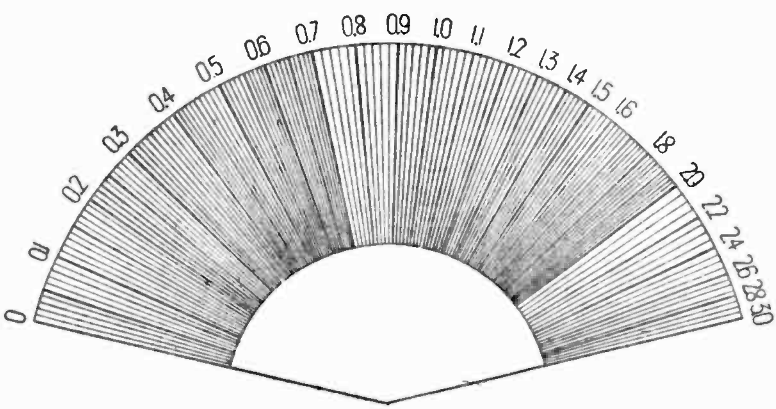
The second requirement stated for the coil was that the effective resistance and the effective capacity be low. Low resistance is desirable in order to secure sharper indication of resonance. There are several reasons for keeping the effective capacity low. This capacity serves to increase the total capacity of the circuit. This increase will be only a small part of the total capacity at the high-capacity end of the condenser scale and hence will not appreciably help in extending the frequency range downward, but it may be a considerable part of the capacity at the low-capacity end of the condenser scale and may seriously limit the upward extension of the frequency range. Another and more serious objection to a large effective capacity is that this capacity is always to a greater or less extent subject to variation as a result of change in the surroundings of the coil. Since this capacity cannot be controlled, it should be, as far as possible, reduced. The practice of surrounding an inductance coil with quantities of miscellaneous insulating material is undesirable in any radio circuit and is especially to be avoided in the case of wavemeter coils. Imperfect insulating materials so used increase not only the effective capacity but also the effective resistance of the coil. This does not mean that all types of manufactured insulating materials are unsuitable for use in frames for wavemeter coils. Probably, however, the best form on which to wind the coil of a wavemeter like that here described is a hollow spool of thoroughly dry wood lightly varnished with an extra grade of insulating varnish. The use of shellac is not considered advisable under any circumstances. The use of wood having even a comparatively small moisture content may seriously affect the accuracy of the wavemeter. Properly selected wood is chosen in preference to manufactured insulating materials, glass, or pasteboard. Many available manufactured insulating materials largely increase both the resistance and the capacity of the coil. While the electrical properties of glass make it well suited for a form, it presents too great mechanical difficulties. Pasteboard is not rigid enough and should not be used under any circumstances.

The wire used may be solid copper double cotton covered, No. 24 B. & S. or larger. The wire should be lightly varnished with a single coat of an extra grade of insulating varnish. Further insulation merely increase the effective resistance and capacity of the coil without compensating advantages. The resistance can often be considerably reduced by the use of braided high-frequency cable. Care must be taken, however, in using the high-frequency conductor to see that all the strands are continuous and well insulated from each other and that every strand is joined at the terminals of the coil. If imperfect insulation exists between adjacent strands, these high-resistance contacts may cause a considerable increase in the power losses. Broken strands seriously increase both the effective capacity and the resistance of the coil. The strands may be tested for continuity by dipping one end of the cable in mercury and joining the separate strands at the other end successively to a buzzer or voltmeter joined to a battery, the circuit being closed through the mercury contact. The enamel may be removed from the ends of the separate strands by carefully heating the end of the wire cable to a red heat and dipping it in alcohol. This procedure makes the strands more fragile and consequently particular care must be exercised to avoid breaking them.

A single-layer coil has generally a lower effective capacity than a multilayer coil of the same inductance and radius. This, together with the greater precision with which specifications can be furnished for winding single-layer coils, was the reason for choosing this type of coil in the table already given. Since appreciable effective capacities exist when there are parts of the circuit near each other which have comparatively large areas and which are at different potentials, it follows that the leads from the coil to the condenser should not be long or close together. An additional reason for having the leads short is found in the third requirement previously stated for a wavemeter coil, namely, that the inductance, capacity and resistance of the coil, including its leads, be kept constant. Long leads are apt to be flexible, and flexible leads, long or short, introduce possibilities of change in inductance, capacity and resistance which cannot be compensated for by any slight advantage they may give in convenience of handling. The best leads are rigid metal terminals soldered to the ends of the wire and screwed to the wooden core. The position of the coil should be such that the plane of the turns of the coil is perpendicular to the condenser plates if the condenser is unshielded. This is to prevent the induced current in the coil from itself inducing eddy currents in the condenser plates. Since it is almost always desired for convenience in coupling to have the plane of the coil vertical and the condenser plates horizontal, this matter will usually take care of itself. A very important precaution in giving the coil permanent characteristics is to draw all the turns tight and so fasten them that with ordinary care in handling they will not shift.

The coils may be attached to binding posts on the wavemeter, so that they may be conveniently connected or removed. Various other methods of attaching may also be used.

The third part of the wavemeter is the device which shows current flow and thus indicates resonance. If a crystal detector and telephone receivers are used, only the one-point (unilateral) connection should be employed; that is, the detector and telephone receivers are joined in a closed circuit, and one point of this circuit is joined to one terminal of the coil. This arrangement is sufficiently sensitive and makes the calibration of the wavemeter fairly independent of the position of the telephone leads, at least so long as they are not closely drawn across some part of the wavemeter or wrapped around it. A more precise indicating device is a thermogalvanometer or a radio-frequency milliammeter. Available types of thermocouple instruments are usually found more satisfactory than the ordinary expansion type of hot-wire instrument, because they respond more quickly to changes of current. The instrument should give full scale deflection with a current of about 0.1 ampere. It should be able to stand a considerable overload. It is generally inserted directly in the wavemeter circuit, sometimes with a shunt to keep low the resistance of the circuit. It is important to note that the presence of the instrument will probably modify the capacity, inductance and resistance of the circuit, so that the wavemeter should be calibrated with the same instrument in the circuit as will be used in measuring frequencies. An inexpensive indicating device and one which is satisfactory when the power output of the generating circuit is large enough, is a miniature lamp, such as a flashlight lamp, inserted directly in the wavemeter circuit. To avoid any possibility of changing the calibration of the wavemeter, the lamp should not be changed if it can be avoided. If it must be changed it should be replaced by one of identically the same kind. The sensitiveness of this device can be greatly increased by having a dry cell and a rheostat in parallel with the lamp in the wavemeter circuit. By adjusting the rheostat until the temperature of the lamp filament is raised almost to the point of illumination, it is possible to have the lamp lighted by induced currents much smaller than would otherwise be required. However, changes in the battery and rheostat will be likely to change the characteristics of the circuit and hence the calibration of the wavemeter. This device should therefore be used with caution.



A Decremeter May be Made Out of the Wavemeter by Using the Above Scale on the Variable Condenser, Providing the Condenser has Semi-Circular Plates.

The wavemeter may be excited by impact, that is, by a source of highly damped waves having only a very few waves in a train. (See "The Principles Underlying Radio Communication," Signal Corps Radio Communication Pamphlet No. 40, p. 278, and Bureau of Standards Circular No. 74.) The wavemeter can then be used as a source of damped waves to determine the frequency to which a receiving set is tuned. The buzzer, in series with the battery, is connected across the condenser terminals, completing its circuit, when the contact is closed, through the inductance coil of the wavemeter. Not more than four volts should be used to operate the buzzer. The buzzer will add to the capacity of the circuit, thereby decreasing its frequency. This decrease will be especially noticeable at the lower part of the condenser scale, where it may amount to several per cent of the frequency. It can be reduced by having short, widely spaced leads to battery and buzzer. If the wavemeter is equipped with both a buzzer and an ammeter or current-square meter, the ammeter must be so connected in the circuit that the current from the buzzer battery cannot pass through the ammeter. If this is not done, the ammeter or current-square meter may be burned out by the current caused to pass through it by the buzzer battery.

The assembling of the parts of the wavemeter must be such that each part is rigidly joined to the rest of the circuit. Mounting in a box is as good a means to this end as any from the standpoint of rigidity and is superior to any in portability and in the protection afforded to the parts. A convenient box mounting is shown in Fig. 1.

The overall dimensions are left to the constructor since the size of the component parts will vary. The box should be substantially constructed so that it will stand considerable handling. The component parts are all mounted on a panel of rigid electrical insulating material which will not absorb moisture. This panel is, in turn, secured to the supporting box. It is possible to use a panel of thoroughly dried and seasoned hardwood which is varnished with an extra grade of insulating varnish. Fig. 1 shows one possible distribution of the component parts. Attention should be given to the convenience of operation and advantageous wiring of the circuit to keep distributed capacities at a low value. The most advantageous arrangement of the instruments on the panel will depend in part on the particular instruments used, and the constructor should work out the best arrangement in each case. Fig. 2 gives a circuit diagram showing the connections as they should appear underneath the panel. These connections should be made of No. 12 solid copper wire soldered into lugs. Where bending is necessary, sharp right-angle bends are used. If it is desired to make a short-wave portable receiving set, terminals for antenna and ground connections can be supplied without decreasing the value as a wavemeter in any way, provided suitable care is used in handling the instrument. A wavemeter should be handled much more carefully than an ordinary receiving set. If it is desired to shield the wavemeter, a copper or brass sheet can be permanently fixed on the under side of the panel and spaces cut in to allow for the terminals and supports of the various units. There should be at least one-eighth of an inch clearance for the terminals. Fig. 3 gives the dimensions and construction of the inductance coils.

The forms are turned in a lathe from thoroughly seasoned wood. Several coats of extra grade insulating varnish applied to this form will be desirable in keeping low the absorption of moisture. The proper number of turns of the correct size of wire is wound in a single layer in the recess provided for this purpose. A light coat of extra grade insulating varnish is applied to the wire to keep it in place and to prevent moisture from changing the distributed capacity of the coil. The terminals of the inductance coil are brought out through the wood form and soldered to the supporting brass terminals. The wood screws holding the coil form to the brass supports should be of brass rather than a magnetic material.

It is desirable that the box be provided with a protecting cover and a carrying handle.

After the wavemeter has been constructed, it must be calibrated. This service has been done in the past by the Bureau of Standards. It has lately been necessary, however, on account of the limited personnel available for this work, to limit the tests of radio materials made by this Bureau to tests of precision instruments which will in turn be used as standards for testing considerable numbers of other instruments, tests for Government institutions and state universities, and a few other tests for which there is a special reason why they should be undertaken by this Bureau. Standardization of instruments of the kind described in this Circular can be obtained from various commercial firms and some college and university laboratories.

Consideration has been given to the transmission of standard wave-length signals from laboratories equipped with precision measuring apparatus. This would make it possible to determine accurately several points on the calibration curve of a wavemeter without sending it to a standardizing laboratory. The carrier waves of some radio telephone broadcasting stations may be adjusted to some particular wave, such as 360 meters, and one point on a wave-length calibration can thus be determined.

A wavemeter transported for standardization should be packed in a wooden box large enough to give room for three inches of excelsior on every side, otherwise the wavemeter may easily receive internal damage which will not appear except in its subsequent behavior. The package should be marked "Scientific Instrument. Handle with Care."

Two cautions are offered as to the use of the finished and standardized wavemeter. The first is, not to subject the instrument to any treatment apt to change its calibration. The second is not to couple it too closely to the source of the radio-frequency current which is being measured. The latter error can be avoided by never having the wavemeter so close to this source that it cannot be brought closer without changing the setting for resonance.

It is possible to make a decremeter out of a wavemeter by placing a suitable scale on the variable condenser. For a wavemeter having a condenser with semi-circular plates or any condenser such that the graph of its capacity against its setting is a straight line, the capacity being very small at zero setting, it can be shown that the decrement scale to be used is one in which the graduations vary as the logarithm of the angle of rotation.* Such a scale, designed for a semi-circular plate condenser, is shown in Fig. 2. This scale may be copied or cut from this circular and trimmed to fit the dimensions of the condenser dial with which it is to be used. It may be made stationary with a moving pointer traveling over it, or it may be mounted on a dial rotating under a fixed pointer. At the setting corresponding to maximum capacity the scale reading should be zero. Since the scales of most condensers read counter-clockwise, this arrangement usually places the decrement scale in the unused space opposite the capacity scale. A measurement of decrement is made by first observing the current squared at resonance, then reading the decrement scale at the settings on either side of resonance where the current squared has one-half its value at resonance. The scale is so constructed that the difference between these two readings is equal to $\delta' + \delta$, that is, the decrement of the transmitting circuit plus the decrement of the wavemeter itself. It is then necessary to subtract the wavemeter decrement from the total just obtained. The decrement of the wavemeter is determined as follows: The wavemeter is coupled and tuned to a source of unmodulated continuous waves. The sum $\delta' + \delta$, is measured as just described. Since the waves are continuous, δ, the decrement of the waves is zero, and the result obtained is δ, the decrement of the wavemeter alone. From determinations of the decrement of the wavemeter made at different points on the scale, the calibration curve of decrement plotted against condenser setting is obtained. The conditions necessary to permit the use of this scale in the manner described are as follows:

(1) The condenser must have semi-circular plates. Condensers with plates of a different pattern will have different decrement scales just as they have different capacity calibrations.

(2) It must be remembered that only when resonance is indicated by a current-square meter is the deflection to be reduced to one-half its maximum value in detuning to either side of resonance. If a milliammeter is used, the reading must be reduced not to one-half its maximum value, but to the maximum value divided by the square root of 2 or to 0.71 of the maximum value.

(3) The generator must have an output sufficiently large that the coupling employed may be loose enough to prevent any considerable reaction of the wavemeter on the generator.

(4) Neither the generator nor its coupling with the wavemeter must be changed during the measurement of decrement.

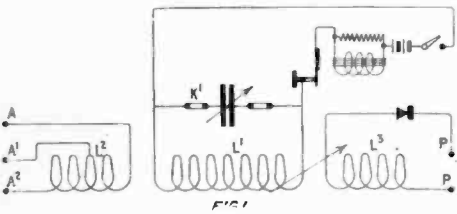
The following precaution is to be observed in measuring the decrement of a transmitting station. The decremeter must be coupled only to the antenna circuit to be measured, not to the primary circuit; consequently it should be kept not less than two meters away from the oscillation transformer, and coupling to the antenna circuit should be obtained by placing the decremeter near the antenna or ground lead, preferably the latter. If the antenna current is small, it will be necessary to make a single turn of small diameter in the lead to which the decremeter is coupled.

*J. H. Dellinger. Measurements of radio-frequency resistance, phase difference and decrement, Proc. I. R. E., vol. 7, pp. 27-61, Feb., 1919. Circular 74 of the Bureau of Standards, Radio Instruments and Measurements, p. 197.

A Wavemeter for Short Wave-Lengths

By Robert E. Lacault

All sorts of new apparatus have been flooding the market but so far the wavemeters remain in the shadow, and I think that some real practical "dope" will be welcomed by many who still use the "guess" type of wavemeter to tune their sets.



Complete Hook-up of the Wavemeter Described in This Article.

First of all it should be remembered that, contrary to a popular belief among the amateurs, a wavemeter is not only used to tune the transmitter, but also to make several measurements often puzzling but in fact quite simple. If you have a little patience and intend to make your station efficient, read this article and make a wavemeter.

Construction of an Amateur Wavemeter

A simple form of wavemeter with which any measurement may be made is shown in Fig. 1; as may be seen, it is composed of three circuits, L_1 and K_1 forming the calibrated circuit, L_2 used as aerial coil and L_3 being the listening circuit which can be coupled to the calibrated one. The constructional details of the various coils, as well as the method of mounting of the various parts in a cabinet, are shown in Fig. 4.

The inductance L_1 is wound on a cardboard tube exactly 3" in diameter, and consists of 21 turns of No. 18 D.C.C. wire. The aerial coil, L_2, which is wound on the same tube, ½" from the winding of L_1, consists of eight turns of the same wire, with the tap at the fourth turn. The two ends and the center tap of this last winding are connected to the three binding posts marked A, as shown in the hook-up. This allows only one section of the whole winding to be used according to the desired value of coupling.

The coil L_3, of the listening circuit, is wound on a piece of wood or cardboard tube 2" in diameter, and 1¼" long. A hole 5/16" in diameter should be drilled through this form to mount a ¼" shaft. The winding of this inductance consists of 26 turns of No. 24 insulated wire, wound in two sections on each side of the shaft, as the rotor of a variometer. Two pieces of flexible cord should be soldered to the ends of the winding for connection to the outside circuit.

On the top of the cabinet is mounted a "Mesco" buzzer, which may be adjusted to give a constant note, and on the panel a crystal detector.

In order that the calibration curve herewith given be used, it is indispensable that a 43-plate, panel type, Murdock variable condenser be used in the calibrated circuit; and that the inductance L_1 is made exactly as described, otherwise the readings would be wrong.

How to tune a Spark Set

To tune a damped wave transmitter the aerial and ground should be disconnected and the secondary of the oscillation transformer moved away from the primary; the wavemeter is then brought near the set

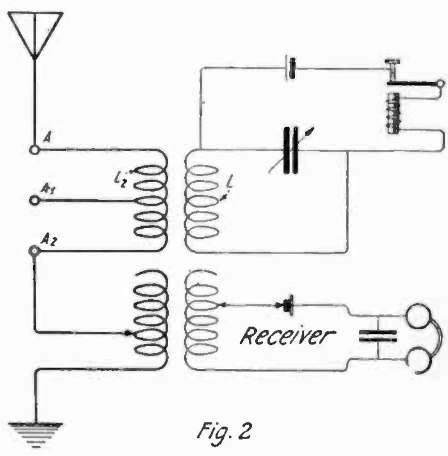
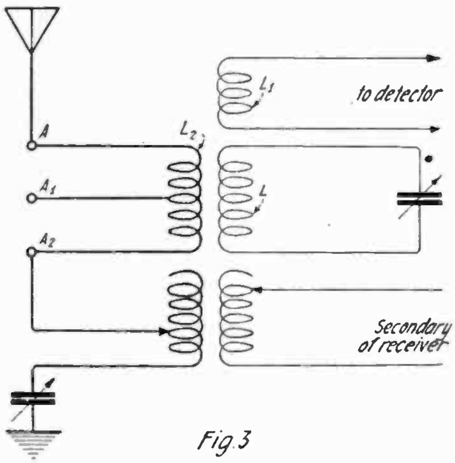


Fig. 2

This Diagram Shows How to Connect the Receiver and Wavemeter to Measure the Natural Wave-Length of an Aerial.

and the key pressed; after the detector is adjusted so that the spark is heard in the phones, the condenser is turned slowly until the sound in the phones is loudest. It will be found that this occurs at a certain point along the scale, and to find exactly at which degree it is sometimes necessary to loosen the coupling between the coils L_1 and L_3, so that the sound is just heard faintly at the maximum, that is at the resonance point of the circuits.



The Hook-up of the Wavemeter Used as Interference Preventer.

By referring to the curve, the wave-length of the transmitting circuit is found in the following way: If, for instance, the maximum sound is heard at 60 degrees on the scale of the condenser, follow towards the right, the line representing this number of degrees on the chart up to the point where it meets the curve, then by looking down under this point, the wave-length is found to be 210 meters on the horizontal scale. If the wave-length found is too high, the number of turns in the primary of the oscillation transformer should be reduced and another reading taken and so on, until the set is tuned to the desired wave-length.

When this is done, the antenna and ground are connected to the secondary of the oscillation transformer which is coupled to the primary and the contact of the antenna moved until maximum reading is obtained at the hot wire ammeter, which should be connected in the ground lead. When the two circuits are in resonance, that is tuned to the same wave-length, the wave-meter should be taken far from the transmitter and another reading taken to find out if two maximums are heard with the same intensity. If so, the coupling should be loosened slightly and the number of turns of inductance readjusted so that the loudest maximum found is on the desired wave-length.

How to tune a C. W. Transmitter

The tuning of a C.W. set is quite different from that of a spark station, and to adjust a tube set to a certain wave-length proceed as follows: First, start the buzzer and adjust it so that it gives a clear and constant note, then adjust the wavemeter on the desired wave-length by referring to the curve and connect a pair of phones to the binding posts marked P. Adjust the detector and loosen the coupling between L_1 and L_3, so that the buzzer is not heard too loudly in the phones.

The wavemeter being set, as explained, is then placed over the inductance of the C.W. transmitter and the set started; the tuning condenser of the C.W. set is then turned slowly until the sound of the buzzer becomes mushy, a very characteristic tone. The transmitter is then set on the wave-length to which the wavemeter was adjusted. The action of the wavemeter in this case is similar to what happens when a spark station is heard in regenerative sets, when the detector tube oscillates; the buzzer acting here as the spark station, while the C.W. set acts as an external heterodyne.

Measuring the Natural Wave-Length of an Aerial

The natural wave-length of an aerial may be easily and accurately found with a wave-meter of the type described in this article by the following method: The receiver being connected, insert in the aerial lead in, one section of the aerial coil L_3 and start the buzzer, the receiver being made apperiodic, that is connected as shown in Fig 2. Then slowly turn the variable condenser until the maximum sound is heard in the phones at which moment the condenser shows the wave-length of the aerial, which is in resonance with the calibrated circuit. However, the value of inductance used in both primary and secondary of the receiver, should be very small, that is, only a few turns should be used, so as to add very little inductance in the aerial itself. The results found are exact, within a few meters, which in practice is sufficient.

If the induction from the calibrated circuit to the aerial is insufficient to give a clear maximum in the phones, both sections of the coil L_2 should be used, and the coupling between the primary and secondary of the receiver made tighter; in any case, the listening circuit L_3 in the wave-meter should be loosely coupled to the calibrated circuit when it in use.

In order to determine if the wave-length found is that of the aerial and not the wave-length of the receiving circuit, some inductance should be added in the primary of the receiver, and another reading taken, which of course should read differently.

Tuning a Receiver for a Certain Wave-Length

When a station sending on a special wave-length which is known in advance is to be received, the receiver can be tuned on this wave-length so as to prevent the missing of a part of the message while tuning the set during the first minutes of the transmission. This is especially useful when it is desired to receive a Radio concert, or some interesting transmission; it is done simply by starting the buzzer of the wavemeter and adjusting the condenser for the desired wave-length, the wavemeter being connected as previously, for the determination of the natural wave-length of the aerial. The receiving set is then tuned as for ordinary transmissions and is adjusted for the message to be received.

Once the receiver is tuned, the wavemeter may be removed from the aerial circuit, although it could be left connected if the buzzer is stopped, to be used as an interference preventer.

Reducing QRM Through the Wavemeter

In case it is difficult to tune in a station, owing to the heavy interference experienced in congested areas such as big cities, the wavemeter may be found useful to reduce the difficulties in tuning. It should be connected, as explained in the previous section, and the set tuned for the station to be received, then the detector and amplifier circuit are removed from the receiving set and hooked up to the listening circuit L_4 of the wave-meter, with the crystal detector short circuited if a V.T. detector is used. The calibrated circuit, then acting as an intermediate or filter circuit, makes it easy to tune in the station to be received if adjusted on the proper wave-length and provided the transmission is sufficiently strong.

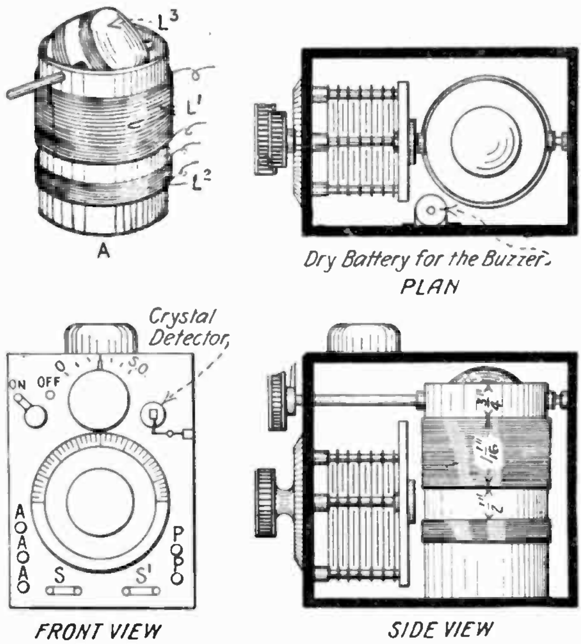


FIG. 4

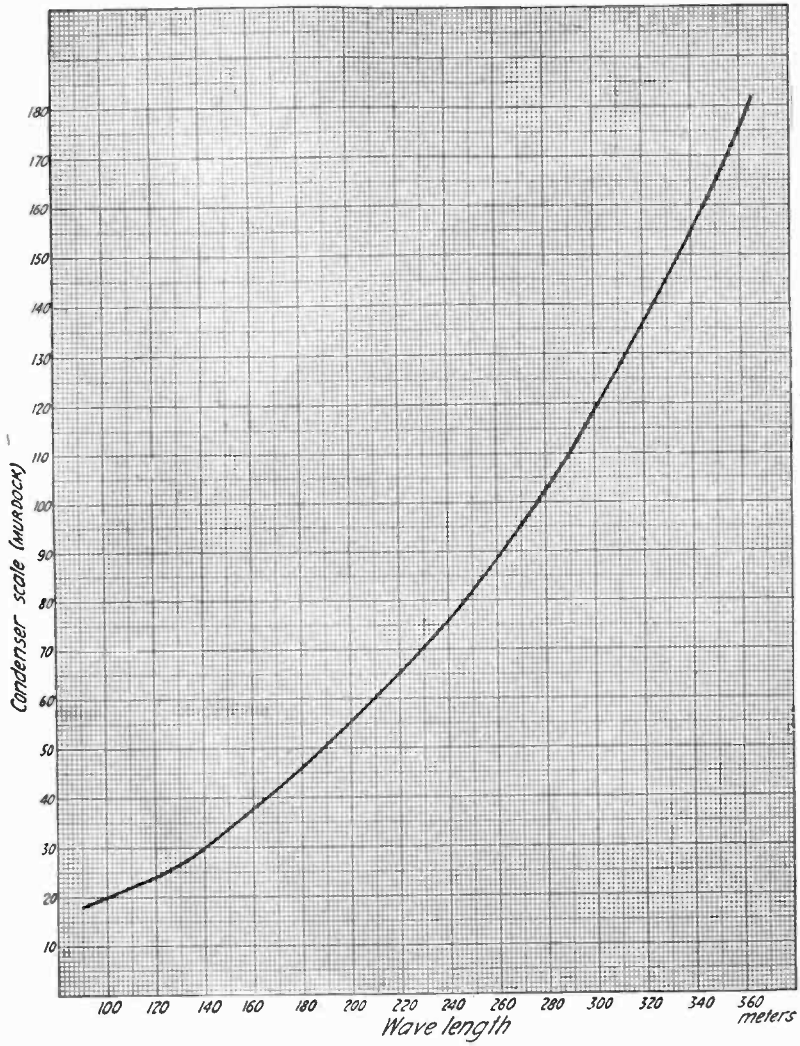
Constructional Details of the Wavemeter and Inductance Used. On the Front Panel, in the Upper Left Hand Corner May be Seen the Buzzer Switch.

Finding the Wave-Length of a Distant Sending Station

Once the receiver of a station is adjusted carefully so as to be exactly tuned on a certain transmission, it is an easy matter to know the exact wave-length of the sending station; this is particularly useful these days to check the wave-lengths of amateur stations which are sending on anything but 200 meters. It is merely necessary to place the wavemeter near the receiving set, start the buzzer and move the condenser K_1 slowly, until maximum sound is heard in the phones; the exact point of the maximum along the scale being found, the wave-length may be known by referring to the chart, as explained before.

Determining Condenser Capacity

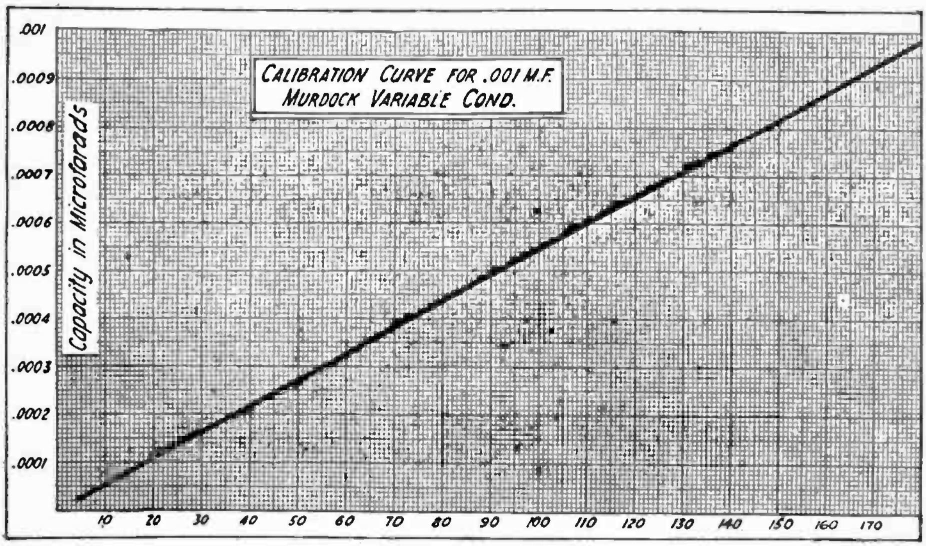
When building a set, the amateur often wishes to know how to make himself the necessary condensers for his apparatus, and in most cases has not on hand the necessary data to calculate accurately the surface of the plates or their number. The wavemeter then again can be used and



The Calibration Curve Showing the Natural Wave-Length of the Calibrated Circuit for Any Degree of the Variable Condenser.

For this purpose, it is desirable that Radio clubs make a wavemeter and inform their members of their wave-lengths, so that all the sets may be tuned within the limit prescribed by the law.

gives more accurate results than any formula which may be employed, for it is difficult to know exactly the constant K of the dielectric and also the variations of capacity due to the pressure to which the condenser is submitted. Consequently, if you have a condenser, the capacity of which you want to know, disconnect the variable condenser of your wavemeter by removing the two connections S S', see Fig. 4, and insert in place the unknown capacity, then start the buzzer and tune your receiving set placed near by so that a maximum sound is heard in the phones; replace now the fixed condenser by the variable and, without changing the adjustment of the receiver, adjust the capacity of the wavemeter until you hear again the maximum sound. At this point, note the number of degrees indicated by the pointer of the condenser, and refer to the chart. Following upward the line from the number of degrees written at the bottom, which represent the scale of the condenser, look horizontally on the left at the crossing of the vertical line with the curve. The horizontal line leads to the scale on the left, which reads in microfarads the capacity of the unknown condenser.



This Curve Shows the Value of Capacity, for Any Position of the Movable Plates, of a .001 MF Variable Condenser.

If it is desired to make a condenser having a greater value than the capacity of the wavemeter, another condenser of known capacity should be connected in parallel with the variable one, and the measurement effected as before. If, for instance, you wish to make a .0018 mf. condenser, first connect an .001 fixed condenser in parallel with the variable, which should be set at 147° for .0008 mf.; then, after a maximum is found in the receiver, as previously described, the home-made condenser is connected in place of the calibrated capacities and the surface of the armatures increased or reduced until the maximum is heard again, without changing the tuning of the receiver.

As may be seen by this explanation, a wavemeter is a very useful thing in a radio station and since it may be built cheaply, there is no reason and no excuse for sending on longer waves than permitted by the law, which is for us very liberal in comparison with the restrictions of the other countries on experimental radio. If you are not rich enough to build a wavemeter, your club can easily make one by collecting only a few cents from each member and allowing them to take the wavemeter home for personal experiments when needed by them.

AN AERIAL CLEANER

If a fish line is tied to the center of an aerial, lots of trouble can be prevented this winter through breakage from sleet and snow, as a little jerk on the line will clear the aerial. It can be insulated with a cleat, where it is fastened to the aerial and the lower end tied out of reach, when not needed.

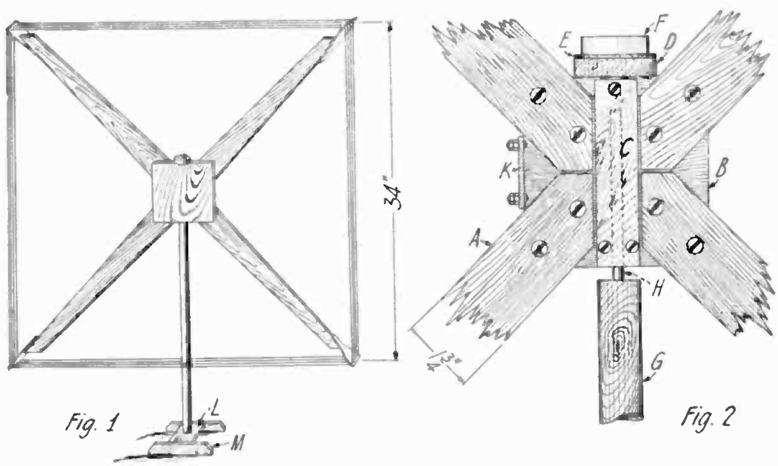
I used this method last winter and it saved my aerial quite a few times.—E. C. GALBREATH.

The Construction of a Loop Aerial

By D. R. Clemons

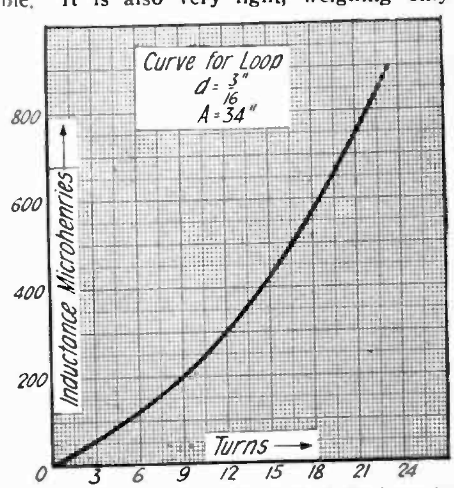
In the experimenter's station a loop antenna may be employed for receiving, or for the "spotting" of transmitters when used as a radio compass. The energy received in the average loop is very small, so that a very sensitive detecting and amplifying arrangement should be used if long distances are to be covered. However, a loop could be used for receiving local broadcasting stations upon a single tube if the distance is not too great. Telegraphic signals may be received over much greater distances, and in this connection it is very interesting to experiment with them.

The design of the loop is more dependent upon the remainder of the circuit and the probable location of the loop during reception. For indoor use it must be reasonably small so that it may be placed upon a table or supported from the ceiling. If it is to be used as a radio compass of reasonable accuracy, its inductance must not be so large, nor the condenser used with it so small that any additional capacity to other bodies will detune it when it is swung about. By allowing a reasonably large condenser—not dependent on the leads and tube capacity alone—it "points" better. It is also possible to feed-back into the loop circuit for regeneration by coupling a tickler coil L3 to a very small coil L2, thus making the signals stronger and the circuit more sensitive. The introduction of coils L2 and L3 may cause the loop to be less accurate, but this may be corrected by using two small condensers in place of C1, the coil L2 being inserted between them as shown in Fig. 4A. In either case the over-all dimensions of the coils must be as small as possible.



Constructional Details of the Loop Frame Work.

The simple loop shown in the sketches is very easily made; and its cost is negligible. It is also very light, weighing only 3½ pounds. As many experimenters might like to build it, simple data will be given.



A Curve Showing the Inductance of the Loop for Different Numbers of Turns.

Since this loop was designed for normal reception on 600 meter stations, the inductance was made 700 microhenries so the capacity for this tune will be somewhat less than 150 micro-mfds., which is obtainable in the small 11-plate condensers on the market. In fact that type is desirable for this work in order that the tune may occur in the central portion of the scale, being less critical to adjustment than would be the case if the condenser were of the larger types. A condenser of 500 micro-mfds. could be used. Since this inductance is too great for use on 360 and 400 meters (the fundamental of the loop is 314 meters) a smaller value of inductance must be obtained. Suppose that reception on 400 meters is desired using the same capacity at C1 as before: the governing factor is the capacity and inductance of the system, their product being known as the LC constant. Since $\lambda = 1884 \sqrt{L \times C}$ where C is known

L may be found by $L = \frac{\lambda^2}{(1884)^2 C}$; or since the LC constant for 400 meters is 0.0450,

$L = \frac{.045}{C} = \frac{.045}{.00015}$, which is 300 microhenries. Then from the curve in Fig. 5, 300 micro-microhenries are found to be 12 turns, but 10 turns would be advisable since the leads tend to add to this. So the loop may be made with 10 turns for 400 meters only; or of 20 turns for 600 and 360 meter work by placing a copper tab on the 10 turn.

The frame is built as follows; four light soft wood strips are cut ⅜" thick and 24" long, tapering from 1¾" at the base to a width of 1" at the outer end. These are then attached by screws to a square section ¾" by 5" square as shown at B in Fig. 2. A block 1"x1"x5" is mounted at C in Fig. 2, a ¼" hole being accurately drilled along its length as shown by the dotted lines. A small bakelite strip K carries the terminals of the loop. The square block D is mounted as shown; E a square of thick felt, the two serving as a small table supporting the floating-dial magnetic compass at F. This compass is graduated into 1 to 359 points. The loop frame is supported upon a round wooden rod G, 20" long x 1" diameter. A length of ¼" brass rod is driven into the rod G, the projection H fitting into the hole of the block C, forming a pivot for rotating the frame. A light base is made of two strips M in Fig. 1, with a block 5" by 10" at L. The rod G fits tightly into a hole in L. Twenty turns of No. 22 cotton covered wire are strung through Bakelite strips shown in Fig. 3. These strips are cut from 3/32" bakelite shaped as shown. Twenty holes are drilled 3/16" apart, a space of 1¼" being blank at the center to divide the winding for passing the rod G. The wood may then be covered with shellac and varnished.

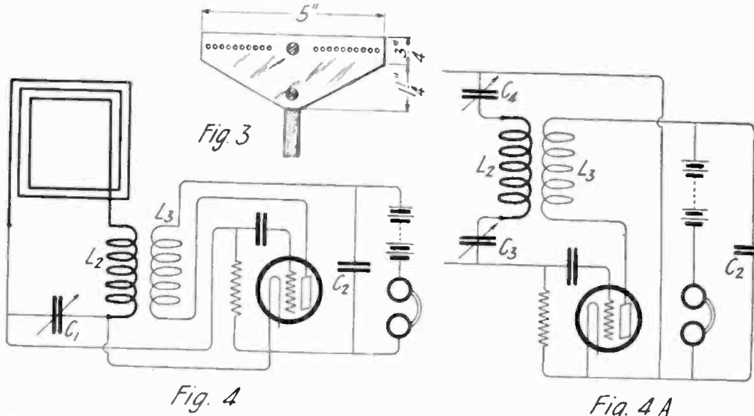


Fig. 3.—End Portion of the Loop Frame for Supporting the Wire. Fig. 4.—A Desirable Circuit for Use With the Described Loop. Fig. 4A.—Insertion of Condenser C-3 and C-4 Will Increase the Accuracy of the Loop.

The loop is 34" on a side; weight 3½ pounds; inductance 700 microhenries having a fundamental of 280 meters. A tap for 300 microhenries is soldered to 10 turns for work on 360 meters. C1 may be a small variable condenser of 200 micro-micro-farads maximum capacity; L2 is a small inductance of 30 microhenries (about 12 turns 3" diameter); L3 is a tickler coil of 800 microhenries (about 80 turns 3" diameter) for 360 meter work. L3 should be of about 1,000 microhenries for use on 600 meters (about 110 turns 3" diameter). C2 is a small fixed condenser of about 0.001 mfd.

If the loop is to be used as a radio compass, the hook-up in Fig. 4A is useful. C3 and C4 are each small variable condensers of 0.0005 mfd. with the other values the same as before.

Employing this loop with a single tube, ship and land stations 1,000 miles distant are located and read clearly. Broadcasting stations may also be located with the loop.

Wiring The Radio Set

By Sheldon Trent

The reason so many constructors make bad jobs of their sets in regard to wiring them is often because they can't solder connections. Soldering is easy once the fundamental secret is learned. The two surfaces to be soldered must be scrupulously clean. They should be bright and lustrous, so that the solder may join them together into a solid unit. However, the least amount of solder compatible with efficiency should be used. A good soldering flux is a necessity. Zinc chloride solution, formed by dropping a few pieces of commercial zinc into a dilute solution of muriatic acid, can be used, or any other of the numerous pastes and solutions on the market. If a paste is used, be careful not to use too much, since it neither aids soldering nor makes a neat appearance. In fact, if the melted flux flows to another connection, a high resistance will be shunted across the two, thus materially affecting the efficiency of the set. A little practice will show just how much flux is best. The paste should be applied so that just a thin coating covers the work, the thinner the better. The "killed acid," zinc chloride, should barely wet the connection. As to the soldering iron, which, by the way, is made of copper, be sure it is hot enough to make the solder flow freely. If it has been heated in a bunsen burner flame, do not heat the iron so much that the flame is colored green by the copper, since this pits the iron and gradually deprives it of its power to retain heat. Moreover, the iron should be "tinned," that is, it should have a thin coating of solder, one-half inch at the tip. To apply this, file the end of the iron on all sides, exposing the bright metal beneath. Then heat the iron to its usual heat, and apply a small amount of flux to the iron itself; wire solder should then be applied so that it coats the instrument all along the tip. This coating makes soldering simpler. Excessive heat will burn it off, so that once it has been applied, care should be taken to regulate the heat.

After both surfaces have been cleaned, flux sparingly applied, and the iron heated, the work may begin. Holding the iron in one hand, melt about an eighth of an inch of wire solder on the tip of the iron and apply the iron to the two parts to be joined. The solder should flow freely to the two surfaces and connect the two parts. If it does not, either the iron is too cold, not enough melted solder is available to flow downward, or the iron is not being held right. If the solder flows, but does not join the parts or adhere to them, the surfaces may be dirty, or not enough flux applied to them.

In inaccessible places, or delicate work, it is sometimes impossible to solder a joint directly. If this is the case, apply solder to each part in turn, and then, pressing them together with pliers, hold the iron against the metal so that the solder applied will again be melted, and the joint sweated together.

This method will be found especially useful at first, when learning the art, and it produces better results than the usual method, although it takes more time.

When first planning the wiring of a set it is sometimes best to make a drawing of it, showing the wiring. With this can be seen the wires which cross each other, and plans may be laid for connections, which have the least possible number of crossings. In wiring two-step amplifiers and such apparatus where induced currents are a factor of inefficiency, especially tube apparatus, care should be taken not to have wires running parallel to each other for any appreciable distance. Well planned wiring pays in the long run.

In wiring transmitters, try always to keep power and radio-frequency circuits separate, as far as possible. In amplifying circuits, keep the wiring of the primary of the amplifying transformer separate and at right angles to the wiring of the secondary. Keep grid circuit wires short.

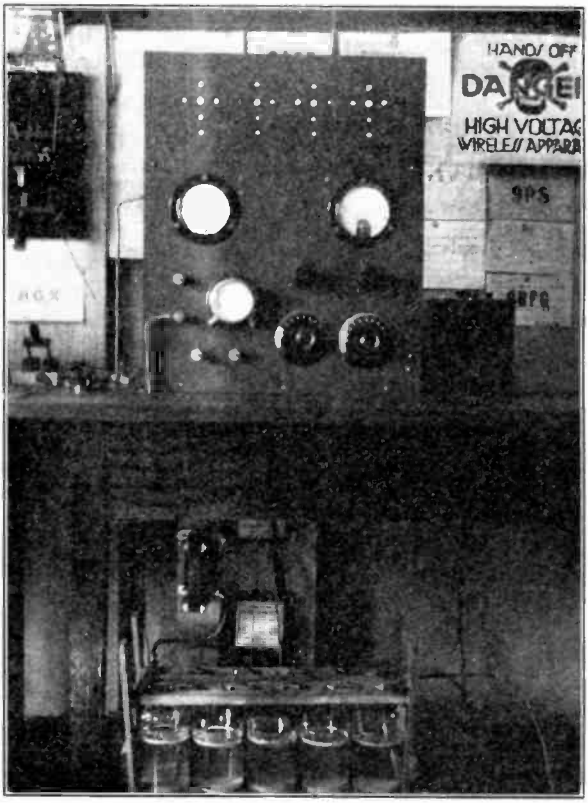
In the small sets where good wiring shows up best, try to make all bends at right angles, and have all lengths of wire on either a horizontal or vertical plane. This gives an orderly appearance to the apparatus.

The Construction of a 10-Watt Transmitter

By Everett W. Thatcher

Today transcontinental relay work among amateurs is becoming frequent and immense volumes of traffic are being handled by them. One great advance in the art of radio transmission has made this possible—the increasingly great number of amateurs who have installed continuous wave transmitters.

The enormous advantages of C. W. are well known by most amateurs. We know the great decrease in interference resulting from its use; we know that no trouble is experienced from noise, blinking of lights, or burning of fuses. We know too, that watt for watt, C. W. will work rings around a spark transmitter of much greater input.



This Efficient 10-Watt Set is Supplied With A.C., Which is Rectified for the Plate Circuit Through the Electrolytic Rectifier Under the Table.

Since the advent of radiophones in amateur circles, C. W. has proven once for all, its superiority over spark as a means of communication. Yet there are still many who cling to the latter method of transmission, either because of the difficulty experienced in securing results from tube transmitters, or because of the expense necessarily connected with the change.

The purpose of this explanation is to give accurate constructional and operating data for a low power C. W. set, which, with a little care in construction and adjustment will produce remarkable results.

The 10-watt set in use at the author's station, 6AWP, has been reported many times over 2,000 miles, and consistant work has been carried on with stations 1,000 to

1,500 miles distant such as 9WU, 9ZAC, 7ZU and 7LU.

Fig. 1 shows the writer's arrangement of the instruments on the panel, and also the rectifier and filter system mounted below the table. Fig. 2 shows the back view of the C. W. Transmitter. The circuit employed in this set is shown in Fig. 3. It is what is known as the Colpitts circuit, and it contains the series condenser in the ground lead which produces the capacity feed-back. The grid and filament terminals are connected across this condenser.

Starting with the 110-volt 50 or 60-cycle A. C. power supply, now available in most homes, the current is "stepped-up" by a suitable transformer. The Acme 200-watt is fine for this purpose, but one may be constructed at considerably lower cost, with two secondary windings of 550 volts each, and a tertiary winding supplying about 10 volts for the filaments.

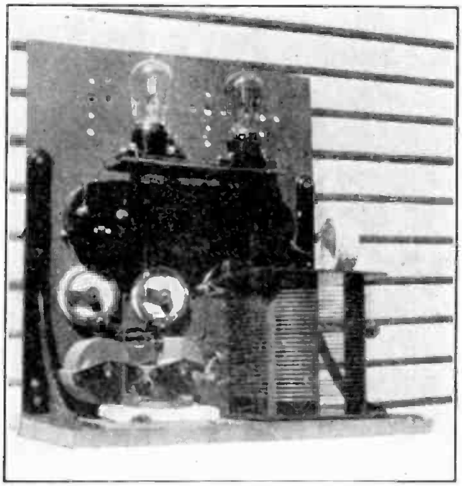
The chemical rectifier, a source of trouble to many experimenters has been used without the slightest difficulty. The following points should be carefully regarded for best results:

1. Only the purest lead and aluminum obtainable should be used.

2. The electrolyte should be made of *distilled* water and 20 Mule Team borax (not soap chips). To insure a saturated solution, warm the water and dissolve as much borax cool. The excess borax settles at the bottom of the vessel, and the clear saturated solution may be poured off.

4. Use one jar for each 50-60 volts.

Using five cells on each side, as shown in the circuit diagram, no trouble is experienced from heating, when 3x½-inch surface is immersed in the solution. Ordinary jelly glasses are used as containers.



Back View of the Transmitter.

The electrodes are bolted together, "U" shaped, and slipped through holes bored in a wood crosspiece, which suspends them in the liquid. In this way, they do not touch the crystals which form in the bottom of the glass, and also they can be raised or lowered at will, until the best operating surface is determined.

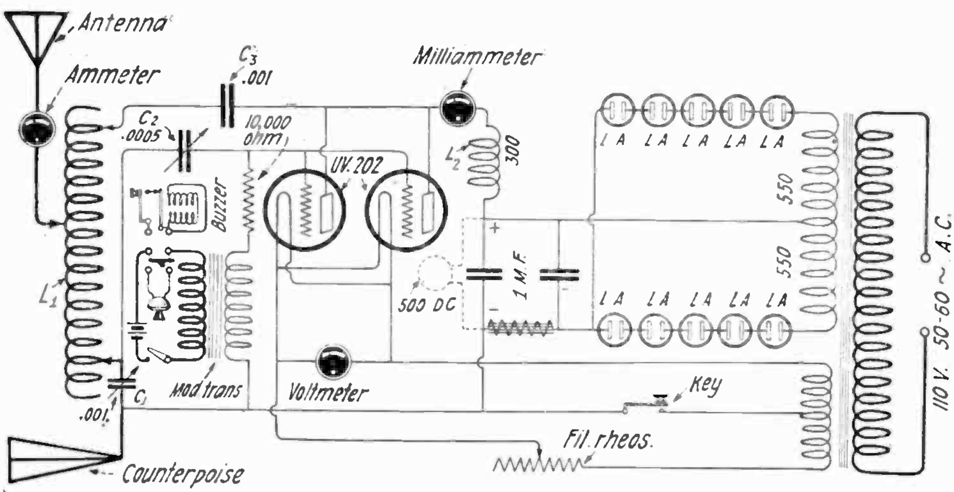


Fig. 4

Complete Diagram of 6 AWPS CW Set. Its Owner Has Had Excellent Results with This Circuit.

3. Mix up sufficient electrolyte for all jars at once and add distilled water as it evaporates.

The filter system consists of an Acme 1½-henry choke in the negative lead, on each side of which, is shunted across to the positive lead, a 1-MF. filter condenser. These should be tested and able to stand at least 750 volts.

The inductance L-2 is a high frequency choke coil. A 300-turn duo-lateral is the best size for this purpose.

The antenna inductance L-1 consists of 25 turns of edgewise wound copper strip, 7 inches in diameter; 25 turns of No. 12 bare copper wire, wound on a grooved bakelite tube, and separated 3/16" will serve equally as well.

C1 is a 43-plate variable condenser such as is used in receiving sets, and C2 should be a 23-plate condenser of the same type. If more than 500 volts are used on the anodes, difficulty may be experienced in sparking between the plates, in which case condensers with greater spacing should be used.

The grid-leak is a variable graphite potentiometer. In place of the small graphite tip, the author soldered a piece of copper braid, ¼-inch long to the contact lever, thus securing positive connection with the graphite at all times.

The secondary of the modulation transformer is connected in series with the grid leak, and the telephone transmitter connected in the usual way to the primary. A D.P.D.T. switch throws from this to buzzer modulator when desired. The key for telegraph work is placed in the lead from the center tap on the filament winding to the ground. This does away with the danger of shock or burn while operating, and also does not burn away the contacts, as is the case in the high voltage circuit.

For connecting up the set No. 14 bare copper wire is used. The wires carrying the filament current are insulated. No. 16 and the flexible connections to the inductance clips are heavy rubber-covered lamp cord.

The instruments are mounted on a bakelite panel, 15x18-inch and ¼ inch thick. The tubes are mounted in a vertical position and in such a way that at any time one or more may be added. With two UV-202 or C302 G. E. tubes, the radiation obtained at 6AWP is 1.7 amperes on 200 meters using a counterpoise ground.

In the adjustment of the set, it is advisable to have the plate tap on the inductance five or six turns above the antenna tap. The key is closed and the ground series condenser adjusted until maximum radiation is obtained. The capacity of C2 is now decreased to a point just above the "break" of oscillation. The radiation continues to rise up to this point, but on passing it, drops to 0. A final adjustment of the grid leak may increase the radiation to a slight extent. The adjustments of the grid condenser and grid leak are rather critical, especially when phone is used.

The filaments are connected in parallel and a constant voltage of 7.5 maintained.

The C. W. transmitter described above has proved exceedingly easy to adjust and operate. The results obtained far surpassed even the best hopes of the owner. The whole trick seems to be in the careful adjustments of the instruments to maximum output. Simplicity was carried out to the fullest extent to make this adjustment easier.

The greatest joy in the work of an amateur comes in conquering distance—talking hundreds or even thousands of miles on a set of low power. C. W. surely "delivers the goods."

A 5-Watt Telephone and Modulated C. W. Set

By **Jesse Marsten**

With the advent of broadcasting, radio has come to the fore as one of the indoor sports and recreations of the public. This new radio public, which listens in every night to the broadcasted concerts and talks, expects to find the air relatively free from interference. This radic public outnumbers the radio amateurs many, many times. The amateurs—many of them operating spark coils or other spark transmitters, which of course furnish most of the interference—are, therefore, finding themselves constantly under fire from the new and inexperienced radio public.

For the amateur to answer that the interference is not due to him and that the fault lies in the type of receiver used by the lay public, is not to solve the problem. In the first place all amateurs do not transmit exactly on 200 meters, and they are prone to err more on the higher side of 200 meters than on the lower. In the second place the decrements of a good many of the amateur spark sets is not what the best practice demands. Fnally when it comes to blaming the type of receiver used by the layman as being responsible for most of the interference, the amateur reaches a point where it is much easier to criticize than to offer practical remedying suggestions.

Some of the very amateurs who protest that they must have the use of the air, and that all the trouble lies in the single circuit receivers in use, fail to see that the cause of the trouble is very frequently under their very noses. To illustrate: In my neighborhood lives an amateur who possesses one of the multiplex receivers which are recommended for the novices. When it comes to reception he has all the frills that the most fastidious amateur will recommend. However, he prides himself on the fact that he is a real amateur, and, therefore, also has a transmitter if you please. He has—I should say, had—a spark coil transmitter which boasted a decrement curve as flat as the Sahara Desert. He broke in on any kind of a receiver and spoiled many a night's good entertainment for the neighborhood. To eliminate such an interference, I was willing to devote some of my time to designing a small five-watt buzzer modulated C. W. transmitter for him. He receives no further complaints now about interference.

The amateur should have no trouble obtaining information as to the circuits and construction of C. W. transmitters. In the different radio periodicals there appear from time to time designs of suitable sets. In the remainder of this article there will be described a five-watt C. W. transmitter from which the amateur may obtain many constructive suggestions. This set was built for use, in the Navy, on small flying boats. It delivers five-watts to the antenna and operates on three wave-lengths; 335, 375 and 425 meters. In this set transmission is accomplished by buzzer modulated C. W., and by telephone, but no provision is made for straight C. W. This latter can be effected by very small changes, as will be shown later on.

The circuits used in this set are shown schematically in Figs. 1 and 2, while Fig. 3 shows the entire circuit, which includes oscillator and modulator. Fig. 1 shows the oscillating circuit of the set. This is the "Meissner" circuit, in which the antenna plate and grid circuits are distinct and independent, inductively coupled to one another. The antenna circuit, which is the load circuit, is fed by the output of the plate oil, while the feed-back coupling is obtained between the antenna and grid coils. The small variable inductance L is used to compensate for variations in antenna capacity, which occur while the plane is in flight. By means of the switch S condenser C may be connected in parallel with the antenna inductance. This condenser has a capacity equal to the estimated capacity of the plane antenna, and is used as a test artificial antenna. Before throwing the set on the antenna it can be connected to the artificial antenna by means of switch S and tested. The set may thus be adjusted and made to

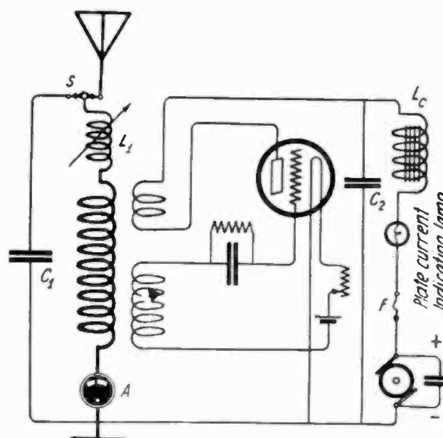


Fig. 1

The Oscillating Circuit of the Transmitter. This is the Meissner Circuit in Which the Components Are Independent of Each other.

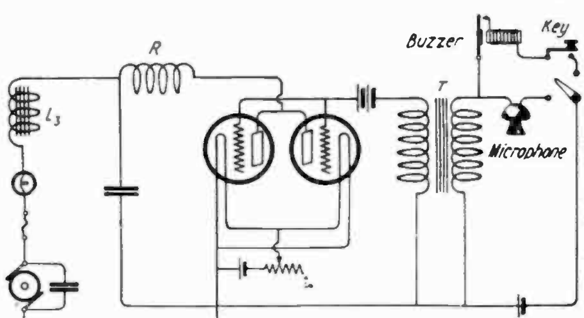
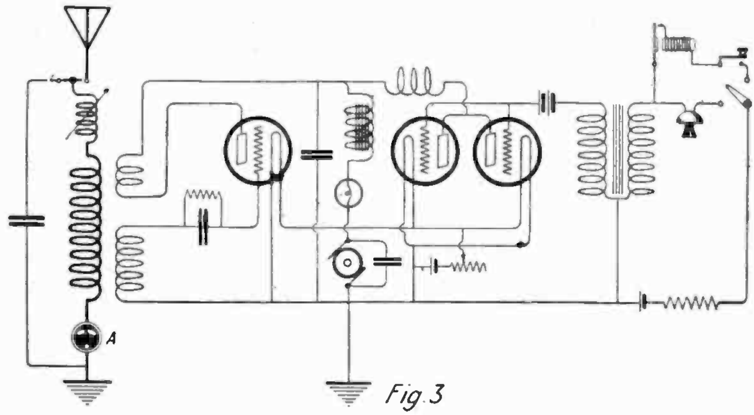


Fig. 2

The Heising System of Modulation is Employed as Shown, With the Two Tubes Connected in Parallel.

work on the artificial antenna and then thrown on the plane antenna when it should work about equally well. A grid condenser and leak are used in series with the grid coil These tubes are exactly the same as the tube used as the oscillator and are the General Electric Type T. tubes having an output of five watts. The Heising system of modula-



The Complete Circuit of the Transmitter Here Described. The Switch in the Upper Right Hand of the Circuit Allows for a Quick Change From Phone to Modulated C. W.

to give the grid of the oscillating tube the proper biasing potential. In series with the plate circuit lead from the positive side of the generator is a lamp used as plate current indicator and an overload fuse F. The condenser C' shunting the generator leads affords protection to the generator for any tion is here employed. The speech voltage is stepped up across the secondary terminals of the telephone transformer T and applied to the grids of the modulator tubes and amplified by these tubes. This amplified speech voltage is developed across the audio frequency choke coil Lc (Figs. 1 and 2) and

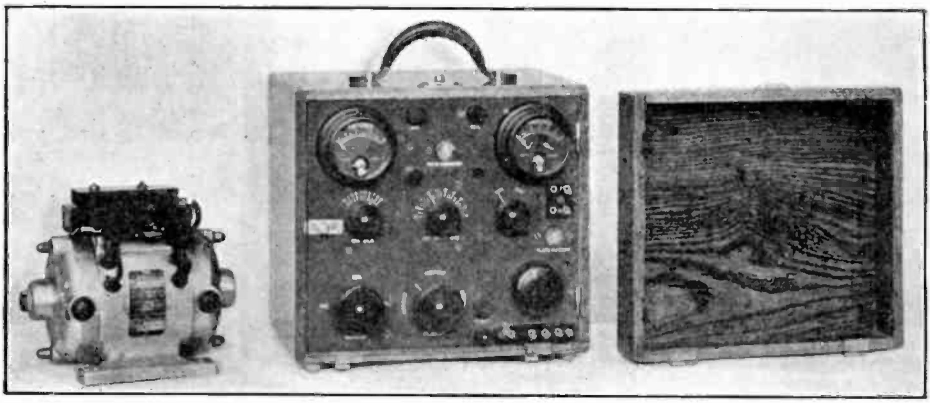


Fig. 4.
Front View of the Complete Portable Transmitter. The Two Meters at the Top Keep Check On the Filament Current and Radiation. On the Left is Shown the Small Generator Which Supplies the Necessary Plate Voltage.

high frequency kick-backs, and at the same time assists in smoothing out any commutator hum which is present. The condenser C_3 is likewise a by-pass for any radio frequency taking the path through the choke coil Lc.

In Fig. 2 is shown a schematic drawing of the modulation circuit employed. Two tubes are used in parallel as modulators. impressed on the plate of the oscillator valve, thereby effecting modulation of the radio frequency generated by the oscillator tube. In order to prevent any radio frequency, from backing up into the modulator tube, a radio frequency choke coil R (Fig. 2) is used between the plates of the oscillator tube and the modulator tubes. In order to secure maximum amplification of the

**Photos by courtesy of General Electric Co.*

speech voltage with minimum distortion, the modulator tubes must be worked on the straight line portion of the grid voltage-plate current curve. This is accomplished by using a negative biasing potential on the modulator grids, which potential is supplied by the use of two small dry cells. By means of the transfer switch S, either the buzzer or microphone may be used for modulation. The key K is used for keying when the buzzer is used.

s the grid coupling control for varying the coupling between grid and antenna coils. Next to this in the center of the panel is the control for the antenna variable inductance for compensating for small changes in antenna capacity. Next to this is the two-point test switch which connects the set either to the panel antenna marked ANT or to the artificial test antenna marked TEST. Directly under the microphone and key jacks, which are to the

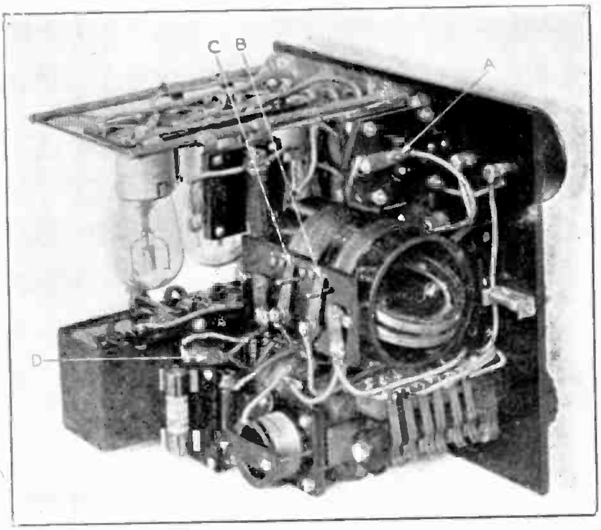


Fig. 5.—Rear View of the Transmitter. Note the Neat and Compact Arrangement of Apparatus.

right of this test switch, is another small lamp used as the plate current indicator. At the bottom left of the set is the send-receive transfer switch. It has three operating positions; (1) Telephone transmission; (2) Buzzer modulated transmission; (3) Reception. When the switch is turned to the transmission points, it automatically starts the dynamotor. Next to this switch is the filament current control. Only one rheostat is used for regulating the current in the three tubes. The two binding posts alongside the rheostat are for an external grid battery. Finally, there is the buzzer and under it the four-point jacks for the power lead connections plugs coming from the battery and generator.

To adapt this current for the transmission of straight C.W., the modulator filaments should be disconnected from the battery. Thus only the oscillator valve and its circuit is operating. A key connected in series with the grid leak in the oscillator circuit will do the trick, for when the key is pressed the grid leak circuit is closed and oscillations are present in the antenna circuit. When the key is not pressed, the grid leak circuit is open, the negative charge of the grid cannot leak off and no oscillations result. Thus, C.W. oscillations are radiated from the antenna in accordance with signals sent out with the key.

Fig. 3 shows the complete circuit diagram including oscillator and modulator. At the top of the panel in Fig. 4 are seen the antenna and receiver binding posts, marked ANT and REC respectively. The meter on the left is a 0-1 radiation ammeter and that to the center right is a 0-6 filament current ammeter. Between the two meters in the center of the panel is a small lamp acting as a wave indicator, used when tuning the antenna circuit. Directly under the radiation ammeter at the left side of the panel

The rear view of the set, Fig. 5, shows the different elements mounted and connected. Naturally all the parts cannot be seen and distinguished as some are hidden from view by other parts. The tube mounting is shown clearly in the photograph. The three-tube sockets are mounted on one base and are tied to two horizontal bars at the four corners of the socket panel by means of flexible springs which take up the vibration, thus preventing the tubes from jarring. Turning the sockets upside down has a great advantage. It facilitates connecting and soldering leads to the socket terminals, thus making connections accessible, which is important when shooting trouble. Directly under the tubes are the "C" batteries for the modulator grids. To the right on the bottom are seen the plate circuit fuse and R.F. choke coil. At the extreme right, on the bottom, are seen six split contact springs making contact with curved metal bars on a cylindrical drum.

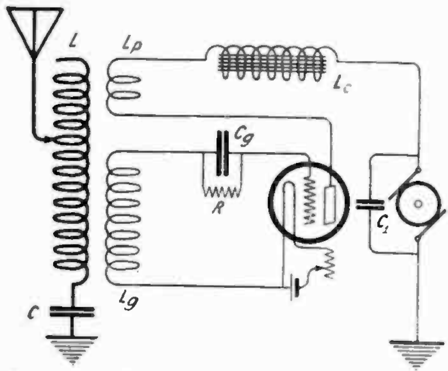


Fig. 6—For Those Constructing a Transmitter of This Type, the Oscillating Circuit Above is Suggested.

This constitutes the send-receive transfer switch. The oscillating coil system is seen directly above this. The antenna and plate coil are wound on the same outer tube inside of which can be seen the grid coil whose inductive relation to the others can be varied. All wires are covered with insulating tubing and it will be observed that all leads, without any exception, are well soldered to the connection posts. All parts are mounted on the back of the panel and securely fixed to same, so that the whole unit may be easily mounted and removed from the containing cabinet.

In order to assist amateurs and new radio experimenters in building such a five watt set as described above, the design data of a five watt set employing the above Meissner circuit will be here given. The oscillating circuit to be used will be exactly as shown in Fig. 6. The data will be suitable for the average amateur's antenna.

The antenna circuit consists of the main antenna inductance L and the series condenser C. This series condenser will be found to be essential in almost every case, for in order to get the proper transfer of energy from plate to antenna, it is necessary to use a fair amount of inductance which will almost always raise the wave-length above the 200-meter mark. The series condenser functions in shortening the wave-length; it should have a value of about 0.0005 mfds. and should be constructed so that its losses are low. A good mica condenser is best. The importance of a good dielectric in the condenser C is often overlooked, but since the condenser carries the entire antenna current, the losses may be considerable if the dielectric is poor. Good mica condensers for transmitting purposes of the required value are available from very reliable manufacturers.

The antenna inductance L may be either one of two types: It may be a copper ribbon coil, in which case the diameter of the coil should be about 6" and about 30 to 35 turns used; ¼" by 1/32" ribbon is sufficient for most purposes. The great advantage of the copper strip coil (wound edgewise is the most convenient) is that air insulation is utilized, and since no solid insulating material is used, leakage losses and dielectric losses are reduced to a minimum. Furthermore, as is well known, copper strip reduces skin effect considerably. The other type of coil is one wound on an insulating tube, using round wire. If an insulating tube is used, the *very best* insulating material should be used. This cannot be emphasized too much, as the losses in a poorly insulated tube may be so great as to vitiate all other good qualities of the set. Bakelite dielecto is about the best material that can be used, and it is recommended that the tube be drilled with holes where-ever feasible so as to insure as much air insulation as possible. The same number of turns as above may be used, namely about 30 to 35 turns. In this case the wire should be, if possible, Litzendraht, having good heavy cross section.

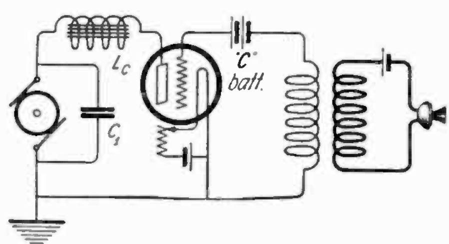


Fig. 7.—A Simple Form of Modulator Circuit That May Be Used.

The plate coil Lp should be wound on an insulating tube about 4" or 4½" in diameter and should have about 30 turns of No. 18 or No. 20 B & S wire. The grid inductance Lg should be wound also on a 4" or 4½" tube and have about 20 turns of wire, 20 B & S gauge. In both cases the coils should be preferably mounted within the antenna coil, each being coupled to the antenna inductance. Th particular arrangement for varying the inductive relations of plate and grid coils to the antenna coil can generally be left to the ingenuity of the constructor.

For most efficient operation it is necessary to use a grid condenser and leak which serve the purpose of giving the grid an average negative potential which is most suitable for maximum output and efficiency. The grid condenser Cg should be between 0.001 and 0.002 mfds. and the grid leak should be about 10,000 ohms. Frequently these values vary for different tubes and a little experimentation or trial will soon show what values of resistance are best. It will generally be found that 10,000 ohms is about the maximum, and intermediate values of 7,000 to 10,000 may yield better results. This is a matter determined by trial and the constructor should experiment with different values of capacity and resistance until the best combination is found.

The modulation circuit as used in this set is shown in Fig. 7 in conjunction with the oscillating circuit. The audio frequency choke coil Lc for best modulation should have a reactance equal to the resistance of the modulator valve, and in the five-watt tubes this resistance is between 4,000 and 5,000 ohms. To secure this reactance for the very lowest speech frequencies, it will be necessary to have a choke coil of about eight henries inductance. The best type of choke coil is an open core type; never use the closed core as there may be considerable distortion due to saturation produced by the direct current to the plate. An iron core having a cross section of about 2½ to 3 square inches and about 5" long should be built of laminated steel sheets, No. 29 standard U. S. gauge, and stacked up until the proper section is secured. This should be insulated either with paper or linen tape and wound with about 5,000 turns of No. 28 enamel wire.

The microphone transformer depends largely upon the type of microphone used. A good stable type of microphone is No. 284-W, which will be found to be quite reliable. The transformer should have a turns ratio of approximately 25 to 1 or 30 to 1. There are some very good transformers on the market which are just suitable for this type of work, and also have side tone windings which enable the operator to listen in on his speech and check his operation. The specifications of a 30 to 1 transformer which will give satisfactory results are as follows: The core consists of a bundle of iron wires stacked to give a diameter of about ½" or it may consist of silicon steel laminations ½"x½"x4", each lamination to be shellacked on one side. The primary consists of 180 turns of No. 20 D.C.C. and the secondary of 5,400 turns of No. 36 enamel wire. The core, it will be observed, is an open core, which is again preferable to the closed core for reasons of possible distortion due to saturation.

It is suggested that the grid of the modulator be biased with a negative potential by means of a "C" battery. The best potential can only be obtained by trial, although an average potential is such as to give a modulator plate current equal to that of the oscillator when operating; this can be best ascertained by trial.

In order to permit any by-passing any radio frequency which may get to the generator terminals, a generator condenser C should be used in parallel with the plate source of potential. This generator should have a low reactance for radio frequencies and hence should have a high capacity. Values above 0.1 mfd. will be found suitable.

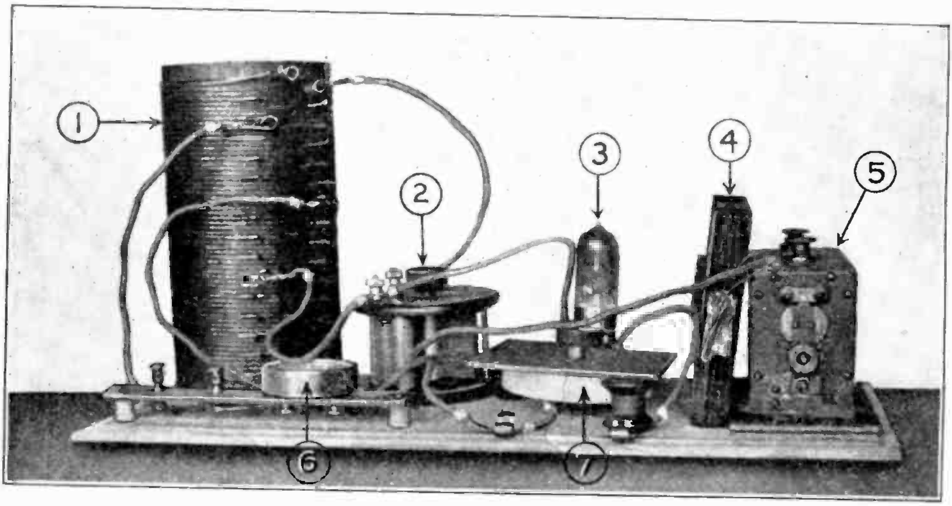
A Spark Coil C. W. Set

By **F. H. Burgess**

It has been definitely established that for low power, short wave communication, a vacuum tube transmitter is vastly superior to any other type. Yet many amateurs are prevented from using C.W. transmitters because of the difficulties encountered in obtaining the high voltage current for the plate circuit of transmitting tubes. In the present article the writer wishes to describe how he built a vacuum tube transmitter operated entirely on a 6-volt storage battery. This storage battery served both to light the filament of the tube and operate a ½" spark coil that supplied the high voltage plate current. The signals sent out by the set were, of course, of the I.C.W. variety, but they had a very agreeable musical note which could be varied by varying the adjustment of the spark coil vibrator and they could be picked up on a crystal receiver, which cannot be done with a pure C. W. transmitter.

A general idea of the appearance of the outfit can be gained from Fig. 1. As is clearly evident, no consideration has been given to appearances. It is an experimental set rather than an exhibition set. All the instruments are mounted on a flat board 22" long and 10" wide, and are connected by means of flexible lamp cord. The connections are readily accessible and can be changed at a moment's notice, thereby allowing a variety of different hook-ups to be tried out without undue trouble. Such a degree of flexibility is never possible with a cabinet type of transmitter.

final operation was to solder onto the coil 31 connecting lugs (one lug every two turns). These lugs consisted of 1¼" pieces of No. 14 bare copper wire bent at right angles at the middle, so as to be the shape of the letter L, and soldered to the wire on the inductance at the required spots.



A Photo of the Spark Coil C.W. Set. The Transmitter Consists of An Inductane (1), a Variable Condenser (2), a Low-Power Vacuum Tube (3), a Large-Capacity Condenser (4), a ½" Spark Coil (5), An Ammeter (6) and a Rheostat (7). The Grid Condenser and Leak Cannot Be Seen.

The spark coil is mounted at the right-hand edge of the board. Beside it stands a large glass plate condenser. Next comes a filament rheostat with the transmitting tube mounted behind it. To the immediate left of these is a .001 microfarad variable condenser. Behind this condenser, and hidden from view by it, is mounted a .005-microfarad fixed grid condenser and a 10,000-ohm grid leak. The left-hand end of the board is occupied by the tuning inductance. In front of this there is a strip of bakelite 1½" wide, 6" long, and ⅛" thick, supported above the base by means of two small wooden blocks. On this insulating strip is mounted a .5-ampere hot wire ammeter, and two binding posts, one for the aerial connection and the other for the ground.

The tuning inductance consists of 60 turns of No. 14 bare copper wire wound on an insulating tube 9" long and 4½" in diameter, with connecting lugs every second turn. After a bakelite tube of the required size had been bought, it was taken to a machine shop where a 60-turn spiral groove was chased around it. Then 80' of No. 14 bare copper wire were procured and wound tightly in the groove around the tube. The

The tube shown in Fig. 1 is a low-power English transmitting valve requiring a filament potential of six volts and a plate potential of 1,000 volts. The filament current is supplied by a 6-volt storage battery and controlled by a 10-ohm rheostat. The same 6-volt battery also operates the ½" spark coil that supplies the high voltage plate current. The secondary potential of the spark coils is of the order of several thousand volts, so a fairly large condenser must be connected across the secondary terminals in order that the voltage may be reduced to a value that will not cause possible damage to the tube. In the present case the condenser consisted of 11 sheets of tinfoil separated by glass photographic plates 7" long and 5" wide.

If an American 5-watt tube is used, some alterations will have to be made in the set. A 1" spark coil can be used with safety instead of the ½" coil, but a much larger condenser will be needed because of the fact that the normal plate potential is only 350 volts.

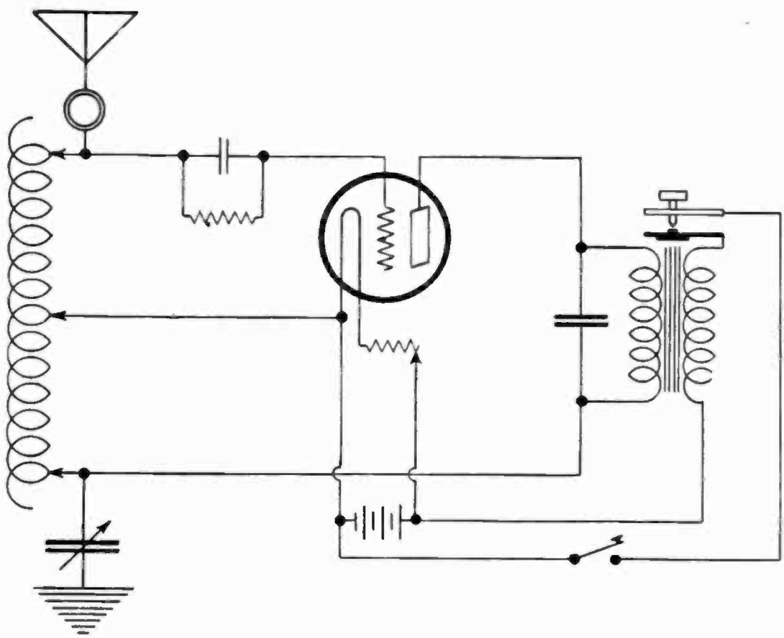
An 8-volt storage battery will be needed since the filament potential required by these tubes is about 7½ volts. A heavier rheostat will also be needed to pass the 2.35-ampere filament current.

A hook-up that seemed to give very fair results with this set is shown in Fig. 2. A .001-mfd. variable condenser was used, but a .0005-mfd. condenser will give just as good results. It may be found that a 60-turn tuning inductance is unnecessarily large since under all ordinary circumstances more than 30 or 40 turns are rarely ever required.

Not every type of spark coil will work successfully with a set of this kind. A three-terminal coil (in which one end of the primary and one end of the secondary are connected to the same binding post) will not give results when the same battery is used both for lighting the filament and operating the coil. Either a four-terminal spark coil must be used or separate batteries must be used for the filament and the coil.

The way in which the secondary of the spark coil is connected to the plate circuit of the transmitting tube also has a considerable effect upon the success or failure of the set. The secondary output of a spark coil is not pure alternating current. It is stronger in one direction than another. Hence, to all intents and purposes it is interrupted direct current, and the secondary may be said to have a positive and a negative terminal. Of course, it is essential to have this so-called positive terminal connected to the plate of the transmitting tube. The only way to find the correct connection is by experiment. Connect the set up in one way and try it out, then reverse the leads from the secondary and try again. The connection that gives the greater aerial current is the correct one.

With a three-wire aerial 80′ long and 42′ high, and a four-wire counterpoise, the set shown in the illustration gives an aerial current of about .5 ampere. The normal working range is from 75 to 150 miles. By using an American 5-watt transmitting tube and a 1″ spark coil, the aerial current can be raised to nearly an ampere. This increases the range to several hundred miles or more.



The Circuit of the Spark Coil Set. As Seen, the Same Storage Battery Supplies Both the Tube Filament and the Spark Coil. When Properly Adjusted This Circuit Is Excellent.

The advantage of a set of this type is that it combines the simplicity of a spark coil transmitter with the sharpness of wavelength and distance covering ability possessed only by a vacuum tube set. To the amateur who hasn't a great deal of money to invest in valve equipment, a spark coil type of I.C.W. set certainly offers a splendid means of overcoming the high voltage plate supply problem at very little cost.

A Vacuum Tube Transmitter Operating on a 6 Volt Storage Battery

By H. M. Pruden

The main draw-back to installing a low-power transmitter of the vacuum-tube type in most amateur radio stations is the necessity of supplying a source of high-voltage direct current for the Plate. For this purpose motor-generator sets have proved very satisfactory, but at the same time quite expensive. The type of tube transmitter that will prove most popular will probably be the one that is the least expensive to install and maintain. Following is a description of a set used by the writer that has certain advantages over the ordinary vacuum-tube type of transmitter, being less expensive to install and operate and at the same time producing more complete and perfect modulation than many of the systems used at present.

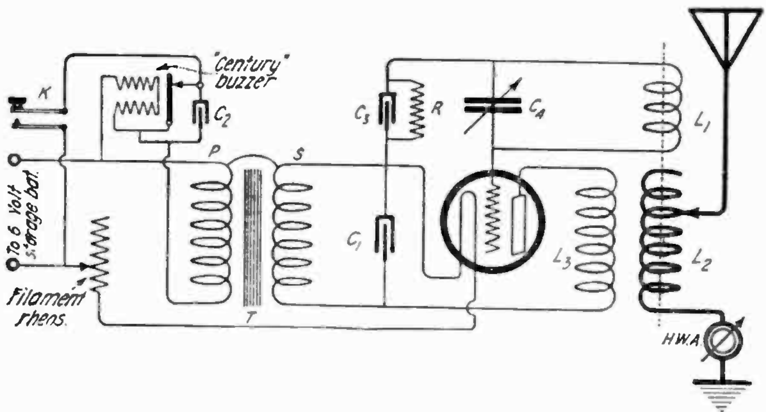


Fig. 1.—Complete Circuit Arrangement of the Vacuum Tube Transmitter Built and Operated by Mr. Pruden.

If alternating current instead of direct current is supplied to the plate of a vacuum tube connected in an oscillating circuit, it is evident that the plate will be positively charged during one-half of each cycle and the tube will oscillate, while during the other half of the cycle the plate will be negatively charged, and the tube will not oscillate. Thus the vacuum-tube oscillator produces a complete wave train for each cycle of the alternating current supply circuit, which is preferably about 500 cycles.

The duration of the positive charge on the plate is one-half the period of the 500 cycle alternating current, or .001 second. Therefore, if the wave-length the set is tuned to is 200 meters, the period of the radio frequency oscillations is 66×10^{-9} seconds, and sufficient time elapses while the plate is positively charged for the oscillator to make 1500 complete oscillations. In actual practice the oscillations begin when the charge on the plate reaches about 30 volts, so if the effective voltage of the alternating current source if 400 or 500 volts, the tube will produce very nearly the entire 1500 possible oscillations. Wave trains produced by this "impulse oscillator" have a very low decrement, and therefore carrying qualities similar to ordinary continuous and modulated waves.

The complete circuit arrangement used by the writer is shown in the Fig. 1. The "Century" type buzzer is used as an interrupter for the primary circuit of the transformer. If a satisfactory 500-cycle interrupter can be built it may be attached directly to the transformer, as is ordinarily done with spark coils. The buzzer proves quite satisfactory for this purpose, however. It will be noted that the primary of the transformer is shunted around the buzzer windings instead of being connected in series with them. This arrangement passes more current thru the primary of the transformer. The tansformer consists of the pimary of a half-inch or one-inch spark coil with a secondary winding of between 5,000 and 10,000 turns of No. 30 or No. 32 S. S. C. magnet wire. The exact number of turns depends upon the size of the core, the primary winding, and the type of tube used in the circuit. The resistance of this winding should be kept as low as possible to reduce losses. The current in this circuit is between 30 and 40 milli-amperes.

Condenser C-1 is a mica condenser of .001 mfd. and its purpose is to complete the radio-frequency circuit from the plate of the tube thru the coil L-2 to the filament of the tube. C-2 is a 1-mfd. paper condenser, and its function in the circuit is to prevent sparking at the contacts of the buzzer interrupter. C-3 is a .005 mfd. grid condenser and is shunted by a grid leak R of 10,000 ohms. C-4 is a .001 mfd. variable and should be immersed in oil to increase its capacity to .005 mfd.

The inductance L-1 consists of 15 turns of No. 24 D. C. C. wire on a tube 4½ inches in diameter. L-2 is 15 turns of No. 18 D. C. C. wire on the same tube, with a space of ⅜ inch between it and the winding L-1. Winding L-3 consists of 28 turns of No. 24 D. C. C. wire wound on a cardboard ring 4⅞ inches in diameter placed *directly over* the winding L-2 on the other tube. L-2 is tapped in two or three places to control the wave length of the transmitter. The coils are all wound in the *same direction* and connected as shown in the diagram, otherwise the circuit may not oscillate.

When this circuit is put into operation, light the tube, depress the key, and adjust the inductance L-2 until the wave length as shown on a wave meter or reciving set is 200 meters, or lower if desired, and then adjust the capacity of C-4 until the maximum reading on the radiation meter is obtained. The final adjustment is on the interupter, which should always be adjusted with the tube lighted and connected to an antenna. Incidentally, it will be noted that the adjustment of the capacity C-4 is not at all critical.

The first model of this type of transmitter was placed in operation at station 2JP in late summer and even under unfavorable static conditions amateurs within a radius of 40 miles reported loud signals. Any one who wishes to build a set of this type can rest assured that his trouble will be amply repaid when the set is complete.

A C. W. Measurement Set

By L. R. Felder

Any radio set which the amateur experimenter builds, for example, a transmitter, receiver, wavemeter, etc., contains all the various radio elements such as inductance coils, condensers, resistances, etc. These elements are either built or bought outright by the experimenter. If they are bought he accepts the manufacturer's statement as to the constants of these elements; if built, he generally approximates their values by a calculation.

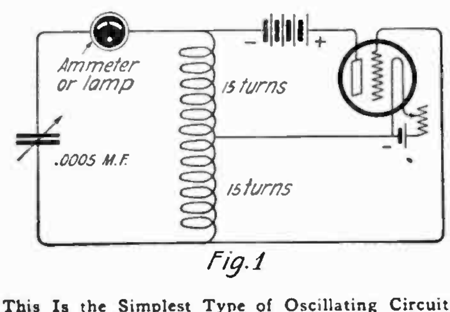


Fig.1

This Is the Simplest Type of Oscillating Circuit. It Was Conceived by Hartley.

For really good work, the experimenter should know accurately the constants of his sets. If he has a tube transmitter he should know, for example, the R. F. resistance of his antenna coil, so that he will have no doubt as to the true efficiency of his set. In his receiver he should also know the resistance of his tuning coils, their inductances, the capacity of his condensers, have calibration curves of his condensers, and know the self and mutual inductances of his coupler, etc. The accurate knowledge of these constants is what distinguishes the advanced experimenter from his more slipshod brother. They furnish the data for future improved designs of sets.

These values can only be obtained by measurement. Measurement in itself is almost a separate field in radio to which the amateur should devote a little more of his time. Measurement usually requires a separate source of oscillations, which should preferably be undamped and steady. Until some time ago a buzzer excited radio frequency circuit was used as the generator of oscillations. While this gave fair results, it never was a very satisfactory source of oscillation due to erratic and freakish operation of the buzzer, changing of the note, sparking at the contact points, etc. Furthermore inasmuch as the buzzer could only supply a very small amount of energy, very sensitive detecting devices had to be employed, such as thermocouples. Such apparatus is of course very expensive and, therefore, unavailable to most amateurs, whereas he is more likely to have R. F. ammeters and milliammeters.

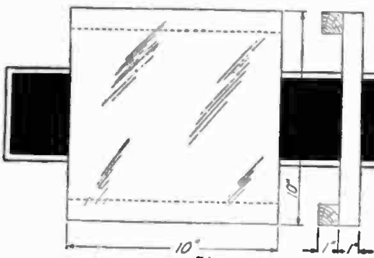


Fig. 2

The Size and Details of Construction of the Mounting Board are Here Shown.

The vacuum tube supplies a means of obtaining a very low-power oscillator which is stable, supplies quite pure oscillations and is capable of furnishing sufficient energy to actuate the detecting devices usually available to most amateurs. It will be the object here to describe the design and construction of a low-power oscillator suitable for measuring purposes, and in future articles to describe the application of this oscillator to amateur measurements.

The oscillating circuit used in this measurement set is of the very simplest type and is designed to utilize a minimum of apparatus since apparatus around a station is generally at a premium. The very simplest type of oscillating circuit requiring a minimum of apparatus and easily constucted, which is suitable for measurement work is the Hartley circuit in Fig. 1.

From this drawing it will be seen that the apparatus required is:

1 Variable condenser.
1 Inductance coil.
1 Tube socket.
1 Filament rheostat.
1 Tube.
1 Flashlamp indicator or ammeter.
1 Plate battery.
1 Storage battery.

The plate and storage batteries which are generally around the station, may be used for this measurement set. When measurements are not being made the only apparatus tied up in the measuring outfit are the other five elements, since the tube need not be tied up unless the outfit is in use.

The oscillating tube may be an ordinary amplifier tube such as U. V.-201, but a low power oscillator tube would be preferable, as more power could be obtained and the amount of current flowing in the circuit under test could be controlled over a wide range of values. On the U. V.-201 tube between 80 and 100 volts may be used on the plate and on the five-watt oscillator up to 300 volts may be used. Filaments should be operated at their rated values, or even slightly under. Since this is a measurement oscillator set, no particular advantage is to be gained by pushing the tubes too hard, and, therefore, it should be conserved as much as possible. The storage battery and filament rheostat in the case of the amplifier U. V.-201 tube should have a rating of six volts and one ampere current carrying capacity respectively, and in the five-watt tube these ratings should be 10 volts and 2.5 amperes current carrying capacity.

The oscillating circuit condenser is a variable condenser, maximum capacity 0.0005 mfd. This condenser in the extreme case will have to withstand a voltage of about 1,000 volts R. F. When using the U. V.-201 amplifier tube this voltage is much lower and the ordinary air spaced condenser will be satisfactory. In the case of the five-watt tube, if air insulation is used, the spacing between the condenser plates should be much greater than ordinarily. Good results have been obtained, however, by the use of oil in the condenser with normal spacing of plates, and its use

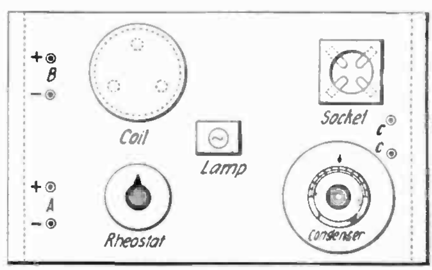


Fig. 3

Convenient Positions for Apparatus on Mounting Board.

is recommended for the higher power oscillating tube. This assures greater safety against arcing over between plates and in the case of an abnormal rise in voltage and and arc-over, the break down in insulation is self-healing. Only a good grade of insulating oil should be used, as the poorer grades contain dirt and grit which may actually bring on breakdowns.

The oscillator coil is made up of 30 turns of 3x16x38 Litzendraht wire with a tap taken off at the center turn for connection to the filament ground. If this Litz wire is not available, No. 20 D.C.C. will do. The coil is wound on a 4" O.D. tube of good insulating material either formica or natural dilecto is best.

In series with the oscillating circuit is placed either a low reading radio frequency ammeter as an oscillation indicator, or if this is not available a small flashlight will do. The construction here described employs the flashlight as the fixed oscillation indicator, but provision is made for the insertion of an ammeter if necessary.

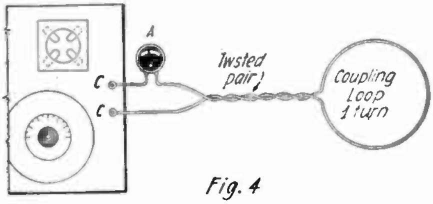


Fig. 4

A Coupling Loop May Be Used. The Method of Connecting Is Shown.

The actual construction of this extremely simple but useful oscillator will probably be determined by the builder's own prejudices and ideas. There are so few elements in this set that no difficult obstacles will present themselves. However, the writer wishes to suggest the following construction which he has used and found simple and convenient.

All the apparatus, excepting the batteries, is mounted on a flat board made of seasoned wood 1" thick and 10" square. (See Fig. 2.) Two strips of wood 1" square and 10" long are fastened to the ends of the baseboard underneath and act as the legs or supports of the base. The disposition of the various parts on the base is shown in Fig. 3. Two pairs of binding posts marked "A" and "B" are used for the external storage and plate batteries, respectively. At the rear of the baseboard are mounted the coil and the valve socket, on neither of which adjustments have to be made. It is for this reason that they are put at the rear where they are out of the way. At the front are mounted the filament rheostat and variable condenser, on both of which adjustments have to be made.

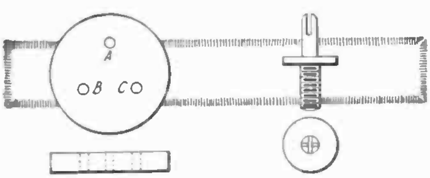


Fig. 5 Fig. 6

Left: Insulating Piece for End of Inductance Tube. Right: Split Lugs Used for the Coil Terminals.

They have, therefore, been placed in the front where the control handles are easily accessible, without interfering with any of the other parts of the set. The small flashlamp and its socket are placed in the center of the board. It will be observed the two large elements, condenser and coil, are placed diagonally on the board, as are also the two small elements, the tube socket and rheostat, thus putting one small and one large element next to one another. This particular disposition of the apparatus makes for economy of space and reduces considerably the size of the entire outfit. The two binding posts at the right serve two purposes. They may be used to connect up a hot wire ammeter in case this is desired, as an indicating device besides the flashlamp. They are also intended, and are so used by the writer, for connecting a one-turn loop for coupling purposes. In general it will be found that sufficient coupling can be secured between the main oscillation coil and the circuit under test. However, if occasion arises where closer coupling is desired without moving the set, a pair of twisted leads connected to a one-turn loop may be connected to the two right-hand binding posts for this purpose, as in Fig. 4. Of course both ammeter and coupling loop may be connected to the binding posts CC, since they are in series in the set.

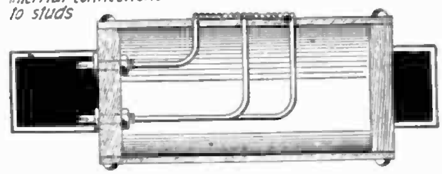


Fig. 7

Method of Connecting the Coil Taps to the Terminal Studs.

All the wiring is done underneath the baseboard and is covered with empire tubing. It may be seen that the set is simple, occupies very small space and in the form made may be easily stored away on a shelf where it will be out of the way when not in use.

With the constants as given above, the set will have a range of approximately 200 to 500 meters. By constructing a number of large coils, each coil larger than the one preceding, greater oscillating ranges may be secured. Thus by the construction of a number of these coils a range from 200 to 3,000 meters may be obtained. If measurements are desired in the 200 to 500 meter range, coil No. 1 (the smallest) is used. If measurements are desired between 600 and 1,000 meters, the next larger coil, or No. 2 is used.

The following construction of the oscillating coil is used by the writer and is recommended for its advantages, which will be apparent. The three taps of the coil (two ends and center) are brought out on the inside of the coil. The ends of the coil are closed up with fibre or dilecto discs and one of them is drilled with three holes, as in Fig. 5. In these holes are fitted a combination of contact stud and split plug, details of which are shown in Fig. 6. These studs are inserted in the end discs and fastened to same by means of screws. The three leads from the coil are soldered to the threaded studs and then the discs are

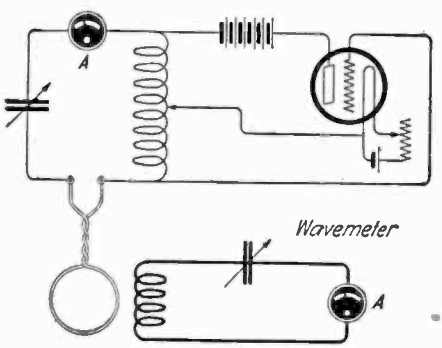


Fig. 8

By Use of a Wavemeter the Transmitting Oscillator Is Calibrated.

inserted in the ends of the coils and attached by hex nuts to the coil tube. Thus we have a closed coil tube with three split plugs making contact with the three-coil terminals. Three holes are drilled in the baseboard where the coil is mounted, the drilling being identical with that of the end disc on the coil, and the holes fitted with metal bushings in which the contact pugs on the coil disc fit tightly. The plugs,

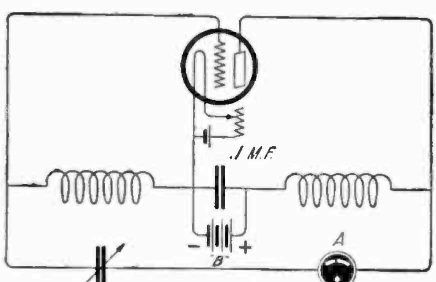


Fig. 9

This Circuit May Be Used Instead of That Shown in Fig. 1.

being split, a good tight fit ensuring positive contact between plug and metal bushing can be secured. Connections on the under side of the base are made from the metal bushing. It will be apparent, therefore, that a coil can easily be removed and replaced merely by pulling it out or by inserting, without making any connections, since connections are made automatically by means of the plug.

The drilling should be made in accordance with some such plan as that shown in Fig. 5. The center tap should be connected to the plug fitting in hole A, while the two end coil terminals are connected to plugs B and C. By making such an arrangement correspondingly on the baseboard, the coil can be inserted ONLY IN THE RIGHT WAY, and thus correct connections are assured. Since there is only one way to insert the coil, this method of building same is fool-proof. It will be apparent that changing coils with this method of construction to secure any desired range of wave-lengths is merely a matter of taking out or putting in the desired coil without making any connections.

In order that this set may be ready for use as a measurement test oscillator it needs to be calibrated. The calibration will have to be made with a well-calibrated wavemeter as follows. In series with the wavemeter coil connect up either a radio frequency ammeter or a flashlamp as indicating device and couple the wavemeter to the measurement set oscillator, Fig. 8. Start the oscillator working at the lowest value of capacity on the variable condenser on which it is possible for the set to oscillate. Tune with the wavemeter until either

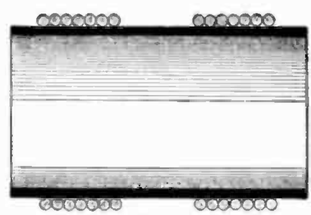


Fig. 10

This Coil Comprises Two Separate Windings. It is Employed in Conjunction With the Circuit of Fig. 9.

maximum deflection is had on the indicating ammeter, or until the flashlamp lights up most brilliantly. Read the wave-length at that setting of the wavemeter. The transmitting oscillator is then oscillating at that wave-length. Do this throughout the range of the variable condenser on the measurement set and make a table, one column reading variable condenser degrees, the other reading corresponding wave-lengths. A curve can then be plotted of wave-length against degrees, which is the calibration of the oscillator. This procedure can be followed with each of the coils. Knowing the calibration of your measurement oscillator you will now be ready to use it in the measurement of your various constants, and in other calibration work.

It might be mentioned here that another simple oscillating circuit suitable for this type of equipment, employing the same apparatus with the addition of a plate battery condenser, as shown in Fig. 9, will also give very excellent results. Some people seem to prefer this form of the circuit in preference to the one given above, but actual trial proves them to be about equal, and there is very little choice. Should this circuit be used, however, the condenser across the "B" battery should have a value of about 0.1 mfd. This acts as a bypassing condenser for radio frequency and should be of sufficient capacity to offer little impedance to the flow of R. F. currents. The coil should in this case be wound on the same tube, but in two parts, half the total number of turns in each part, and the two parts separated about ⅛", as in Fig. 10.

Construction of an Electrolytic Rectifier

By Kenneth M. Swezey

In most localities, except in the immediate vicinity of power stations, alternating current is supplied to the homes that are equipped for electricity. The reason for this is because of the greater ease and economy of transporting alternating current over direct current. Power can be transferred over the long stretches at a high potential and low current strength, and then reduced by means of transformers to the correct voltage for district and individual use. You can readily see that this procedure allows the use of a smaller gauge wire, thus lowering the expense of the distributing system.

Alternating current is far from being a disadvantage to the work of the experimenter. It can be used the same as direct current for lighting lamps, and can also be used for running motors. If you possess alternating current you can rig up a "spark" radio transmitter, capable of covering great distances, at a small outlay. You can also, by its use, investigate the fascinating realm of high frequency currents, and perform all the spectacular stunts that are usually left to the laboratory, or to the wizard of the stage.

However, alternating current (or more simply, A. C.), cannot be used in places where a steady uni-directional current is required, such as for charging storage batteries, or for electro-plating. But still we have a method of overcoming this difficulty by means of what we call a rectifier. This piece of apparatus so changes the current that it becomes in effect a pulsating direct current.

There are five types of rectifiers in common use: the commutator, the magnetic vibrator, the mercury arc, the vacuum tube, and the electrolytic. For small storage battery charging purposes the magnetic vibrator, the electrolytic and the vacuum tube type are the most convenient. Of them all, the electrolytic is the easiest and simplest to construct at home. For those who can afford to buy them, the other two types are to be recommended, as they are efficient, compact and little bother. However, for those who care to make a rectifier of the electrolytic type, the following principles of operation, and the details of construction of a de luxe model, are given.

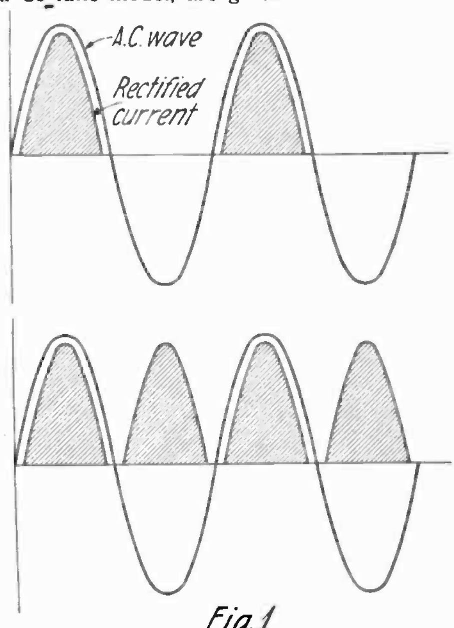


Fig. 1

The Top Sine Curve Shows the Direct Current in Relation to the Alternating Current Where Half-Wave Rectification is Employed. The Lower Curve Shows Full Wave Rectification.

Let us bring to our minds the experiment that illustrates the electrolytic decomposition of water. There are two electrodes used; one at which the current enters the solution, called the anode, and the other at which the current leaves, or the cathode. When a cell or a battery is connected to the proper terminals, the water is found to split into its component parts—hydrogen and oxygen. Hydrogen is given off from the cathode, and oxygen from the anode. As water is composed of two parts hydrogen to one part oxygen, its decomposition can be used as a positive indication of polarity. This is particularly useful to know when working with storage batteries. If the ends of the two leads that come from a storage or any other kind of a battery, are immersed in a receptacle of water that has been slightly salted or acidulated (this to lower the resistance), the lead from which the most gas, or the greatest number of bubbles, is given off, is the negative.

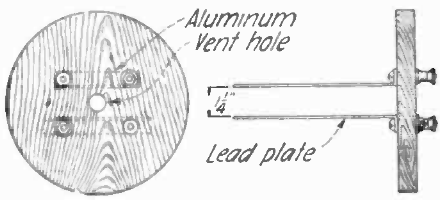


Fig. 2

The Lead and Aluminum Plates Are Attached Directly to the Wooden Jar Covers.

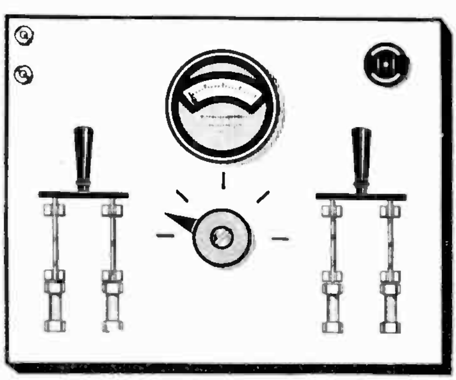


Fig. 3

General Layout of the Charging Cabinet.

Now aluminum has the outstanding property of readily combining with oxygen, forming oxide of aluminum. Almost instantly a piece is cut, it is coated with a thin coating of oxide. However, this is so very thin that it is practically transparent to the human eye. But its presence is unmistakably proved when soldering or welding is attempted, as it renders these operations next to impossible.

Advantage is taken of this property of aluminum, in the electrolytic, or Nodon. rectifier. One electrode or plate is made of this metal, and the other of some chemically inactive substance such as platinum, carbon, iron, or lead. Lead has some advantages over the others mentioned, and is therefore generally used. These electrodes are immersed in a solution of aluminum phosphate and water.

If a potential is applied to this electrolytic cell in such a way that the lead plate is made the anode, a current will flow readily from the lead to the aluminum, hindered only by the resistance of the electrolytic. But if a potential is applied with a reverse polarity, so that the aluminum is the anode, the oxygen will so affect this metal that a tough skin of oxide will be formed that completely covers the plate. This oxide is a nonconductor, and hence the current is shut off.

When placed in an A. C. circuit the effect of such a cell can readily be imagined. During one-half of an alternation the current would be allowed to flow, but during the other half the current would almost completely be shut off. The resultant current flowing through the circuit would be intermittent, and in single direction—in the direction of lead to aluminum. The direct current in relation to the alternating current is shown by Fig. 1. It is to be observed that only one-half of the alternating current cycle is made use of, and that the direct current is intermittent. By using a number of cells with the proper connections. both halves of the alternations can be made use of, and a current having an outline similar to that represented by the second curve in the same figure can be obtained.

Passing from theory, let us look at the practical side of the question. The amount of current that a rectifier will pass is limited, on account of the heating of the liquid. Five amperes is the maximum that can be passed continuously through one of the size to be described. Another disadvantage is the waste of power due to the high voltage of the supply and the necessary series resistance. Regardless of these faults, however, a rectifier of this type will be useful about the home and laboratory wherever an alternating current is available, and a direct current of low amperage is wanted. It would be ideal for charging storage batteries of 60 ampere-hour capacity, or less, and for experimental work.

Four jars are necessary. These may be of glass, metal, or glazed earthenware. It is evident that the greater the exposed surface, the greater will be the cooling facilities, so bear this in mind when making your selection. Procure jars that are as large as convenient. A good size is about five inches in diameter and six inches deep. If you use metal you should cover the interior surface with several coats of pitch or asphaltum varnish. A dull black paint or pigment applied to the exterior will increase its heat radiation surprisingly.

Procure your metal sheeting, and if you intend using jars of the size mentioned, cut four strips of lead about four inches wide and six inches long, and four strips of aluminum about three inches wide and also six inches long. This metal stock should be at least one-sixteenth of an inch thick.

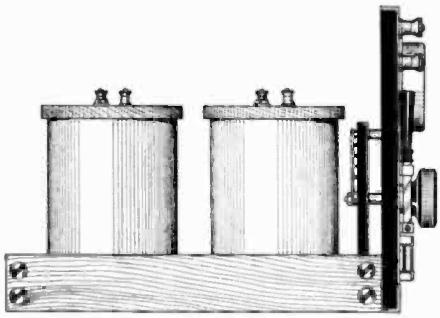


Fig. 4

Side View of the Complete Rectifying Outfit.

Thicker material has the good quality of giving longer service. If you intend to use jars of a size different from that mentioned, make the plates and other fittings in proportion. If your metal is very thin the cutting can be done with a pair of tinner's shears, but the thicker metal may have to be cut with a hack saw. It is imperative that you use the purest aluminum obtainable, for otherwise the rectifier will not function properly. If you have some old lead pipe around, that is between an inch and an inch and a half in diameter, you can use this in place of the lead sheeting. Simply cut off a six inch length, slit one side parallel to its axis, and flatten it out.

Next cut four discs of well seasoned wood, or some other insulating substance, about six inches in diameter. These discs can either be turned out on a lathe, or cut by the more laborious method of the scroll saw. Bend over one end of each of the lead and aluminum strips, about a half inch down, at an angle of 90 degrees. Fasten the strips to the discs by means of a screw and a binding post through each lug, as shown in Fig. 2. A lead and an aluminum plate goes on each disc. Space the plates about an inch and a quarter, and be sure that they are rigid. It is well to drill a hole in the center of each cover to allow the gases to escape. Paint the exposed metal parts above the electrolyte with the asphaltum varnish to prevent corrosion.

The electrolyte to be used is a saturated solution of ammonium phosphate in as pure water as it is possible to obtain. The chemical must also be pure. To make a saturated solution it is fairly safe to allow a pound of the phosphate to a gallon of water. Stir it until it is thoroughly dissolved, and see that no sediment remains at the bottom. A mineral oil, such as paraffin oil, can be floated on the surface of the solution in the jars to help prevent evaporation, and also prevent sparking at the surface of the liquid. This latter, although pretty to look upon, causes a rapid deterioration of the plate at the point of occurence.

A tray is next in the order of construction. Make this of the form shown, and of well seasoned wood, from a half to seven-eighths of an inch thick. Allow enough space for the four jars, with a slight separation between them to admit a circulation of air.

The panel can be made of marble, bakelite, or even hard wood, and should be of the width of the tray and of a height depending upon the size and number of instruments that you intend to use on it; the arrangement in the drawing being only suggestive. It can be fastened to the tray with screws along the bottom, or small brackets can be used at the sides. If it is made of wood, paint it with shellac or some other insulating varnish.

The instruments shown include an ammeter, a rheostat, and two double pole knife switches. The switches can be fused to take care of a possible short circuit or other accident. The meter will indicate the amount of current that is allowed to pass into the

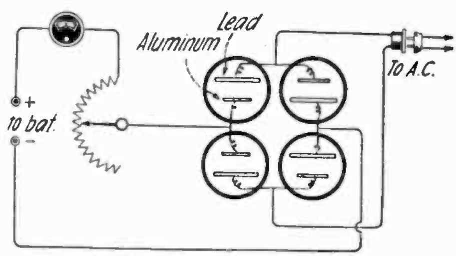
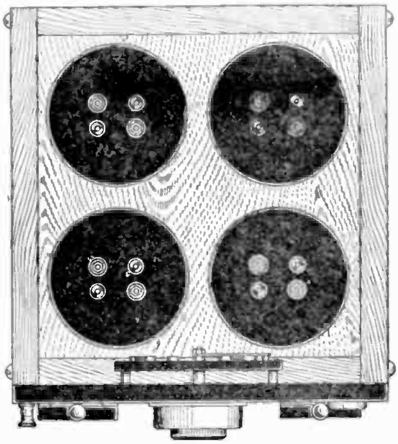


Fig. 5

Circuit Diagram of the Complete Rectifier Outfit.

battery by the rheostat. One of the switches is connected on the input, or A. C., side, and the other is connected on the direct current output side. The rheostat should be designed to adequately handle five amperes at 100 volts. Binding posts can be mounted on the D.C., and a flush connection plug on the A.C. side of the apparatus.

Now you can make the necessary connections. Use number 14 or 16 rubber covered wire for this purpose. Before connecting permanently, you must "form" the aluminum plates. Otherwise, when first connected up, the rectifier will have the effect of short circuiting the line. You can do this forming process by connecting the rheo-



Top View of the Rectifier and Control Cabinet.

stat and the ammeter in series with the A.C. leads and the rectifier, the jars being arranged as they are in the diagram. Leave the D.C. leads open. Cut in a fairly large amount of resistance and turn on the "juice." A current will flow at first, but will gradually die down to almost zero. Now cut out some of the resistance. A rise in current will take place, but this current will also gradually die down. Keep up this process until all the resistance of the rheostat has been cut out of the circuit, and the rectifier refuses to pass any appreciable current. When this condition is reached, the plates have been formed, and the rectifier is ready to be connected up in the manner shown in the diagram. Be sure and get the right polarity connection on your meter. This can best be determined by experiment. A reversed polarity will tend to move the indicating arrow backward. The lead from the aluminum plates, on the output side, is positive. It is best to mark this near the output binding posts, to avoid mistakes.

The outfit is now ready for service, and if you have followed instructions carefully it will give *good* service. The only cause for poor results is faulty construction, or the use of impure aluminum or ammonium phosphate. Add water from time to time to make up for that lost by evaporation. If excessive heating is experienced you should cut in more resistance, thereby lowering the current. Three or four amperes can be delivered for many hours at a time without undue heating. With larger jars, or with a special cooling arrangement, greater amounts of current can be successfully passed.

A High Frequency Buzzer

By D. R. Clemons

In the experimenter's laboratory measurements of frequency, inductance and capacity with other investigations are carried out by means of a wavemeter. In this connection, the wavemeter may be excited and adjustments made by connecting a receiver and detector to the circuit under test, or the

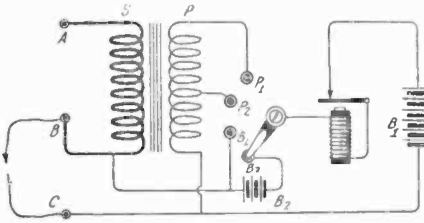


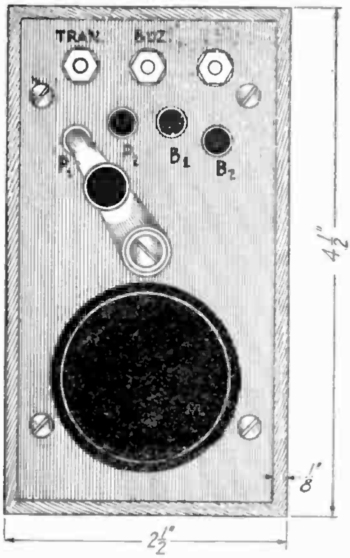
Fig. 3

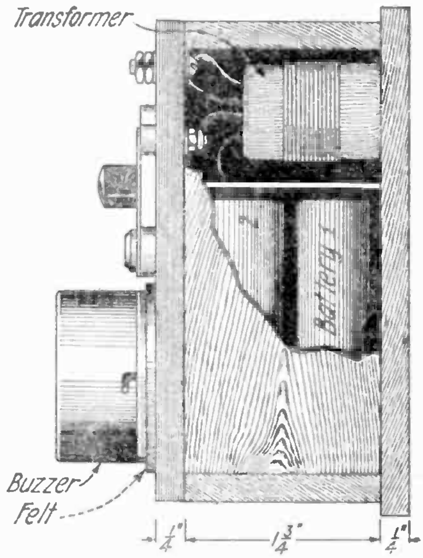
Diagram of Connections of the Buzzer Set.

test circuit may be excited and detection made on the wavemeter. Two readings may be taken, one by exciting the circuit and then by exciting the meter; invariably there is considerable difference. One appreciates a reasonable degree of accuracy in such work, but it is not common for one to take caution in considering the additional capacity of the excited circuit. It is true that such changes as noted above are not great, but in some cases even a small error cannot be tolerated. The capacity of the exciter should always be known and considered in calculations.

Circuits are generally excited by means of a buzzer and several cells of battery. One cell may operate through small inductances, but several batteries may be required if the inductance coil is large. Now, the leads attached to the system possess considerable capacity, also the cells of battery. Such capacity is in shunt to the standard condenser in the test circuit, which results in greater capacity than is accurately known. Too, the capacity of a buzzer test of this sort is rarely the same for two different circuits, due to other arrangements of instruments. It would be desirable to employ a buzzer exciter of fixed dimensions and capacity that would not vary. Such an instrument will be briefly described and shown by the accompanying sketch.

As a large battery is often required, two different voltages are included in the unit. A high-frequency buzzer is mounted upon a small formica panel also carrying a 4-point bent around the outside of the coil, completely enclosing it. Fig. 2 shows the position in the case. Two 3-volt flashlight batteries obtainable at Woolworth stores are





With a Constant Frequency Buzzer Such as This One, It is Easy to Conduct Tests in Frequency, Capacity and Inductance Measurements.

switch and terminals. A very small wooden box supports the panel and contains two 3-volt batteries and a small transformer, the latter being used for bridge measurements. Two extreme values of sound intensity are helpful in bridge work, so that three turns only may be used in a primary by placing the switch arm on P-2, Fig. 3, or the total of 10 turns for maximum primary strength on P-1. The transformer is 1" long and has a ¾" diameter made by winding 10 turns of No. 26 enamel on a core of fine iron wires. A primary tap is taken from the third turn. The secondary is 500 turns of No. 4 silk-covered copper wire. After windings are in place the core wires are connected as shown in Fig. 3, and stored in the small box of the unit, Fig. 2. Two flexible 10" leads are employed for connecting to the circuit.

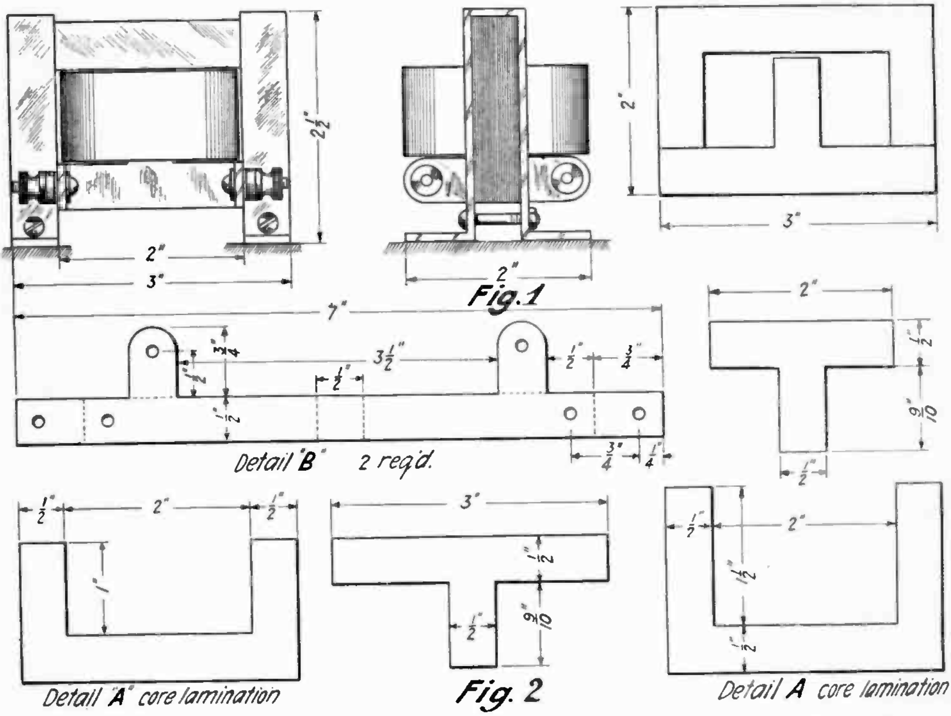
After completion, the unit is carefully measured to determine its leads and internal capacity for different settings. These values are marked on the bottom and are always considered when the exciter is used. Since this little device has been assembled, its capacity has never changed. That of makeshift arrangements could never be known without extensive measurements for every hook-up. Such a device, although simple, has been of great value and finds constant use. I am sure it could also be of great use to others engaged in this work.

Construction of a Modulation Transformer

By Charles H. Fulghum

The use of a properly designed and well-constructed modulation transformer in radiophone transmitting circuits is the most efficient and practical method of modulating the output of the transmitter at voice frequencies.

Modulation by the absorption method is excellent—when it works—but it demands an excellently balanced circuit, and is always a source of loss of more or less of the output energy. The same is true of inserting the microphone directly in the antenna circuit, and to a certain extent, when modulation is accomplished through the agency of impedance devices placed in the antenna circuit, i. e., magnetic modulators, etc. In the former case there is soon reached a limit to the amount of energy that can be handled, while, in the latter, by using properly designed instruments, almost unlimited energy may be modulated with but little distortion.



Constructional Details of a Modulation Transformer Which Will Give Good Results With a Phone Set of Any Power.

Modulation by modulation transformer methods calls for the use of properly designed transformers. Induction coils of various sizes are often used for this purpose, but they are at the best but makeshifts, and the results obtained are convincingly unsatisfactory.

The modulation transformer has affected a number of designs, but the one here described has proved as satisfactory as any. Moreover, it is very easily and cheaply constructed.

The materials needed for the construction of the modulation transformer herein described are as follows:

1 lb. No. 29 gauge Silicon transformer steel,
3 oz. No. 40 enameled copper wire,
75 ft. No. 30 enameled copper wire,
4 in. No. 10 varnished cambric tubing, or "spaghetti,"
20 ft. thin oiled paper, 1 inch wide,
8 mica or fibre washers,
4 binding posts,
2 brass machine screws, oval heads, 8-32 with nuts and washers,
2 strips brass or aluminum 2 x 8 inch, 3-32 inch thick.

The first step in building the modulation transformer is the construction of the core; this is of the "shell" type, lap joints, with an air gap in the magnetic circuit. When completed, the core measures 3 inches long, 2 inches wide, and ½ inch thick, external dimensions. The cross-sectional area of the magnetic circuit is .25 square inches.

The laminations for the core are cut to the dimensions given in Detail A, Fig. 2. Of the U-shaped pieces 1 and ½ inches long (inside measurement), 16 pieces will be required, and the same number of T-shaped pieces 2 inches long. Of each of the other T and U-shaped pieces, 17 will be required.

The transformer iron used should be the best grade silicon transformer steel, in laminations of No. 29 gauge or approximately .014 inch thick. The iron should be purchased in laminations measuring 2 by 3 inches, and the T and U-shaped pieces can be cut from these by clamping a number of them together and cutting away the surplus material with a hack-saw. A saw with very fine teeth should be used for the work.

If the laminations when purchased are not varnished, the constructor should varnish them before he assembles the core. This can be done by dipping each lamination in a thin solution of orange shellac in denatured alcohol. The laminations should be thoroughly dried before assembling the core.

The assembly of the core is very simple. One point should be noted: The top and bottom laminations should be U-shaped pieces with 1 inch legs, and T-shaped pieces 2 inches long. In Fig. 1 the arrangement of the top and bottom laminations is shown. The reason for doing this is obvious; when the shorter edges of the completed core are clamped together there will be no loose laminations. The remainder of the core is stacked with short and long pieces alternately. When the core has been completed it should be clamped firmly together and bound in several places with stout cord. The two sections of the core can then be separated so the primary and secondary windings can be slipped over the central leg.

It should be noted, by referring to Figs. 1 and 2, that provision has been made for an air gap of .1 inch in the central leg of the core. This gap, which provides for a certain amount of magnetic leakage, is of material value in reducing speech distortion so common in closed core type modulation transformers.

The primary and secondary windings are wound on a mandrel .7 inch in diameter. The easiest and best way to wind the coils is to fit the mandrel to an ordinary breast drill and use a revolution counter to check up on the number of turns.

The mandrel should first be wound with several turns of oiled paper and over this about four turns of heavy bond paper is wound and well shellacked. This should then be baked until dry. Upon this the primary is wound, consisting of 200 turns of No. 30 enameled copper wire wound in three layers. Each layer should be separated from the next with a turn of oiled paper, and over the last layer, six turns of the oiled paper should be placed. Directly over this is wound the secondary, which consists of from 6,000 to 8,000 turns of No. 40 enameled copper wire wound about 200 turns to a layer, each layer separated from the adjacent one by a turn of oiled paper. The final layer is wound with several turns of oiled paper and completed with four wraps of well-shellacked bond. The completed windings should then be impregnated by immersion in hot paraffin for two hours.

Leads 3 inches long, consisting of three No. 30 bare copper wires twisted together, should be soldered to the ends of the primary and secondary windings, care being taken to secure them to the coil in such a manner that they cannot be broken off.

The two brackets which clamp the core together and serve to support the transformer are cut from sheet brass or aluminum 3/32 inch thick. The template and dimensions are given in Detail B, Fig. 2, for the brackets and the manner in which the brackets are bent is shown in the illustrations of the completed transformer in Fig. 1. All holes are 3/16 inch, although it may be necessary to ream out the holes for the binding posts, depending upon the size of screw they are fitted with.

The assembly of the transformer is clearly shown in Fig. 1. The coil is placed over that portion of the T-shaped section of the core, which forms the central leg of the completely assembled core, and the other section fitted in place. The edges of the core are then slipped into the brackets and the bolts which clamp the brackets to the core tightened until the core is held firmly in place. If the brackets have not been bent exactly to the dimensions given, it may be necessary to "shim" up the edges of the core with thin strips of cardboard until the brackets can be clamped tightly to the core.

The binding posts are mounted with insulating washers on either side of the bracket arm, in order to prevent them from grounding through the brackets. The washers are preferable, although washers cut from heavy fish paper or micarta will answer the purpose just as well.

The leads from the primary and secondary windings are covered with short sections of "spaghetti" and soldered to the binding posts. In soldering all the connections of the transformer it is well to use a non-corrosive soldering paste, and to use as little of it as possible.

When completed, the transformer should be tested for grounds or open circuits. If faults are found, they should be corrected and care taken to prevent their reoccurrence.

The use of the transformer requires but little mention, as this subject has been more or less completely covered in texts and papers treating with this topic and should be familiar subject matter to the reader. The few following notes may, however, be of value.

The primary or microphone circuit should include a battery of from four to eight volts. The correct amount depends a great deal upon the location of the transformer as a modulated device and upon the microphone used with the transformer. High potentials in the primary circuit should be avoided, as they tend to cause deterioration of the microphone granules and are usually a source of speech distortion. The correct voltage of the primary circuit can only be ascertained by trial, but usually it falls within the limits stated above.

If the transformer is to be used in constant current systems of modulation on powers to exceed ten watts, it is recommended that a speech amplifier hook-up be used, for the current carrying capacity of the secondary is limited and with excessive powers the windings may be burnt out.

Where the transformer is inserted some place in the circuit of a single oscillating tube, it will often be found of material value to shunt the secondary with a condenser. Modulation will not be affected, but the output of the set will be increased.

Two Practical Radiophone Circuits

***By* John Scott-Taggart**

The subject of radio telephony is coming so much to the front that it needs no introduction in articles giving accounts of apparatus which has proved successful in establishing communication over comparatively long ranges, as for example a distance of 300 miles.

The principles on which the circuits here described are based, are at this date not new, but the circuits themselves will, no doubt, be of interest to those whose knowledge of the subject from a practical point of view, is not extensive.

of the oscillatory energy in a manner proportional to the microphonic potentials, the E.M.F. of the oscillations, in the grid circuit will vary. Consequently, the oscillatory circuit in the aerial will be correspondingly modulated.

In Fig. 1, the vacuum tube V_1 acts as the primary course of continuous oscillations or, as it is sometimes called, the *master oscillator*. The circuits shown for this oscillator are rarely used in England although they have been frequently employed in France and the United States. A

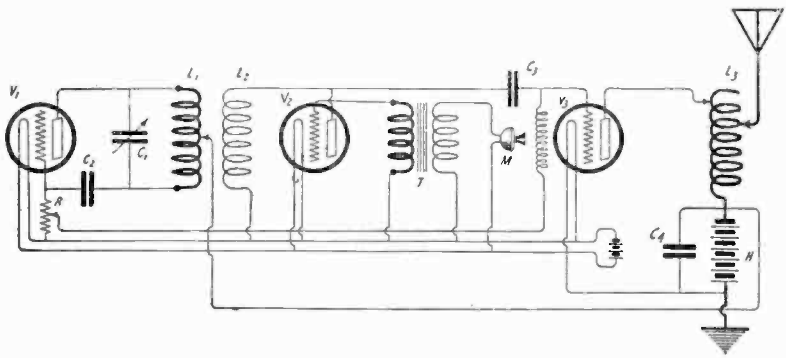


Fig. 1.—A Very Efficient Radiophone Circuit in Which a Master Oscillator is Used in Conjunction With an Amplifier and Modulator Tube. The Same A and B Batteries are Used for All Tubes.

Both the circuits employ the principle of using a three-electrode valve as an amplifier whose output circuit is coupled to an aerial system. This use of the valve is an obvious development of the high frequency amplifying properties of the triode vacuum tube, and the arrangement is frequently employed in radio telephone work.

The circuit of Fig. 1 depends for its action on the use of a three-electrode valve as an absorbing element connecting across the input side of an amplifying tube. If steady, continuous oscillations are induced into the grid circuit of such a tube unmodulated amplification takes place. If, however, we cause the microphone in conjunction with another valve, to divert some

single inductance coil L_1 is shunted by a variable condenser C_1, and the frequency of the oscillations produced is practically equal to the natural frequency of this single circuit. A tapping is taken from about the middle point along L_1 to the anode or plate battery or D.C. generator H and thence to the filament. The condenser C_2 is the grid condenser.

The grid leak R has a value of about 10,000 ohms. It should preferably be wound with resistance wire and have tappings. When such a system oscillates, the grid at every positive H.F. half-cycle absorbs an electron current of several milliamps which results in a comparatively steady potential drop along the resistance

R. This potential drop gives the grid of the first valve a suitable negative operating potential.

The oscillations in L_1 are now passed on to a coil L_2, constituting the grid input circuit of the amplifying tube V_2. The condenser C_3 acts as a blocking condenser. of Fig. 1 may be varied experimentally in various directions. The anode of V_3 may be given a positive potential by including a source of potential between the foot of L_1 and the filament. Another variation is to connect the foot of the secondary winding of T to a point on the grid leak R, so as

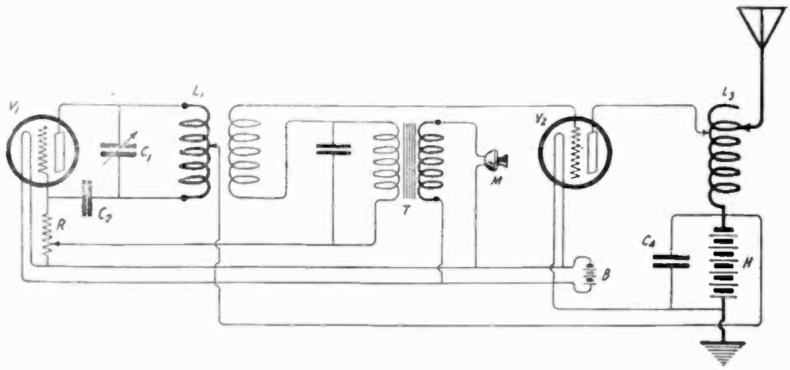


Fig. 2.—In This Circuit Using Only Two Tubes the Output of the Amplifier is Controlled Microphonically and Gives a Clear Modlation. An Experimental Set of This Type May Easily Be Built by the Amateur.

The grid of V_2 is connected through a choke-coil Z to a point on the grid leak R of the first valve. A suitable negative potential is in this way communicated to the grid of V_2. The choke-coil Z is to prevnt this potential communicating circuit shorting the oscillatory current in Lz. The coil Z is preferably an air-core choke of high inductance. Its natural period of oscillation should preferably equal the frequency of the oscillations supplied by V_1. Under these conditions, the choke will have a maximum impedance. Auto-transformer connections are shown in the anode of plate circuit of V_2. The tapping from the anode to the coil L_3 enables the output impedance to be varied and the maximum power to be obtained. The tapping from the aerial will vary the tuning of the aerial circuit which, of course, should correspond to the oscillation frequency employed.

The circuit, so far considered, would act as a continuous wave transmitter, and a key might be inserted so as to break either the anode circuits of V_1 or V_2 or both. By connecting a third valve V_3 in the position shown, radio telephony may be obtained. The valve V_3 will damp the oscillations in L_1 since it will conduct when the oscillations make the anode of V_3 positive. The degree to which V_3 will conduct will be approximately proportional to the grid potential of V_3. This grid potential is varied during speech transmission by the E.M.F.'s supplied by the microphone M and the step-up transformer T. From this we will see that the oscillatory potentials applied to the grid of V_2 will be modulated. The circuit to give the grid of V_3 a negative potential. The method of using single filament and anode batteries is frequently employed. The filament battery is also made to act as a microphone battery.

Another Practical Radiophone Circuit

The second radio telephone circuit which is capable of giving very excellent speech depends on an entirely different principle. The actual high frequency oscillations are not modulated or interfered with, but the output of the amplifier tube is controlled microphonically. Fig. 2 shows the arrangement. A master oscillator tube V_1 is again used. The input circuit L_2 of the amplifier tube V_2 is coupled to L_1 The grid of V_2 is given a high negative value by taking a connection from the grid leak R. The microphone transformer T is so connected that the normal or "base-line" grid potential of V_2 is continuously varied when speaking into M. Let us assure that—E volts are required to cut down the anode current of V_2 to zero, so that the tube V_2 is being used at the foot of its grid-potential—anode-current curve. Let us now consider that the amplitude of the induced oscillations in L_2 is E volts. If the grid base-line potential be made—E-e volts, the induced oscillations will never produce any oscillatory current in the outfit circuit of V_2 since even the positive peaks of the oscillations only bring the operating point to the foot of the curve. If, however, we apply additional positive potentials to the grid, the grid-base-line potential will become less negative, and the oscillations will cause the operating point to travel up and down a portion of the anode current curve. Oscillatory currents will be generated in the anode and aerial circuits having an amplitude corresponding to the amount of the curve used. This will depend upon the magnitude of the added potentials which are in practice the low-frequency potentials supplied by the microphone transformer T.

Both of these circuits, particularly the second, have proved of considerable value for medium powers and can be recommended for this purpose. The writer has produced some distinctively original radio telephone systems which have produced particularly pure articulation and it is hoped that an opportunity to discuss these will occur in the near future.

Loading Coil Design

By Ralph H. Langley

Of all the various parts of a radio transmitting set, there is probably no one of them that is responsible for more avoidable losses than the loading coil. Even in the small amateur set, working on low wave-lengths, the loading coil may eat up as much as all of the energy that would otherwise be supplied to the aerial. In the larger sets, and in using higher wave-lengths, the design of the loading coil becomes increasingly important.

Loading coils have been made in all sorts of shapes, and with all sorts of material. They have been wound as helixes on square forms, and octagonal forms, and round forms. They have been made of litzendraht (stranded wire with each strand insulated from the others), they have been made of solid wire, and of tubing and of copper strip. It is obvious that there must be some best form, and some best conductor to use.

Litzendraht would undoubtedly be the best kind of wire to use, if it were not for the fact that it does not permit of making easy adjustments. The amount of inductance in the loading coil must be carefully adjusted, not only when the set is first tuned up, but at frequent intervals afterward, due to changes in the capacity of the aerial, or changes in the wave-lengths of the primary circuit. A coil made of litzendraht cannot have any sliding contacts, and making taps on such a coil is a matter of considerable difficulty.

In making the choice between the solid wire, the tubing and the strip, we have only one thing to consider. High-frequency currents travel in the surface of the wire. This eliminates the solid wire, because it has less surface for a given amount of copper than any other form. The next point is that the inductance, and also the resistance and the losses, of a coil depend on how many turns we can put in a given space. This shows us that the strip will be better than the tubing. As a matter of fact, any tubing which could be used would have less surface than a thin copper strip made with the same amount of copper. So we see that the strip is better for two reasons.

There will be less copper for a given inductance in a round coil than there will be in a square one or an octagonal one. There are two ways to make a round coil, however. We can wind it in a helix (as when it is wound on a tube) or we can wind it in a spiral (like the hair-spring in a watch). Since we have decided on the copper strip, we will choose the spiral form of coil, because it is very much easier to wind the strip in this form.

There is a very simple formula for the inductance of a flat spiral coil, which anyone can use. If we let

L = the inductance of the coil in centimeters,
n = the total number of turns,
a = the mean radius of the coil (the inside radius plus the outside radius, divided by 2) in inches,
b = the width of the copper strip in inches,
c = the radial depth of the coil (the difference between the inside radius and the outside radius) in inches,

then we have

$$L = \frac{32 \times n^2 \times a^2}{0.23a \quad 0.44b \quad 0.39c}$$

This formula is very accurate, and can be used to find the number of turns required for a given inductance as well as to find what inductance a given coil will have.

Building coils of this kind is quite simple. Any hard wood will do for the frame, provided it is boiled in paraffin. It is then only necessary to build a wheel having four or six spokes, and to put saw slots in the spokes to set the copper strip into. If four spokes are used, the frame for the coil can be a square of wood. The spokes can run all the way across, being jointed together at the center. If six spokes are used, a hub can be made to hold them, and no outside frame will be needed. Such a coil as this can easily be fastened to the wall, and connections made by means of little copper clips made of the same copper strip.

For the usual amateur set, the strip should be ¼"×1/32". It should have rounded edges if possible, so as to cut down the possibility of sparking. Strips of this kind can be purchased from any of the large metal dealers.

A sliding contact can be arranged on this kind of a coil without much difficulty. If the coil is made with a hub, a rotating arm can be mounted on a bearing at the center of the hub, and arranged with an insulating handle. The little contact clip must then be made so that it can slide along the copper strip of the coil, and also slide in and out on the rotating arm. With this arrangement, tuning can be done with power on, and will be very much quicker and more accurate than when the power has to be shut off each time, and the clip has to be moved a whole turn.

Coils of this kind are equally suitable for the primary. If two of them are used, one for the primary and one for the secondary, they can be hinged together to give the coupling variation. In this case, one coil will be fastened to the wall or table, and the other will swing on the hinges. One spoke in the swinging coil should be made longer so as to act as a handle to use in getting the proper coupling. An oscillation transformer of just this kind has been used in Army Pack Sets for years, and is highly efficient and very satisfactory in operation.

In making connections to a coil of this kind, it is better to make the permanent connection at the outside end of the coil, and to increase the inductance by moving the adjustable contact in toward the center. The outside turns of the coil have greater inductance than the inside turns. This means that the amount of copper in circuit (and consequently the losses) will be less for any particular inductance if the outside turns of the coils are used.

Two coils made in this way may be used to make a transmitting variometer. For this purpose they should be hinged together in the same way as for an oscillation transformer, but the method of connection will be different, and one coil is to be placed upside down with reference to the other. This is in order that when the two coils are closed together they will oppose, and thus give minimum inductance. When one coil is swung around so as to come in line with the other, they will give maximum. This maximum will be about 40 per cent greater than the sum of the separate inductances of the coils, due to the mutual inductance between them. The two outside ends sould be connected together by a flexible connector, and the circuit brought to the middle of one coil and taken from the middle of the other.

In building coils of this type, it is not profitable to make the inside radius much less than 1½", as the turns at this radius and less have very small inductance. For the ¼" × 1/32" copper strip, the spacing of the turns cannot be much less than ⅛". It will usually be best to make it about 3/16" in order to be sure that there will be no sparking between turns along the supporting spokes, and in order that the little pieces between slots may not break out. A small "fret-work" saw should be used to make the slots.

If we build the coil as explained in the preceding paragraph, and then figure its inductance by our formula, we shall find that for five turns it will have 3,350 centimeters, for ten turns it will have 15,700 centimeters, and for fifteen turns it will have 32,500 centimeters. Now, for a wave-length of 200 meters and an aerial whose capacity is 0.0004 microfarads, we will need a total of 28,200 centimeters. The 15-turn coil would therefore be suitable for the secondary of the oscillation transformer. A similar coil, calculated to give the proper inductance for 200 meters when used with the primary capacity, can be built for the primary of the oscillation transformer.

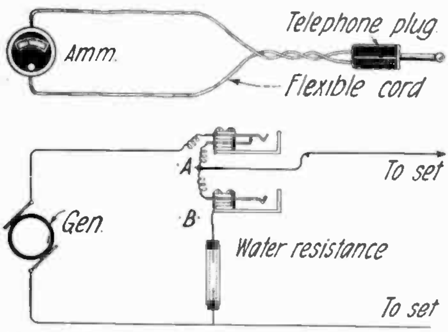
Concerning the efficiency of coils of this type, it is only necessary for us to notice that they are standard in the Army and Navy, and also with the large commercial radio companies.

Meters for C. W. Sets

By **J. F. Zweighaft**

The advantages of the C.W. set are so numerous and obvious that every ham wants one. The one big disadvantage is the cost; C.W. transmission calls for a motor-generator, at least one tube, and several meters for controlling the output and input of the set. Almost everyone has a hot wire meter left over from the days of the spark coil, so this item can be discounted. But how about the well-nigh indispensable milliammeter and the voltmeter? I have solved this problem on my own set in a very satisfactory way at a nominal cost.

The usual small ammeter that appears on the dashboard of nearly every automobile has great possibilities; don't sniff at it scornfully. It can be obtained in a junk-yard or purchased for about $2 in a supply store. Remove the short piece of heavy wire inside, across the two binding posts and lo, you have a good milliammeter! This shunt will usually come off without any trouble and it only remains to calibrate the instrument. This is easily done in the following manner.



Showing Method of Plugging in the Meter. When in Jack "A" it Reads in Amperes While in Jack "B" it Functions as a Voltmeter

Take a six-volt circuit, say a storage battery, and connect it in series with a one thousand ohm receiver and your milliammeter. By Ohm's Law, the current flowing will then be .006 amperes or 6 milliamperes. Note the point indicated by the needle on the meter and, with fair accuracy, it may be said that other points on the scale will represent proportionally different currents. For example, if, when using the apparatus described above, the needle on the ammeter pointed at 5 amperes, then "5 amperes" would indicate a current of 6 milliamps and in a like manner, "10 amperes" would indicate a current of 12 milliamps and so on. It becomes a simple matter then to draw out a new scale and paste it over the old one.

The next step is to convert our milliammeter into a voltmeter, reading from 0 to 500 volts or more. This is accomplished quite easily by inserting a resistance in series with the instrument, but inasmuch as this resistance would have to be of the order of 50,000 ohms, it would seem an appalling task to wind it by hand. I have found that a specially arranged water resistance will answer perfectly and it has the added advantage of being adjustable so that the voltmeter can be used over a much larger range.

The resistance is simply a glass tube about ½" in diameter and about 5" long with a rubber stopper at each end. A small copper wire (about No. 4) is pushed through each stopper and a separate hole is left in the upper one to allow escape of the small amount of gas formed by electrolysis. The tube is now nearly filled with water, put in series with the milliammeter and an E. M. F. of say 110 volts, D. C. In all probability the needle of the milliammeter will not be deflected at all. We now make up a dilute (about 5 per cent) solution of common salt and add this to the water, drop by drop. At once the milliammeter will begin to show a deflection and when the needle has reached the "5-ampere" mark on the old scale, we call this point "110 volts." Similarly, the "10-ampere" mark will indicate 220 volts and so on. As the average automobile ammeter does not read higher than 20 amperes, it will be necessary should we desire a voltmeter reading up to 1,000 volts, to make the 110 volt mark correspond to a point rather less than "3 amperes" on the old scale, by increasing the resistance. The resistance can be adjusted, within limits, by pushing one of the wires further into the solution, thus altering the range of the voltmeter. As certain chemical changes will occur if the instrument is in use frequently, it is good policy to check it up against a known voltage from time to time and, if necessary, adjust the wires in the solution until the reading is accurate.

After calibration, the voltmeter scale can be pasted immediately below the milliammeter scale and our redesigned meter mounted on the panel. The connections to the set are best made through a plug and two jacks, as shown in the diagram. When inserted in the closed-circuit jack (A), the instrument will function as a milliammeter and when in the open-circuit jack (B) it will function as a voltmeter.

A DIAL INDICATOR

A dial indicator now manufactured by a prominent dealer in radio supplies may easily be duplicted by the amateur, at small cost. You all have left-over switch points, long covered with dust; carefully remove one from Hon. Junk Box and, with care, file a narrow groove, half-way across. Use a small file, and be sure that the end of the groove is at the center of the contact.

The indicator may be placed close to the dial and directly over it. The groove is lined up so that it will form a continuation of the marks on the dial. This type of indicator may be used with either bevel or straight-edge dials.—LEON NETTLETON.

Regeneration and Super-Regeneration

By Jesse Marsten

The super-regenerative receiver recently disclosed by E. H. Armstrong has created a furor of excitement in radio circles. It is the main subject of conversation, particularly among the newcomers and the very latest species of "radio experts." However, not only does investigation show that they do not understand the action in a super-regenrative receiver, but it also shows that there is a glaring lack of understanding of the action of simple regeneration.

Fig. 1.—A Circuit With a Source of Voltage and a Resistance.

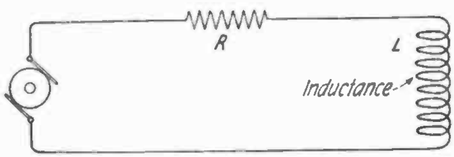


Fig. 2.—The Same Circuit, to Which Inductance Has Been Introduced.

The reason for this is these people are not grounded in the fundamental principles of electric circuits and have been overfed on popularizations which avoid mention of these principles. There is no royal road to radio knowledge. The kid amateur in a backwater town who operates his small spark coil and crystal receiver and who reads about volts, amperes, and ohms, stands more of a chance to understand super-regeneration than his modern brother, just entering radio, who spends several hundred dollars on the latest tube outfits and wants to hear the world. It is reasonable to expect that the man who understands the principles of oscillations in electric circuits is in a better position to understand regeneration than the one who never heard of the quenched gap. The desire to listen to Chicago talk via radio and to be up to date (which, in the minds of many new-comers and "radio experts," necessitates a certain contempt for anyone daring to speak of spark transmission) cannot take the place of a knowledge of fundamentals in understanding radio developments.

It is difficult to keep from stressing too strongly the importance of knowing fundamental basic principles. A knowledge of simple fundamentals will go much farther in clearing up such subjects as regeneration than all the sugar-coated popularizations invented. To say that in a regenerative receiver the amplification increases as the feed-back coupling is increased up to a certain point, and that beyond this point *"the tube spills over,"* thus destroying amplification, as so many popularizers say, may be perfectly clear to one who already understands regeneration; the writer fails to see where this sheds any light on the subject for the novice. It may seem easier to digest than an explanation involving the resistance reactions interposed by feed-back coupling, but if values are to be measured by end results it is preferable to go to the trouble of learning something about resistance than to read about "tubes spilling over." These sugar-coated explanations seem to be devices for encouraging the radio new-comer to avoid thinking.

The following explanation of regeneration and super-regeneration is based on the action of resistance in circuits. It is not as easy reading, perhaps, as reading about "tubes spilling over," etc., but it is an attempt to present the fundamental electrical principles involved in an explanation of radio phenomena. It is an attempt to make the reader do a little more than simply read.

Fig. 1 represents an electric circuit containing a source of voltage, G, and a resistance, R. If the voltage is constant in value a current also constant in value will flow through the circuit and its value will be limited by the resistance. The smaller the resistance the greater the current and vice versa. In this case the current value is reached almost instantly. These are all elementary and well-known facts.

If the same constant potential is applied to a circuit containing resistance and inductance, as in Fig. 2, the current does not reach its maximum value immediately, but gradually rises from zero to its final value. The growth of current in a circuit containing resistance and inductance is represented in Fig. 3. The reason that the current takes some time to reach its final value is that inductance in an electric circuit behaves as an inertia and retards the growth of current. Such a circuit is said to have a "time constant" which depends upon the values of the inductance and resistance. This time constant is a measure of the length of time it takes for the current to build up to its final maximum value.

If in the above circuit there is a current flowing and the impressed voltage is removed, the current will gradually drop to

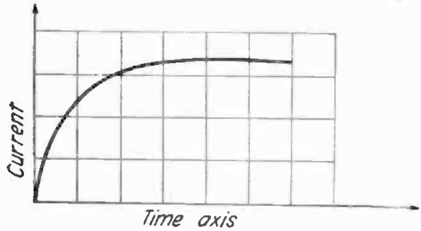


Fig. 3

Fig. 3.—Graph, Showing Growth of Current (D. C.) in a Circuit Containing Resistance and Capacity.

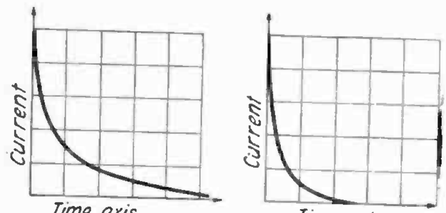


Fig. 4 Fig. 4-a

Fig. 4.—Decay of Current (D. C.) in a Circuit Containing Resistance and Inductance. Fig. 4 (a) Showing Highly Damped Current.

zero according to some such curve as in Fig. 4. When the voltage is removed the current that is flowing has all its energy dissipated in the resistance of the circuit and, since there is no longer an impressed voltage to maintain this current, it dies down to zero. *The greater the resistance, the less time it takes for the current to die down to zero; the less the resistance, the more time it takes for the current to die down to zero.*

Suppose that while the current is still flowing the resistance, by some means, is reduced to zero. What happens? At the instant the resistance is reduced to zero the current has a definite value. *Since there is now no resistance to consume the energy of the current and there is no resistance to oppose the flow of current, the latter will continue to flow in the circuit regardless of the presence of the impressed voltage.*

If the impressed voltage is removed at the instant the resistance of the circuit decreases to zero, then the current will continue to flow at that value which it had at the instant the impressed voltage was removed.

Let us now consider oscillating current circuits, as in Fig. 5; namely, circuits containing resistance, inductance, and capacity. The principles and facts outlined above for direct currents hold here also, except with these changes: In the first place the current is oscillating or alternating. When the oscillating voltage is applied, an oscillating current flows and builds up in value as indicated in Fig. 6. As with direct currents, it takes appreciable time for the oscillating current to build up to its maximum value. The time it takes is again determined by the *time constant* of the circuit which in this case is determined by the values of the inductance, capacity and resistance.

This current which builds up in value when the voltage is impressed is called the "forced oscillation," since the existence of the current depends solely upon the presence of an applied external voltage. The frequency of this "forced oscillation" is the same as the frequency of the impressed voltage, regardless of what the natural frequency of the circuit is.

When this applied oscillating voltage is removed the "forced oscillation" current decreases to zero according to the curve shown in Fig. 7, exactly as in the case of direct current and for the same reason. The time it takes for the current to drop to zero depends largely upon the value of the effective resistance of the circuit. The greater the resistance the less time it takes for energy of the current to be consumed and hence the less time it takes for the current to drop to zero, and vice versa. When the current drops rapidly to zero, as in Fig. 4, it indicates that the circuit resistance is extremely high. The circuit is then said to be "highly damped" and the circuit has a "high decrement," and vice versa.

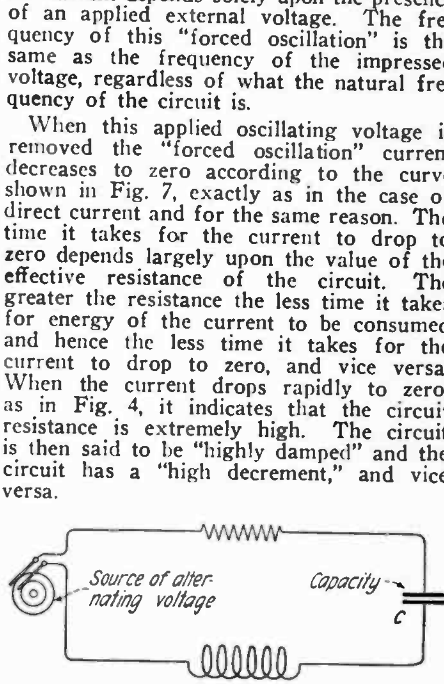


Fig. 5

Fig. 5.—Adding Capacity to a Circuit Excited by Alternating Voltage and Including Resistance and Capacity.

Thus far the action of the oscillatory circuit is the same for alternating currents as the action of the previous circuits described for direct currents. We now come to an important difference. An oscillatory circuit had a natural frequency of vibration or oscillation of its own. This natural period is determined by the value of the inductance and capacity in the circuit. If an instantaneous electrical impulse of any sort is applied to such a circuit it will vibrate—*i. e.*, an oscillatory current will flow through it and the frequency of this oscillation will be the same as the natural frequency of the circuit. Such an oscillation is called a "free oscillation." This free oscillation dies down to zero after the voltage pulse is removed for the same reason and in exactly the same way as the forced oscillation when the impressed voltage is removed.

Thus when an external voltage is applied to an oscillatory circuit, two oscillations result: One, a forced oscillation having the same frequency as the applied voltage, which oscillation lasts as long as the voltage is impressed; two, a free oscillation having the same frequency as the natural frequency of the circuit. While the forced oscillation persists during the time the voltage is impressed, the free oscillation dies out. These two oscillations are graphically shown in Fig. 8.

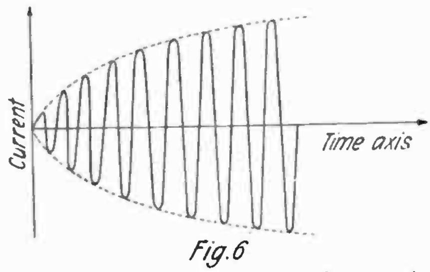


Fig. 6.—How the Current (A. C.) Increases in a Circuit Containing Resistance, Inductance and Capacity.

In place of the alternating current generator applying the impressed voltage to the circuit, we may consider the generator replaced by an antenna circuit inductively coupled to the circuit as shown in Fig. 9. In this case the voltage impressed on the oscillatory circuit will be that due to the voltage induced in the circuit by the antenna signaling voltage. The forced oscillation in circuit II will have the same frequency as the antenna frequency and the free oscillation will have the frequency of circuit II. The value of these oscillations will be a maximum, however, when the two circuits are in "resonance"—*i.e*, when the frequency of antenna circuit and circuit II coincide, just as the swing of two pendulums is a maximum when the pendulums are of the same length, have the same weight, etc. In this case the forced and free oscillations will have the same frequency. This is the general case in all radio circuits, since radio circuits coupled to each other are generally tuned to each other.

In the general case here described it is the forced oscillation which is of greatest importance and the free oscillation which is of negligible importance as far as the production of signals is concerned. The free oscillation, while it lasts a finite time, is practically instantaneous and dies down to zero, while the forced oscillation persists as long as the applied voltage (which is the received signal in the antenna) lasts, which is many times longer than the free oscillation.

Now, as the resistance of the circuit decreases, the oscillating current for a given voltage increases. When the resistance reaches zero the current has reached a very large value. If now the impressed voltage is removed, the current continues to flow in the circuit at the value it had when the voltage was removed. Once a current has been started in a circuit and the resistance reduced to zero, this current will continue to flow, regardless of the presence of an external voltage, since there is no resistance to consume its energy or "damp" the current. As there is no impressed voltage and current flows, this current may be regarded as the free oscillation.

Let us now consider the application of the above outlined principles to the regenerative receiver. In Fig. 10 is a circuit of a simple bulb receiver. The signaling voltage in the antenna is impressed by inductive on the secondary circuit II and a free and forced oscillation will, therefore, flow in the secondary circuit. The free oscillation dies out in a very short period of time, as explained above, while the forced oscillation builds up in value until its further growth is limited by the resistance of the secondary circuit. As a result the audibility will be limited in the same way. If it were now possible to introduce some means whereby the resisatnce of the secondary circuit could be gradually decreased there would result a corresponding increase in the oscillatory current, thus producing louder signals. This is in effect what occurs in the regenerative receiver.

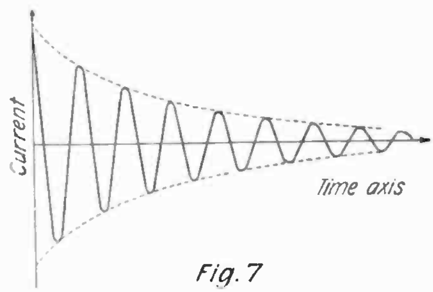


Fig. 7.—Decay of Current (A. C.) in Circuit Containing Resistance, Inductance and Capacity.

To understand how this is accomplished, suppose we connect in series with the telephones of Fig. 10 a coil whose position may be altered with respect to the secondary coil, L, as in Fig. 11. This coil, called the tickler, produces the regenerative action. Suppose the position of this coil is such that it has no effect on the coil L, thus its axis may be perpendicular to the axis of coil L, or it may be at a considerable distance from coil L, so that in either case there is no transfer of energy from one coil to the other by induction. In this case conditions will be practically the same as for the circuit of Fig. 10—*i.e.*, the signal is definitely limited, for a given received voltage, by the circuit resistance.

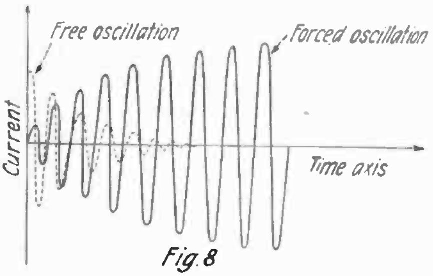


Fig. 8.—Forced and Free Oscillations Resulting from the Application of an External Voltage to an Oscillating Circuit.

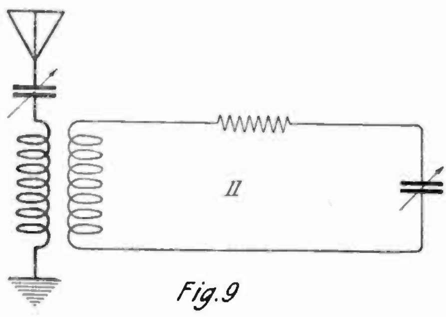
Suppose now that the tickler coil, T, is changed in position so that it is either moved up closer and closer to coil L, or it is rotated so that its axis is more and more parallel to the axis of coil L. The coupling between the two coils is then increased, and due to this increased coupling there will be a transfer of energy between the two circuits. A voltage will be induced in coil L by the tickler T, and as the coupling increases this induced voltage will also increase. This induced voltage will have the effect of overcoming or counteracting the opposing resistance reaction of the entire circuit, thus resulting in increasing the oscillation current over its original value. The more the tickler coupling is increased, the larger is the voltage induced in coil L, and the more is the circuit resistance counteracted, with the result that both current and signal become greater and greater. In other words, the effect of the regeneration is to decrease the resistance of the oscillation circuit, thereby resulting in large increases in current and audibility of signal.

As the regeneraton increases we see that in effect the resistance of the circuit is made to decrease. Hence, from the principles explained at the beginning of this article, it will take a longer time for the free oscillations to die out, for the smaller the resistance of the circuit the less the damping of the circuit. Now suppose that the coupling between the tickler and coil L is made so close that the voltage induced in coil L is sufficient to counteract entirely the circuit resistance. In this case the resistance of the circuit will in effect be reduced to zero. Since there is no resistance now to impede the flow of current, the free oscillations will continue to flow. However, when the resistance of the circuit drops to zero the circuit becomes unstable and any slight variation in filament current, or plate voltage, or in the circuit will result in the circuit generating self-sustained oscillations, which will destroy any amplification. These self-sustained oscillations have a paralyzing effect on the tube, and will drown out any other oscillations which may be present.

This, then, is the limiting condition of regenerative amplification. So long as the tickler coupling does not result in completely annulling the circuit resistance, regenerative amplification can be obtained. As soon as the coupling becomes great enough to result in reducing the circuit resistance to zero, the free oscillations persist and destroy any amplification of the signal voltage which may have been secured.

What this regenerative amplification accomplishes is this: It reduces the circuit resistance from a high value to an extremely low value, but higher than zero, and thereby increases the current to very large values; hence also the audibility.

Apparently further amplification which might be obtained by a continued increase in regeneration—*i.e.*, a continued decrease in circuit resistance below zero to negative values is prohibited by the introduction of self-oscillations. It is obvious that if this decrease in circuit resistance could be effected without the introduction of self-sustained oscillations amplification of unheard-of values would be obtained.



This Shows the Equivalent of a Tuned Circuit Comprising Inductance Capacity and Resistance.

In this case we would have a circuit with a negative resistance. We saw how a positive resistance had the effect of limiting the value of a forced oscillation current, and damping out the free oscillation current. We also saw that when the resistance of a circuit was reduced to zero, the forced oscillation current was maintained at the value it had when the resistance became zero, while the free oscillation was not damped out, but continued to flow at the value it had when the resistance became zero. When a circuit has a negative resistance, not only is there no resistance to limit the value of the forced oscillation current or to damp the free oscillation, but an exactly opposite effect is had—namely, whatever free oscillation current there is in the circuit at the time the resistance has become negative, steadily increases in value and approaches infinity. In the case of the circuit having a positive resistance it was noted that it was the forced oscillation which was of dominant importance, most

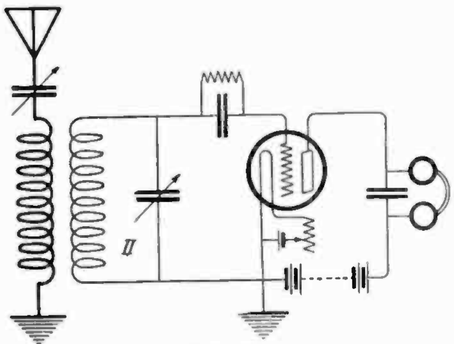


Fig. 10

Hook-Up of a Vacuum Tube Acting as Rectifier in a Receiving Circuit.

of the energy being in the forced oscillation. However, in the case where the resistance is negative and the free oscillation steadily increases in value, it is this free oscillation which is of major importance and the forced is of minor importance. Furthermore, this free oscillation has the property of starting with a value which is proportional to the applied voltage (in the case of a signal, it is proportional to the antenna voltage), and during any finite period of time the free oscillation maintains this proportionality. Hence it will be seen that, since the free oscillation in a negative resistance circuit may rise to enormous values, and since its value is proportional to the applied signaling voltage, it will repeat the transmitted signal with tremendous amplification, provided *the circuit does not break into self-oscillations which will destroy any amplification.*

As in regeneration, so in this case it is the self-oscillations, which are generated when the circuit resistance becomes unbalanced, that destroy the amplification which would otherwise be obtained. If some means could be devised to prohibit the generation of these paralyzing self-oscillations of the system, the tremendous amplifying effect of the free oscillations could be secured. This is precisely what is done in the Armstrong super-regenerative receiver.

Armstrong has discovered that if a regenerative circuit having a negative resistance is made positive at intervals, so that the circuit is alternately positive and negative, the circuit will not generate self-sustained oscillations, which will paralyze amplification. It takes a certain finite time for a negative resistance circuit to break into self-sustained oscillations. Up to the instant when the circuit is ready to generate these undesired oscillations, the circuit resistance is negative and hence the enormous amplifications possible with this circuit are secured. At the instant when the circuit is ready to oscillate on its own, it is made to have a positive resistance, thus inhibiting the tendency to oscillate, and the amplifications secured are, therefore, not destroyed.

There are three methods whereby the above effect can be secured. These will be described in principle. The first method secures the necessary change in resistance by means of a variation in the plate voltage of the regenerating tube. Fig. 12 indicates schematically the disposition of the circuits and tubes with respect to one another; R is the regenerating tube, O is an oscillating tube, I is the regenerative circuit associated with tube R, and II is also an oscillating circuit associated with tube O. The circuit I and tube R are adjusted for the regenerative condition. It will be observed that the plate of tube R is connected electrically to the oscillating circuit II. Hence the oscillating voltage due to circuit II is superimposed on the plate voltage of R. Now, when the plate voltage of R

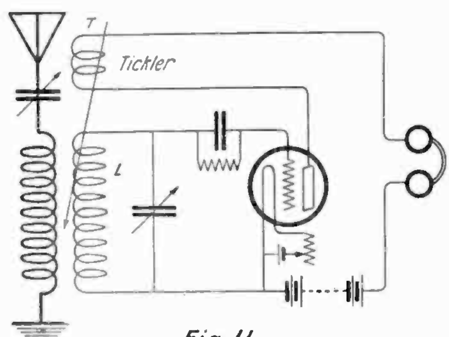


Fig. 11

Simple Regenerative Circuit.

is increased, the regenerative effect is correspondingly enhanced, while when it is decreased, regeneration decreases; if it is sufficiently decreased, regeneration disappears. When the positive half of the oscillating voltage due to circuit II is applied to the plate of R, the plate voltage increases and super-regenerative effect is secured with enormous amplification, while when the negative half is applied, the circuit does not regenerate, and hence the troublesome self-oscillations are not developed. The frequency of the oscillations in circuit II may be adjusted so that maximum amplification is secured, which frequency will be such that for the period of time which it takes for circuit I to break into self-generated oscillations, the positive half of the oscillating voltage due to circuit II is applied

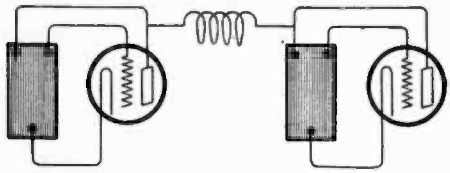


Fig.12

Super-Regeneration May be Accomplished by Variation of the Plate Voltage of the Amplifier.

to the plate of tube R; and at the instant the tube is about to oscillate the negative half of the oscillating voltage due to circuit II is applied to the plate of tube R.

The second method of periodically changing the effective resistance of the receiving circuit, so that it is alternately negative and positive, is by varying the resistance of the grid circuit of the tuner circuit. This is shown in principle as follows: Fig. 13 shows again the regenerating tube R with its associated circuit I, and the oscillating tube O with its associated circuit II. It will be observed that a point of the oscillating circuit II is connected to the grid of circuit of tube R. During the negative half of the oscillating voltage wave from tube O, a negative voltage is applied to the grid of tube R; hence there are no losses in the grid circuit, and if the tickler in circuit I is very closely coupled, super-regeneration is secured with high amplification. On the positive half of the voltage wave from tube O, the grid of R is positively charged, high losses take place in the grid circuit of R, which means a high positive resistance in circuit II, and hence any tendency of circuit I to generate self-oscillations is destroyed.

The third method of securing the requisite alternate change of circuit resistance from positive to negative is a combination of both of the above methods.

The exact value of the frequency at which the circuit resistance varies from positive to negative—namely, the frequency of oscillations generated in circuit II, is a matter which depends upon what is being received. Thus, for radio telephone signals or signals which are modulated at the transmitter it is necessary that the frequency be above audibility so as not to interfere with the

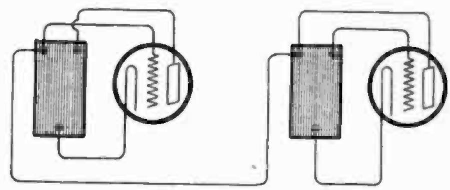


Fig.13

Another Method of Super-Regeneration Consists in Varying the Resistance of the Grid Circuit.

incoming modulated signals. For C. W. signals, which have not been interrupted at the transmitter end an audible frequency may be used.

Radio Frequency Amplification

By John M. Avery

Since a triode will repeat in its plate circuits, with increased amplitude, currents of any frequency impressed on its grid, it may be used as an amplifier of either radio or audio frequencies, in conjunction with some detecting device, preferably another triode. Briefly, if amplification is is desired at radio frequencies, the radio frequency amplifying triode is connected in such a manner as to boost the incoming signal before it reaches the detecting device, while for audio frequency amplification it is connected in such a manner that it receives the incoming signal after detection.

Futhermore, the sensitivity of a triode as a detector varies very nearly as the square of the voltage applied to its grid. It will be seen then, that if an extremely sensitive receiver is desired for long distance reception, radio frequency amplification may be preferable while if very strong signals are desired from those already detectable, audio frequency amplification is the preferable method.

The general trend of present-day radio seems to be toward decreased power at the transmitting station and increased sensitivity at the receiver, and at the same time, toward the spanning of great distances with a minimum of power. It is in these instances that the effectiveness of radio frequency amplification is most appreciated, and with it, we will be concerned in this article.

With every change in wave-length there is a corresponding change in its radio frequency component, and the shortest wavelength in practical use today bears a frequency relation to the longest wave-lengths of about one hundred to one. Due to this wide frequency range which it is necessary to amplify in order that radio frequency amplification may be applied to any radio station which may be operating today, different manufacturers have resorted to different expedients as inter-valve couplings. In general these may be divided into the following classes:

1. Resistance coupling.
2. Choke coil coupling.
3. Tuned impedance coupling.
4. Air-core transformer coupling.
   a. Aperiodic.
   b. Tuned.
5. Iron-core transformer coupling.
   a. Aperiodic.
   b. Tuned.

These divisions are merely arbitrary, many of the inter-valve couplings at present utilized being a combination of one or more of these divisions, as will be noted later.

thousand, however, the amplification may be found to be less than unity, i.e., a decreased signal strength will result. It has been shown that this is due to the high internal capacitance of our American triode, which, though small in itself, is markedly detrimental in this type of amplifier. French experimenters have constructed special valves for use with this circuit in which the grid and plate leads enter the tube through the side walls, rather than through the base, decreasing this capacity value to negligibility.

The circuit diagram shown in Fig. 1, represents the proper connections for a resistance coupled amplifier of four stages, and a triode detector. This is probably the easiest type of amplifier to construct, and should be of especial interest to those attempting to receive foreign stations working

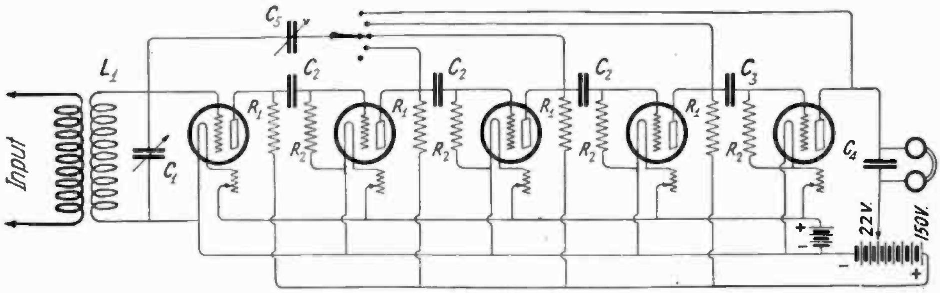


Fig.1

A Four Stage Resistance Coupled Radio Frequency Amplifier. Successive Stages are Controlled by a Switch.

With the exception of utilization in the Armstrong super-heterodyne receiver, resistance couplings do not seem to be in favor in the United States, although they are almost universally used in Europe, particularly in England and France, experimenters in the latter country using them to cover the entire wave-length band in present use.

on long wave-lengths (2,500 to 20,000 meters). Referring to the diagram, L-I is the normal secondary of the receiving transformer, with its tuning condenser, C-I. The grid condensers of the amplifier tubes, C-2, have a capacity of .0005 mfd., and the detector tube, C-3, a capacity of .0001 mfd. The coupling resistances, R-1, the main feature of this circuit, are non-inductive re-

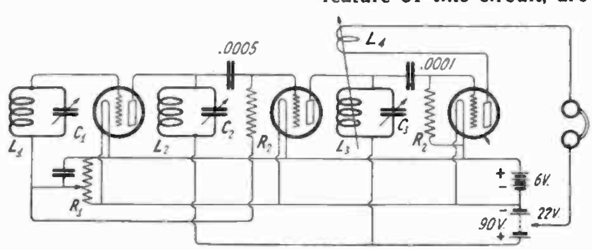


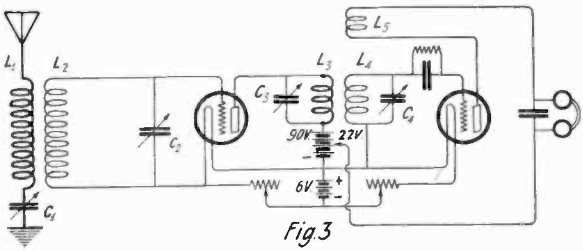
Fig. 2

Circuit of a Tuned Impedance Amplifier, Using Fixed Inductance and Variable Capacities.

Resistance coupled amplifiers function well at wave-lengths over one-thousand meters when employing the average American triode, with increasing efficiency at the longer wave-lengths. At waves below one

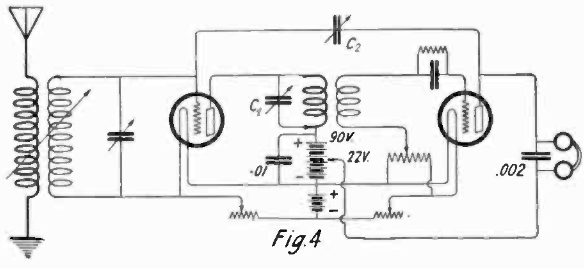
sistances of 50,000 ohms each. These may be lavite units or any other type having a constant value. Resistances R-2 are the normal grid leaks, connected between the grid and the negative filament terminals in the amplifying triodes, and between the grid and the positive filament terminal in the detector. They have a value of one megohm (one million ohms) each.

A fixed condenser is shown in shunt to the head-phones at C-4, having a capacity of .001 mfd.



Cascade Amplification Employing Loosely Coupled Inductances. Variable Condensers are Provided for Tuning the Respective Circuits.

At C-5 a variable condenser having a maximum capacity of about .0001 mfd. is connected, attaining energy feed-back from either the amplifiers or the detector tube into the first amplifier, through the action of which either oscillation or regenerative amplification is obtained. A five-point switch is shown for selecting the amplifier tube through which the feed-back is desired, and having an "out" position. In the construction of this switch space the contacts well and widely separate the leads from it, or undesirable oscillation may



A Circuit Employing the Usual Inter-Valve Amplifying Transformers. Additional Amplification is Obtained by Feeding Back the Resultant Energy Through Condenser C2.

occur in the amplifier. Use nothing but mica or air dielectric fixed condensers in the various grid circuits. The use of paper condensers will introduce boiling and frying noises.

The amplifier just described may be successfully combined in a super-heterodyne receiver without changing any of the values indicated above.

Small choke coils may be substituted for the 50,000-ohm resistances in the amplifier just described, attaining practically equal results. The author utilized the bobbins of several sets of 2,200-ohm Federal receivers for the purpose after having dismantled the receivers and removed the bobbins with their soft iron cores from the aluminum cases and the magnets. Two bobbins (the complete electro-magnet system of a single receiver) were connected in series and in the amplifier plate circuits, and mica condensers of .002 mfd. substituted for the normal grid condensers described for the resistance-coupled amplifier. With the circuit thus connected, good amplification was secured at a wave-length of 1,500 meters, and both regenerative amplication and self-oscillation were attained down to 500 meters wave-length, through proper adjustment of condenser C-5. The only advantage apparent to the writer, however, was economy of plate voltage which while using VT-1 tubes in both cases, was only 70 to 90 volts with the choke coils as compared to 150 volts with the resistances.

Particularly efficient as intervalve couplings are tuned impedance circuits, properly connected. Referring to the circuit diagram, Fig. 2, L-1, C-1, is the normal secondary tuning circuit. To this is directly connected an amplifying triode, having in its plate circuit a tuned circuit L-2, C-2, the electrical values of which must correspond to those of the secondary circuit, L-1 C-2. The direct current from the supplementary plate battery B-1, finds a path of low resistance through the inductance of coil L-2 but the combination of the coil condenser, when tuned to any particular frequency, form a practically infinite impedance to that frequency, with the result that the radio frequency energy is impressed on the grid of the next triode in the cascade, through its grid condenser. Due to the fact that only frequencies approximating that to which the impedance circuit is tuned are amplified, great selectivity will be found to be a feature of this circuit. As a matter of fact, the tuning becomes so sharp that more than two such stages are difficult of adjustment. For additional regenerative amplification or the reception of undamped waves, a tickler coil may be included in the plate circuit of the detector triode as at L-4, coupled magnetically to either L-3 or to L-1. Grid leak resistances R-2 may have values of one megohm, and the stabilizer R-1 about 200 ohms. The purpose of the stabilizer is to prevent undesirable oscillations from being set up in the amplifying circuits when the impedance coupling circuits are in resonance. An enterprising firm has recently placed similar combinations of an inductance with a variable condenser for use in this circuit on the market, having a wave range of from 200 to 600 meters. Should the experimenter desire to construct such an amplifier, it is recommended that honeycombs of the "duolateral" type be used for the inductances. Since the wave-length range of this device is dependent entirely upon the frequency to which the impedance circuits can be tuned, the following table of duo-lateral coils has been prepared as being suitable as impedances when shunted by a variable condenser of .001 mfd:

TABLE I
Duo-lateral Coil Values for Tuned Impedance Amplifier

Wave-Length Range	L-1, L-2, L-3,	L-4
150— 350	DL 25	DL 35
300— 700	DL 50 or 75	DL 50
450— 1,000	DL 100	DL 75
800— 2,000	DL 150	DL 100
1,750— 4,000	DL 250	DL 150
4,000— 8,500	DL 500	DL 250
6,000—12,500	DL 1,000	DL 500
12,000—20,000	DL 1,500	DL 750

A variation from the inter-valve coupling, just described, lies in the use of loosely coupled tuned circuits between the tubes, in which case the energy is transferred from the plate circuit of the preceding triode into the grid circuit of the second by induction. Ordinary receiving transformers (improperly, "loose-couplers"), having both the primary and secondary windings shunted by variable condensers for wave-length adjustment purposes may be used. The circuit diagram is represented in Fig. 3. In the diagram, L-1, L-2 are the windings of one receiving transformer tuning the antenna and first triode grid circuits to resonance with the desired station. At L-3, L-4 is a second tuning transformer coupling the amplified energy from the plate circuit of the first amplifier tube into the grid circuit of the detector tube (or another amplifier). A tickler coil L-5, may be coupled to L-4 for further regenerative amplification or for self-heterodyne as a beat receiver. By selecting large values of inductance at both L-2 and L-4 (as compared to their shunt capacitances), a favorable "voltage step-up" action may be attained, and this in conjunction with proper coupling between L-3 and L-4

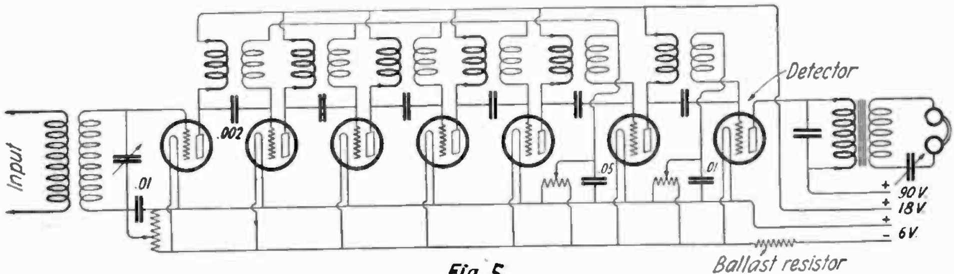


Fig. 5

A Radio Frequency Amplifier Circuit Using Semi-operiodic Coupling Transformers, Doing Away With the Necessity of Variable Condensers for Tuning.

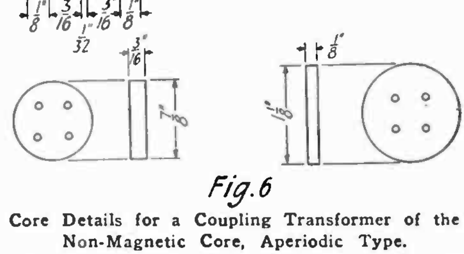


Fig. 6

Core Details for a Coupling Transformer of the Non-Magnetic Core, Aperiodic Type.

will result in enormous signal strength from signals formerly entirely inaudible. While more than one or two such amplification stages are undesirable, due to the extremely critical tuning, for such purposes as reception at a predetermined wavelengths, for which the entire receiver is calibrated, as in radiophone work or in the working of telegraph schedules between stations, it may be recommended or even preferred. The author recently assembled a receiver using four such stages, with stabilizers, and obtained some remarkable signal strengths from Pacific Coast stations in New York City.

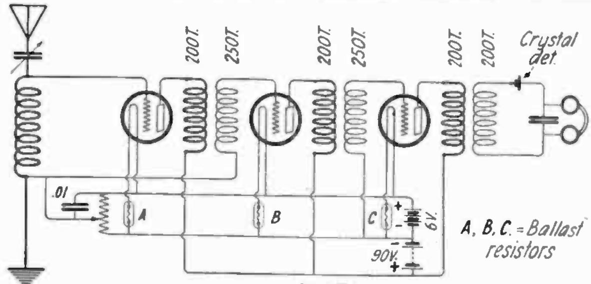
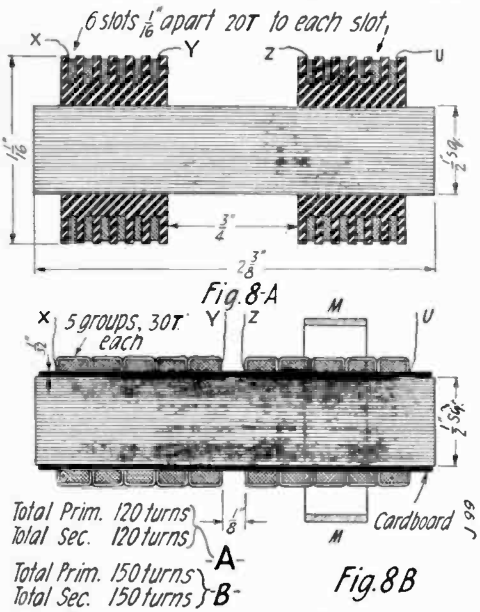


Fig. 7

Aperiodic Type of Transformers Designed for 600 Meter Work Are Used Here. The Number of Turns for Each Winding is Designated.



The Constructional Details of Two Iron Core Transformers are Shown Above. The Copper Ring M in Fig. 8B Serves to Broaden the Effective Wave-length of the Transformer.

It appears that two-coil intervalve transformers are now the more popular type among manufacturers, and although they have all been developed from the circuit just described many variations have entered into their construction increasing in some respects their effectiveness. A great many radio frequency amplifying transformers have appeared on the amateur markets on both sides of the Atlantic, and it is noted that the general trend is to design them so as to have fair efficiency over rather limited wavelength range, and being equipped with a plug system so that other wave-length range transformers may be easily substituted in some sort of mounting. American manufacturers equip their transformers with standard four-prong plugs so that they may be plugged into ordinary triode sockets of the types supplied on the American market, while British manufacturers equip theirs with four pins to plug into the standard four-prong valve holder in use there.

Fig. 4 represents a two-tube receiver of English design, in which a two-coil intervalve transformer is used. The transformer, designed to cover a limited wave-length range, is supplied in eight different sizes in order to cover the wave-length range of 200 to 20,000 meters. They are wound with a turn ratio of 1 to 1 on an ebonite form about an inch in diameter with No. 44 S. W. G. enameled copper wire, the number of turns varying with the wave-length range. Maximum signal strength is attained by tuning the primary of the transformer by means of a shunt variable condenser C-1 to the frequency of the wavelength it is desired to amplify. Additional amplification is then secured by a feed-back condenser C-2, connected between the plate of the detector triode and the grid of the amplifier triode, as shown.

With the aim of eliminating the necessity for these additional tuning controls, various types of aperiodic or semi-aperiodic transformers have been developed.

One type, a British development, has an air core and a ratio of 1 to 1 wound with No. 45 SWG Eureka resistance wire to a resistance of about 24,000 ohms for each coil. This resistance value is above the critical value, and renders the transformers nearly aperiodic, and when connected, as per the diagram Fig. 5, have a working range of from 1,500 to 25,000 meters. Small mica or ebonite condensers are connected between adjacent plates and grids as indicated, the whole forming a combination of transformer coupled and resistance-capacity coupled amplifier. A seven-stage amplifier on this principle is used at practically all the commercial stations for transatlantic reception.

Fig. 6 represents the core details of a very easily constructed and at the same time very efficient intervalve coupling transformer, of the non-magnetic core, aperiodic type. The five discs indicated in the drawings are turned out from bakelite or ebonite and bolted together by means of 6/32 round head brass machine screws as shown. The windings are to consist of No. 38 enameled copper wire, the primary and secondary being wound in the separate grooves A and B shown. A three-stage amplifier, recently made by the writer for commercial 600-meter reception, brought in signals from Bar Harbor to Miami during daylight hours, and from Cape Race to Colon, and Darien, Panama, with strong intensity at night. The efficient wave-length range was found to be from 475 to 800 meters, with peak efficiency at 600. The number of turns used for primary and secondary windings are shown in the diagram, Fig. 7.

be arranged to vary both windings simultaneously as follows:

Switch Point	Primary Turns	Secondary Turns
1	70	75
2	80	87
3	95	98
4	120	125
5	150	175
6	200	250

If several stages of amplification are used, it would be quite possible to mount the transformers and their switches in tandem, so that simultaneous turn variation could be accomplished from a single control knob, an idea, which, while not original with the author, certainly has its merits.

Several radio frequency transformers have appeared on the market employing an iron or other magnetic core. In some forms of transformer a laminated thin sheet iron core similar to that usually employed in the construction of audio frequency amplifying transformers is used, either with a closed or with an open magnetic circuit, while others have for a core finely divided soft iron imbedded in paraffin. This latter method, I believe, originated in England, where, in one form of amplifier utilizing a number of stages, this paraffin-iron core is so arranged that it may be varied in and out of the transformer windings, changing the inductance and impedance of the

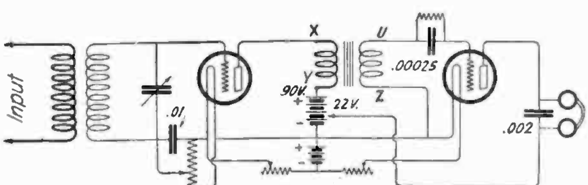


Fig. 9

One Stage of Radio Frequency Amplification Employing the Iron Core Type of Transformer.

Since the wave-lengths at which highest efficiency is attained varies with the number of turns in the windings, certain manufacturers have devised switching arrangements whereby portions of the windings may be cut out of circuit. To cover the range from 175 to 600 meters with greatest efficiency the author would recommend that two small 6-point switches

windings to the most favorable value for the desired wave-length. The most important effect of the introduction of a magnetic core is that the efficient wave-length range is broadened.

The constructional details of two American-made iron core transformers will, no doubt, be of interest.

The detailed cross-sections of both transformers will be seen in Fig. 8. where a great similarity will be noted. For the transformer of Fig. 8A an efficient wave-length range of from 175 to 450 meters is claimed, with peak efficiency at 360 meters, while for that of Fig. 8B, a range of 200 to 500 meters is claimed, with the same peak. Both transformers, however, have proven to be of very high efficiency in practice.

The core for transformer of Fig. 8A is composed of thin, soft iron laminations, measuring ½"x⅝", thoroughly varnished and piled up in a stack ½" high. Two special bakelite bobbins fit tightly over this core as shown in the cross-section, and are so arranged that the adjacent primary and secondary coils are separated by ¾". Six narrow grooves are cut into each of the bakelite bobbins, each spaced 1/16" from the next. Twenty turns of No. 38 enameled copper wire are wound into each slot so formed, the series of six slots being wound in the same direction and without breaking the wire.

The completed transformer will have a primary and secondary winding, each consisting of 120 turns of wire. The starting and finishing ends of the wire have been labeled in the drawing "x, y, z, u," and in connecting up the finished transformer the method of connection indicated in Fig. 9 must be followed closely.

The core for the transformer of Fig. 8B is a duplicate of that of Fig. 8A, but there is a slight difference in the windings. Here the windings, which are of No. 28 S. C. C., consist of a primary and a secondary, each of five stagger-wound coils of 30 turns each, a total of 150 turns to each winding. In this second transformer the windings are placed directly upon the iron core, and insulated from it by a single thickness of heavy waxed pasteboard. The wire leads, which have been labeled in a manner similiar to that for the previous transformer are connected in the same manner as indicated in Fig. 9.

A copper ring M is placed over the windings, and serves to broaden the effective wave-length range of the transformer. If this ring is adjusted while signals are being received, maximum amplification can be centered at any desired wave-length.

It will be found, especially when more than one stage of amplification is employed, that under certain conditions of filament adjustment and plate voltage, oscillations will be set up in one or more of the amplifier stages. Occurring only in one stage they manifest themselves as a "mush" note in the head phones, whether detection is done with a triode or a crystal rectifier. If more than one stage in the cascade amplifier is set into self-oscillation a squeal or "beat-note" will be heard in the head phones. As a preventative of such self-oscillation a voltage divider (commonly, a "potentiometer"), may be shunted across the filament battery terminals, with a sliding contact connected to the lower ends of the secondary windings as shown in Figs. 7 and 9.

A half-microfarad telephone condenser may be connected across the voltage divider in order that it will not have a damping effect on the tuned circuits.

Damping

By Louis Frank

There are certain subjects which are of basic importance in the consideration of any radio topic or problem, and these subjects should therefore be thoroughly understood by the amateur at the start of his radio career.

A simple example drawn from popular everyday mechanics will show at once both the significance and importance to radio of this subject of damping. Suppose we have a pendulum attached to some point of support as in Fig. 1, and suppose that the pendulum is swinging. The distance of the bob from the center line OO to the farthest outside point of any swing, as OA, is called the *amplitude* of the swing. Suppose now we arrange a scale over which the pendulum bob swings, so that we can study the motion of the pendulum more easily. Suppose at the start of the swing that the pendulum swings to point A on the scale, then its initial amplitude will be OA. The pendulum now begins to move back towards C and when it reaches O its energy of motion carries it on towards point B, on the other side of the starting line OO. But due to the fact that the motion of the pendulum meets with numerous resistances, such as the friction at the point of support P, air resistance, etc., the pendulum bob will move a distance OB which is slightly less than the initial distance OA. When the bob reaches its second position OB, it comes back again on its return path towards O and from there it continues on towards A. This time the bob moves only a distance OC which is less than the distance OB for

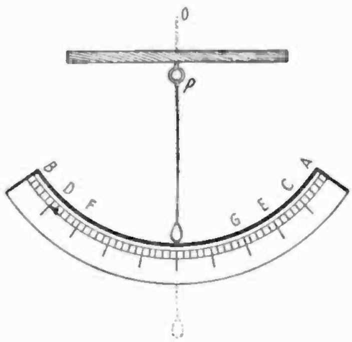


Fig.1

An Oscllating Pendulum Illustrating the Subject of Damping.

the same reason, namely, loss of energy due to resistance to the motion of the pendulum. Thus the bob keeps swinging to and from the axis OO, but each time the amplitude steadily decreases due to the above mentioned resistances, until the pendulum comes to a stop, when the amplitude is zero.

A visual comprehension of what occurs may be had as follows: Suppose we draw a line OO as in Fig. 2, which line we will call the axis. At right angles to this another line is drawn along which we will scale off distances OA, OB, OC, etc., on either side of the axis, equal to the various amplitudes of the swings of the pendulum. Above the axis OO indicates that the swing of the pendulum takes place to the right of the point of support, and below indicates that the swing is to the left. If the position of the pendulum bob is thus plotted graphically for each moment we will have a curve such as shown in Fig. 2, which shows that the amplitude of the pendulum oscillations gradually decreases to zero.

This reduction of the amplitude of swing is said to be caused by the *"damping"* of the pendulum and the swings or oscillations are said to be *"damped."* This *damping* was seen to be due to the various resistances to the motion of the pendulum. The greater these resistances are the greater will be the damping of the swings. Thus suppose that to the pendulum bob there is attached a sheet of cardboard or other material having a large surface area. There will then be a greater air resistance to the motion of the pendulum since the entire pendulum has to move through a great volume of air. If the amplitudes of the swings are now plotted in accordance with the method of Figs. 1 and 2, we will have a motion of the pendulum as represented in Fig. 3, where the decreases in amplitude are much greater and the oscillations cease in a very short time. Such a pendulum is said to have a "high damping" or a "high decrement," while a pendulum which swings as in Fig. 2, in which the decrease in amplitude is small from oscillation to oscillation and in which it takes a long time for the amplitude to decrease to zero, is said to have a "low damping or decrement." If there were no resistance interposed to the motion of the pendulum, or in other words if there were no "damping" or "decrement," there would be no falling off in amplitude at all.

The application to radio will be immediately evident. In radio we deal with electrical circuits containing capacity, inductance and resistance, and in these circuits there flow oscillating rado frequency currents. Just as in the case of the pendulum the resistance in the circuit obstructs the flow of the electric current and dissipates a portion of the energy. As a result the successive amplitudes of the oscillating current grow smaller and smaller and finally decrease to zero, due to the "damping" or "decrement" of the electric circuit. That is, this decrease in amplitude will take place if the circuit is left to itself, unless the current supply is continuously replenished by some outside source.

Thus we see that DAMPING is that property of an electric circuit which results in a decay of energy in that circuit. If the decay of energy is very rapid, or would be very rapid if allowed to decay, we say that the circuit has HIGH DAMPING or HIGH DECREMENT. If the decay of energy is slow the circuit has LOW DAMPING or DECREMENT. Circuits having low and high damping would then have current amplitude curves as shown in Figs. 2 and 3 respectively—when the currents are actually damped.

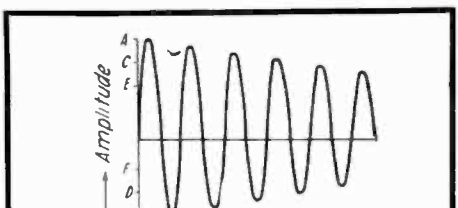
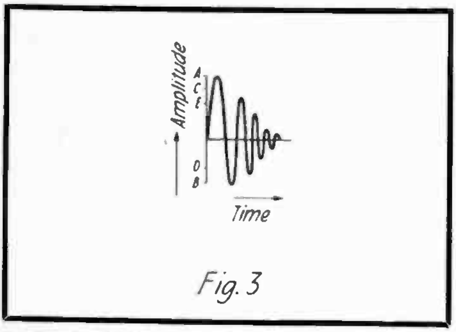


Fig. 2

A Visual Illustration of the Damping of a Pendulum Movement Due to Resistance.

This 'ast clause should be carefully pondered over in order to fully understand the significance of the *idea of damping.* There are many cases in radio in which the current amplitude in a radio circuit remains constant—does not decay. This does not necessarily mean that the circuit has no damping. The circuit may have damping and does dissipate energy, but this dissipation of energy—which would otherwise cause a decay in the current amplitude—is replenished and compensated for by an outside source of energy which maintains the current amplitude constant. Thus, to come



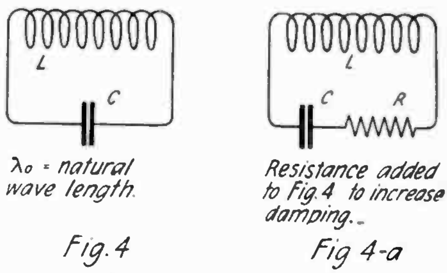
A Graphic Study of Highly Damped Oscillations with a Corresponding High Decrement.

back to our analogy of the pendulum, if an outside source of mechanical energy, say a person, gave the pendulum a push at the proper time always, its amplitude of swing would not diminish but would remain constant, in spite of the air resistance and the dissipation of energy due to it. The external source of energy, namely, the person, is always making up for this loss of energy by giving the pendulum a push. In other words the dissipation of energy still is there, and the pendulum still has its inherent damping. The more the resistance to its motion, the greater is the damping of the pendulum, and the more the person has to push the pendulum to make up for it. The damping of the pendulum asserts itself in a decrease of the swing only when left to itself after the first push. Similarly in radio, the damping of a circuit produces a decay in the current amplitude only when the circuit is left to itself after it has been given an impulse. But even if the current amplitude does not decay due to the help of an external source of electrical power, the damping of the circuit is present, and it exerts its various effects on the operation of the circuit as will be explained later. In other words the decay of energy due to damping takes place only when the circuit is left to itself after an electrical impulse has been imparted to it, *but the damping is present regardless of whether this decay takes place or not.*

While *damping* is the property of the circuit resulting in a decay of energy, *decrement* is the quantitative measure of this decay and tells just how much the current amplitude decreases from cycle to cycle for any given circuit.

What are the factors on which the damping, and hence decrement depend? In the first place from our explanation of the meaning of damping given above it will be clear that it depends upon the resistance of the circuit, since resistance always dissipates energy. The damping or decrement of a circuit is directly proportional to the resistance of the circuit, regardless of what the resistance is. Thus it may be the resistance of a spark gap, ohmic resistance of coils, resistance due to dielectric losses in condensers or insulators, antenna or ground resistance, resistance due to corona loss and brush discharge and so on. In other words the total resistance of a circuit due to any causes determines the damping.

If there is an extraction of energy from the circuit due to other causes there will be an increase in the damping. For an extraction of energy from a circuit is equivalent to inserting a resistance in the circuit which resistance dissipates the same amount of energy as was previously extracted. There are two main causes, apart from the above mentioned resistances, for the loss of energy in a circuit. These are (1) radiation and (2) the presence of neighboring circuits. In the first case energy is radiated from a circuit and therefore extracted from the circuit, and results in an increase in the decrement of the circuit. Obviously some circuits radiate more than others



Left—A Circuit with Low Damping. Right—Same Circuit with Added Resistance Giving High Damping.

and will therefore have a greater "radiation decrement." Antenna circuits have relatively high "radiation decrements" while closed circuits have small "radiation decrements." In the second case the presence of neighboring circuits results in increased damping due to the fact that the neighboring circuit extracts energy by induction. Obviously the closer the coupling between the two circuits the more will the extraction of energy be and hence the greater the damping.

The damping is found to be dependent also upon the ratio of capacity to inductance in the circuit. Without going into the mathematical analysis, it may be said that it is found that the ratio of the total energy dissipated in a circuit to the total energy transferred in one cycle between condenser and inductance is given by the "decrement" of the circuit and is equal to

$$\text{decrement} = \delta = \pi R \sqrt{\frac{C}{L}}$$

where R is the total circuit resistance due to all causes mentioned above, C is the capacity of the circuit, L is the inductance of the circuit.

Now that we have an understanding of the meaning of damping and know the circuit factors on which it depends let us consider its various effects in radio design and operation and its importance.

In spark telegraphy the importance of damping is very great. The presence of a spark gap in a radio circuit increases its damping greatly for a spark gap has a very high resistance. Except in a few special cases the sparks are not timed to keep the current at a constant amplitude, and as a result the current amplitude decays after the fashion of the curves in Figs. 2 and 3. This damping in a spark transmitter results in great inefficiency. The greater the damping the greater the inefficiency. For consider the two cases shown in Figs. 2 and 3, the first being a circuit having low damping, the second a circuit with high damping, and suppose that the same power was imparted to each circuit. Evidently this power is more rapidly petered out in the highly damped circuit than in the other. Thus the circuit with the low damping radiates its power over a longer period of time than the other and hence will carry farther. In other words a low damped circuit uses a given amount of power over a longer period of time than highly damped circuit, and hence will be more efficient. A highly damped circuit gives just one rapid impulse to the antenna and then promptly dies out, whereas the low damped circuit uses the same power more economically and makes it last longer.

Another harmful effect of damping will be seen from the following. Suppose we have a circuit as shown in Fig. 4, containing only an inductance and capacity. This circuit will have a definite frequency, since both inductance and capacity are fixed. If currents of different frequencies are passed through this circuit and measured, and then plotted as shown in Fig. 5, we will have a so-called "resonance" curve. This shows that the circuit responds very strongly to currents of its frequency, but very weakly to currents of other frequencies even though near its own frequency. In other words this circuit has a sharp resonance curve and will therefore tune sharply to any incoming radio waves. Suppose now we add some resistance in this circuit and again obtain its resonance curve. The curve will now appear as in Fig. 6, showing that its curve is now broader and it responds strongly to a wide band of wave lengths. In other words by increasing the resistance of the circuit, which is the same thing as increasing the damping or decrement of the circuit, we have changed a sharply tuned circuit into a broadly tuned circuit. This is very bad for radio transmission or reception. In the case of spark sets we have these broadly tuned waves on account of the high damping. Consequently even if a receiving circuit is not tuned to the transmitting the transmitter will interfere with it, because it transmits over a very wide band of wave lengths. It is for this reason that spark transmitters today are coming into great disfavor because they cause most of the intereference with people who are listening to the broadcasting.

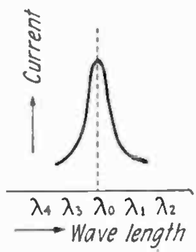


Fig. 5

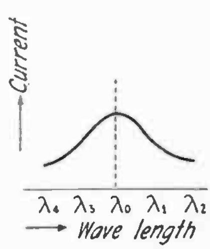


Fig. 6

Left—A Resonance Curve Plotted Against the Circuit of Fig. 4.

Right—Curve Corresponding to the Circuit of Fig. 4-a.

However not only does this apply to the highly damped, broadly tuned spark transmitter but the same reasoning applies to the receivers. For receivers may be poorly designed to have high resistance and the wrong ratio of inductance and capacity. As a result a receiver may also have a high damping and hence be broadly tuned. Thus even if a transmitter has a low decrement the receiver may be interfered with because its own tuning is broad. This may occur even if the transmitter has a continuous wave. Here then we have a case where the current amplitude is not damped, and in which the damping effect of a circuit is nevertheless displayed. We see then the importance of having a very low damping both in transmitters and receivers for less interference is thereby created.

Often the high damping is due to poorly designed antenna and ground system. Care should be taken that these two very important parts of the set have as little resistance as possible. The actual design of these two parts will be taken up in a special article on antennae in this book.

In the case of transmitting antennae, what is desired is maximum radiation of energy.

Radiation of energy, we saw, is one cause of high damping since energy is extracted from the circuit. Thus in transmitters the object should be to decrease the wasteful resistance and hence decrease the damping due to this, but to also increase the radiation decrement, for this will mean that more energy is being radiated. Here is one case where high decrement is desirable.

The control of the damping factor is very important in the design of wave meters. The accuracy of wavemeter measurements depends largely upon the sharpness of tuning of the wavemeter. We saw above that a circuit with high damping does not tune sharply. Hence it is important to design wavemeters carefully so that their decrements are low. The coils must be wound to have a minimum resistance in the first place. Secondly the ratio of capacity and inductance must be proper. From the formula given above for the decrement of a circuit we see that high capacity increases the damping. Hence the value of the capacity must be kept within bounds. Further the inductance must not be too low or else the damping will increase. However, a high inductance means more wire and therefore high resistance. In other words there is conflict here which must be properly solved if low damping is to be secured.

In the above cases we have seen how a high damping factor was very undersirable and produced harmful effects. There are cases, however, where a high damping is very desirable and these will now be considered. First in the case of telegraphy on sea when it is desired to transmit distress signals when the ship is in danger. In sending distress signals it is necessary that every possible ship on the sea should hear this signal so that aid will be promptly forthcoming. However it is possible that the receivers on these ships will be tuned to different wavelengths. Hence in order to have the distress signals come in on all these receivers the wave radiated from the transmitter of the distressed ship should be very broadly tuned so that it covers a wide band of wave lengths. We saw above that high damping resulted in a broad wave. Hence in such cases the broad wave or high damping is not only desirable but necessary. In such cases the operator frequently works with his spark gap directly in the antenna which results in very high damping and very broad tuning.

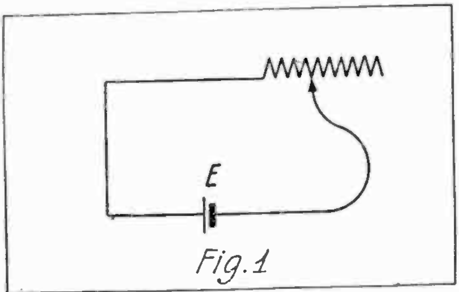
High decrement is also of importance in the reception of radio telephony. Except for the special case cited in the previous paragraph best results can be obtained in telegraphy only if the decrement is low. In telephony it is desirable that the decrement be high. The reason for this is that with low decrement the speech received on the receiver is indistinct and drummy. In order to receive faithful copies of speech it is essential that the receiver should follow the variations of speech very closely and without any lag. Now speech variations take place very rapidly, hence the transmitters and receivers must be so designed that the currents in them follow these variations and fluctuations. We saw above that in a low decrement circuit the current persists and is sustained for a very long time. It would therefore be very difficult for a low decrement circuit to follow changes and fluctuations very rapidly, since the currents in such circuits tend to persist. However in a high decrement circuit we saw that the current does not persist and is not sustained. Hence a high decrement circuit is more capable of following fluctuations and variations rapidly and without lag. It is for this reason that best speech is obtained on receivers having high decrements.

In general, however, for most work in radio communication low damping is desirable. It is for this reason that spark equipment and other apparatus producing damped waves are fast going out of use and in their place is coming continuous wave apparatus. A minor advantage accruing from this is that calculations become somewhat simpler. With damped waves it was always essential to take into consideration the decrements of transmitter and receiver in all calculations, and this made things very cumbersome and complex. With undamped waves this is no longer necessary and calculations approach more nearly those of simple alternating currents.

Matching Impedances

By Prof. W. Palmer Powers

It is quite generally known that certain vacuum tubes operate exceptionally well with certain amplifying transformers, and it is therefore evident that there is some feature in the design of such transformers which is responsible for this result. There are, of course, many reasons why a certain



A Battery Connected To a Variable Resistance. The Current Flow Varies With the Variation of Resistance.

transformer may operate more satisfactorily. The question of designing a transformer to match a particular tube, however, brings out a fundamental fact which many of us have taken as more or less empirical. We are told that the plate impedance of the vacuum tube must be equal to the input impedance of the transformer for best operation. It is the purpose of this article to point out why this condition is desirable, and to discuss briefly the results when such a condition is not obtained.

Let us consider the case of a battery connected to an adjustable resistance as in Fig. 1.

The battery has a generated voltage of six volts (assumed constant), and an internal resistance of one ohm (assumed constant). Our problem is to determine the resistance of the external circuit for maximum power output. If we assume various values for the external resistance we can compute the total resistance by adding to this the internal resistance of the battery. If we then divide the total voltage by the total resistance, we shall have the current. The corresponding power output (watts) can then be computed by any of the following formulas: where W = power output, E = terminal volts, r = external resistance, and I = amperes.

Fig. 2 shows a table of assumed external resistances with their corresponding values of terminal volts, current and power output.

Fig. 3 shows how these quantities vary with the external resistance and indicates clearly that, for a particular value of external resistance, the output is a maximum. Considerable information can be gained from the study of this output curve. The output is expressed by the three equations given, and one should notice that they are identical statements. Equation 2, and equation 3 are readily reduced to equation 1. The curve of Fig. 3 brings out the fact that maximum power-output results when the external resistance equals the internal resistance. Just why this occurs can best be determined by inspection of the expression for power-output and noting how each factor varies with a change in external resistance.

Balancing the external resistance against the internal resistance produces a maximum power output. This is not the condition of maximum efficiency, but nevertheless it is desirable in many cases where output at any cost is wanted. It is interesting to note that when this adjustment is made, the losses equal the output and the voltage falls to one-half of its maximum value. This question

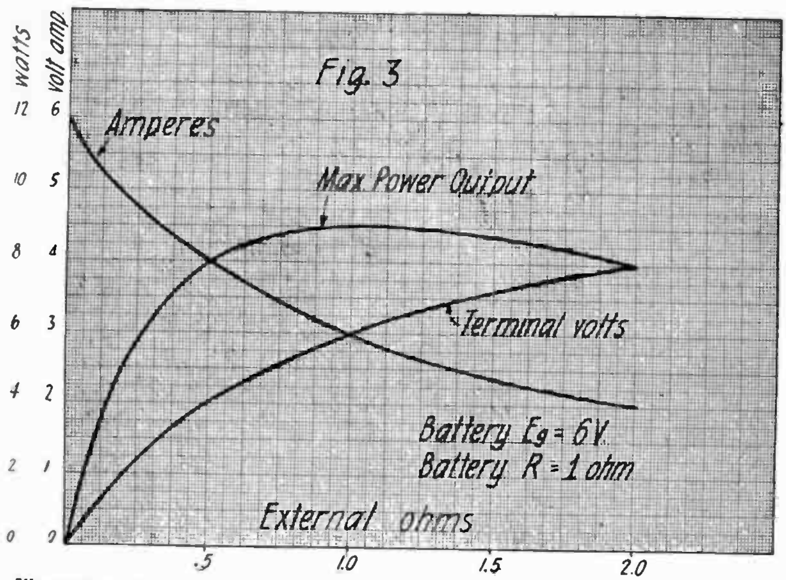
External Resistance	Total Resistance	Amperes	Power Outfit	Load Voltage
.0	1.0	.6	.0	1
.25	1.25	4.8	5.74	1.2
.50	1.5	4.0	8.0	2.0
.75	1.75	3.43	8.81	2.57
1.00	2.0	3.0	9.0	3.0
1.25	2.25	2.66	8.8	3.32
1.5	2.5	2.4	8.63	3.6
1.75	2.75	2.18	8.3	3.82
2.0	3.0	2.0	8.0	4.0

$W = E \times I$ Equation No. 1
$W = I^2 \times r$ Equation No. 2
$W = E^2 \div r$ Equation No. 3

of matching resistances comes up in many engineering problems, and one should not get the impression that it is applicable only to vacuum tube work.

The problem of a vacuum tube feeding a transformer is not vastly unlike a battery feeding a resistance. The tube may be considered as a source of voltage (E); this voltage operates through the plate circuit, the impedance being considered constant.* the tube (as in the battery) is equal to the current times the internal resistance.

Fig. 4 shows a diagram of a vacuum tube feeding a circuit which is general; that is, the load circuit contains resistance and reactance. Fig. 5 indicates the relations of



Curves, Illustrating the Relation Between Resistance, Volt-Amperes and Watts. The Maximum Power Output Is Seen To Be Slightly More, Above 1.0 Ohm, Than At the Point of the Arrow.

The impedance of the tube is equivalent to the internal resistance of the battery. The external circuit is equivalent to a resistance for power considerations. The maximum output (for a given voltage) will occur when the external ohms are equal to the internal ohms if the circuit is of the nature of a resistance. By inspection of the curve in Fig. 3 we see, however, that there is no serious loss in output if this value (equal to internal resistance) is exceeded. It is true that the external ohms may be twice the internal ohms without serious loss in output. In fact, most operators are familiar with the fact that when two telephone sets are connected in series the signal strength is only slightly reduced. This is due to the fact that the high impedance reduces the current; the reduction in current causes an increase in terminal voltage of the tube. Hence the energy per telephone set is not reduced to one-half of the original value. The terminal voltage is equal to the vector difference of the generated voltage and the loss of voltage in the tube. The loss in

* While manufacturers give approximate values of tube impedance, they are not strictly constant in value. For the purpose of study, however, we may to advantage consider the tube impedance as constant.

the various quantities (resistance and reactance ohms) for such a circuit.

In Fig. 5, r represents the *equivalent* resistance of the load, and x represents the *equivalent* reactance of the load. The true power delivered is given by the following equation which is simply the current squared times the resistance:

$$\text{Output} = E^2 r/(R+r)^2+x^2.$$

If x is reduced to zero the output will be increased. If we then make the external resistance equal to the internal resistance (R=r) the output will be a maximum. One may easily determine this fact by assuming various values for the external resistance, having assigned constant values for the voltage (E) and the internal resistance (R).

For the case of a load circuit of constant reactance the output will be a maximum when the external resistance is equal to the square root of the sum of the squares of the internal resistance and the reactance of the load. $r = \sqrt{R^2+x^2}$. This also may be seen if one assigns fixed values for E. R. and x in the above equation. It is interesting to note that this indicates also that the resistance values are to be made equal when there is no reactance.

For the case of constant power factor in the load (x and r being proportional) the maximum power output will result when the internal resistance is equal to the impedance of the load. This is quite a usual case, for example, a reactance coil of fixed winding space and fixed space factor. In such a coil, the reactance varies with the resistance. If the number of turns are doubled, the inductance is approximately four times the original value, the resistance is also increased four times because of the double length and the reduction in area by one-half.

In applying this idea of balanced impedance to the use of vacuum tube amplifiers, it is well to keep in mind that the desired result is *power* amplification. The tubes are ordinarily used as *power* amplifiers and are so arranged as to deliver maximum power. The voltage amplification is ordinarily obtained by the use of transformers, the transformer, of course, not being a *power* amplifying device. For minimum distortion, it is advisable to have no reactance in the load circuit. It is then apparent that the external load equivalent resistance should be equal to the resistance of the plate circuit of the tube.

To obtain the maximum output, we must arrange this balance between the internal and external ohms. Many circuits behave like simple resistance circuits for a certain frequency because of the fact that they are operating at resonance. Any tuned circuit comes under this classification. A tuned transformer (tuned radio frequency), or a simple tuned reactance coil operate as resistance units. It is possible to treat such circuits as resistances when matching them against a tube, the problem being solved once the equivalent resistance of the combination is determined. The equivalent resistance of a tuned reactance coil, is determined by obtaining the conductance of the combination (coil and condenser in parallel) and then taking the reciprocal of this term. The equivalent resistance of a tuned radio-frequency transformer (referred to

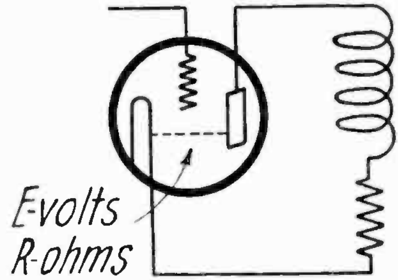


Fig. 4

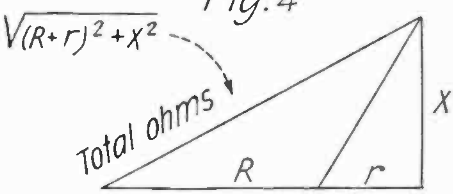


Fig. 5

A Vacuum Tube Feeding Circuit, Containing Resistance and Reactance, and Below It the Relation of the Various Quantities For Such a Circuit.

the primary circuit) is found by obtaining the conductance of the secondary (condenser and coil); taking the reciprocal and then dividing by the transformation ratio squared.

High Frequency Resistance

By L. R. Felder

The measurement of inductance and capacity with the aid of the C. W. oscillator is a relatively simple matter as compared to the measurement of resistance. This is because inductance and capacity, though they vary somewhat with frequency, may be considered as having practically constant value over the range of radio frequencies. Resistance, on the other hand, varies considerably with the frequency. Thus, a certain coil which measured 3 ohms resistance at 600 meters was found to have a resistance of 7.3 ohms at 200 meters. Furthermore, the effective resistance of a coil depends upon a variety of factors, such as distributed capacity of the coil, proximity of other coils and circuits, manner in which the coil is wound, etc. As a result, it is apparent that resistance and its measurement are worthy of special study.

The first important point to be made in this connection is the distinction between the resistance of wire for direct current and for alternating current. Experiment and theory show that the resistance of any given wire is less for direct current than for alternating current of high frequency, and that this resistance for alternating current increases as the frequency increases. This increase of the resistance with increase of frequency of the current is due to a phenomenon called "skin effect." The reason for this increase in resistance with frequency will at the same time make clear the reason for this peculiar name "skin effect." For the benefit of the novices and new amateurs it should be noted that the

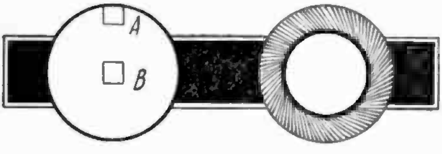


Fig. 1 Fig. 2

Fig. 1.—A Flow of Direct Current is Uniformly Distributed Over the Entire Cross-Section of a Wire. Fig. 2. An Alternating Current Flows Only Through the Outer Surface of a Wire.

larger the cross-section of the wire through which the current flows the less will the resistance of the wire be, and vice versa. With this important principle in mind, the explanation of "skin effect" is as follows: A direct current always flows in one and the same direction. This is why it is called a direct current. Since it does not change its direction of flow, the current has sufficient time and chance to diffuse and distribute itself uniformly over the entire cross section of wire. In other words (see Fig. 1), as much current flows through unit area of the wire at point A as at point B. Thus the entire cross section of the wire is used to conduct the current uniformly, the wire is therefore used most efficiently and its resistance at direct currents is a minimum. Suppose, then, that

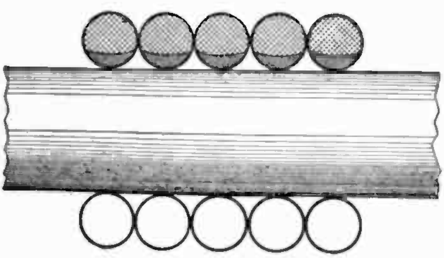


Fig. 3

The Current Density in a Coil of Wire is Greatest on the Inside as Shown by the Shaded Portions.

the current could only flow through a part of the cross section of the wire, say, for example, it could only flow through the outer portion of the cross section of the wire, the shaded ring in Fig. 2. Then, obviously, only a part of the cross section of the wire would be conducting the current, and, according to the principle emphasized above in this paragraph, the resisatnce of the wire would be greater for this current which traversed only a part of the cross section of the wire. This is what happens when alternating current of high frequency flows through a wire.

Alternating currents change their direction of flow through a wire; they are therefore called alternating currents. For a certain length of time—depending upon the frequency of the current—the alternating current flows in one direction through the wire. Then it reverses its direction and flows in the opposite direction through the wire, and so on. The current only flows in one direction a very short period before it reverses its direction. As a result the current is not given very much time to penetrate from the outside of the wire to the center, and, therefore, does not have the chance of diffusing and distributing itself uniformly over the entire cross section of the wire. Thus by the time the current has

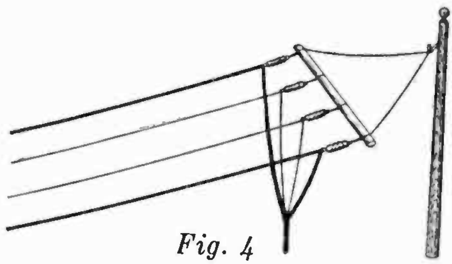


Fig. 4

Showing the Distribution of R. F. Current in a Four Wire Flat Top Inverted "L" Antenna.

penetrated to the bottom of the shaded ring in Fig. 2, it may reverse its direction and must begin again to bore its way in towards the center of the wire. Of course, the current distributes itself very rapidly, but it should be kept in mind that when we are dealing with radio frequencies we are dealing with frequencies of the order of 500,000 times per second, hence it can be seen that the alternations are so rapid that the current has a chance to flow only on the outside of the wire. Thus, for alternating currents, since only a portion of the conducting wire is used, that is, the effective cross section is smaller, the resistance of the wire must be greater.

If the above explanation is the case, it stands to reason that the greater the frequency of the current, that is, the more rapidly it changes its direction of flow, the less chance it has to penetrate to the center of the wire. Thus for very high frequencies, like radio frequencies, the current only has an opportunity to flow through the top layer of the wire, just through a skin on the wire, as it were. At these frequencies, then, the cross section of the wire utilized by the current is extremely small, hence its resistance must be very high, and increases with the frequency of the current. Since the current at radio frequencies only flows through a skin on the wire this phenomenon is called the "skin effect." This will make clear why direct current resistance is always much less than radio frequency resistance, and because of this "skin effect" at radio frequencies it will be clear why it is so important to keep down the values of the coil resistances in sets. We see now why such a statement as "The coil in my set

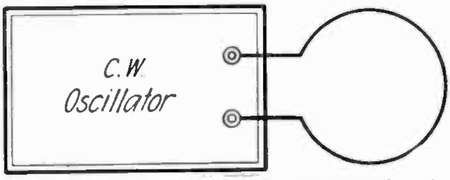


Fig. 5.—The C. W. Oscillator as Referred to in This Article is Represented by This Symbol.

has a resistance of 5 ohms" has no meaning at all, and may in fact be misleading. For the coil may well have a resistance of 5 ohms at direct current, while at the wavelength it is used, say 360 meters, its resistance may be as high as 10 ohms. Whenever one gives the resistance of an inductance coil, or any other item, for that matter, one should always specify at what wavelength it has this resistance.

The great importance attaching to this "skin effect" in high frequency work may, perhaps, be more evident when we consider that it manifests itself not only in ordinary conductors carrying current, but also in coils and antennae. For example, when a straight conductor is wound in the form of a cylindrical coil as in Fig. 3, there will result a redistribution of current throughout the cross section of the wire composing the coil. Both theory and experiment show that this redistribution takes place in the manner shown in Fig. 3, namely, the current density is heaviest on the inside of the coil wires, shown by the heavy shading, while it decreases as the outside of the coil wires is approached. The "skin effect" phenomenon in antennae is especially predominant in those having three or more wires, of forms other than the cage type.

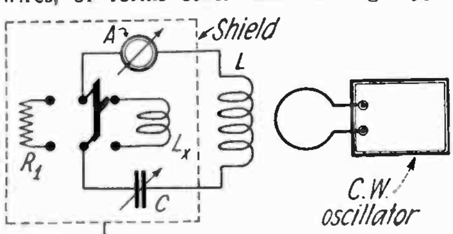


Fig. 6

Circuit of Apparatus Used for the Measurement of Resistance. In This Case a Standard Resistance is Employed.

Consider a four-wire antenna of the flat top type, say an inverted "L" antenna. The current flowing in the flat top behaves exactly in the same way as the current in a wire, namely, at radio frequencies it flows on the outside conductors. In the case of the antenna here considered there are two central wires and two outside wires, hence the current tends to flow more in the outside wires and less in the center wires. This "edge effect," as it is sometimes called when talking of antennae, is equivalent to a reduction of the effective cross section of the antenna wires, and hence results in increased resistance of the antenna.

These preliminary remarks should make it clear how important is a good understanding of the subject of resistance, and how important it is to be able to measure this quantity correctly. In the case of direct currents one can frequently calculate the resistance of a coil or wire almost as accurately as if one measured it. In high frequency work, calculation is almost always out of the question, due to such complications as distributed capacity in the coil, the manner in which the coil is wound,

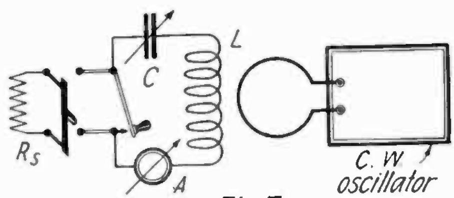


Fig. 7

Another Method in Which the C.W. Oscillator is Used for the Measurement of Resistance.

the presence of skin effect, and so on, all of which factors are so indefinite as to defy calculation. In radio work, therefore, determination of resistance is always a matter of measurement.

In the measurement of resistance, most of the methods employed require some kind of a standard resistance. This standard must meet some very stringent requirements if it is to be any good. Thus, for example, its self-capacity and inductance must be negligible at the frequencies used in order that it should not influence the tuning of the circuit. This is generally obtained by the use of very thin and very short resistance wire. Secondly, its resistance must be constant over a very wide range of frequencies; in other words, its "skin effect" must be negligible. This extremely difficult requirement is met in practice by the use of very thin resistance wire having very high specific resistance. Experiment shows that wire such as manganin, German silver, etc., having high specific resistances and very small diameters, has practically constant resistance from direct current through the radio frequencies. The use of such wire as a standard will, therefore, permit of accurate measurements. A further advantage of a resistance standard having high specific resistance is that high resistances may thus be secured with very small lengths of wire.

There are a number of methods of measuring resistance at radio frequencies, each of which will be given with the necessary precautions to be observed to insure accuracy. In every case the C. W. oscillator will be used as the exciting source of oscillations to which the circuit to be measured is coupled. This C. W. oscillator will be represented as in Fig. 5.

Methods of Resistance Measurement.

Substitution Method. In this method, the apparatus, the resistance of which is to be measured, is replaced by a standard resistance. Suppose it is desired to measure the resistance of a coil Lx at a given wave-length. Coil Lx is connected to a circuit as in Fig. 6. This circuit contains another inductance L, whose value need not be known, a variable condenser C, a milliammeter A. A double throw double pole switch is used to connect either the unknown coil Lx or the standard resistance R_1 in circuit. The oscillator is adjusted to the required wave-length and loosely coupled to the measured circuit *only through coil L*. With the D. P. D. T. switch thrown so that unknown coil Lx is in circuit, tune circuit by means of the variable condenser C to resonance with the C. W. oscillator. Carefully note the reading on the R. F. milliammeter A, and call this reading I_1. Then this current is given by the equation

$$I_1 = \frac{E}{Rx + R}$$

where E is the E. M. F. induced in coil L by the oscillator

Rx is the resistance of the coil, which is to be found

R is the resistance of the rest of the circuit, which resistance is constant.

Now quickly throw the D. P. D. T. switch over so that the standard resistance is connected in place of the unknown inductance and vary condenser C until resonance is again secured with the C. W. oscillator. This is necessary since the elimination of coil Lx has resulted in detuning the circuit. Adjust the standard resistance quickly until the same reading is secured on the milliammeter as before, namely I_1. Let R_1 equal the value of the standard resistance inserted. Then

$$I_1 = \frac{E}{R_1 + R}$$

Since I_1, E, and R are the same as in the above first equation it follows that the inserted resistance R_1 is the resistance of the coil Lx. Since both measurements are carried out with the same current indicated by the ammeter, this method is sometimes called the "equal deflection" method.

Errors and Precautions. This method requires careful and detailed discussion in order that the reader may appreciate the difficulties encountered in accurate measurements. In the first place consider the factor R which is assumed to be constant in both measurements above. This factor R is the total resistance of condenser C, coil L and ammeter A with connections, at the wave-length used. Now since L and A are not varied we may properly assume that their resistances remain constant. However, condenser C is at a different setting in both measurements due to retuning the second time. Hence the assumption of constant resistance for C may or may not be correct, depending upon the type of condenser used. A loss-free condenser should, therefore, be used, have an air dielectric, in which case the above assumption of constant resistance is permissible.

In the second place the accuracy of the above measurement is based upon the assumption that the voltage induced in the measured circuit—factor E in the above equations—is constant in both measurements. It is permissible to assume that the C.W. oscillator generates a constant current. Hence, allowing constant coupling between the oscillator and coil L, and E. M. F. induced in coil L electromagnetically is constant. However, unless proper precautions are taken the oscillator may also induce voltages in coil Lx, which is under measurement, and which is not present in the second measurement. Hence the E. M. F.'s induced will be different in both measurements and the accuracy will be worthless. To avoid this, coil Lx should be removed as far as possible from the C.W. oscillator to prevent any such induction. Then again there is the great possibility that besides electro-magnetic induction there may be considerable electrostatic induction which may be different in both measurements, and especially on account of the absence of coil Lx in the second measurement, would not be the same. Hence the assumption of equal induced voltages on which the accuracy of the measurement depends, would be invalid. In order to avoid this unequal induction of capacity voltages the best precaution to observe is to shield the entire circuit excluding the coil L, thus concentrating the inductive action on this coil only, since it is always in circuit during the measurements. As a further precaution the shield should be grounded as indicated in Fig. 6.

In the above measurement we have assumed that the standard resistance necessary to produce equality of current in both measurements was available. This will be the case if the standard resistance is continuously variable, which it is not very likely to be, hence we have to consider the second case of the substitution method, namely the case of unequal deflections.

The circuit is the same as in Fig. 6. Three observations are necessary (1). With only C, L and A in circuit, tune to the oscillator and observe the ammeter reading, I_1, which must be given by the equation

$$I_1 = \frac{E}{P}$$

where E is the constant E. M. F. induced in the circuit. R is the total circuit resistance of C, L and A.

(2) Insert coil Lx to be measured whose resistance (unknown) is Rx and again tune to the oscillator and note the ammeter reading I_2, which is given by

$$I_2 = \frac{E}{Rx + R}$$

(3) Substitute a known standard resistance Rs in place of the unknown coil Lx and again tune to the oscillator and note ammeter reading I_3 which is

$$I_3 = \frac{E}{R + Rs}$$

From these three equations, by eliminating the factors of E and R, we find that the unknown resistance Rx is given by the equation

$$Rx = \frac{\frac{I_1}{I_3} - 1}{\frac{I_1}{I_2} - 1}$$

Thus from these three observations of current we can find the value of any unknown resistance. Since this method, in principle, is the same as the preceding method except that three readings are taken, the same precautions have to be observed as mentioned for the other method.

The method given above applies to any element of which the resistance might be desired. Thus if the resistance of condensers is to be measured, the same procedure is followed, substituting the unknown condenser for the inductance Lx.

The above substitution method is suitable if the resistance of single units is desired. However, if the resistance of a circuit is desired, as for example an antenna circuit, the following resistance variation method is used.

Resistance Variation Method. The circuit used in this method is indicated in Fig. 7, in which L, A, C is the circuit whose resistance is to be found. Rs is a standard resistance whose value is known and which may be cut in and out of circuit at will by means of the single and double pole switch, as shown. The measurement is made as follows: With the standard resistance cut out of the circuit entirely, the oscillator circuit resonates with the oscillator. The reading of the ammeter A is then noted which reading we will call I_1. Then this current is given by

$$I_1 = \frac{E}{Rx}$$

Where Rx is the resistance of the circuit which is under measurement. Now by means of the two switches the standard resistance is cut into the circuit, which standard we will call Rs and again the circuit is tuned to the oscillator. The ammeter reading is noted, which we will call I_2. This current will be given by the equation

$$I_2 = \frac{E}{Rx + Rs}$$

where E is the constant voltage induced in the circuit by means of the coupled oscillator. From the above two equations we find that

$$Rx = \frac{Rs}{\frac{I_1}{I^2} - I}$$

from which the circuit resistance can be found. In this way the resisatnce of any circuit may be found, as, for example, a wavemeter, antenna, secondary circuit of a transmitter, etc.

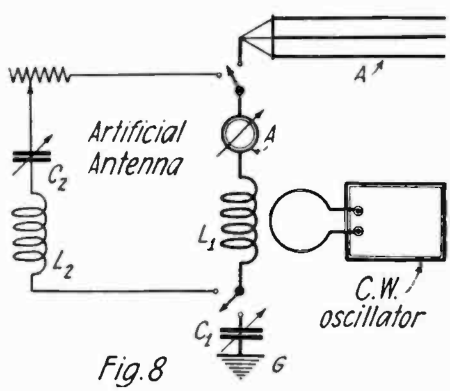


Fig. 8

System Used for the Measurement of Antenna Resistance.

Errors and Precautions. In this method, as in the previous substitution method, errors may arise due to unequal voltages being induced in both measurements, hence destroying the validity of the above calculations. To avoid this, shielding and grounding are resorted to as in the above method. Loose coupling between oscillator and circuit is absolutely essential; otherwise the introduction of resistance in the circuit may result in a different reaction on the oscillator than when the resistance is absent, in this way producing a different current in the oscillator and, therefore, changing the induced voltages. Very loose coupling will prevent any reactions between circuit and oscillator, regardless of the load in the circuit.

One of the very most important resistance measurements which ever have to be made is the measurement of antenna resistance. This measurement in practice is made almost daily, as the efficiency of any station is primarily dependent upon the resistance of antenna and ground. It is, therefore, desirable to give a special method for the measurement of antenna resistance which method has been found suitable in practice. Of course the resistance of an antenna may be measured by one of the methods above described, but the following is a special method worked out for antenna and is called the artificial aerial method.

Artificial Aerial Method. The principle of this method is essentially as follows: Suppose a given voltage in the antenna under measurement produces a certain current. If we can substitute for this real antenna and artificial antenna whose constants are exactly identical with those of the real antenna and which constants are known, we should then be able to produce in this artificial antenna the same current with the same voltage, as with the real antenna. Knowing the constants we then have the resistance of our antenna. In practice, this method works out as follows:

The scheme of connections is shown in detail in Fig. 8. We have the antenna A and ground G whose total resistance is to be measured. This antenna is connected to an inductance coil L_1 for coupling purposes to the oscillator, a loss-free air variable condenser C_1 (zero resistance) for tuning the antenna to the wave-length at which the measurement is to be made, and a sensitive R. F. milliammeter A. On the other side of the two throw-over switches S_1 and S_2 we have an artificial antenna composed of the following: An inductance L_2, which is equal in value to the inductance of the antenna; a variable air condenser C_2 which is loss free (no resistance), and permits tuning to the required wave-length and brings the total capacity up to the total antenna capacity with C_1 in series; and a variable resistance standard Rs. Thus we have in the artificial antenna the exact constants of the real antenna, except that the resistance of the antenna is concentrated in the standard Rs.

The throw over switches S_1 and S_2 are thrown so that the real antenna is connected in circuit. The oscillator is *very loosely* coupled to coil L_1 and condenser C_1 is adjusted so that the antenna tunes to the oscillator. The reading of the ammeter A is noted. Call it I. The throw over switches are now thrown over to the artificial antenna. C_2 is now adjusted to tune to the oscillator, and the standard resistance Rs is adjusted until the ammeter A reads the same current as before, namely, I. The resistance at which this occurs is the resistance of the antenna and ground.

It will be observed that coil L_1 and ammeter A are in both circuits, hence only the real antenna and ground are actually measured. Extremely loose coupling is essential in order that no reactions be produced on the oscillator. Both condensers C_1 and C_2 must be loss-free air condensers, otherwise their resistances will vitiate the accuracy of the measurements. There is only one possible error in this measurement, and that is the resistance of coil L_2, which is in place of the antenna inductance and which has been assumed to be zero. Actually the coil L_2 has some resistance. It is neglected because the antenna generally has a very small inductance, say 20 microhenries and, therefore, a very few turns will suffice to reproduce this inductance. However, for absolutely accurate results it will be essential that the resistance of coil L_2 be measured and added to the value of Rs to give the true antenna and ground resistance.

This covers in general the methods of resistance measurement. Of course there are other methods, but they depend upon th use of damped sources of oscillations, such as those produced by a buzzer and are fast coming into disuse due to uncertainty of buzzer operation, and to the superiority of C.W. oscillations for measuremnet purposes.

Different Types of Coupling

By Louis Frank

A considerable amount of the advice generally given the new amateur centers around the desirability of using loose coupled circuits in his receiver. Furthermore, he seems to get the impression that the only type of coupling is that produced by the proximity of two coils as in the average two circuit tuner, that is, inductive coupling. It seems, therefore, advisable to discuss this question of coupling, point out the different types and the particular uses of coupling in radio.

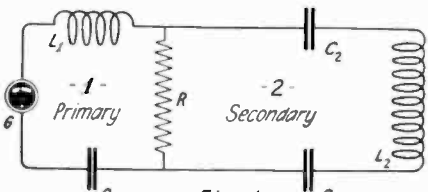


Fig. 1

A Resistance-Coupled Circuit.

Whenever two circuits are connected together so that there is a transfer of energy from one circuit to the other, these circuits are said to be coupled to each other. In general this is accomplished by one circuit inducing a voltage in the other circuit as a result of which a current flows and energy is available. The circuit in which the voltage is induced or the circuit to which the energy is transferred is called the *secondary circuit*. The circuit which does the inducing or transferring is called the *primary circuit*.

There are three main types of coupling: 1. Resistance coupling; 2. Inductive coupling; 3. Electrostatic coupling.

Of these three, the first one, resistance coupling, is least important, as far as practical uses or amplications are concerned. The circuit in Fig. 1 illustrates this type of coupling. In it the primary circuit consists of L. C. R. in series with G the source of voltage. The current flowing in circuit 1 produces a voltage drop across the resistance R, which is called the *coupling resistance,* and this voltage causes a current to flow in the secondary circuit 2, consisting of R L_2 C_2 C_3. For any given circuits and a given amount of energy in the primary, the greater the voltage drop is across the coupling resistance R, the greater will be the coupling and the greater the amount of energy transferred to the secondary. It will be evident, however, that this particular method of coupling two circuits together is wasteful and inefficient, since a very large portion of the total energy is wasted in the coupling resistance R in the form of heat. It, therefore, has a very limited field of application.

Its main application is in the field of resistance coupled amplifiers, as illustrated in Fig. 2. Here the coupling resistances are the plate resistances R in the plate circuits of the amplifier tubes. The voltage generated across the first plate resistance R, in the detector circuit is applied to the secondary grid circuit of the succeeding amplifier tube by resistance coupling. After amplification it appears as a larger voltage across the resistance R_2 which is coupled to the next stage and still further amplified. The particular advantage of the resis-

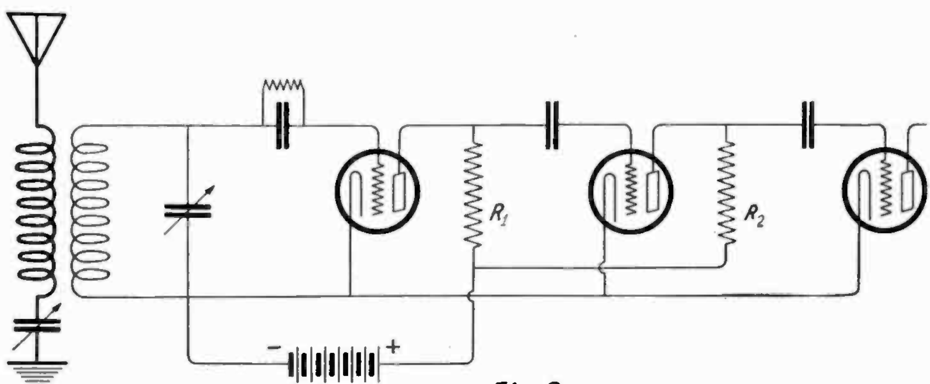


Fig. 2

A Resistance-Coupled Circuit Applied to a Cascade Amplifier.

tance coupling here is that this type of amplifier is more stable than transformer or inductance coupled amplifiers, and does not result in howling. Furthermore, it is possible to use a larger number of stages of amplification with resistance coupling than it is with other types of coupling. The energy wasted in the plate coupling resistances is not considerable because of the fact that the plate currents are so exceedingly low. Apart from this use, resistance

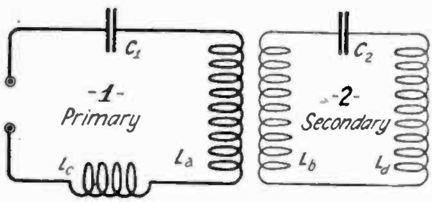


Fig. 3

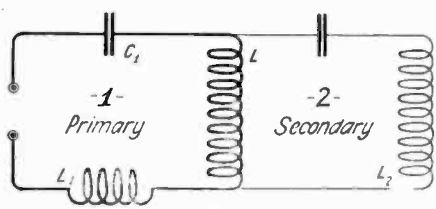


Fig. 4

Inductive Coupling May Be Accomplished by Electromagnetic Induction as in Fig. 3 or Direct Inductive Coupling as in Fig. 4.

coupling is hardly ever utilized purposely, and so we will leave it and pass to the other two more important types of coupling.

Inductive coupling may be accomplished by the two following methods: 1. Electromagnetic induction; and 2. Direct inductive coupling. These two methods are illustrated in Figs. 3 and 4 inductance in both primary and secondary respectively. In Fig. 3 it will be observed that the coupling takes place, due to mutual inductance between primary and secondary circuit, while in Fig. 4, coupling is effected by a common inductance in both primary and secondary circuits.

In direct inductive coupling, as in Fig. 4, consideration will show that this is a case of a combination of inductive and conductive (resistance) coupling. Not only is there a voltage induced in the secondary circuit, due to the inductance L, but since the inductance L also has some resistance the voltage drop due to the resisance will also be active in the secondary circuit. Thus, a case of direct inductive coupling includes resistance coupling. However, at radio frequencies the reactance of the inductance, namely, 2fL, is generally much greater than the resistance, hence the effect of the resistance coupling is negligible and usually not considered.

The degree of coupling is generally expressed qualitatively by the expressions "*loose*" and "*close*" coupling. Consider the circuits of Figs. 3 and 4. By saying that the secondary circuit (circuit 2 in each case) is coupled to the primary (circuit 1 in each case) we mean that the primary circuit transfers energy into the secondary circuit. This is due to the effect of current flowing in the primary circuit. Now if current flowing in the primary circuit has such an effect on the secondary circuit, then it is reasonable to expect that current flowing in the secondary will have a like effect on the primary. Now when the circuits are so arranged that the primary circuit induces voltage in the secondary, but that the secondary has very little or no reaction on the primary, then we say that the circuits are *loosely coupled*. If, however, the secondary has a considerable effect or reaction on the primary and induces back into the primary another voltage, then the coupling is said to be *close*.

This qualitative idea of coupling may be expressed accurately by a factor called the "Coefficient of Coupling." In either of the above cases of inductive coupling there is an inductive which is *common* to both primary and secondary circuits. In the case of the direct coupled circuit of Fig. 4, inductance L is common to both circuits. In the case of the electro-magnetic coupled circuit of Fig. 3 it is the mutual inductance which is common to both circuits, which may be designated as M. The coupling coefficient is then defined as the ration of the common inductance to the square root of the product of the total inductance of the primary circuit by the total inductance of the secondary circuit, as in the equations following, which hold in order for the direct coupled circuit and electromagnetic coupled circuit respectively:

$$\text{Coefficient of Coupling } k = \frac{L}{\sqrt{La\ Lb}}$$

$$\text{Coefficient of Coupling } k = \frac{M}{\sqrt{La\ Lb}}$$

where La and Lb are the total inductances of primary and secondary circuits.

It will be seen from the above that the coupling in a direct coupled circuit can be increased by making the common inductance L larger. In the case of the magnetically coupled circuit the coupling can be increased by making the mutual inductance larger, and this is accomplished by bringing the two coils La and Lb closer together. By bringing these two coils La and Lb closer and closer, untill they are practically superimposed on each other, it will be evident that the magnetically coupled circuit may be reduced to an equivalent direct coupled circuit in which the common coupling inductance is equivalent to the two superimposed inductances, as shown in Fig. 5.

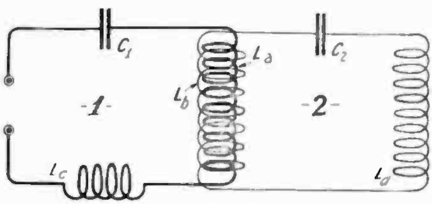


Fig.5

In This Circuit the Common Coupling Inductance Is Equivalent to the Two Superimposed Inductances.

The practical importance of coupling in reception is in the aid which it lends in the elimination of interference and the selection of the frequency, which it is desired to receive. This may be readily shown by the use of reactance curves. Consider the circuit of Fig. 6, which is equivalent to that in Figure 6 (a), as explained in the previous paragraph. The reactance of the circuit, Fig. 6, is given in the graph of Fig. 7. It will be observed in this graph that the reactance curve crosses the zero axis at two points, namely f. and f_2. In other words there are two frequencies at which the circuit reactance reduces to zero and at which maximum current therefore flows, but between these two values the reactance rises to extremely high values and approaches infinity. Hence by the use of such a circuit as Fig. 6, it is possible to suppress and eliminate any undesirable frequency and receive another frequency either larger or smaller than the one suppressed.

It is a property of all coupled circuits that there are two frequencies at which the reactance is zero and current, therefore, a maximum. The interference created by these two frequencies depends upon how far apart the two zero-reactance frequencies are, and the distance apart is determined largely by the degree of coupling. For very close couplings the two frequencies are very far apart. This explains why many people who have tuned their sets to 360 meters often receive equally well on 600 meters and therefore experience considerable code interference. Their coupling is so close that the two zero reactance frequencies may turn out to be 360 and 600 and consequently they receive very loud signals on 600 as well as 360. On the other hand, for very loose coupling the two zero reactance frequencies come very close together, say 360 and 380 meters, and thus the possibility of interference with stations transmitting at higher wave-lengths is considerably reduced. This is the real explanation for the high selectivity of the loosely coupled receiver, and why amateurs recommend it.

Not only are these principles of coupling important for reception, as explained above, but they are equally important for transmission. Thus a closely coupled transmitter also has two frequencies of zero reactance or maximum current considerably separated from one another and hence will be more apt to create considerable interference since it transmits at two frequencies. If it were loosely coupled, its two zero reactance frequencies would be very close to one another or would coincide, and hence would create little or no interference. (This, of course, does not apply to certain special types of transmitters which are especially designed to operate with close couplings such as quenched gap transmitters.) It will be evident that a transmitter which has its two peaks at 200 and 205 meters will create much less interference than one which has its two peaks at 200 and 300 meters.

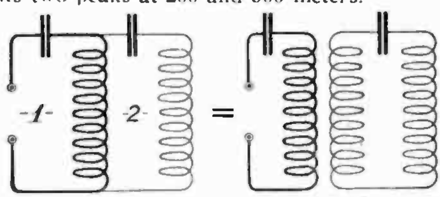
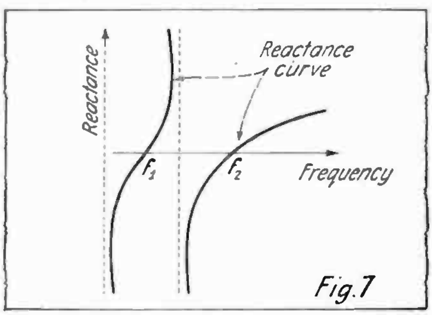
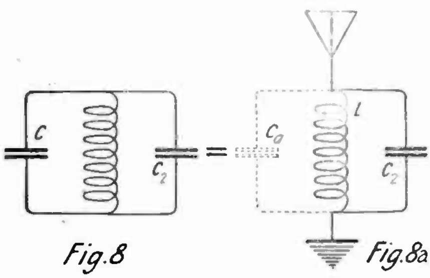


Fig.6 Fig.6a



The Circuit of Fig. 6 Is Equivalent to that of Fig. 6a. The Reactance Curve of Fig. 6 Is Shown Just Below. Note That the Circuit Reactance Reduces to Zero at Two Different Frequencies.

Another interesting and important application of the above principles of coupling is in the suppression of undesirable harmonics in certain transmitters. It is well known that an arc transmitter generates a fundamental frequency and harmonic frequencies. Sometimes one or more of these harmonics are quite intense and are, therefore, undesirable since considerable interference is created. In laboratories, when measurements are made, these harmonics are naturally very troublesome and must be eliminated. This can be accomplished by the so-called "fly-wheel" circuit which is nothing more than an application of the direct coupled circuit of Fig. 8, which is equivalent to that of Figure 8 (a) in an actual antenna circuit, where the antenna capacity Ca is substituted for the lumped capacity C. The reactance curve for this combination is given in Fig. 9, where it will be seen that there is a zero reactance frequency f_1 at which the current will be a maximum and an infinite reactance frequency f_2 at which the current will be zero. Thus the fly-wheel circuit is adjusted until it is in resonance with the undesired harmonic when it becomes the infinite reactance frequency and then the antenna circuit is tuned to the desired frequency or zero reactance frequency. In this way the objectionable harmonic is eliminated. Should there be more than one objectionable harmonic, it becomes necessary to introduce a fly-wheel circuit for each harmonic to be suppressed.



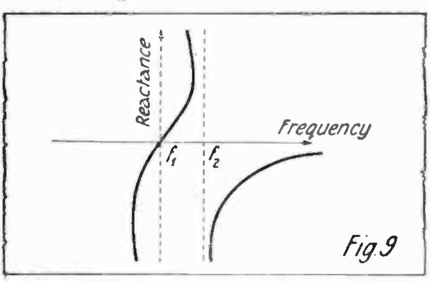


Fig. 8 is an Application of the Direct Coupled Circuit and Has Its Equivalent in Fig. 8a. It Will Be Seen from the Curve that it is a Zero and Infinite Reactance Frequency.

We finally come to capacity or electrostatic coupling, in which the transfer of energy from primary and secondary circuits are effected by means of a condenser. A simple electrostatically coupled circuit is illustrated by Fig. 10. In the case of capacity coupling we again have different degrees of coupling, loose and close. The coefficient of coupling is here defined as the ratio of the common capacity reactance to the square root of the product of the

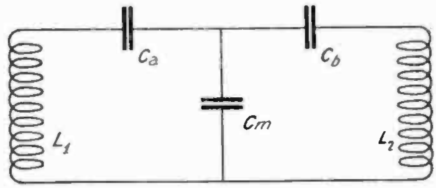
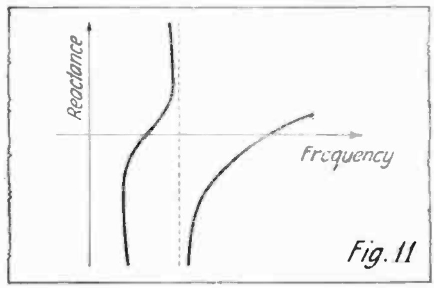


Fig. 10



An Application of the Capacity Coupled Circuit Is Shown in Fig. 10. Like the Inductively Coupled Type this Circuit Has Two Zero Reactance Points, But They Are Very Close Together.

primary capacity reactance and the secondary capacity reactance. In the case illustrated in Fig. 10, this turns out to be given by the expression:

$$k=\frac{\sqrt[O]{Ca\,Cb}}{CM}$$

From this expression of reactance it appears that the smaller the common capacity, the greater is the degree of coupling. This is consistent with the above definition, since the capacity reactance varies inversely with the capacity. Thus we see that in capacity coupled circuits in order to increase the coupling we decrease the common or mutual capacity and vice versa, whereas in inductively coupled circuits, to increase the coupling we increase the common or mutual inductance. This is the first difference between inductive and capacitative coupling.

The reactance curve of a capacity coupled circuit, such as Fig. 10, is given in Fig. 11. It will be observed that, as in the inductively coupled circuits, there are two zero reactance frequencies. However, mathematical analysis shows that even for very closely coupled circuits these two zero reactance frequencies are very close together. In other words, in the electrostatic coupled systems it may be considered that there is only one zero reactance frequency.

This is another point of difference between the inductively coupled circuits and the capacity coupled circuits. As a result of this difference it is found that the electrostatic coupled circuits are superior to the inductively coupled systems from the point of view of sharpness of tuning.

In general the inductively coupled circuits find a larger sphere of application than the capacity coupled systems and they are used in almost all variety of transmitting and receiving circuits in commercial application. The capacity coupled circuits are used to a small extent in receiving systems, but very little in transmitting systems. One particularly important application of the capacity coupled circuit in transmitters is the case of the Colpitts circuit as used in tube transmitters, Fig. 12. This circuit is an excellent one and is very much favored by amateurs, as it is well adapted to their low capacity antennae.

It is hoped that the explanation of the various types of coupling and illustrations of the applications and uses of coupling

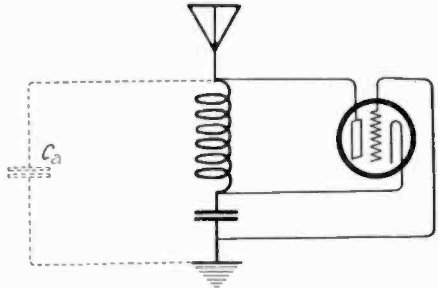


Fig. 12

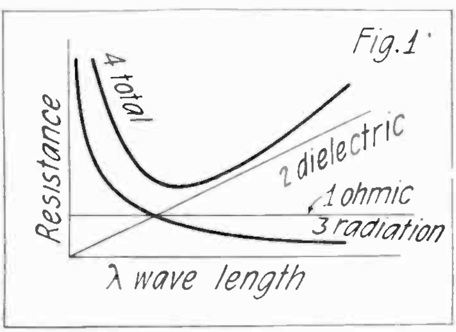
The Colpitts Capacity Coupled Circuit as Used in Tube Transmitters.

will clear up any vague and hazy notions which may have existed.

Principles of the Antenna System

By Louis Frank

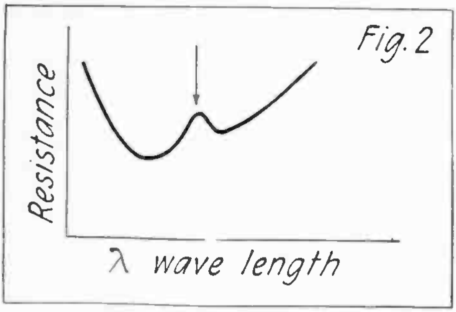
It has been stated of the antenna system that it is the mouth and ear of the radio set; it is the mouth of the transmitting station since it does the talking, as it were, and sends out into space the radio waves; it is the ear of the receiving station, since it reaches out into space to gather in the radio waves. A transmitting and re-



Curves Designating Resistance Losses, Due to Various Factors.

ceiving station which is otherwise well designed but which has a poor transmitting and receiving antenna is like a healthy person who is deaf and dumb. That person has the strength to talk and thus reach people, and could utilize in various ways the sounds which are always coming his way, if only his talking and hearing muscles were in commission. So with a radio station. The power for transmission may be available since the transmitter is well designed, but the transmitting antenna does not radiate, is not able to radiate this available power because it is poorly designed. The receiving set would be able to make loudly audible the numerous signals which are always impinging upon the receiving antenna if only the antenna were not so wasteful of energy. No matter how well your other parts of the set may be designed and built, if your antenna is no good it can safely be said that your station is no good. A real antenna and ground system is easily half your station problem solved. It will, therefore, be the object of this article to explain just what is required of a good transmitting and receiving antenna and how these requirements may be fulfilled in practice. The advantages and disadvantages of different practical types of antennae will also be considered.

The requirements for receiving and transmitting antennae are different since their functions are different. The function of the transmitting aerial is to radiate waves into space, while that of a receiving aerial is to gather in these waves. As a result, it is to be expected that their design would be different. As a general rule it may be said that any good transmitting antenna will also make a fairly good receiving antenna. But the converse of this is not a true statement, as pointed out by Mr. Stuart Ballantine in "Radiotelephony for Amateurs." In fact a very good receiving antenna may make an abominable transmitting antenna.

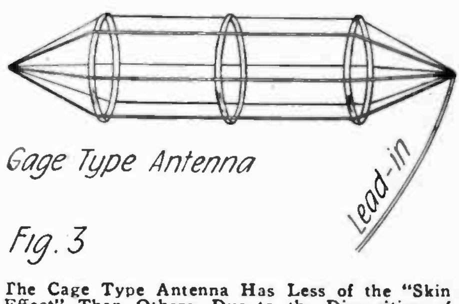


Illustrating a Possible Resistance Curve of an Antenna, Plotted Against the Wave-Length.

The inefficiency of most antennae is almost always due to too much wasteful resistance made up of a number of different factors which may be enumerated as follows:

1. Resistance due to ordinary ohmic losses as the resistance of the antenna wires, of the lead-in wires, of the ground system.
2. Resistance due to losses in the imperfect dielectric surrounding the antenna.
3. Resistance due to USEFUL losses, namely radiation of energy from the antenna.

Let us consider each of these factors in turn. The first one, namely ohmic losses, is generally fairly constant over a wide range of wave-lengths. There is a small variation of this resistance with wave-length owing to eddy currents and skin effect, but as this variation is small compared to other variations and the total resistance, we may represent this factor as being constant, and this is shown in Fig. 1, by curve 1, which is a straight line parallel to the wave-length axis. The second factor, losses due to absorption in the imperfect dielectric is due to the fact that the antenna condenser is an imperfect condenser. In the neighborhood of antennae will generally be found such structures as trees, buildings, masts and so on. All of these, while they may not be directly under the antenna, are nevertheless in its electric field. As a result, since these structures are imperfect dielectrics having considerable absorption resistance, much energy will be lost in them. This absorption resistance of dielectrics is found to be directly proportional to the wave-length and hence is represented by the inclined straight line in Fig. 1, namely curve 2. The third factor, namely the radiation resistance, is the useful resistance, and this depends upon a number of factors, such as the shape and type of the antenna, the height of its center of capacity and the wave-length. It is inversely proportional to the wave-length and hence is represented by the hyperbolic curve 3, in Fig. 1. The total antenna resistance which is the sum of these three components, is, therefore, represented by the curve 4 in Fig. 1. The well known fact is thus brought out by this curve that the total resistance of an antenna is not constant, but depends upon the wave-length, and is a minimum at a certain wave-length and increases on either side of this optimum wave-length. It might be pointed out here as interesting information that some antennae show a resistance curve with one or more peaks in it, as in Fig. 2. These peaks showing sudden rises of resistance indicate that at these wave-lengths there is considerable extraction of energy from the antenna circuit (which is equivalent to an increase in antenna resistance), and this extraction may be due to some tuned circuits in the neighborhood of the antenna circuit, or some dead hanging on ends of coils which are absorbing energy and oscillating at their own natural frequency, or the presence of some other tuned antenna in the neighborhood, or the presence of nearby absorbing metal masts or buildings.



The Cage Type Antenna Has Less of the "Skin Effect" Than Others, Due to the Disposition of Its Wires.

Of the above three components, the first two are wasteful and result in lowering the antenna efficiency, and the last component, namely the radiation resistance, is the useful component. The greater this resistance is the more efficient will the antenna be as a radiator of electric waves. The total power used up in the antenna is given by the product I^2R where I is the current in the antenna, and R is the total antenna resistance. The useful power delivered by the antenna, namely the total power radiated is given by I^2Rr where I is again the antenna current, while Rr is the radiation resistance. As a result, the efficiency of an antenna as a radiator of electric waves will be given by the quotient of the latter divided by the former which reduces to

$$\frac{I^2Rr}{I^2R} = \frac{Rr}{R} = \text{Efficiency}$$

The problem of the good design of a transmitting antenna is therefore, the problem of making the above ratio as great

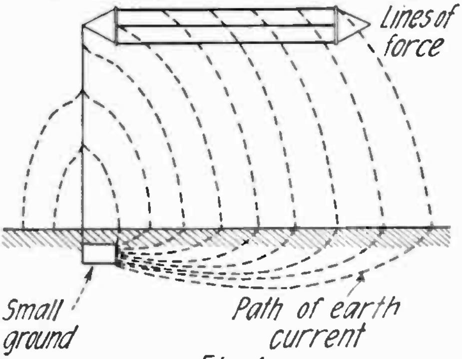


Fig. 4

There is a Considerable Loss of Energy When a Small Ground is Employed, Because of the High Resistance Path of the Current Through the Earth.

as possible, increasing the radiation resistance and decreasng the other wasteful resistances, which are the leaks in the antenna system. A certain amount of energy or power is pumped into this antenna system, but the greater part of this leaks out by way of these wasteful resistances. As a result, the efficiency of most antennae is surprisingly small.

Now let us see how the wasteful resistance may be reduced. The ohmic resistance makes up a considerable part of this resistance. The current flowing in a transmitting antenna is quite considerable, as currents go, and as a result, the wires heat up, which represents a loss. The first precaution to observe would, therefore, be to use antenna wire having a large surface area. The larger the current in the antenna, of course, the larger should be the area of the antenna wire. Wire having a large diameter is quite satisfactory, although if solid, there is a disadvantage due to the presence of skin effect which raises the resistance. Flat copper strip would be about the best type of wire to use, since it affords sufficiently large area to carry the current, and at the same time it is almost entirely surface, hence reduces the skin effect to a minimum. However, this wire may be somewhat unwieldly to string as an antenna, although it is so used, and, therefore, the next best bet is to use a stranded antenna wire, such as phosphor bronze. This type of wire also reduces the skin effect considerably, and at the same time affords superior mechanical properties to the other types of wire, since it is very much stronger.

There is one type of antenna which reduces the skin effect more than any other, and this is the cage type of Fig. 3. The reason why this particular disposition of the antenna wires reduces the skin effect will be clear from the following. Skin effect crowds the current to the outside of any conductor or system of conductor through which it flows; as a result, the current density on the outside of the wire or system of wires is greatest and an increase of resistance results from this irregular distribution of current density. An antenna is a system of conductors and the same things happen here. When a flat top antenna is used, for example, having more than two conductors, say four, there are two outside conductors and two inside conductors. The result of the skin effect, or edge effect as it is called in Mr. Ballantine's book, in explanation of this phenomenon, is to crowd the current to the two outside wires, thus making the current density non-uniform and hence increasing the resistance. In order to avoid this effect it is necessary to construct the antenna so that its wires are all equi-distant from the center, that is, they are all on the surface of a cylinder. The cage antenna permits of such construction as can be seen from Fig. 3. This explains why the

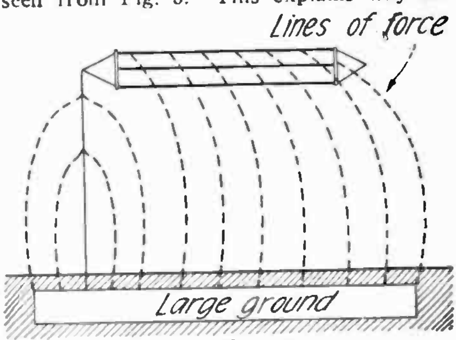
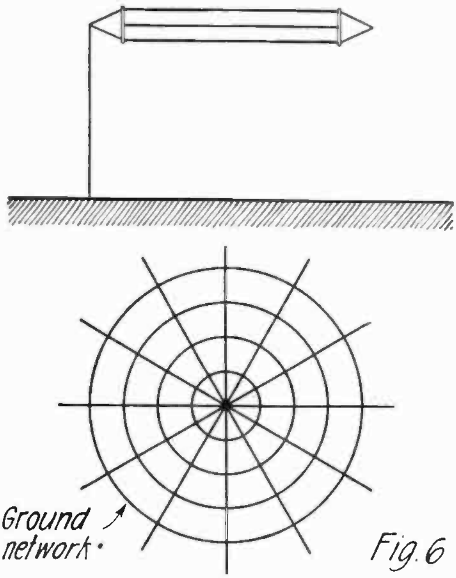


Fig. 5

By Employing a Large Ground of Good Conductivity, the Resistance of the Earth is Not Encountered.

cage antenna has such excellent low resistance properties. There will also be a saving in losses if the lead-in of the antenna is likewise made into a cage.

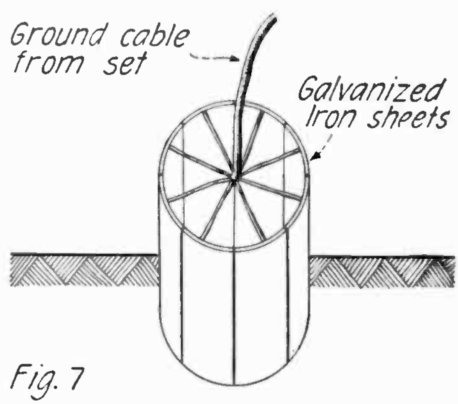
The second chief source of ohmic losses is in the ground resistance. It may be said with considerable certainty that most of the grounds built by amateurs are good heat generators. An amateur will spend seven days and nights winding an inductance coil in a special way which he thinks is ultra-efficent, and right on top of that he will stick a rod in the ground, connect his set to it and call it a ground. That is no more a ground than if he dug up the earth and stuck the wire from his set into the earth. A good low resistance ground is *no less* important than an efficient radiating antenna or an efficient hook-up. The losses in the ground are due to non-uniform current density in the ground, and its importance will be plain when one considers that the current at the base of the antenna is the heaviest, and hence heat losses will be heaviest. Fig. 4 shows clearly what happens in the ground.



A Low Resistance Ground Can Be Constructed of a Number of Radial Wires, with Connecting Jumpers, as Shown Above.

The electric lines of force extend from the antenna outward and downward towards the ground, and through the ground to the ground wire. Now if the ground has very small surface area, say it is a water pipe or a small copper plate the lines of force have to travel over a longer earth path to reach it. As a result there will be a greater loss of energy than would be the case if the travel were shorter; and if the earth is poorly conducting, as is very often the case, the ground resistance will be still further increased. Secondly, when the earth has such a small area the current is concentrated in very small space, the current density increases, and the heat losses increase with it. On the other hand if a large ground is used and is symmetrically disposed around the antenna the electric lines of force coming from the antenna will be directly over the ground, and will have a much shorter path to travel through natural earth before they reach the ground wires. Hence the resistance due to this cause will be lower. On account of the large area of the ground the current density will be smaller and losses thereby diminished.

In order to secure shorter earth paths for the ground currents and low unifom current density in the gound it is absolutely essential to use large grounds. This is the only solution. There are two very good types of grounds which will fill the bill. The first is the direct ground in which metallic plates are buried in the earth. The plates should be large and numerous so that they extend along the length of the antenna and overlap it on all sides. The ground should, wherever possible, be symmetrically disposed about the antenna itself. If a number of plates are buried, these should be connected to each other by means of heavy wires soldered to each plate. Another way would be to use a number of large radial wires coming from a center and extending out a little beyond the antenna, and connecting these wires at intervals by means of heavy copper jumpers, as illustrated in Fig. 6. This is quite a common form of ground for large stations and gives most excellent resistance properties. A type of direct ground which is about the best so far devised is the so-called "Round Ground" named after H. J. Round of the English Marconi Co., who is supposed to have invented it. This type of ground has been under investigation by the Bureau of Standards and their results point conclusively to the superior advantages of this ground system. It is schematically shown in Fig. 7. A circular trench is dug in the ground about 2 or 3 feet at the greatest depth and about 15 to 20 feet in radius. A metallic cylinder is then made up of a number of galvanized iron plates, or other



An Excellent Type of Low Resistance Ground, That is Easily Made. It is Far Superior to the Usual Type of Ground.

sheet metal, which need not be soldered together, but which should overlap each other by a few inches. In this construction avoid, wherever possible, any sharp jutting edges. To each plate a heavy wire should be soldered and these wires brought radially to a central point to which the heavy ground cable from the set is brought. The ground should be placed directly under the antenna. This ground is quite easy to make and for those amateurs who have transmitters, will certainly prove an eye-opener, when they consider the results.

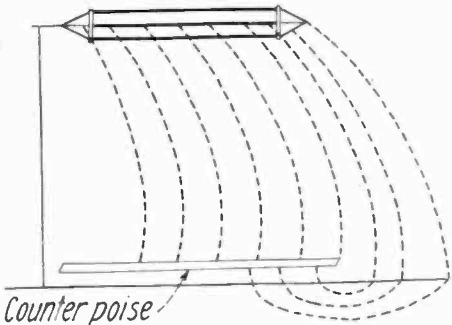


Fig. 8

The Counterpoise is Extensively Used in Conjunction with C. W. Transmission. There is No Direct Connection to the Ground.

The second type of ground which fulfills the necessary requirements for a low resistance ground is the so-called "counterpoise" ground. The counterpoise is essentially a network of wires placed directly above the ground under the antenna and insulated from the ground and antenna. This usually has a very large area and as a result gives a uniform distribution of ground current with low current density. Fig. 8 shows the paths of the lines of force from the antenna and the ground currents. It is seen that the lines of force emanating from the antenna go directly to the counterpoise, with the exception of a small percentage on the fringe of the counterpoise. The counterpoise thus eliminates largely the wasteful earth currents, which contribute so largely to the ground losses. It is for this very good reason that the counterpoise ground generally has the lowest resistance of all ground. (Although the recent experiments made at the Bureau of Standards seem to point out that the above mentioned ROUND GROUND is a very close competitor with the counterpoise for first honors.)

The construction of a counterpoise ground should be guided by the following practical considerations. First, the area should be as great as conditions permit, and should embrace completely the aerial structure. If possible, it should extend a little beyond the antenna boundaries on all sides. The counterpoise should be placed about 3 feet above the surface of the ground, but the important precaution to observe is that this height should be uniform over the entire counterpoise. Otherwise, if one point is higher than the others, the capacity of the antenna to this point will be greater and there will be a greater current density at this point resulting in non-uniform distribution of current with consequent rise in resistance. A network of wires should preferably be employed, radiating from a common circle, and these should be connected together at intervals by means of soldered jumpers, as in the direct ground network. Where wooden stakes are used to support these wires great care should be taken that they be very well seasoned, for if they are not, there is going to be considerable loss due to leakage to the ground. Wires should not be directly connected to the stakes, but should, of course, be well insulated by non-hygroscopic insulators. Long glazed procelain insulators will do quite well. Under no circumstances use unglazed procelain. More will be said about insulation later. There has been some talk about grounding the counterpoise and securing better results than with the counterpoise alone, but it is best to avoid this, by all means. Unless it is properly done, the effect of grounding the counterpoise may be to vitiate entirely the desired action of the counterpoise, the object of which is to do away with the ground. So the best advice is to keep hands off this stunt until you are more familiar with the ways of counterpoise antennae.

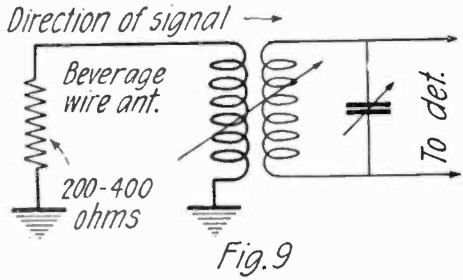


Fig. 9

A Modified Form of the Beverage Antenna. It Consists of a Single Wire, One Wave-Length in Length, and Grounded at its Free End Through A Resistance.

Finally, with regard to ohmic losses, the question of joints and connections arises. The novice is always apt to be careless about this, largely because he does not know and because he is ignorant of the effects of poor joints. It is very difficult from the writer's experience anyway, to convince the novice that a poor joint may work havoc with his set. SODLER ALL JOINTS as a matter of principle. The experience of years proves this is important. This, then covers the causes for high ohmic resistance antennae, how they may be reduced, and also covers the good design and construction of the most important types of grounds.

We now come to a consideration of losses due to dielectric absorption in the imperfect dielectrics surrounding the antenna. This factor is probably most often overlooked by amateur and novice alike. They can understand and see where wires offer a resistance, but either do not understand or consider unimportant the fact that there may be large losses in the insulating dielectric around the antenna. When a voltage is applied to a condenser, the condenser receives its normal instantaneous charge, but right after this experiment shows that there is a small additional charge which piles on the condenser. The first instantaneous charge may be recovered by discharging the condenser. The second small additional charge cannot be recovered, but is lost in the condenser as heat.

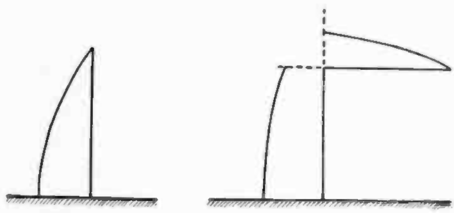


Fig. 10 Fig. 11

Showing the Distribution of Current Along An Aerial of the Vertical Type, In Comparison With the Current Distribution In a Horizontal Aerial.

That energy is wasted. This is due to what is called dielectric absorption. This loss may, therefore, be considered as the result of a wasteful series resistance in the condenser. The more imperfect the insulating dielectric is, the greater is its resistance. This is exactly what we have in the case of our antenna. The antenna and ground or counterpoise constitute the plates of a condenser, and the medium in between, and surrounding it is the dielectric. It is obvious that this medium will be far from perfect and must therefore entail considerable losses due to absorption. Even if a very poor dielectric such as wooden buildings is not directly near the antenna system there may result considerable absorption losses in it. The electric field of the antenna extends over a considerable distance around the vicinity of the antenna and may extend far enough to be influenced by poor dielectrics. It is of course, out of the power of the amateur to change the antenna dielectric, but a certain amount of reasonable care can be exercised by him when constructing his antenna.

In the first place he should erect it, as far as circumstances permit, in the most open place possible, removed from tall structures and trees, but if structures are near, the matter cannot be helped, and the antenna should then be very well insulated from them. This business of erecting antennae near trees or with their help ought to be exploded. Some of these new radio companies issuing instruction leaflets generally tell the purchaser to use a tree for a support wherever possible. As a matter of fact, the advice ought to be wherever possible do *not* use a tree. Keep away from trees, for they are a very important source of dielectric loss. If trees *must* be used as one of the means of supporting an antenna wires should be kept as far away from the tree as possible. Use long insulators in series to keep the wires away from the trees.

We now come to one point in this matter of dielectric losses, which is unknown to a large number of amateurs, and this is the matter of insulation. Every bit of insulation used in or near your antenna increases the possibilities of dielectric losses, for an insulator is a dielectric and as such will absorb energy. It is for this reason that in high grade work and in commercial practice designs are made so that air insulation is used as much as possible. Thus spiral inductances in commercial practice are wound on a bakelite back, but this bakelite panel is drilled with a few 3-inch and 4-inch holes, so that air insulation is prevalent. So in antenna structure use insulators wherever necessary only. Now the fact that a certain material will insulate against certain voltage does not necessarily mean that it is a good insulator, as is so commonly supposed. A good insulator for radio purposes must satisfy a number of conditions: (1) it must be insulated well; (2) it must have a low capacity between its terminals; and (3) it must be a good dielectric. What most amateurs do not know is that a certain material may be a good insulator without being a good dielectric. It may insulate well and still have large dielectric absorption. There are enough good insulating products which at the same time are good dielectrics on the market today, and there is no excuse for using poor material. In general materials which absorb moisture are extremely bad, and such materials are wood, fibre and unglazed porcelain. Electrose, bakelite and hard rubber are all good materials and they are sufficiently reasonably priced to warrant their use.

Wherever metal may be used as well as insulation, the metal should be employed, in this way helping to reduce the possibilities of dielectric absorption. Thus in the case of the cage antenna, the wires are supported by hoops. Now, as these wires are electrically connected at the lead-in anyway, they may, without hurting the operation, be connected by a metallic hoop, say of copper. In this way the use of six or seven insulating hoops is avoided and the absorption losses no doubt considerably decreased. In the case of a flat top antenna, spreaders are used. Rather than employ green, unseasoned wood, which would result in considerable loss, the spreaders could very well be made of metallic tubing, around which the individual wires are wrapped, since the wires are connected together at the ends.

Wherever possible, then, use metallic material instead of insulating material, unless the chances of eddy current losses are too great. In the cases outlined above, these losses would be negligible.

Good insulation must be employed in certain places to reduce losses due to induction. Thus guy wires must be broken up by means of insulators and it is very desirable when setting up metallic masts to mount them on an insulating base. The larger the number of insulators used in breaking up the guy wires, the better the results will be. The antenna itself should be as far away from the supporting metallic masts as possible.

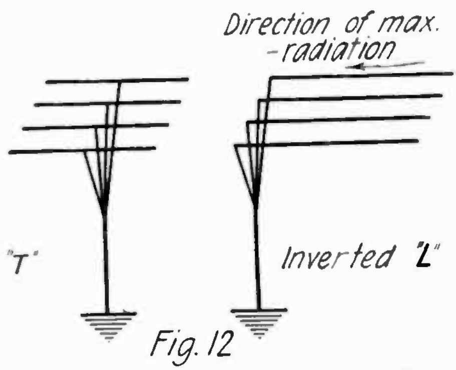
This covers quite thoroughly the chief causes for wasteful resistance of the antenna. If the above explanations and precautions are carefully followed, and the methods above advanced are put into practice the amateur will find that he has reduced his wasteful resistances as low as possible. This is, however, only part of the problem. The above applies equally well to transmitting and receiving antennae, since a good transmitting antenna will generally make a good receiving antenna. However, for transmission his problem is only partly solved. Having reduced his wasted energy as low as possible, an effort must now be made to increase his useful radiated power. In other words, how can we design or operate our antenna so that its radiation resistance is a maximum?

Transmitting Antennae

The radiation resistance of an antenna is found to depend upon two factors: (1) the effective height of the aerial, that is, the height of the center of capacity of the antenna; and (2) the wave-length of transmission. This radiation resistance is given by the equation

$$R = K\frac{h^2}{\lambda^2}$$

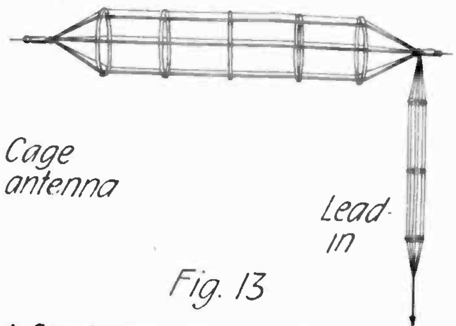
in which K is a constant, h the effective height of the antenna, and λ is the wave-length. It will thus be seen that the greater the wave-length, the lower the radiation resistance, and the higher the antenna the greater is the radiation resistance. What we require therefore for transmission is great height. When we come to the question of wave-length and radiation we strike another point on which the amateur often lacks information. What is required for good work is a maximum of energy *to be radiated*. Most amateurs confuse this requirement with maximum current in the antenna. Maximum current in the antenna does not necessarily mean that you are radiating at maximum efficiency. Maximum radiation takes place at a certain definite wave-length for each antenna, and *this wave-length is the fundamental wave-length of the antenna.* If it were possible to design the antenna so that it radiated as its natural wave-length without the insertion of extra coils or condensers, the antenna would be operated at maximum efficiency. It is true that more current could be obtained from the antenna at another wave-length, but the radiation would not be as efficient as at the fundamental. The antenna should, therefore, be designed so that its natural wave-length is right near the fundamental. Of course it may be necessary, in fact it will be necessary, to use some loading inductance for coupling purposes, hence the antenna should be operated with a series condenser to bring the operating wave-length on the fundamental.



Antennae of the Inverted "T" and "L" Types. They Are Both Good Radiators.

Antennae built in accordance with the foregoing will be good transmitter aerials, as the foregoing has been written from the transmission point of view. However, they are also of good design for reception, and can be used for both, but where special antennae are required for reception, other considerations enter. While it is desirable to reduce all antennae losses to as low a figure as possible, and is essential for transmission, this is not so important when it comes to reception. If there are some losses they can easily be made up by amplification. The chief and special requirement of receiving antennae is to overcome the effect of disturbing atmospherics or static. The response of an antenna to a signal divided by the response of the same antenna to static is called the "signal-static" ratio. The larger this ratio is, the better will the antenna be, since the effect of static is then small. Considerable research has been done and is still being done by all large companies to develop an antenna which will make this "signal-static" ratio as great as possible. Some of the simpler solutions to this problem will be given in brief detail.

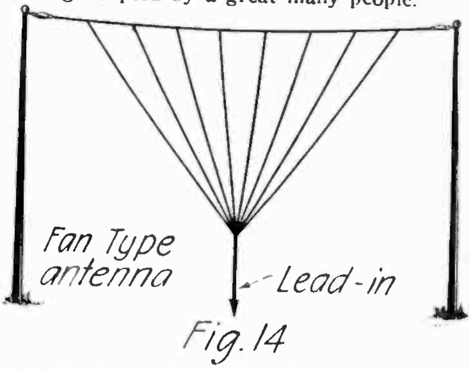
For reception only the simplest type of an antenna for the novice is the single wire antenna. When stretched a length of about 100' and about 30' to 40' high, quite good results will be obtained. This type of aerial has no special constructional features, but should be well insulated at the ends. It has a strong directional effect on the horizontal wire.



A Cage Antenna, with a Cage Lead-in. Having Its Capacity Concentrated at the Top, Makes it an Efficient Radiator.

A special application of the single wire antenna is the so-called Beverage wire, named after its inventor. This type of antenna is shown in Fig. 9 and is a simple wire equal in length to one wave-length, say 200 meters, one end of which is grounded through a non-inductive resistance of value equal to the "Surge Impedance" of the antenna which is theorectically, $R = \sqrt{L/C}$, where L and C are the inductance and capacity of the antenna per unit length. The resistance is placed at the end of the antenna nearest the transmitting station. At the other end of the antenna the usual coupling coil is placed, to which is coupled the receiving set. The value of the surge impedance for most one or two-wire antennae is generally between 200 and 400 ohms. This antenna has a marked directional characteristic, receiving best signals coming from the direction shown by the arrow in Fig. 9. Furthermore it reduces the effect of static considerably and provides a very favorable signal-static ratio. We cannot go into the theory of the Beverage antenna at this point, but it may be stated that the action of this antenna, when its length equals one wave-length, is such that the signal builds up to a maximum at the receiver end, and a minimum at the resistance end, while static builds up to a maximum at the resistance end where it is run to earth, and a minimum at the receiver end, thus securing a high signal-static ratio. It was with this type of receiver antenna that Godley first picked up in England the amateur trans-Atlantic signals.

One of the most important, simple and practical types of receiving antennae is the loop antenna. The loop antenna, as far as picking up signals goes, is far less efficient than the outdoor aerial, since the signal voltage in the outdoor aerial is easily 50 times as great as that picked up by the loop. However, due to the fact that we are able to amplify these weak signals greatly, it does not matter very much that its efficiency is small. It is only in the transmitting aerial, where amplification is out of the question that we must have aerial efficiency. The loop requires that radio frequency amplification be used, for the signal voltage is so low that it will not operate the tube detectors. In order to bring up the voltage to the value required for operating the detector it is necessary to amplify by radio frequency methods. The loop has remarkable directional properties, receiving best in the direction of its plane, and very poorly in other directions. As a result this enhances its value from the point of view of static reduction. For static is a phenomenon which strikes the antenna from all directions. If then the loop receives from only one direction, it can be influenced only by the static in coming from that direction. Furthermore although it receives signals poorly, it also receives static poorly, and as a result it has a good signal-static ratio. For these reasons the loop is finding quite a deal of favor these broadcasting days, and is being adopted by a great many people.



A Fan Type Antenna. These Are Very Good Radiators, if They Are Designed Correctly. They Have the Advantage of a Comparatively Low Resistance.

In the construction of a good receiving loop for the low wave-lengths, the following must be considered. The tuning condenser is connected across the ends of the loop. What is desired is that the maximum voltage be developed across the condenser for operating the amplifier tubes. In the first place the larger the inductance the greater will be the voltage, hence it is desirable to design the loop so that it will operate with a low capacity. Of course a smaller loop and larger capacity will also tune to the received wave-length, but a lower voltage will be developed across the condenser, for the voltage is directly proportional to inductance and inversely proportional to capacity.

We must, therefore, work the loop with small capacity, say about 0.0002 mfds. The voltage induced in a loop is proportional to the area of the loop and the number of turns. Hence the larger the area and the number of turns, the greater the induced voltage. In order to keep both factors large it will be found necessary to space the loop wires considerably apart. A loop in the low wave-length range, say between 200 and 500 meters, would consist of approximately five turns wound on a form 5' to 6' square, the turns being spaced about 2 inches.

When a novice or amateur builds an antenna solely for receiving purposes he will find the single wire type or loop type the most convenient and the best for his purpose. If he also wants to use it for transmission, he will have to use one of the following types.

Different Types of Practical Antennae Compared

The very first type of antenna used for transmission was the vertical one. Later developments all lead to some form of large area surface being employed in conjunction with a vertical wire, as for example the flat top, or fan, or umbrella, etc. The reason for this was that these proved better radiators. The explanation is as follows: The distribution of current along a plain vertical antenna is as shown in Fig. 10. It is seen that the current distribution is not uniformly strong, it being a maximum at the earth and minimum at the upper end. Now the radiation from an antenna is directly proportional to the current in the antenna, *assuming uniform current distribution*. If the distribution is not uniform, the radiation must be necessarily weaker than that calculated for the current at the base of the antenna. The addition of a large area surface has the effect of making the distribution more uniform, as shown in one instance by Fig. 11. Hence for the same current at the base of the antenna the large area antenna will radiate better than the vertical. A second reason why the large area improves the antenna is the following. It was stated previously that for maximum efficient radiation the antenna should be operated at its fundamental or very near it. Now in a vertical antenna the fundamental wave-length is about four times its height. In order to operate such an antenna at its fundamental without putting too much loading coil in (which would reduce efficiency) the antenna would have to have an enormous height. Thus suppose we wanted to operate at 200 meters. In order that the fundamental of the antenna be 200 meters, the vertical antenna would have to be 50 meters or over 160' high, which is entirely out of the question. The effect of the large area is to increase the capacity and, therefore, the fundamental wave-length, thus enabling the effective height of the masts to be considerably reduced. Finally since the large area increases the capacity of the antenna, it will require a smaller voltage to produce a given current in the antenna than with the vertical wire, or in other words a given voltage will produce a larger radiation current for the large area antenna than for the plain vertical wire affair. All these considerations point to the large area antenna in preference to the simple straight wire antenna.

The simplest types of antennae most commonly used are the inverted L and T types. These are indicated in Fig. 12 and derive their names from their similarity to the shapes of an inverted L and a T. Both these types of antenna act very much the same and there is little choice between them, except that one is more convenient to install than the other in certain places. They are largely used on board ships, in fact almost exclusively. The chief difference between these two types is that the inverted L has some direction effect, maximum radiation occurring in the direction shown by the arrow in Fig. 12. This effect is not very pronounced when the length of the flat top is not much greater than the vertical height. However, when the horizontal portion is made large compared to the vertical portion, the directional effect is very pronounced. This directionl effect is utilized by the large trans-Atlantic stations which point away from the station to which they are transmitting and thus secure maximum effects at the receiving end. The chief advantage of this type of antenna for the amateur is the ease and convenience of construction and the low cost. Results obtained with this type of antenna when the proper precautions outlined in the beginning are observed and when used with a good ground are very satisfactory. This is a good type of antenna for the beginner to try, a after he has had some experience with this he can go to the other more advanced ones. For transmission it is preferable to use the inverted L rather than the T, since a greater effect is produced by the use of the complete flat top in the L type than by the use of only half as in the T type.

The practical antenna nearest in shape to the above flat types is the cage type shown in Fig. 3. This has a number of advantages over the above and others which make it a great favorite among advanced amateurs. In the first place it has excellent resistance properties as explained in a previous paragraph owing to the disposition of the antenna wires as the elements of a cylinder, thereby reducing the skin effect. In the second place it offers a very high capacity top which is advantageous to good radiation. In bringing down a lead-in from such an antenna it is desirable to use a cage lead-in of the form shown in Fig. 13. This lead-in again reduces the skin effect, and at the same time, due to the tapering form, keeps the center of capacity high where it belongs. The capacity of the cage is proportional to the diameter of the cage, and due to the taper, the high capacity is at the top while the low capacity is at the bottom. Amateurs have obtained some remarkable results with this form of antenna, especially when used in conjunction with a counterpoise ground.

A less common type of antenna which is beginning to come into some use by amateurs is the fan type shown in Fig. 14, the name being due to its shape. The disadvantage of this type is that the current distribution is very irregular and hence its radiating properties are not as good as those above. However, it has the advantage of having low resistance and the large number of wires in parallel give it a very high capacity which results in large currents for any given voltage. Another disadvantage is that although it has a high capacity, its center of capacity is too near the earth, which is bad for radiation. Then there is the difficulty of installing such an outfit, although it requires only two masts. It is, nevertheless, quite good, although the cage type is to be recommended in preference to it

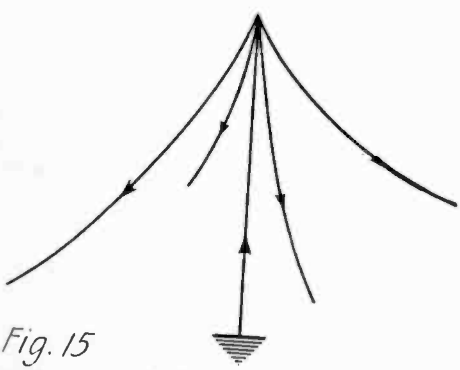


Fig. 15

An Antenna of the Umbrella Type. It Has a High Capacity, Therefore Good Radiation Qualities.

Finally we have the umbrella type of antenna shown in Fig. 15. This has also the advantage of high capacity, which gives it a very good current distribution curve and high radiation current for a given excitng voltage. However, these advantages are somewhat neutralzed by the following effect. The exciting current flows up the central vertical wire and down the side spreaders, as shown by the arrows in Fig. 15. Thus there is a partial opposing effect of these currents and radiation effect is thereby decreased. However, the other two advantages make up largely for this, and this type of antenna is largely used abroad in high power stations. For amateur work it is not recommended, as it is awkward and difficult to construct properly and takes up entirely too much space. One field of use in which it has found great favor is for portable antennae.

All in all, from a consideration of the foregoing, the best types of antennae for the amateur to construct, if he is going to transmit and receive, is the cage type or the flat top type. Of the two, the cage type will be found the better. A good cage type antenna should have the following construction: Six No. 7 x 18 phosphor bronze wires spaced around a circle 3' in diameter. Length of the top portion should be about 75', if possible, and as high as conditions permit. The lead-in should also be a cage tapered very strongly so that the diameter half way down is very small, say about 6 inches.

Special Types of Antennae

In conclusion, a word should be said about some recent developments of special types of antennae. The Beverage wire antenna is one, but this has already been discussed. Another recent development is the use of loop antennae for transmission. The loop in reception is quite old, but using the loop for transmission is a new phase. Fairly good radiophone transmission has been accomplished at the Boston Radio Show. The loop being a closed circuit has very poor radiating properties as compared to an open oscillator like an antennae. However, for short distance work it has been found that the loop will transmit quite well, and in fact distances as great as 50 miles have been covered. The importance of this lies in the fact that in it there may be a solution of the interference problem, since the directional effect of the loop may be employed in transmission as well as in reception.

Another type of antenna, which has been developed recently, is the condenser type. This consists of two large metallic areas either in the form of metal plates or a number of wires, closely spaced, each set of wires forming one plate of the condenser. The lower plate may very conveniently be the metallic top of a roof on a house. The advantage of this type of antenna is that since the condenser plates are so large, the electric field is concentrated in the space within these plates thus producing low dielectric losses. However, the radiation resistance of such an antenna is extremely low, hence for good results it is necessary to have a lead-in of very low resistance and the loading inductance must likewise be a very low resistance affair. Although there is not very much detailed information on these, some experimenters are said to have radiated almost as effectively with the condenser antenna as with the open type.

In concluding this article it is hoped that the explanations and antenna theory and practice will be of some assistance to those contemplating building stations.

The Relation of the Antenna to Detection Efficiency

By Louis Frank

In a previous article of this book, the principles of the antenna system are told in complete detail. Any of the multiple wire antennae there given are suitable for transmission and reception. However, if only reception is to take place, then a single wire antenna will be found to be completely satisfactory. In this case certain important questions arise which, if properly answered, will result in greatly improved reception under the various conditions and circumstances which arise in radio reception.

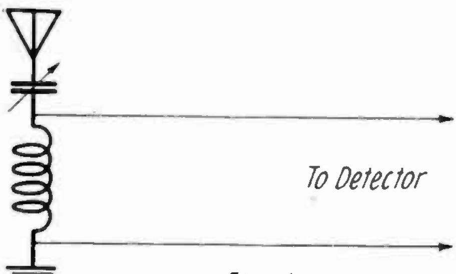


Fig. 1

A Single Circuit Tuner Which May Be Used With Any Type of Detector.

Such questions are: How long and high should the antenna be made when employing crystal detectors? How long and how high when employing non-regenerative tube detectors? How long and how high when employing regenerative single circuit tuners, and when employing regenerative double circuit tuners? Can the antenna ever be made short and low without sacrificing detection efficiency, and, if so, when? What are the requirements for good detection when employing crystal detectors or non-regenerative tube detectors, and when employing regenerative tube detectors? These questions are the heart of the reception problem. Most amateurs think that it is always essential to make the receiving antenna as high and as long as possible. This notion is erroneous and would not be so prevalent if the relationship between antenna height and detection efficiency were thoroughly understood. This article will, therefore, be devoted to an explanation of this matter.

Obtaining Loud Signals

In radio reception the condition aimed for is to receive the signal as loudly as possible. Especially is this the case when receiving broadcast entertainments, for it is often desired to entertain a roomful of people. Now the loudness with which the transmitted signal is received depends upon the efficiency of the detector, the efficiency of the tuner and the antenna. Naturally, the more efficient the tuner is, the louder will the received signal be, but the efficiency of the tuner is entirely a matter of the proper design of the tuner, and this will not be considered here, as it is a large subject in itself. We are at present concerned solely with the antenna and detector. Now the efficiency of the antenna was considered in detail in a previous article in this book and methods were given for eliminating wasteful losses and increasing efficiency. We must, therefore, consider here the specific problem of the relationship of the antenna to detection efficiency. The efficiency of the detector depends upon conditions which differ for different detectors, but in all cases the detector efficiency depends upon the signal voltage applied to the detector. Let us consider each detector separately.

Crystal Detector

In the case of the crystal detector the efficiency depends upon the extent to which it rectifies. Some crystals rectify imperfectly while others rectify well. The rectification of any crystal is proportional to the square of the voltage applied to the crystal.

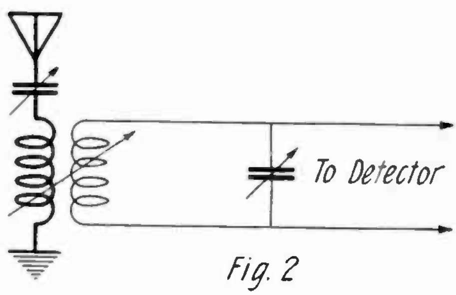


Fig. 2

This Two-Circuit Tuner Is More Selective Than the One Shown in Fig. 1; It May Be a Loose Coupler, a Vario Coupler or Any Kind of Coils Coupled Together.

In other words, the greater the voltage which is applied to the crystal, the better it rectifies, and hence the better it detects. Now in the case of a crystal receiver, the voltage applied to the crystal detector is obtained either directly, as in the case of the single circuit tuner (Fig. 1), or indirectly by induction, as in the case of the two circuit tuner in (Fig. 2), from the antenna. The problem of most efficient detection is, therefore, a problem in obtaining the maximum possible voltage from the antenna.

The antenna is the means of collecting the radio energy which travels through space. The larger it is and the higher it is, the more energy it extracts from passing radio waves. Hence the longer and higher the receiving antenna, the greater will be the voltage developed in it, and therefore the greater will be the voltage transferred and applied to the crystal detector. In the case of crystal receivers, therefore, maximum detection efficiency will be secured with long and high antennae; the longer and higher, the better. The object of height in the antenna is largely to overcome absorption effects of structures around it, for if the antenna is too low, much of the energy in the passing wave trains will be absorbed by the surrounding structures and so fail to act on the antenna. If the antenna is made higher than the surrounding structures, this disadvantage is avoided. The object of length in the antenna is to collect as much of the energy from the passing waves as possible. The length cannot be made too great, however, for then the fundamental wave-length of the antenna will be so great that sharp tuning will be impossible; in fact, it may not be possible to tune to the low broadcasting wave-lengths at all then. So that in tuners employing crystal detectors, maximum results will be obtained with long and high antennae. Good, practical values are about 100′ to 150′ long (it is not necessary to go beyond 150′) and as high as conditions permit, which generally is in the neighborhood of 50′ or 60′ maximum above ground.

The non-regenerative tube detector is also a "voltage operated device," that is, its response is directly proportional to the voltage which is applied to the grid of the detector tube. The voltage applied thus is the signal voltage, and the magnitude of the signal voltage depends upon the received current in the antenna. This depends upon the size of the antenna, the longer and higher the antenna, the greater the voltage. Thus for non-regenerative tube sets, the antenna should be constructed to have great length and height, as for the crystal tube sets.

Coupled Circuits Are More Efficient

When using a single circuit set as in Fig. 1, the voltage which is applied to the detector, crystal or tube, is the voltage direct from the antenna. However, when using a double circuit set employing a loose coupler or variocoupler arrangement, as in Fig. 2, the voltage applied to the detector is obtained by induction from the antenna primary circuit. Now in this case the virtue of this arrangement is that it enables the operator to adjust the intensity of the signal voltage which is applied to his detector. By properly proportioning his primary and secondary he can so arrange the set that the transfer to energy from primary to secondary is accompanied by a rise in the voltage. Further adjustment can be secured by increasing or decreasing the coupling between primary and secondary until the signal of the proper strength is secured.

The above arrangement will be found to be very important at times, especially in reducing the signal voltage applied to the detector. It sometimes is necessary to reduce rather than increase the signal voltage applied to crystal or non-regenerative tube detector. This will be clear from the following phenomenon which the reader has probably often observed. While listening to the broadcast entertainments he has heard a sudden loud signal interfere with the concert or speech, after which the concert or speech was no longer heard. Then after a short while, if he has left his adjustments as they were, the concert or speech gradually begins to come in faintly, slowly increasing to normal intensity. The sudden loud signal was due to a very powerful signal voltage, probably from some powerful spark transmitter or transmitter very close to the receiver. Now, when an excessive voltage strikes a detector tube or crystal it paralyzes the detector and prevents it from operating. This paralyzing action lasts for a shorter or longer time, depending upon circumstances, and then the detector gradually recovers, and the signals or broadcasting begin to come in again. In order to avoid such paralyzing signals it may be necessary to reduce their effect on the detector by decreasing the signal voltage applied to the detector and this can be accomplished by the two-circuit tuner by means of the coupling arrangement. By loosening the coupling the voltage induced from antenna into the secondary is thus reduced and the paralyzing effect avoided. It will also be clear, therefore, that this arrangement will simultaneously reduce interference from such stations by reducing their effect on the detector.

Regenerative Tube Detectors

We come finally to the case of sets employing regeneration. Here the conditions for maximum efficiency in detection are entirely different from the above cases. Armstrong has shown that where regeneration is employed maximum sensitivity in detection is secured when the signal voltages applied to the grid of the tube are extremely small. The smaller the voltages thus applied, the more sensitive is the tube as a regenerative detector. Here we have a case almost the exact opposite of the non-regenerative tube detector. Since this is true, it is evident that with a regenerative set we can dispense with long and high antennae, for nearby reception since the long and high antennae yield large signal voltages, which in this case produce inefficient reception. To secure the necessary low voltages for the regenerative tube detector, we have three possibilities:

1. The use of a loop antenna. This will generally be inadequate for most purposes, unless the receiving station is located very close to the broadcasting station, because the signal voltage thus developed in the loop will be entirely too small to actuate the detector. It should be remembered that while the regenerative tube detector is most sensitive on small applied voltages, there is a lower limit beyond which the tube will not respond to the signal. In such cases it is necessary to employ one or two stages of radio frequency amplification to secure results. But where the receiver is close to the transmitter, the loop will be found to be fairly satisfactory.

2. When using a long and high antenna, the use of the above mentioned loose coupler or variocoupler will be found to give relief from insensitiveness. For by reducing the coupling between the antenna and secondary, the amount of energy transferred into the secondary from the antenna is reduced and thus the voltage applied to the grid of the tube detector is also reduced, thus giving the required low voltage. Now this feature has a great advantage, which is its adjustability, for the coupling, and hence the applied grid voltage may be varied until the maximum loudness is secured in the phones.

3. The third and possibly best direct way to secure the necessary low voltage to give maximum sensitivity in detection on regenerative sets is the use of short antennae. Since the long and high antenna gives high voltages, the short antenna will give low voltages. This probably explains why so many people using regenerative sets are getting such good results by using a wire running around the wall moulding, or by using a single wire running through the hall. These antennae are short and low compared to outside antennae, and therefore develop the necessary low voltages in them.

We thus see that here is a case where long and high antennae are not essential to sensitivity in detection, and that a low short antenna will sometimes yield good results. This should be very carefully considered by people buying or using such regenerative tube sets, especially if their landlords have objections to the installation of antennae on roofs, or where it is impossible or impracticable to install long antennae. Short antennae, and low ones, may be easy to install, and some landlords may not have any objection if they are shown that it will be short and low. Furthermore, in the event of difficulties even with the installation of short antennae, there is always the stand-by of the indoor antenna, of one or two wires. A single wire in the ordinary hallway or run around the moulding of a room will give a sufficient volume signal to operate the phones and be heard when phones are pulled away from the ear. And, as the writer witnessed the other night, a single wire about 15′ to 20′ long running through a hallway operated a regenerative set with two stages of amplification so that the music, when applied to a pair of receivers in an ordinary phonograph horn (no loud-speaker) was heard very loudly throughout an entire flat of five rooms. Those intending to install receivers will do well to give this matter their attention to their own advantage, and thus avoid antenna installation trouble, which often holds many people back from buying radio sets.

Theory of Crystal Detector Operation

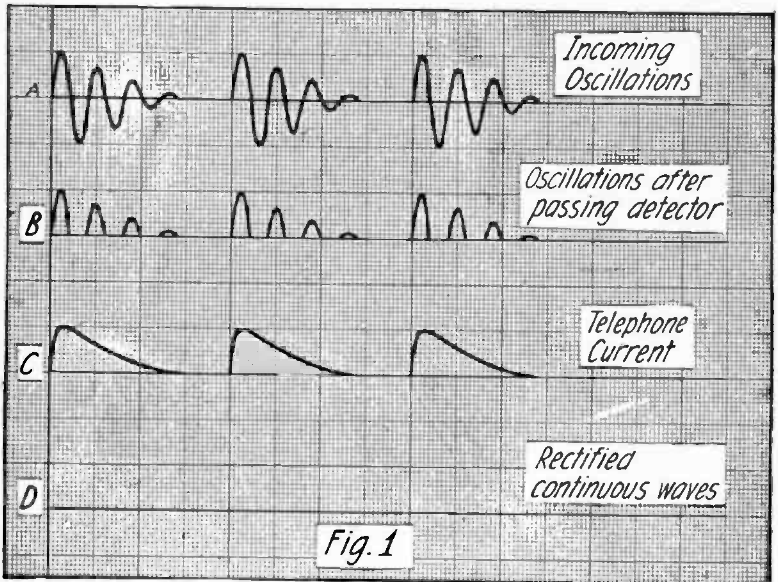
By **Bert T. Bonaventure**

With the advent of the wave of popular radio and its attendant flood of crystal detectors, there are, no doubt many users who would like to know the whys and wherefores of this most essential part of their radio equipment. Many owners of receiving sets have fussed and fumed with their crystals, more with a neophyte's enthusiasm than with a clear understanding of the operation of the detector, through the lack of which understanding they have not been able to get the best possible results from their sets. Fortunately, this stage of aimlessness is beginning to pass and the radio fan is beginning to ask pertinent questions about the functionings of his apparatus. By far the most important single instrument in a receiving set is the detector and in this article, the writer will describe the operation of the crystal in detail.

Crystal detectors are divided into two main groups, with some crystals possessing properties of both classes. In the first group are the crystals which possess the property of unilateral conductivity; that is, a current of electricity is able to flow through the crystal much better in one direction than in the other. In the second group are the crystals which do not adhere to Ohm's law over a range of applied voltages. These crystals possess a non-linear voltage-current curve. In both cases, detection is accomplished by a rectification of the incoming signal. The rectified current charges the phone condenser and is smoothed out therein before the condenser discharges into the telephone receivers, thus producing an audible sound. The most sensitive crystals are furnished by the first group, but they are also accompanied by the disadvantage that they are easily jarred out of adjustment. Since they require an extremely light pressure of the catwhisker wire in making contact on the surface of the crystal, if the table or set is subjected to even a small jolt, the adjustment is lost. This annoyance is rendered still more disagreeable by the fact that the whole surface of the crystal is not uniformly sensitive and more or less time is lost in finding a new spot which responds well to the incoming signals.

Crystals of the second group are more stable in operation as a heavier pressure is usually used at the point of contact. Such crystals are favored on board ships where the rock and roll of a vessal will knock a sensitive galena crystal out of adjustment, requiring the repetition of part of the message being sent.

Galena is by far the most sensitive crystal of the first group, with iron pyrites (fool's gold) a close second. If a piece of galena be examined closely, it will be seen that the surface is covered with fine serrations running in but one direction. Upon breaking the crystal the serrations can be seen running in a perpendicular direction, thus showing the formation of the substance as cubic. On a bright, smooth surface it will be found that the sensitivity is usually zero, the maximum sensitivity occurring at places where the serrations are located or where a depression is formed by the criss-cross ridges.



A Graph Illustrating the Original Energy Impressed Upon a Reception Circuit, its Character Upon Being Rectified, and the Consequent Telephone Current.

Just what the action is that goes on in the crystal, which enables it to rectify high frequency currents, is a subject open to dispute. Fleming found that this rectifying power is lost when the rectifying substance is powdered and moulded into rods under great pressure. Heating the compressed rod in an electric arc could not restore its previous properties, the rectifying power seeming to depend on the crystaline structure. With other substances, rectification seems to depend on a surface action, which Goddard calls surface rectification, maintaining that these solid rectifiers operate in a manner similar to the electrolytic rectifiers.

Quite a number of hypotheses have been advanced to explain the action of crystal detectors, the assumptions being that the phenomena depend on thermo-electric properties, photo-chemical properties, electrolysis in solids, electrostatic attraction, etc. The thermo-electric theory seems to be the most plausible. With this hypothesis, the observed phenomena depend on three main conditions, viz:

1. Temperature variation of resistance.
2. The Peltier effect. (Absorption or generation of heat by the passage of a current through a junction of dissimilar metals.)

3. The Thompson effect. (The production of an EMF between different parts of the same substance at different temperatures.)

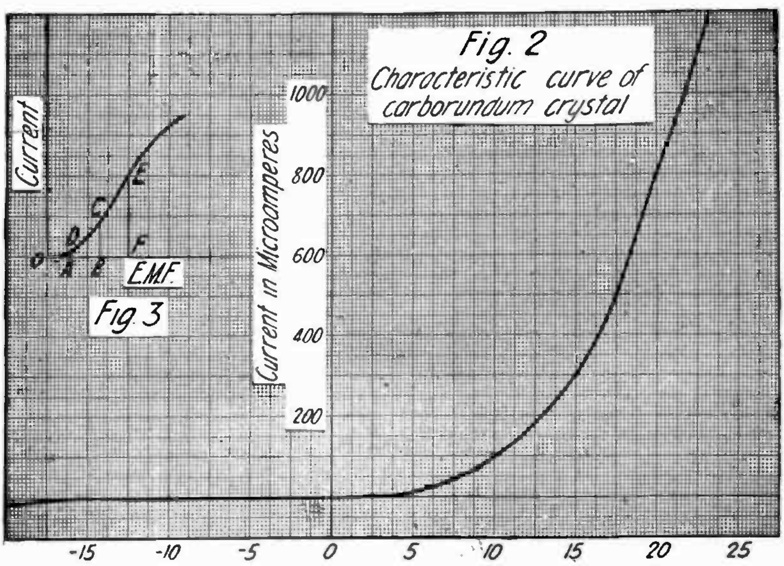
Just which phenomenon or combination of phenomena produces the rectification, and the considerations, pro and con of their effects, involves a discussion which cannot be entered into in this paper, both for lack of space and on account of its highly technical nature, being primarily a matter of pure physics. Those inclined to delve more deeply into the nature of these phenomena will find a full and elaborate discussion in a paper by W. D. Eccles, (Proc. Phys. Soc. Lond. p. 273, vol. 25, 1913).

In brief, the incoming signal traverses a point of very small cross-section (therefore of high resistance) and the energy in the wave train is dissipated as heat at the contact of the catwhisker wire and the crystal. The temperature of the locality of the contact is raised by this heat generation, introducing the Thompson and Peltier effects. Being a junction of dissimilar metals, a direct electromotive force is produced, giving rise to sound in the telephone receivers.

Most of the good rectifying substances are oxides or sulphides. Other good rectifiers use a metal and a non-metal contact. Among the list of the substances which give good results as contact detectors are silicon, boron, graphite, tellurium, arsenic, chalcopyrites ($FeS+CuS$), bornite ($3Cu_2SFe_2S_3$), molybdenite (MoS_2), zincite (ZnO), brookite (TiO_2), iserine ($[FeTe]_2O_3$), psilomelane (MnO_2), cuprite (Cu_2O), cerussite ($PbCO_3$), etc. Of these, the most common types are zincite and chalcopyrite (Perikon), zincite and bornite, iron pyrite and gold, carborundum and steel, silicon and gold, galena and graphite, platinum or copper, Some of these crystals also come under the category of the second group, such as carborundum and silicon. It is interesting to note that good contact rectifiers possess strongly contrasted photo-electric properties.

The operation of crystals of the first group is as follows:

It is assumed that the transmitter sends out wave trains that are damped and occur at an audible frequency, say 500 cycles per second. When the receiving set is tuned to the incoming wave, the potential difference that is applied to the detector is of the form A in Fig. 1. The telephone condenser acts as a low impedance by-pass for the radio frequency current around the phones and allows this potential to be applied undistorted in wave form to the detector. Assuming that our crystal is a perfect rectifier, the lower half of each oscillation will be suppressed so that the rectified current has the form B, Fig. 1. The telephone condenser stores these individual pulses which occur at radio frequency and discharges finally into the telephone receivers the wave form of the current being indicated at C. Since these wave trains are arriving at the rate of 500 per second, hence 500 of these rectified, smoothed-out pulses actuate the receiver diaphragm, thus producing a 500 cycle note. Since the crystal is an imperfect rectifier, the wave form shown at B



Characteristic Curve of a Carborundum Crystal Showing the Relative Current at Various Applied Potentials.

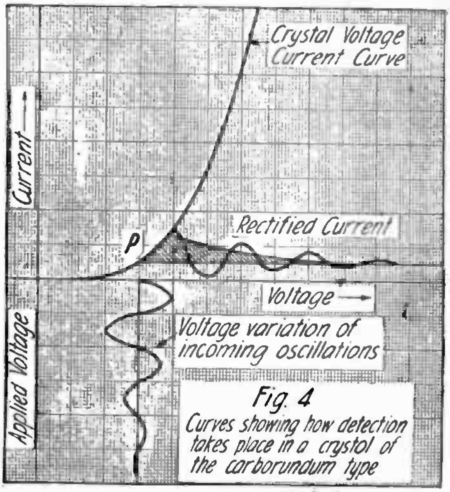
is not quite a true representation of the conditions actually existing in the receiver. The crystal allows a small part of the reverse cycle to pass and this negative current would be shown below the zero line of the time axis. However, the upper half of the cycle preponderates to such an extent that this reverse current detracts but little from the effective telephone current. Should a continuous wave signal be received, the telephone current exists as a more or less steady uni-directional flow due to the fact that the incoming oscillations keep the phone condenser fully charged at all times, thus supplying the telephone receiver with a steady current as shown at D, Fig. 1.

The relation between the high frequency energy received and the D. C. energy supplied to the phones is a linear function but if plotted on graph paper, does not pass through the origin, showing that there is an initial value of the high frequency energy below which rectification will not take place. The efficiency of some forms of detectors, (the ratio of D. C. energy to H. F. energy supplied) was found by Eccles to be 9.3 per cent. for the carborundum detector, 13 per cent. for the Perikon detector, and about 3 per cent. for a graphite-galena detector.

This brings us to the crystals of the second group. The best insight into the operation of these crystals is obtained from a study of their characteristic curves. Such a curve for carborundum is shown in Fig. 2. This curve, except for numerical magnitudes, is typical of crystals of this type. It is seen from Fig. 2, that when a small voltage is applied to the crystal and is gradually increased, the current through the crystal increases, but more rapidly than the voltage after a certain critical voltage has been applied. Up to the critical voltage, the increase in current is at a slower rate than the increase in voltage. When the voltage is reversed, the current is also reversed but it is considerably less in value for the same potentials applied (unsymmetrical characteristic with respect to the current axis), showing that the crystal possesses unilateral conductivity also. It has been found that with carborundum, this rectifying power increases with increasing temperature, reaching a maximum sensitivity at from 400° to 500° Centigrade.

In operation such a crystal is clamped between two electrodes and a potential is applied, being regulated by a potentiometer. Thus there is a certain amount of current always flowing through the crystal. The potential of the applied EMF is adjusted so that the crystal operates on the knee of the curve, the potential being in the direction in which the crystal conducts best.

When electrical oscillations are impressed on this detector, they are super-imposed on the uni-directional current already flowing through it, thus periodically increasing and decreasing the value of the effective EMF. Since the current-voltage curve is non-linear, the current increases suddenly with the application of a small additional EMF. When the signal EMF is in the opposite direction so as to detract from the unidirectional voltage on the crystal, the decrease in current is small as compared to the increase produced by the same potential, if reversed in sign.



Illustrating the Voltage Characteristics of a Carborundum Crystal.

Fig. 3 will make this more clear. Suppose the local EMF is equal to OA. Then an increase in voltage due to an incoming oscillation, positive wave AB, causes a sudden increase of current BC-AD. By its negative wave OA, it produces a decrease in current, AD. Hence rectification takes place in a positive direction. Suppose the local EMF applied is OB. Then the oscillatory EMF produces no rectification at all for the reason that the curve is practically straight on each side of point B. Suppose the local EMF applied is equal to OF. Then the oscillatory signal EMF produces negative rectification since the negative wave produces a greater decrease in current than the increase produced by the positive wave.

The actual phenomena can be inferred by referring to Fig. 4. By adjusting the potentiometer so as to apply a voltage corresponding to the point P on the characteristic curve, the crystal is in a condition for best reception. The damped oscillatory EMF is represented by the sine wave form on the Y axis directly below P. The variation of EMF across the crystal is the algebraic sum of the undirectional EMF applied and that due to the incoming oscillation.

Condensers

By Jesse Marsten

A condenser consists essentially of two or more conducting plates, of one shape or another, with an insulating medium between the plates, which is called the "dielectric." By virtue of its construction this apparatus has the ability to store in the dielectric between its plates a certain amount of energy. The measure of its ability to so store electric energy is called the "capacity" of the condenser, and this capacity is directly proportional to the energy it can store. The capacity of a condenser is also dependent upon other factors: in general it is directly proportional to the area of the plates, to the number of plates, and to a constant K called the "dielectric constant" which depends upon the material of the dielectric. For air this factor is unity, but for all other dielectrics this factor varies generally between 1 and 10. The capacity is also inversely proportional to the spacing between the condenser plates, the closer the spacing the greater the capacity. A condenser so built by design to have a capacity is called "lumped" or "concentrated" capacity, in contradistinction to "stray" or "distributed" capacity which arises accidentally between metallic parts of a circuit which are at different potentials.

Condensers may be classified in a number of ways, but for our purposes they may be divided as follows:

I. Transmitting condensers

II. Receiving condensers.

Each of these classes may be further subdivided into the following groups:

(a) Fixed condensers

(b) Variable condensers.

Generally it will be found that transmitting condensers are seldom, if ever, variable, while receiving condensers may be either fixed or variable depending upon the purpose for which they are intended.

The ideal condenser would have absolutely no losses due to any cause and its capacity would remain constant over a wide range of temperature and voltage conditions. Ideal condensers do not, of course, exist, but the nearest approach to it is the air condenser whose losses are very small. It is for this reason that air condensers are generally used as capacity standards.

The causes for the departure of practically built condensers from the ideal lie mostly in the perfections of the dielectric. There exists losses, of course, also in the plates and plate leads of the condenser due to their resistance, but these losses are very small. The chief imperfections may be enumerated as follows:

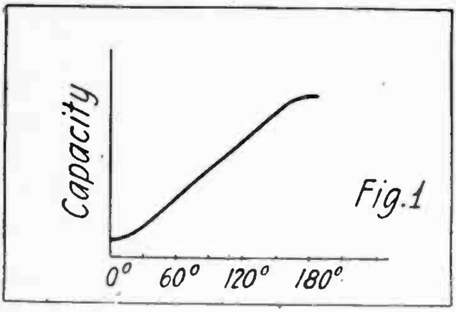
(a) *Leakage.* The currents flowing through a condenser should be a true capacity current flowing by virtue of the capacity effect and not by virtue of any conductance. However, due to the imperfection of the dielectric, the condenser may have some conductivity and hence there will be some flow of current which is a conduction current through the resistance of the dielectric. This current is leakage and results in a total loss of energy. Not only may there be leakage of current through the dielectric, but there may also be leakage of current across the surface of the dielectric between the plates.

(b) *Dielectric Assorption.* This is really the chief and most important source of condenser losses. When a voltage is applied to an ideal condenser it is charged instantaneously, and when it is discharged it is also discharged instantaneously. In the case of imperfect dielectrics something else happens. When the voltage is applied to the condenser an instantaneous charge flows into it, but immediately thereafter is a small continuously decreasing current in addition which flows into the condenser and which seems to be absorbed by it. This represents an energy loss which appears as heat.

(c) *Brush and Corona Losses.* These occur only in the case of transmitting condensers which are operated at high voltages. At high voltages ionization of the air occurs and leakage of current takes place at points favorable to it, namely, where there are sharp edges, at corners, points, etc. This leakage is made evident by a thin bluish discharge and when this brushing is really powerful the ionization is accompanied by the generation of ozone which can be detected by its peculiar odor.

The above imperfections exist in both transmitting and receiving condensers, but the last is, of course, solely a transmitting condenser phenomenon, since high voltages are not present in receivers. They all result in increasing the effective resistance of the condenser, hence in increasing the losses. The extent to which they increase the losses depends upon the frequency of the current, and may generally be represented as increasing with the wavelength. The importance of minimizing these losses is at once apparent when we consider that a poor transmitting condenser may increase the resistance of its circuit by several ohms and thus cut radiation, and in the case of reception, where incoming energy is extremely small as it is, it will reduce the audibility factor.

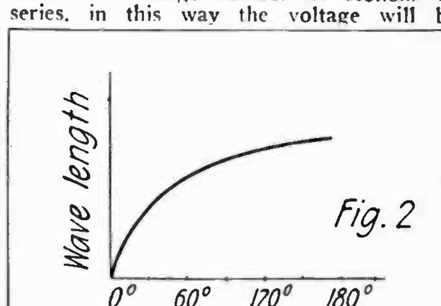
The problem of reducing the losses in condensers is then one of reducing the losses in the dielectric. The resistance due to plates and plate leads may of course be reduced by using good conduiting material for these and making the leads as short as possible. If air could be used efficiently and economically in transmitting condensers this would be the best type of dielectric to use. But air has a low dielectric constant, hence would require great bulk to give high capacities. Furthermore, its dielectric strength, ability to withstand high voltages, is not great. Compressed air has a larger dielectric strength, but these condensers are bulky. Glass used to be very popular, as in the case of the well known Leyden jar, but they have high brush losses, and are easily breakable, thus requiring frequent renewals. The best and most suitable dielectric for transmitting condensers is mica. This dielectric has been found to have very low dielectric losses, less than any other dielectric, excepting air, and it approaches air very closely. Also it has a high dielectric strength which enables building of condensers to withstand high voltages. Its high dielectric constant also permits the construction of high capacity condensers in very small space, which makes these condensers very convenient since they may be built in small units. In the case of variable transmitting condensers, liquid oil is usually used as the dielectric in an ordinary air condenser. A good grade of mineral oil has fair dielectric properties, and it has one added advantage which makes it a favorable type, namely, its self-healing properties, when a breakdown occurs. When the voltage between condenser plates becomes too great a breakdown occurs, and an arc takes place between the plates. If the dielectric is a solid one the dielectric is pierced by the arc-over and is spoiled. It will never be able to withstand the high voltage any more since it will spark over at the injured part. In the case of the oil dielectric this does not happen. When the arc-over occurs new liquid oil flows into the space at which the arc occurs and the dielectric is immediately healed.



Capacity Curve of Semi-Circular Plate Condenser.

An interesting point in connection with transmitting condensers is the breakdown voltage. This voltage depends upon the dielectric, of course, but is subject to different conditions from breakdown at constant voltage. A condenser will withstand a high voltage at direct currents indefinitely. But it may not withstand such high voltage at radio frequencies indefinitely. After a while it breaks down, and this breakdown is due to a cumulative effect in time. As time goes on the losses heat the dialectric, and this heating deteriorates the insulating properties so that it heats up still more and the cycle repeats itself, until a point is reached where the insulating properties have deteriorated to such an extent that it can no longer withstand the voltage. Amateurs do not generally understand this and think that breakdown is always due to poor dielectric or excessive voltage. This cumulative effect will explain many breakdowns.

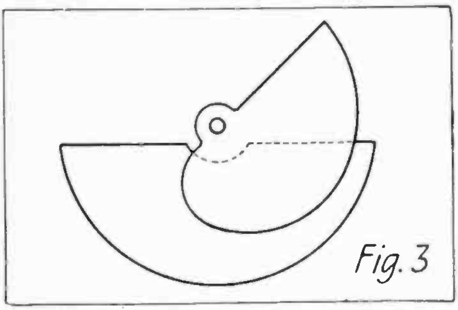
The above details apply particularly to transmitting condensers. In purchasing transmitting condensers the only sensible thing to do is buy one of the standard reliable makes employing mica as dielectric for fixed condensers. Inquire about the voltage it will withstand. if it is not marked on the condenser; reliable manufacturers have no hesitation in giving the maximum voltage and current carrying capacity. If the amateur builds his own condenser made of mica he should observe the following: If high voltage is to be applied build the condenser so that there are a large number of sections in series. in this way the voltage will be distributed over a larger number of condensers in series, thus reducing the possibility of breakdowns. If high current-carrying capacity is the chief requirement, the condenser should be built of a large number of sections in parallel, distributing the current so that the heating effect is a minimum. If both requirements of high



Wave-Length Curve of Semi-Circular Plate Condenser.

voltage and current-carrying capacity have to be met, then the condenser should be built of sections in series and in parallel. When using oil variable condensers, the chief precaution to observe is that the oil is a good grade of mineral oil with no particles of grit in it.

Receiving condensers do not withstand any voltages to talk of, nevertheless, they must be just as good as transmitting condensers, since the received energy is so small and every bit of energy lost in the condenser means so much weaker signal. Air and mica are the chief dielectrics used in receiving condensers. Paper and paraffined paper are frequently used for the



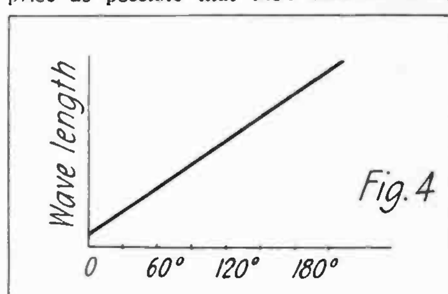
Specially Shaped Plates for Wavemeter Condenser.

cheaper types of equipment. The chief source of losses in air condensers is that in the dielectric. The dielectric losses are not confined to the dielectric itself between the plates of the condenser, but also to the dielectric and insulating material in any part of the electric field of the condenser. Thus insulating bushings, end plates, supporting posts are dielectrics, and unless these are of the very best the losses in them will be considerable.

The variable air condenser most commonly used consists of the usual type of semi-circular plates, half of which are fixed and the other half movable, these plates interleaving. Maximum capacity is obtained when they are completely interleaved, minimum when they are not at all interleaved, and intermediate values in between. Such condensers are rated by their maximum capacities, as 0.0005 microfarads. The semi-circular plate condenser gives a straight line variation of capacity as shown in Fig. 1, and when used in conjunction with an inductance coil to make a wave meter it gives a wave-length curve as in Fig. 2. From this curve we learn that for small increases in capacity at the lower end of the scale there are large increases of wave-length, while at the upper end of the scale small increases in capacity give smaller increases in wave-length. Thus the wave-length scale is crowded at the lower end, open at the upper end, and non-uniform throughout the length of the scale. This results in inaccuracies when used in a wave meter.

In order to secure a uniform wave-length scale, and hence greater accuracy in wave meter measurements, it becomes necessary to use another type of condenser with specially shaped rotor plates. This is shown in Fig. 3. This is the so-called wavemeter type of condenser employing semi-circular stator plates, but specially formed rotor plates, with shaft eccentrically located. This particular type of condenser does not give a straight line capacity curve, but in conjunction with an inductance coil does give a straight line wave-length curve as in Fig. 4. This shows that the scale is uniform and not crowded at any part, hence accuracy in measurement can be secured.

The prospective purchaser of variable condensers would do well to examine the condenser carefully and see that it meets with most of the following requirements. In the first place, if a receiving condenser is desired, the semi-circular type is preferabe. If, however, the condenser is desired solely for wave meter use the special shaped plate condenser above mentioned should by all means be used. The amateur might just as well become educated to the use of the proper instruments for each purpose in hand. The first requisite in construction is rigidity. All parts should be securely fastened so that motion of plates will produce no loosening of parts. Some manufacturers today are so intent upon turning out as much junk at as cheap a price as possible that their manufacturing



Wave-Length Curve for Special Shaped Wavemeter Condenser.

and assembling methods are not the most commendable and disgraceful rickety affairs are to be seen all over. If loosening of parts occurs there will be a variation of capacity of the condenser. The parts used in the assembly should be substantial. It is preferable not to buy a condenser with stops, as when the rotor plates strike against the stops jarring is produced which ultimately may result in loosening of nuts and hence altering the spacing of plates and capacity. Plates used in the construction of the condenser should be stocky and not too thin, and should be level and not warped. Otherwise one plate which is warped may just strike its neighbor and produce a short circuit. Likewise the spacer washers should be examined to see that they are uniform. The spacing between rotor and stator plates is small enough as it is and any variation in washer thickness may result in stator touching rotor and hence producing short circuit. End plates should be of the very best insulating material, rigid and stocky, and not warped. For a warped end plate will also produce short circuit, since the stator plates are attached to it. Turn the knob on the condenser and listen carefully to hear whether there is any scraping or brushing of plates. A short or touching of plates is easily detected that way. Note whether the movements of the rotor plates are jumpy or smooth and regular, and avoid those condensers whose movements are jumpy. The smooth motion of the condenser permits you to tune better since you can cover the entire range of capacity by turning the knob. The jumping or hopping motion does not permit of good tuning, for when you turn your knob the plates jump over a large angle, due to poor mechanical design. There are loads of such condensers on the market. Be sure that the condenser has lugs attached for soldering your leads to it. Pick the condenser which has a minimum of insulating material in its construction. This material should be hard rubber or bakelite. Fibre or composition end plates should always be avoided. Avoid, if possible, the choice of a condenser which has insulating material for bearings. Such a bearing is likely to wear with time, resulting in displacing the shaft holding the rotor plates and hence resulting in altering the capacity, and loosening the shaft in bearings. These are the chief things to look after when buying a condenser and are worth while looking after.

Monographic Charts for Measuring Capacity, Inductance and Wave-Length

By **Z. W. Van Slyck**

Quite often the amateur wishes to make some calculations of inductance or capacity, or to measure the wave-length of a circuit, so that it will be able to tune up a certain station. The great obstacle is the use of formulae which are not familiar and look so complicated that they discourage the amateur in his attempts.

To simplify this and render easy any operation, the three charts accompaning this article were designed. With these charts it is possible to calculate the capacity of a condenser if the surface of the armatures is known and also to determine the surface of tinfoil and thickness of dielectric necessary for a certain capacity. For the calculation of inductance, no operations are necessary, and the value of any coil may be found in centimeters if the dimensions and size of wire are known. The third chart gives the wave-length of any circuit, when the capacity and the inductance are known.

The following examples show how simple it is to use these charts:

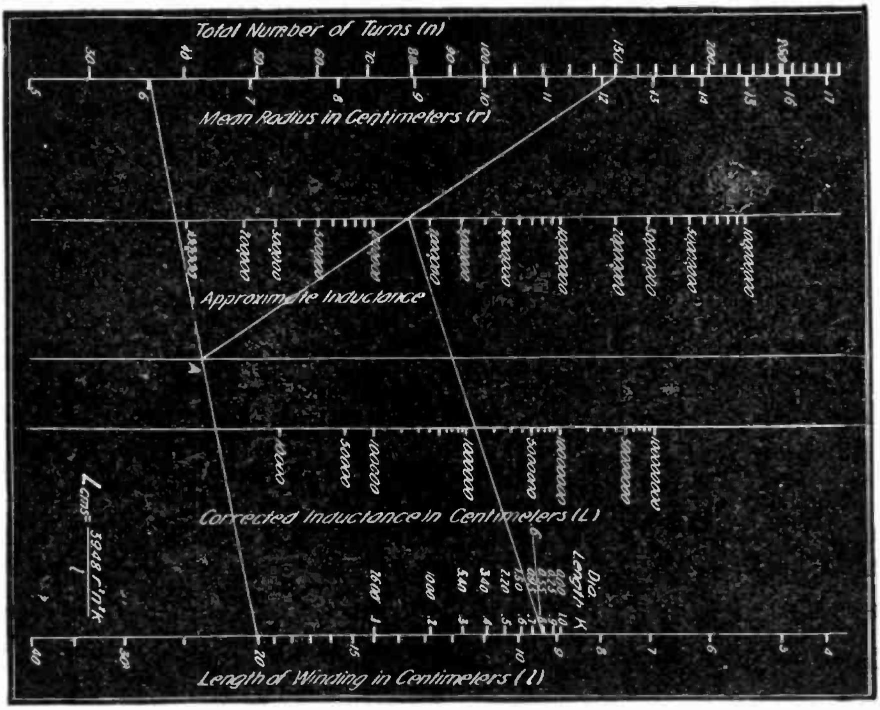
Calculation of the Capacity

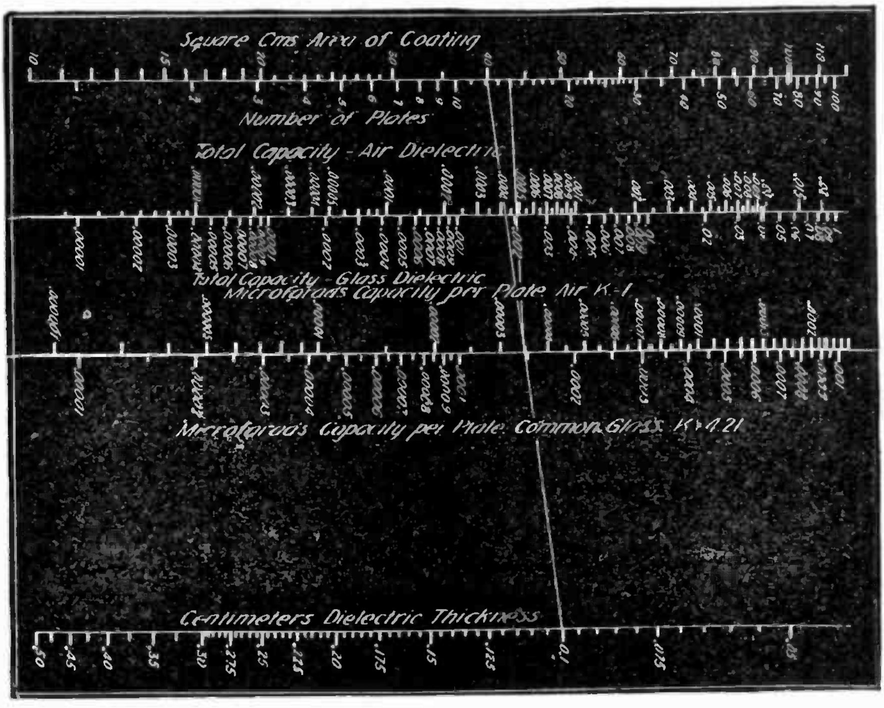
Suppose we wish to construct an air dielectric condenser whose maximum capacity will be .0005; suppose we decide that the safe separation between plates is 0.1 cm., that is 1 millimeter, and that the size of our plates will permit an area of 40 sq. cms. Referring to Chart 1, on the next page, we connect the points 0.1 on the right with 40 on the left, and read .000035 on the center scale, which is the capacity per plate. Connect this point with the required capacity, in this case it is .0005 on the left center scale, and extend the line to the left scale, where we read 12, which is the required number of plates.

Calculation of the Inductance

Now suppose we have a tube upon which we can put a winding of 150 turns in 20 cms., and the mean radius of a turn will be 6 cm., connect 6 on the left of Chart 2, on the left of the next page, with 20 on the right scale and mark intersection on the reference line, point A in this case. Connect A with 150 on the left and on the left center scale read 600,000 cm. inductance. Connect this point with .6 (12/20) on the right, and read a corrected inductance of 1,300,000 cms. on the right center scale.

It may be mentioned that one inch is equal in length to twenty-five milli-meters and four-tenths, or two centi-meters, five milli-meters and four-tenths.





Here is Something Practical, Which Will Greatly Help the Amateurs to Determine the Inductance of Coils, Capacity of Condensers and Wave-Length of Circuits.

Calculation of Wave-Length

A chart for the calculation of wave-length is given herewith. A single setting is required, the constant 59.6 being incorporated in one of the scales.

Some value of inductance larger than those shown in the scale may be used; the value of capacity being .0005, and inductance 1,300,000, it is found that the combination would respond to a wave-length of approximately 1,520 meters. To find

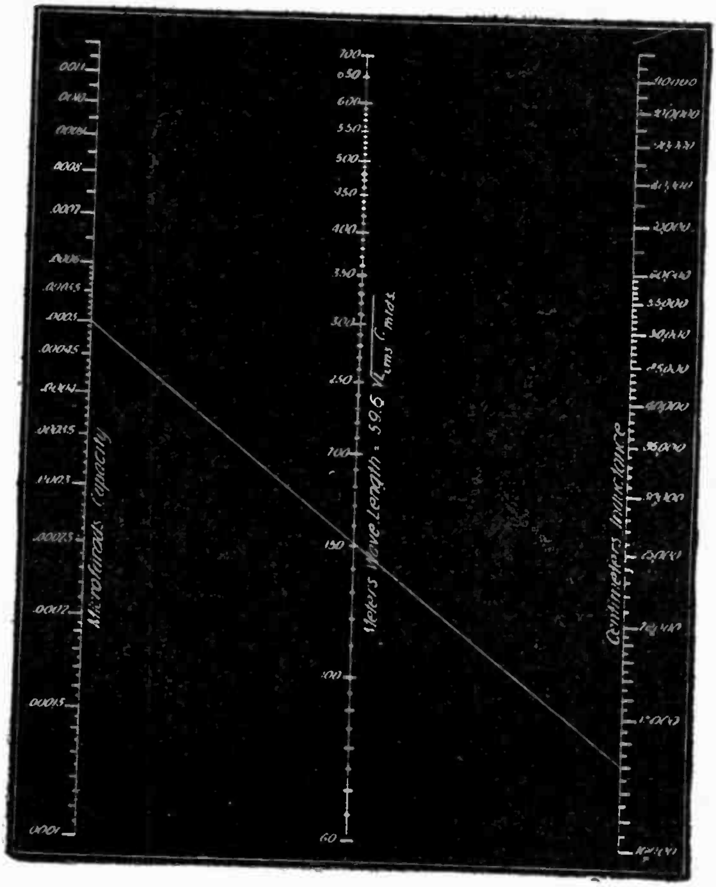


Chart for the Calculation of Wave-Lengths.

For instance, if, in a circuit having an inductance of 13,000 centimeters, we connect the capacity of .0005 mf., the circuit will have a wave-length of about 152 meters, as shown by the white line drawn on the chart, as an example. If, to an inductance of 32,000 centimeters, we connect a capacity of .0002 mf., we find that the wave-length is the same, for by joining 32,000 on the right scale, to .0002 on the left one, the joining line crosses the wave-length scale at the same point.

this, connect .0005 mf. on the left with 13,000 on the right and read 152 on the center scale. Since the square root of the number by which 13,000 must be multiplied in order to get 1,300,000 is 10, multiply 152 by 10 and get 1,520 meters, the correct wave-length to which the circuit will respond.

All these charts are accurate enough for practical measurements that the amateur wishes to make when building apparatus, or to determine the characteristics of his instruments.

Fundamental Operation of Vacuum Tubes

By **David S. Brown**

When the old audion was in common use it was customary to connect it up in one standard circuit and to operate it (in respect to applied voltages, etc.) in one so-called "only correct" method. Modern developments and experiments have so far shown what goes on inside and outside the tube that a thorough understanding of certain principles of theory enable the operator to use a great variety of circuits for a great many purposes. And although the theories have all been bottled up in books, nevertheless the average man is somewhat in the dark even yet, mainly because of his limited understanding of the technical expressions and theories used in those books. With the hope of giving the "average man" a fair knowledge of vacuum tube operation, this article is undertaken. No attempt will be made to give theory and hence no apology is necessary for the omission of the customary explanations found in most articles on the vacuum tube. However, it must be remembered that only through a clear understanding of the action of the tube can come intelligent operation.

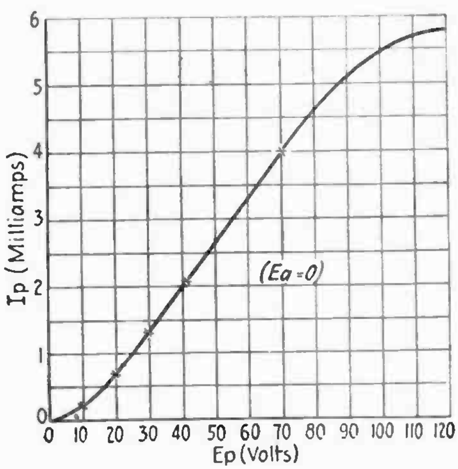


Fig. 1.—A Simple Graph for Those Not Familiar With the How and Why of It.

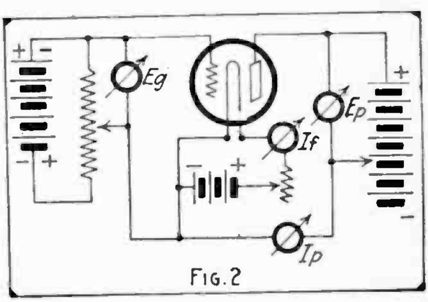
It is assumed that nearly everybody understands how to read graphs or curves. For the benefit of those who may be in doubt, refer to Fig. 1. The heavy horizontal line is called the "abscissae"; the vertical one the "ordinate." They are also referred to as the "axes." Where the two lines intersect is the point which represents zero (whether it be volts, amperes, seconds or any other measure of dimension). Positive values are to the right of zero on the abscissae and above zero on the ordinate. To the left and below zero are the negative or minus values. The units used are always designated on each curve.

"I" stands for *current.*
"E" stands for *voltage.*
"P" stands for *plate circuit.*
"F" stands for *filament circuit.*
"G" stands for *grid circuit.*

Thus "I" means *current flowing in the plate circuit.* "E" means voltage or *potential of the grid.* This latter is measured, considering the filament as zero and the grid as so many volts "positive or negative with respect to the filament."

Old type audions were not very uniform. It was necessary to "juggle" the plate voltage and the filament current for best results. On the other hand, the more recent "high vacuum" tubes are made so nearly uniform that definite instructions can be given for any type tube.

When the filament of a tube is heated, a current will flow through the circuit consisting of the plate, the plate battery, the phones (or any other instruments used in connection therewith) and the filament. This current varies with the temperature of the filament and also with the voltage of the plate battery. As was previously mentioned, with old audions it was necessary to adjust and readjust the filament current and plate voltage until the proper relation was obtained. With all the tubes now being built for army, navy and amateur use,



The Circuit Employed for Obtaining the Static Characteristics of Tubes. Note the Meters in the Various Circuits.

these figures are fixed because of the design and nearly uniform construction of the tubes. The VT-1 (Western Electric

"J") operates on 1.1 amperes filament current. Other tubes are rated as follows:

VT-11 (General Electric) 1.1 amps.
VT-21 (DeForest) 1.1 amps.
Marconi (Moorehead) 0.7 amps.
0.7 amps.
VT-2 (W. E. transmitter) 1.36 amps.

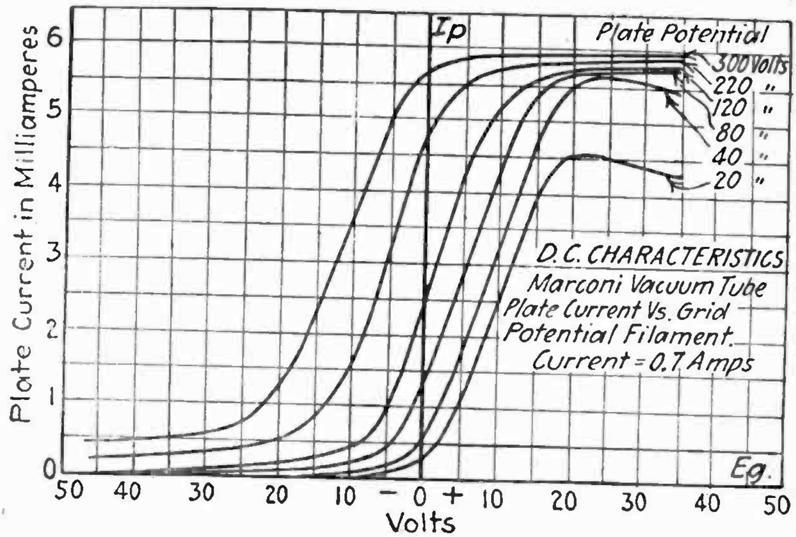
It should be noted that of these only the Western Electric tubes are burned at a dull red heat. All the others have tungsten filaments and are heated to a bright light. However, care should be taken not to burn them above their rated currents, as the filaments burn out quickly when overheated.

Fig. 1 shows a curve representing the values of plate current I_p obtained when E_p is varied and I_f is kept constant. This curve does not represent any particular tube. *As E_p increases, I_p also increases up to a certain point (called the point of saturation) beyond any increase in voltage will cause no further increase in current.* This is shown by the top part of the curve which ceases to go up but flattens out.

Action of the Grid

Without attempting to explain theory, the action of the grid in an audion is simply that positive charges on the grid *increase* current in the plate circuit while negative grid charges *decrease* the plate current. Both of these actions are limited. If the grid is made positive to a certain degree, the "saturation" point is reached similarly as in the E_p-I_p curve. More plate current can be obtained, however, by increasing the plate voltage and also by increasing the filament current. The grid may be made so negative that the plate current will be nearly or, sometimes, entirely stopped. Fig. 2 shows the circuit used for obtaining the static characteristics of tubes. The filament is lighted by the usual "A" battery and the current shown by the ammeter marked "I_f". The plate or "B" battery is variable, the voltage registering on the voltmeter "E_p". Plate current is indicated by a milliammeter "I_p". The potential of the grid is shown by the voltmeter "E_g" and is varied by means of the potentiometer. This grid battery is arranged so that the positive or the negative terminal may be applied to the grid (the reversing switch not being shown).

Suppose now that we have a circuit containing one of the Marconi-Moorehead tubes. We adjust I_f to 0.7 amperes and the plate voltage E_p to 20 volts. Next we move the potentiometer slider all the way up so that there is no voltage on the grid. The grid is then said to be at zero volts with respect to the filament. The plate anmeter will indicate about 0.3 milliamperes. Now we will adjust the potentiometer so that the grid is five volts positive to the filament. The I_p jumps to about 1 milliampere. At 10 volts grid potential, I_p increases to 2.5 milliamperes. We take



Curves at Different Plate Voltages in Respect to Changes of Grid Voltage Showing the Plate Current Flowing in That Circuit.

a few more such points and then reverse the grid battery to make the grid more negative than the filament end. This decreases our I_p below 0.3 milliamps. At 10 volts (negative) on the grid, the plate current is practically zero. If we plot all these points, we will get a curve similar to curve "a" in Fig. 3. There the various distances to the right of "O" represent positive values of grid potential. Distances to the left of "O" are negative grid values. Above "O" (i. e., vertical distances from the E_g axis) are positive current values corresponding to each value of grid potential.

If we now change our E_p to 40 volts and repeat all of the preceding processes, we will get a curve like "b" and likewise other plate voltages as shown by "c," "d," "e" and "h."

From such a family of curves it is possible to see just how and where to operate the tube for the various purposes, e. g., amplifying, detecting, etc. This particular set of curves represents the characteristic action of the Marconi-Moorehead tube as shown in the Marconi Company's booklet.

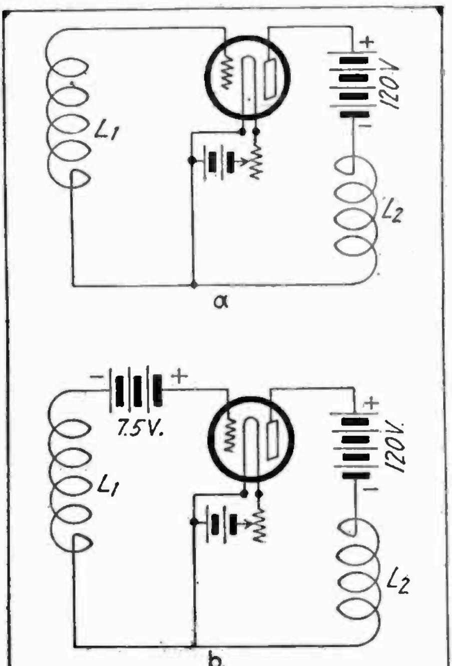


FIG. 4

By Providing a Grid Voltage Such That the Tube Is Operated About the Middle of the Straight or "Steep" Part of the Curve You Can Have Your Tube Amplify As Well On 40 Volts As When Using 120.

However, they hold good for *only* that one style of tube and then only when the filament is heated by 0.7 ampere. Curves will be given later for other makes of tubes. As these characteristics differ in each make of tube, any tube can not well be used hit-or-miss in place of another. The circuit should be made to accommodate the particular tube at hand. In only one particular are all present-day tubes practically alike.

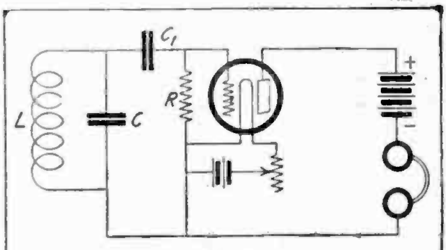


FIG. 5

Simple Circuit of the Vacuum Tube with a Grid Leak Resistance.

They may generally be used as detectors on 20 volts plate, as amplifiers on 20 to 80 volts, and as power oscillators on from 200 to 300 volts.

One important feature for efficient operation is that the impedance, i. e., alternating current resistance of the plate circuit should approximately equal the internal impedance of the tube. For example, in all sets made by the Western Electric Co. for the army the VT-1 was used as both detector and amplifier. The VT-1 has an internal resistance (resistance between plate and filament) of about 20,000 ohms. They therefore made their telephone receivers and the primaries of the amplifying transformers about that same resistance. The VT-1 would then operate most efficiently when used with the W.E. phones or amplifying transformer (or with others of equal impedance). Note, however, that each different make of tube has a different internal resistance and also that the 20,000 ohms above mentioned does *not* mean D.C. resistance. The D.C. resistance of phones is generally from 2,000 to 3,000 ohms per pair. Sooner or later manufacturers will probably advertise the impedances of their various head sets, amplifying transformers and vacuum tubes so that the purchaser may be able to balance up his apparatus for best results. For example, the writer recently saw a standard make of phone on the back of which was stamped "Resistance—D.C. 3,200, 800 cycles 13,500."

The adjustment of the grid potential is very important for effective operation. It varies for each make of tube, for each voltage used on the plate, and for each use to which the tube is put.

The V. T. Amplifier

The simplest action of the vacuum tube is probably that of amplifying. Suppose the tube connected as in Fig. 4a. The filament is at normal heat. the grid at zero volts and there is no current in the filament-grid circuit. Consider now curve "d" in Fig. 3. From this curve it will be seen

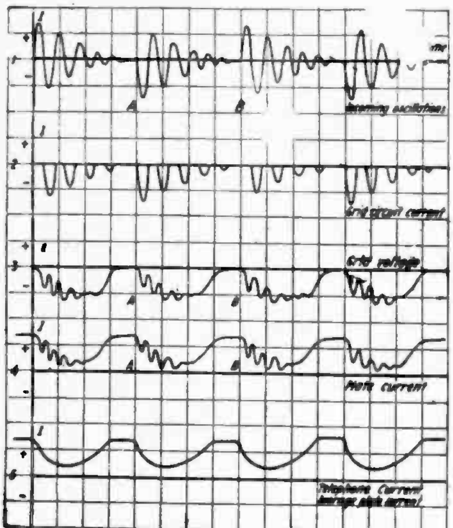


Fig. 6

Graph Showing Incoming Oscillations, Grid Circuit Current. Grid Voltage, Plate Voltage and Resultant Telephone Current.

that the plate current is a steady, direct current of value 2.5 milliamperes. Now suppose an alternative current of small magnitude to be impressed on the *input* transformer secondary L_n. This will cause the grid voltage to vary, becoming alternately positive and negative as the induced current varies. The changing grid voltage will automatically control the current in the plate circuit, I_p, as indicated by the curve. For example, let the grid vary from plus 5 volts to minus volts. At plus 5 volts, the corresponding I_p (from the curve "d") is about 4 milliamps. At minus 5 volts, I_p is 1 milliamp. Hence a current in L_n which causes the grid to alternate from plus 5 volts to minus 5 volts will cause the plate current to vary from 4 to 1 milliamps. *The best amplifier then is, obviously, the one which will give the largest variation in plate current from the smallest given variation in grid current.*

Suppose we had employed 40 volts E_p instead of 120 volts. The grid changes from plus 5 to minus 5. Curve "b" shows the corresponding change in I_p to be 0.2 to 1.8 milliamps. This is not nearly as large as the variation obtained with the same tube using 120 plate volts; and 40 volts would then appear to be not as good for amplifying. But let us connect a 7.5 volt battery with its positive terminal to the grid and its negative terminal to L_n, as shown in 4b. Now our plate current goes away up; curve "b" shows it to be 2.5 milliamps. Let the grid again vary 5 volts up and down. The grid is already at 7.5 volts, so therefore, such a variation will make the grid alternately 7.5—5.0 and 7.5+5.0, that is, the grid will vary from plus 2.5 to 12.5 volts. That causes a variation in I_p of from 1 to 4 miliamperes, which is the same as was formerly obtained with E_p of 120 volts. In other words, we can get the tube to amplify as well on 40 volts as we did on 120 volts *provided that we make the grid voltage* (without incoming signals) *such that the tube is operating about the middle of the straight or "steep" part of the curve.* In Fig. 3, the curve is steep for 120 volt plate when the grid is at zero potential; for 20 volt plate when the grid is at plus 10 volts; for 220 volt plate when the grid is about minus 5 volts. These, then, are the voltages necessary on the grid for using the tube whose curves are shown, as an amplifier.

According to the "electron theory" electricity is composed of small unit charges of electricity. Negative charges are called "electrons." Each atom of mass is supposed to consist of a positive electrical charge and various negative electrons. The electrons are free to move about. If a copper wire carry current, although we say that the current flows from the positive to the negative terminals of the battery or generator, in reality it is now supposed that the electrical current is a stream of electrons moving in the conductor from negative to positive. This may be somewhat confusing at first, but a little thought will

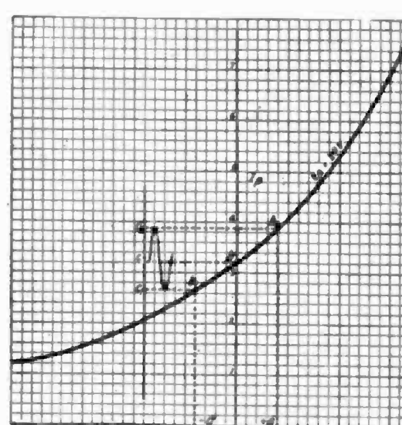


Fig. 7

Graph Showing Incoming Oscillations, Grid Circuit Current, Grid Voltage, Plate Voltage and Resultant Telephone Current.

soon give the idea of an electrical current actually consisting of small negative charges moving from negative to positive.

It is easily conceivable that a positive current could be considered as a negative current in the other direction.

If the conductor is heated to a certain temperature, not only will the electrons flow as before, but also will some of the elec-

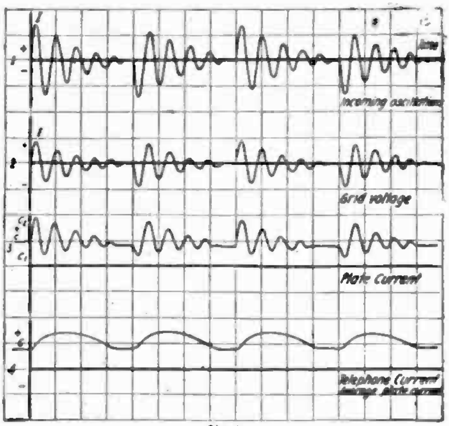


Fig 8

The form of Variations for Different Circuits for This Type of Detector.

rons break through the surface of the conductor and fly off into space in all directions. However, it is known that positive charges attract negative charges, and, therefore, if we place a positively charged conducting body near the conductor which is giving off electrons, some of the radiating (negative) electrons will be attracted to it.

This brings us back to Figures 1 and 2. In Figure 1, a filament is heated by its battery current of I_f amperes. Under normal conditions (and at the proper temperatures) electrons will be given off by the filament. The plate is connected to the positive terminal of the "Plate (B) Battery," as shown. Hence the plate is positive with respect to the filament and will attract the negative electrons from the filament; the electrons will, of course, pass to the plate through the vacuum inside of the tube. Thus occurs a flow of electrons from filament to plate and, conventionally, a current of electricity is said to flow through the plate battery, the plate and the filament. If the plate were negatively charged, no electrons would be attracted to it, and no current would flow in the circuit. The tube is, then, conductive in one direction only and is a *rectifier*.

It is obvious that what happens in the filament-plate circuit will also happen in any similar circuits, such as that of the filament and grid. If the grid is positively charged, it will allow a current to pass from filament to grid; if negatively charged, it will prevent any current. Refer now to Figure 5. Incoming oscillations will induce an alternating current in the circuit L. C. The charges of electricity in C will cause the grid to become alternately positive and negative, decreasing and increasing by the same amount. When the grid is negative (with respect to the filament), no current can flow in its circuit, as was just explained. But when the grid is positive, negative electrons will flow to the grid and will be stored up in the grid condenser C_1. The next oscillation will repeat this process and add a negative charge to the grid condenser C_1. Thus the grid condenser stores up more and more negative charges as long as the oscillations continue. It will be plainly seen that as the *grid condenser* becomes more negative the *grid itself* becomes more and more negative with respect to the filament.

Now, Figure 3 shows the relation between plate current and grid potential. As the grid becomes negative, the plate current decreases. Therefore, it may be said that by means of the grid condenser incoming oscillations cause a gradual decrease in the plate current. If the oscillations were to continue, the grid would become so negative that the plate current would be stopped. So it is necessary to remove the negative charge from the grid condenser after each group of oscillations has been rectified.

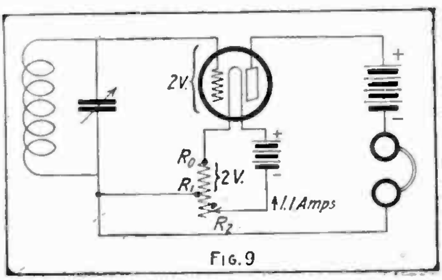


FIG. 9

By Utilizing the Drop of Potential of the Filament Rheostat the Grid Voltage May Be Obtained.

Old type audions contained a certain amount of gas which acted as a conductor and permitted the negative charges to leak off the grid to the filament and neutralize themselves with the positive charges on the other plate of the Condenser C_1. The new high vacuum tubes do not permit this action because of the absence of any gas. A conductor of some kind must be connected from the grid to the filament over which the charges can flow. This conductor should be of such a resistance that no current will flow in it until the condenser C_1 has been fully charged, i. e., not until the end of the group of oscillations. If the resistance is too high, or else entirely absent, the charges will accumulate until they are large enough to pass through the vacuum of the tube. This action will be noticed by a constant "put, put, put" sound in the telephones. The resistance just described is called the "grid leak." It is shown as "R" in Figure 5. The actual value of it depends upon various things, but it is

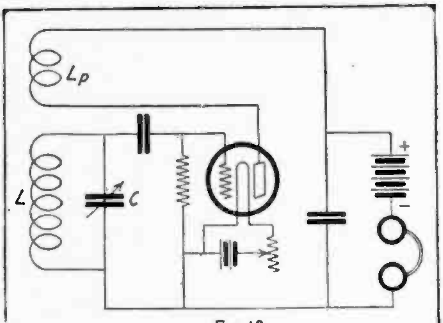


FIG. 10

Circuit Employed for Beat Reception. It is the Well Known "Tickler" Method.

almost always between one and four million ohms. Both the Marconi vacuum tube and the V T 1 are supposed to operate best on two million ohms, although the writer has generally had better results using four or five million ohms with the V T 1.

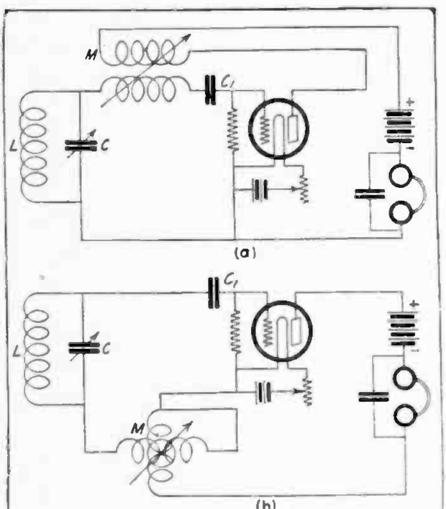


FIG. 11

Here Are Two of the Well Known Feed Back Circuits.

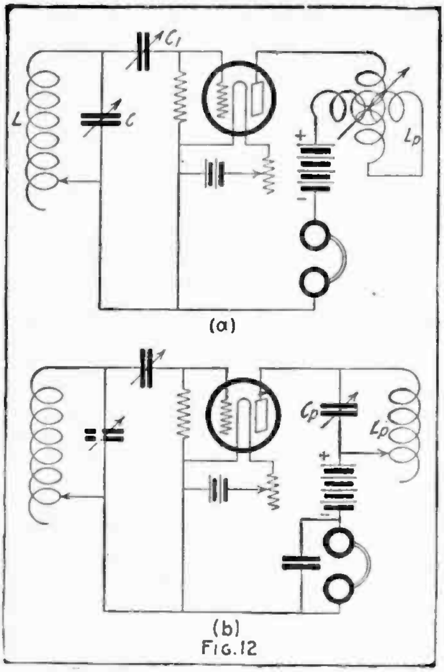
We assume that the reader understands the distinction between radio frequencies and audio frequencies, and also the fact that neither the telephone receivers nor the ear will respond to radio frequency variations. It must also be understood that damped radio waves are transmitted in groups. Each wave (or oscillation) will be of a radio frequency while the wave train consists of groups of the radio frequency waves. Such a wave train is illustrated by curve (1) of Figure 6. In the case of a 500-cycle set working on 600 meters wave length, there will be 2 × 500. or 1,000 *groups* of oscillations per second. And each group will consist of oscillations of a frequency of 500,000 cycles per second. For example, in curve (1) from O to A will be 1/1000 of a second, and will contain oscillations of radio frequency (say 1,000,000 per second).

These incoming oscillations in the antenna circuit will induce similar oscillations in the circuit LC of Figure 5. They will then be rectified by the tube and will cause a current in the grid-filament circuit, as shown in (2) Figure 6, and, according to the discussion above, will cause the grid voltage to vary, as shown by curve (3). At point O in (3) the grid is at zero volts. It then becomes more and more negative until the oscillations cease, when the negative charge leaks off by means of the "grid leak" and the grid again becomes zero potential. Such action occurs as at points A and B.

With no incoming oscillations, the plate current has a certain constant positive value. But the negative charges on the grid reduce the plate current according to curve (4) is Figure 6. When the grid charge leaks off and the grid becomes zero again, the plate current also becomes normal, as at *A* and *B*.

It will be noted that the plate current varies at a radio frequency, following faithfully the radio frequency incoming oscillations. However, the *average* current in the plate circuit varies just *once* for *each group* of oscillations. If the groups are of a frequency of one thousand (for a 500-cycle set) then the average current in the plate circuit will show just one thousand variations per second also. As the telephone receivers respond to this *average* plate current, it will be seen that the phones will be acted on by a current varying one thousand times per second, and will produce the well-known 500-cycle note.

This so-called "detector action" may also be obtained without a grid condenser by making use of the shape of the characteristic curve. Figure 7 shows an enlarged view of the lower portion of curve "a" of Figure 14. As noted, the E_p is 20 volts while the grid is (without incoming oscillations) at zero volts. I_p is a steady current of 3.2 milliamperes (as shown). If a train of oscillations is impressed on the grid, the grid voltage will vary, becoming alternately positive and negative as the impressed voltage varies. Suppose the first variation causes the grid to go from zero to +3 volts, to zero to —a volts and back to zero again. This will cause first an increase and then a decrease in the plate current (as described in the discussion of the amplifier). Referring to Figure 7, when the grid is at zero volts, I_p is *b* milliamperes; when E_g becomes $+a$ volts I_p becomes b_2 milliamperes, and E_g $-a$ volts shows I_p as *b* milliamperes.



Here Advantage is Made of Tuning the Plate Circuits.

If we project the points b, b_1, b_2, onto a vertical line (corresponding to the I_p axis) we get the points, C, C_2, C_1 as representing the exact values of I_p as E_g varies from zero to +a, to —a volts. But although the variation of grid voltage was assumed equally as great each side of zero, i. e., zero to +a equals —a to zero, it will be plainly seen that, due to the shape of the curve C C_2 is greater than C C_1. Therefore the average value of I_p has been increased from C to value C_1+C_2. The next change

2

in grid voltage will not be as great as + and —a because the oscillation in I_p will not be as great as from C_1 to C_2. Nevertheless, the *average* plate current will remain greater than C as long as oscillations continue in the grid circuit. (Note that the value C is the same as b, which was given as normal I_p for zero voltage on the grid).

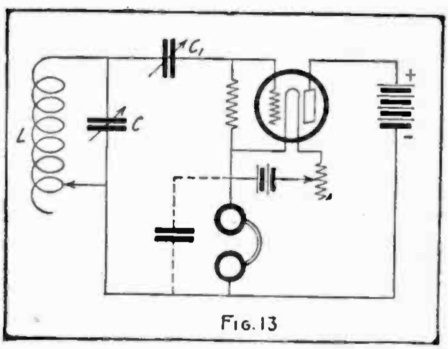
Fig. 8 shows the form of variations of the different circuits for this type of detector action. As before, curve (1) is the incoming oscillation. Curve (2) shows the *voltage* impressed on the grid by the incoming oscillations. Curve (3) shows the variations in plate current while curve (4) shows the *average* plate current. The small letters correspond to the letters of Fig. 7. Here again we have an average plate current with the number of variations per second corresponding exactly to the number of incoming wave trains per second. And the telephones again give us the note of the transmitting set.

Analytically, in order to work our tube as a detector without grid condenser, we must operate it on the *bend*, or "knee," of the curve. And, as with the amplifier, it is necessary to adjust the voltage on the grid so that the tube actually is operating at the "knee" of the curve. Fig. 14 shows us that we can obtain detector action with the Marconi-Moorehead tube using 20 volts plate by making the grid O volts, using 40 volts by making the grid—2v; using 80 volts by making the grid — 5v; etc.

Obviously, the advantage of such a detector set is the elimination of the grid condenser and the grid leak. The grid voltage may be obtained by actually inserting a battery of the required E.M.F. in series with the grid, or, more practically, by utilizing the drop in potential of the filament rheostat. For example, in Fig. 9, suppose we wish to make the grid two volts negative, and the tube consumes 1.1 amperes.

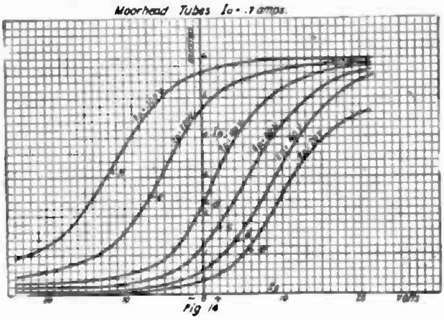
By Ohm's Law $R = \frac{E}{I} = \frac{2.1}{1.1} = 1.82$ ohms.

We connect our grid lead to point R_1 of the filament rheostat where R. R_1 equals 1.82 ohms. Then when 1.1 ampere flows in the filament circuit, the potential drop across R. R_1 will be 2 volts and the grid will be 2 volts *negative* with respect to the filament. Should we merely reverse the direction of the filament battery, the grid would become 2 volts *positive* with respect to the filament.



For Longer Wave Lengths it is Necessary to Place a Condenser Across the Phones.

The question of oscillating audions brings up several principles which are not involved in either detection or amplification. The first thing which must be clearly understood is "coupling." The reader is so familiar with the term that there should be no necessity for more than reminding him that energy may be transferred from one circuit to another by "coupling," whether it be *conductive, inductive* or *capacity.* The next thing of importance is the phenomenon of "beats." The theory of beats is too lengthy to be given here; and the reader is referred to any text book on Physics. Beats are explained also in many radio texts and in the Proceedings of the Institute of Radio Engineers, Vol. 1, No. 3.*



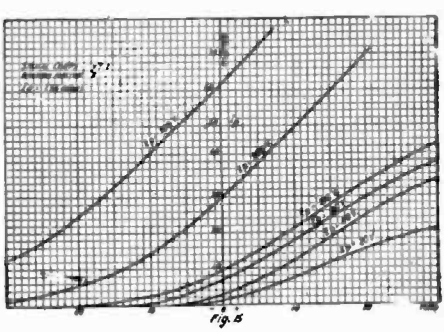
Characteristic Curves of the Marconi Moorhead Tubes.

Let us arrange an ordinary detector set as shown in Fig. 5 and add to it an inductance in the plate circuit. Such an arrangement is illustrated in Fig. 10, where L^p is the plate inductance. Consider the filament lighted normally and no oscillations coming in on the grid (through LC). As we know, there will be a certain, steady Direct Current flowing in the plate circuit, the amount depending on the characteristic curve as already explained. A steady current in the plate circuit will plainly cause a steady magneto field around the coil L^p Let us now turn L^p so that it is inductively coupled to the coil L. As the field of L^p cuts through the turns of L, it induces a current in L. This current lasts only momentarily but, of course, long enough to affect the voltage of the grid. Now, a change in the grid voltage causes a change in plate current. And a change in plate current causes a change in the magnetic field of L^p. This change of field intensity again causes a momentary current in L which again changes the voltage of the grid. Thus we find the varying plate current, by induction, to be continually varying the grid voltage, and this varying grid voltage to be automatically varying the plate current. So, when once started, this system settles down to a steady generation of oscillations, the plate battery furnishing the power and the grid automatically varying it into the form of undamped oscillations.

*P. 78—John L. Hogan, "The Heterodyne Receiver."

It will be plainly seen that for a maximum strength of oscillation, the greatest possible variation in the plate current must be obtained. This occurs when, as explained for amplifiers the tube is operated on the *steep* part of the curve. The system of producing oscillation as just described is fundamentally that used for both transmission and reception.

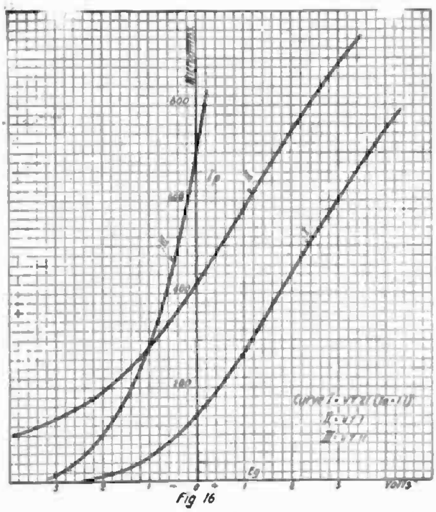
The oscillations generated as explained above are, of course, at a radio frequency. The exact frequency depends upon the values of inductance and capacity in the circuit. Suppose we tune the circuit to a wavelength slightly below 600 meters, so that the frequency is 1001000. Now some undamped transmitter on 600 meters is tuned in on the aerial. The incoming oscillations of a frequency of 1000000 per second will be impressed upon the circuit LC. There are now two separate and distinct series of oscillations in the same circuit; and the result is the production of beats. In this case there would be 1001000 minus 1000000 or 1000 beats per second. These beats are amplified by the audion in the usual way and cause the telephone to vibrate 1000 times per second, producing thereby the 500 cycle note. The number of beats and, consequently, the note in the telephone, depends only upon the difference in frequencies of the incoming oscillations and the local oscillations. As the frequency of the local oscillations may be changed at will, the note received may, therefore, be made anything the operator wishes.



Curves for the V T II.

Such an oscillating audion system is called a "self heterodyne" or "autodyne." There are very many circuits which give the same effect as that of Fig. 10. Sometimes two local frequencies are generated which produce local beats. These result in either a pleasant musical note in the telephones or an unpleasant howl. The operator can easily stop this by loosening his coupling or changing the frequency of the oscillating circuit. It is sometimes caused by too small capacity in the grid condenser or by too low filament current.

The plate feed-back coil "L_P" is generally called the "tickler coil." When it is loosely coupled to the grid inductance L, no oscillations are produced. As it is brought close to L and just as the oscillations start, a sharp click will be heard in the telephones. That point just beyond where the click occurs is the most sensitive point of operation and the maximum amplification generally.



This Shows the Lower Working Portions of the Common Vacuum Tubes, VT I, VT II, and VT 21.

The tickler coil may be made in any form. One very convenient system uses a "variometer" inductance. One coil is considered merely as a continuation of the grid inductance, while the other coil is the tickler. Two typical circuits are shown in Fig. 11 *a* and *b*. Here M is the variometer. It is used precisely as described in the preceding paragraph.

A somewhat different circuit for undamped waves is that of Fig. 12 *a* and *b*. The grid circuit is tuned to the incoming signal and the plate circuit is then tuned until maximum signals are heard. The plate tuning is usually accomplished at short wavelengths by a variometer and at long wavelengths with both inductance and capacity.

The third system of oscillating audion consists of a capacity feed-back and has no tickler coil. This is frequently called the "ultra-audion." It is particularly satisfactory for short wavelengths. For longer wavelengths it is necessary to put a condenser across the telephones. The simple circuit is shown in Fig. 13.

Fig. 14 shows the characteristic curves for the Marconi-Moorehead tubes. By the aid of such a family of curves it should be possible to determine the correct grid voltage at which to work the tube for the desired results. The only thing to be remembered is that for amplification, detection (with grid condenser) or oscillation the tube must be operated on the straight part of the curve, while for detection without grid condenser the tube must be operated on the lower bend. Fig. 15 shows the curves for the VT2. This tube is usually used as a transmitter but works also as either detector or amplifier.

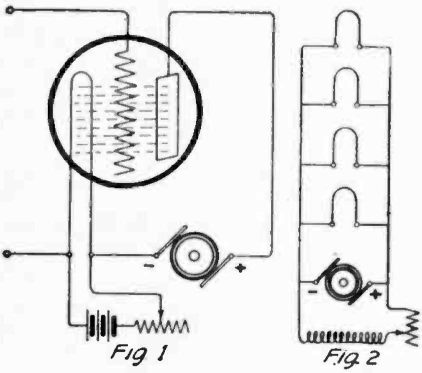
Fig. 16 shows enlarged the lower working portions of the curves of the common tubes, namely VT 1, VT 11, VT 21. They all operate on 1.1 amperes filament current and usually 20 volts plate. The VT 11 and 21 are steep on zero grid volts while it is necessary to make the VT1 slightly positive for best results. On the other hand, for detection without grid condenser all three should be somewhat negative on the grid.

As previously mentioned, the internal impedance of the VT 1 in about 20,000 ohms, while that of the VT 21 is around 60,000 ohms. For amplification the VT1 has a constant of 8 while the VT 21 is between 10 and 12. These data would indicate that the VT 21 is a better amplifier than the VT1; and, of course, because of the different internal impedance, the two tubes are not to be operated efficiently in the same circuit with the same impedance phones or transformer.

Operating Characteristics of Vacuum Tubes

By **W. C. White, E. E.**

The three-element vacuum tube is becoming a fairly common tool to the physicist, electrical engineer and experimenter, and the literature on the subject has grown so rapidly, that at the present time it is really voluminous.



When the Filament of a Power Tube is Operated From a D. C. Source Through a Resistance, One End of the Filament Carries More Total Current Than the Other End; it is Therefore Better to Supply the Filaments With a D. C. Generator and Regulate the Field.

Its theory of operation is quite widely known and is found in most modern textbooks on physics and radio communication. Radio literature is also generously sprinkled with vacuum-tube circuit diagrams.

It is not the purpose of this article to take up any of the fundamental theories of operation of the tube or its circuits, but to furnish information and give help to those who experiment with these devices.

It is also not the intention to attempt to cover the field of tube operation, but merely to call attention to certain phases of the subject not widely known or appreciated.

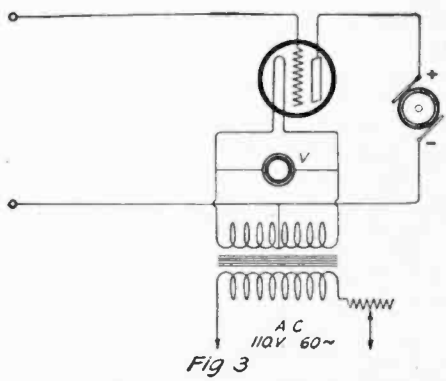
It is a rather usual occurrence to those working with vacuum tubes in an experimental way to encounter unlooked-for difficulties and obtain unexpected results.

A number of these more unusual effects will be discussed; first those of a general nature, next those occurring when the tube is used as an oscillator, and finally a few when the tube is used for a number of other purposes.

A tungsten filament type of tube is assumed to be used in the experiments outlined in the paragraphs to follow, and most of the discussion relates to power tubes.

Certain properties of a tungsten filament as an electron emitting source will first be mentioned, for although these are simple they will bear enumeration because of their importance in obtaining satisfactory results with such a type of tube.

The electron emission and life of a filament are quite sensitive to changes of filament current. A 1 per cent. change in filament current causes about a 25 per cent. change in life and approximately a 10 per cent. change in total electron emission. An increasing filament current decreases the life and increases the emission.



On Power Tubes it is Preferable to Use A. C. to Light the Filaments. This Diagram Shows How the Connection From the Plate Circuit is Made in the Center of the Transformer Winding.

Owing to the fact that, like most other metals, tungsten has a positive temperature coefficient of resistance, a certain percentage change of current gives a correspondingly greater change of voltage. Numerically this amounts to a 1¾ per cent. change of voltage for a 1 per cent. change of current. Therefore life and electron emission from a tungsten filament are more subject to current change than voltage change of the filament.

Although in the past it has usually been the custom to operate the tungsten filaments of vacuum tubes at an approximately constant current by means of an ammeter operation at constant voltage is to be recommended as giving a much longer life to the filament.

In operating tungsten filaments in vacuum tubes, observance of the three following rules will greatly increase the useful life of the tube:

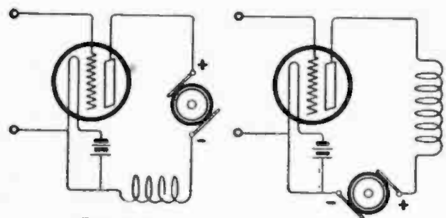


Fig 4A Fig. 4B

No. Choke Coil Should Be Connected Between the H. T. Generator and the Filament as in Fig. 4A. Fig. 4B Shows the Correct Place to Connect the Coil.

(1) The most favorable adjustment of the set, of which the tube is a part, is the one which gives the desired result with the lowest value of plate current.

(2) The filament current or temperature should not be materially raised to give a slightly increased output or signal strength which is not vitally necessary.

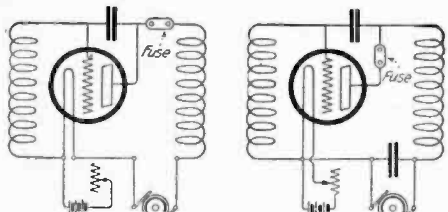


Fig 5A Fig 5B

Fig. 5A Shows Three Common Errors That Are Often Found in C. W. Circuits. Fig. 5B Shows the Right Connection to the Filament, and How to Avoid Resistance in the H. F. Circuit by Shunting the Generator With a Condenser and Inserting the Fuse in the Plate Connection.

(3) Do not, for any length of time, exceed the maximum filament rating, and in all cases reduce the filament temperature to as low a value as is consistent with satisfactory operation of the apparatus.

Most tubes are designed for operation in one or two designated positions: that is, vertically or horizontally, with a certain side or end up. It is advisable to observe this feature because a hot tungsten filament has a tendency to sag, and if this is not prevented or compensated for by operation in a certain designated position, there are liable to be changes in the electrical constants of the tube, caused by changes in distance between the electrodes.

If for some reason the vacuum in a tube becomes faulty, it is usually noted by the characteristic glow due to ionization of the gases present. If gases evolved from the metal parts or glass, due usually to the heat from an overload, are the cause of this glow, it will be blue in color; whereas, if it is due to air leakage, it will appear purple or pink.

Occasionally a tube will be met with which, when the filament is energized, shows a sort of yellowish-white smoke in the interior near the filament or it fails to come up to a normal brilliancy at the rated amperage and a dark-blue color forms on the plate and grid. Both these effects are due to considerable amount of air leakage, but are formed under different conditions.

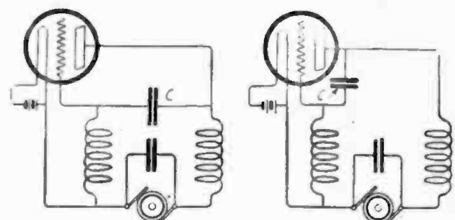


Fig 6A Fig 6B

To Avoid Capacity Effects From Long Leads to the Grid and Plate, the Condenser Should Be Connected as in Fig. 6B.

The smoke or powder formed is an oxide of tungsten which exists in several forms and varies in color from a very light yellow to a very dark blue, depending upon the conditions at the time of its formation.

One limit to the possible output of a tube as an oscillator is the amount of energy that can be dissipated safely in the form of heat. If it is attempted to dissipate too much energy, the glass and electrodes will be liable to evolve gas which reduces the vacuum. If the tube is enclosed in a small unventilated space, normal operation may overheat the glass of the bulb and cause it to evolve gas. This is most likely to occur where a number of tubes are operated in parallel, thus causing a considerable energy dissipation in a small area.

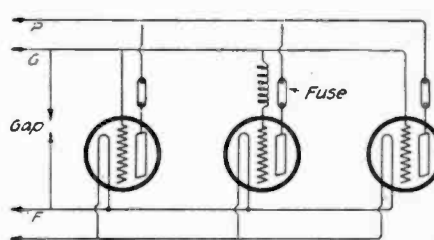


Fig. 7

To avoid the Production of Ultra High Frequency Oscillations When Several Tubes Are Used, a Small Inductance Should be Inserted in the Grid Circuit to One Tube as Shown.

When the filament of a power tube is operated from a direct current source through a regulating resistance, the plate current causes an inequality in the filament current This action is represented in Fig. 1. The electron emission occurs along the

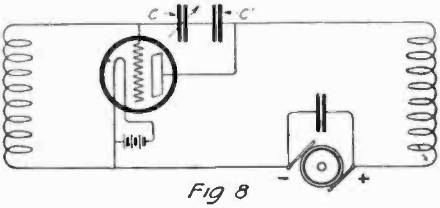


Fig 8

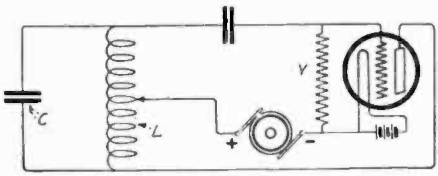


Fig. 9

Fig. 8 Shows How a Protective Condenser C1 is Inserted in Series With the Variable Turning One to Prevent the Latter From Breaking Down. Fig. 9 is a Simple Hook-up for Low Power in Which a Higher Capacity C May be Used and Still Maintain Oscillation.

length of the filament and therefore one end of the filament will carry more total current than the other end; this causes one end of the filament to be the hotter, which for the same amount of emission, will shorten the life. The relative resistance

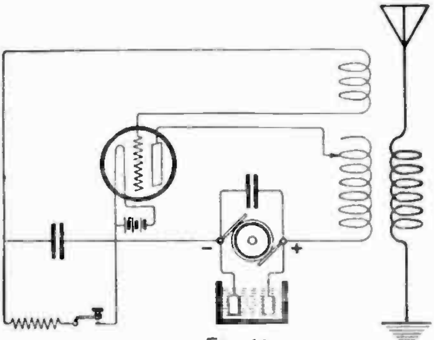


Fig 10

When a Plate Voltage Above 500 Volts and a Power Over 50 Watts is Used, a Protective Device Such as Aluminum Cell Lightning Arresters Should Shunt the D. C. Generator and the Condenser Connected Across.

values of the regulating rheostat and the filament, and also the location of the point of connection between the filament and plate circuits, determine the amount and direction of this effect. As shown in Fig. 1, the plate current causes the filament temperature to decrease at the positive filament terminal. This is the safest and best mode of connection.

If, however, the filament is operated from a few cells of storage battery or directly from a low-voltage direct-current generator so that the resistance in series with the filament is small, it is immaterial whether the return from the plate circuit is made to the positive or negative terminal of the filament; the heating current in the negative side of the filament is increased by the same amount. A considerable resistance in series with the filament is essential to any alteration in the distribution of the flow of plate current through the filament circuit as a safety precaution. As the plate current is usually in the neighborhood of 2 per cent. to 7 per cent. of the filament current, and as a 3 per cent. increase of filament current halves the life of a tungsten filament, the importance of this effect is evident.

If a low-voltage direct-current generator is used for filament lighting, it is usually connected in circuit as shown in Fig. 2, the filaments being directly connected to the

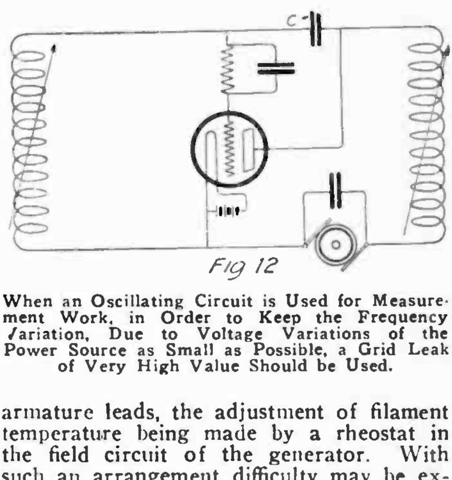


Fig 12

When an Oscillating Circuit is Used for Measurement Work, in Order to Keep the Frequency Variation, Due to Voltage Variations of the Power Source as Small as Possible, a Grid Leak of Very High Value Should be Used.

armature leads, the adjustment of filament temperature being made by a rheostat in the field circuit of the generator. With such an arrangement difficulty may be experienced with the generator not building up if the filaments are left in circuit. This is owing to the fact that the cold resistance of a tungsten filament is very low, only one-thirteenth to one-sixteenth of its normal operating resistance. Therefore, if a small low-voltage direct-current generator is used at full load to supply tungsten filaments, the cold resistance of the filaments may be so low that it acts as practically a short circuit on the armature and prevents the generator from building up.

On power tubes it is preferable to use alternating current for filament excitation.

The chief reason for using A.C. is that it obviates the unbalanced condition of a D.C. filament current, as described in a previous paragraph. It is also more practical to generate and distribute the low-voltage high-current energy for filament operation by means of A.C.

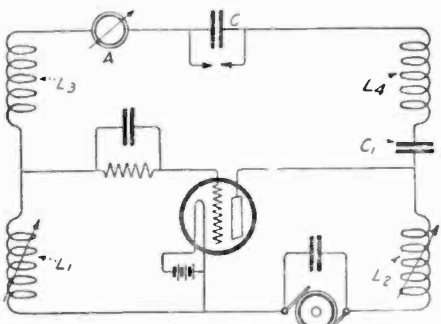


Fig 13

This Circuit is Particularly Efficient When it is Desired to Obtain High Voltage, High Frequency Energy to Test Dielectrics and Measure Dielectric Losses.

In using A.C. for filament excitation the filament terminals should be connected directly to the transformer low-voltage terminals, the regulating resistance being placed on the power side. Also the return of the grid and plate circuit should be made to a center tap of the coil supplying the filament. This mode of connection assures minimum disturbance in the plate and grid circuits from the frequency of the filament source. Both these points are shown in Fig. 3.

Some points in connection with the use of tubes as oscillators will next be taken up.

In the various diagrams of connections which are shown herewith, each one is simplified so as to more clearly show the point under discussion. For this reason many diagrams for clearness or simplicity omit features which in another paragraph are shown to be advisable.

In all tube oscillator circuits there is an inductance in the plate circuit across which the high-frequency voltage is set up. Care should be taken that this inductance is not placed between the filament energy source and the plate energy source, as shown in Fig. 4a. Both of these sources have usually a large capacity or a certain resistance to ground, so that a circulating current will flow through the coil and through each source to ground. For the type of circuit shown the correct arrangement is shown in Fig. 4b. The importance of having the circuit correct in this respect is greater the greater the power and the higher the voltage used.

In arranging an oscillating circuit to deliver high-frequency energy, it is important to reduce to a minimum the losses in the high-frequency circuits. Not only should the wires used be of low resistance and the condensers have low losses, but it is best to trace through the circuits carrying high-frequency currents to be sure that the resistance is a minimum.

Three common errors in this respect are shown in Fig. 5a which represents a capacity coupled oscillator circuit. In this diagram the high-frequency current of the oscillating circuit must pass through a resistance path comprising the filament in parallel with its resistance and battery source. Also it must pass through a fuse in the plate circuit and through the plate voltage source. In Fig. 5b the same circuit is shown with these three errors corrected; the first, by changing the wiring so that the return of the grid and plate circuits is brought back to the same filament terminal, the second, by changing the fuse position, and the third, by shunting the plate circuit generator with a by-pass condenser.

For miscellaneous laboratory work the capacity coupled type of circuit is a very convenient one to set up and operate, usually giving little trouble. However, if the circuit happens to be set up in a certain peculiar way, very puzzling results and failure to operate may sometimes occur, particularly if a tube of low impedance is used or several tubes are placed in parallel.

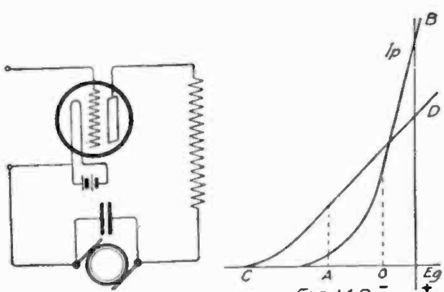
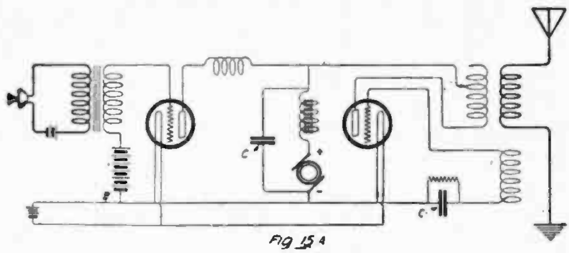


Fig 14A Fig 14B

Fig. 14A Shows an Amplifying Circuit Where a Resistance is Connected in the Plate Circuit, While Fig. 14B Represents the Electrical Characteristics of a 3-Element Tube.

This arrangement is shown in Fig. 6a. If, as shown in this diagram, the leads from the coupling condenser C are connected to the plate and grid coil terminals rather than to the corresponding tube terminals, as shown in Fig. 6b very high-frequency oscillations may occur, a second capacity coupled circuit being formed the capacity between the electrodes acting as the coupling condenser and the leads between the grid and plate coils and the corresponding tube terminals acting as the grid and plate inductances. This condition is accentuated by having these leads long and the leads to the coupling capacity short.



This is the Typical Radiophone Circuit Using One Tube as Modulator and One as Oscillator. This Hook-up is the Most Efficient When Only Two Tubes Are Used.

This unexpected production of ultra high-frequency oscillations is often a very troublesome problem in high-power tube apparatus when a considerable number of tubes are operated in parallel. The low impedance of the tubes in parallel accentuates the effect. One expedient which often aids in overcoming this difficulty is the insertion of a very small inductance (a few microhenries) in one or more of the grid leads close to a tube grid terminal.

This coil is shown in Fig. 7. This figure also shows fuses in the plate circuit of each individual tube, a very desirable feature on high-power high-voltage tubes. This fuse should blow at two to four times the rated plate current of the tube.

This Fig. 7 also shows another desirable feature for high-voltage power-tube circuits. In experimental work with oscillating circuits unusual conditions may occur which will cause transient voltages to be set up between the grid and filament which will reach peak values many times higher than that set up in normal operation. It is impractical to design and construct a tube and base to stand up under this very abnormal voltage, which only occasionally occurs, due to incorrect adjustment. A safety spark gap should therefore be provided between the grid and filament terminals at or near the tube socket or mounting. This gap should be adjusted to between one-thirty-second and one-quarter inch, depending upon the plate voltage employed and the number and type of tubes used. This precaution should be taken on any tube or group of tubes delivering over 50 watts of alternating current energy or operating at a plate potential above 2,000 volts.

In one of the simplest and most frequently used forms of capacity coupled circuit there is a precaution that should be observed.

This is illustrated in Fig. 8. It will be noted that the coupling capacity C has one of its terminals connected through the grid coil to the negative terminal of the high-voltage plate source, while the other side of this capacity is connected through the plate coil to the positive terminal of the high-voltage source. Very often this capacity C is a variable air or oil dielectric condenser, and its breakdown due to high frequency high voltage will therefore short-circuit the generator on D.C. source. The resultant arcing inside the condenser may also burn the plates badly.

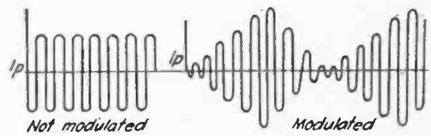


Fig. 15 b

When the Circuit of Fig. 15A is Used for Radiotelephony the Amplitude of the Oscillations Increases Above the Normal Value and Decreases to the Minimum Possible, Insuring Perfect Modulation.

This possibility may be prevented by the use of a second capacity C_1 which should be large in capacity in comparison with C. The condenser C_1, if it is at least one hundred times the value of C, need not be a low loss condenser. It is necessary, of course, that the condenser C_1 safely stand the voltage of the D.C. source.

In a typical form of oscillating circuit, as shown in Fig. 9, the frequency of oscillations is principally determined by the value of the capacity C and inductance L.

As far as the natural frequency of oscillation is concerned, it will remain constant as long as the product of L and C is constant. However, it will be found that the type of circuit shown in Fig. 9 will only oscillate at a given frequency in a satisfactory manner when the capacity C is under a certain limiting value. This is explained by the fact that certain values of high-frequency voltage are necessary on the grid and plate. If the capacity C is very large the tube will not supply sufficient energy to pass enough current through C to set up across it the necessary grid and plate high-frequency voltage. The lower the value of resistance and the lower the losses in the oscillating circuit, the larger the value of C that may be used and still maintain oscillations.

For the type of circuit shown in Fig. 9 the limiting value of C, for the usual types of small tubes running at reasonable values of plate voltage, is in the neighborhood of a maximum of .001 microfarad for a frequency of one million cycles (300 meter wave-length). This is necessarily a very approximate figure because of the many factors which are involved, but it at least gives the experimenter an idea of what not to use.

In the use of high-voltage direct-current generators operated singly or in series, it has been found that when they are employed for supplying energy for tube-plate circuits a considerable strain is imposed on the insulation of the armatures. This is particularly noticeable when the tubes are used for radio telegraphy and telephony where the load fluctuates rapidly, or is switched off and on suddenly, for the generator is practically at ground potential.

This strain which is imposed on the machine is in the form of a voltage surge which momentarily raises the generator voltage several fold. One terminal being grounded, the strain occurs on the insulation between the frame or armature core and an armature conductor which at the instant is near the positive terminal or brush.

A condenser shunted across the generator terminals, described in a previous paragraph, also acts as a sufficient protection against these voltage strains in the case of very small machines. In the case of generators, singly or in series, for voltages above 500 and power outputs above 50 watts, some sort of protective device to safely limit and discharge this voltage should be used. For this service aluminum cell lightning arresters are very suitable. They should be connected across the generator terminals. In Fig. 10 one protective cell is shown in circuit.

These cells consist of a pair of oxidized aluminum plates immersed in an electrolyte. Many different electrolytes are used to meet special requirements, but for experimental purposes covering a short period of time a saturated solution of borax is satisfactory. These cells are connected in series, and when the oxide film is properly formed one cell should be used for each 300 volts of rated generator voltage. These cells involve the same general principles as the familiar electrolytic rectifier.

These cells, owing to the thin oxide film acting as a dielectric, have considerable electrostatic capacity between electrodes, which is an added advantage in their use as protective devices on generators supplying oscillating vacuum tubes.

In certain experiments it is often desired to keep the frequency variation of a tube acting as a high-frequency oscillator as small as possible. This is particularly desirable in the calibration of wave-meters and in measurement work. The variation of frequency due to voltage variations of the power sources can be greatly minimized by using a very high value of grid leak resistance R, as shown in Fig. 12. This applies to practically all types of oscillating circuits.

It is often desired to obtain high-voltage high-frequency energy to test dielectrics and measure dielectric losses. Fig. 13 shows a type of circuit very suitable for using an oscillating tube for this purpose. The frequency of oscillation is largely determined by the period of the simple series circuit comprising L_1, L_2, L_3, L_4, and C. The condenser C_1 is merely for safety, as explained in a previous paragraph, and is large in comparison with C. Maximum output is obtained by variation of L_1 and L_2. The voltage obtained may be computed by measuring the frequency with a wave-meter and reading the current at A, passing through the condenser C of known capacity value. A spark gap across C may also be used to check the value of voltage obtained.

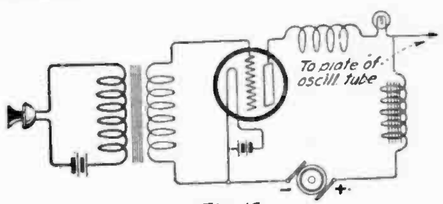


Fig 16

A Simple Device to Control the Modulation in a Radiophone; A Small Lamp is Connected in the Plate Circuit of the Modulator Tube. It Flashes When the Microphone is Spoken Into if the Circuit is Properly Adjusted.

For high voltages the capacity C should be small and the inductance in circuit large. It is also important to have the losses low in the inductances and capacity.

In most power tubes the higher the plate voltage that can be used the greater the output. Tubes may fail to stand up under an increased voltage for many reasons, but there is one factor in connection with this limitation that is usually overlooked. This factor is electrolysis of the glass. In most of the types of small-power tubes all the lead-in wires are usually carried through a common stem and seal. When this is the case the plate voltage that may be used is limited by electrolytic action in the glass of this seal between the plate and grid leads. Hot glass is an electrolytic conductor; that is, the metallic elements in the glass appear at the negative pole. This electrolysis in the course of time, if continued, will ruin the seal, making it leak air, and sometimes even cracking it. An early indication of this electrolysis which appears long before leakage occurs is a blackening of the grid leads in the glass of the seal near the vacuum end. This action takes place at the grid lead, because this is usually the most negative one when the tube is oscillating.

Therefore, if tubes of this type are operated considerably above their rated plate voltage the life is liable to be terminated by leakage of air into the bulb through the seal rather than filament burnout.

In the various circuits described, the source of D.C. potential for the plate has been shown in series with the plate inductance. The shunt feed method of connection is just as satisfactory, but is sometimes not quite so convenient for the experimenter with limited apparatus.

Also the various circuit diagrams have for the most part shown, for the sake of simplicity, a battery as a filament source and a D.C. generator as a plate source. The filament battery may, of course, be replaced by a generator or transformer and the plate generator by a battery or a rectifier system for producing D.C. from A.C. at commercial frequencies.

There are a few points of interest that arise when a tube is used as an amplifier for alternating currents of appreciable energy (several watts at least), and when it is used as a voice current amplifier and modulator in radio-telephony.

A very common form of graphical plot employed to show one of the electrical characteristics of a three-element tube is given in Fig. 14b. The curve A-B illustrates the well-known relation between grid voltage and plate current. This curve assumes a constant plate voltage. However, in many amplifying circuits a resistance, as in Fig. 14a, is included in the plate circuit.

When an alternating E.M.F. is connected between filament and grid a corresponding variation in plate current occurs. Therefore an alternating voltage is set up across the resistance in the plate circuit and the voltage of the plate is no longer constant being higher than normal voltage while the resistance is discharging and lower when it is charging. For this reason the grid voltage and plate current will not follow the curve A-B. They will, however, follow a curve of the type C-D, because at the low-plate current the plate voltage is higher than normal and therefore a higher negative voltage is required to bring the plate current to zero, while at the higher plate-current end the actual plate voltage is lower and so the plate current is lower.

In most amplifying circuits it is usually desired to keep the grid negative during practically the entire cycle of operation, and therefore the grid is made normally negative by a so-called biasing potential. It is also usually desirable to make this normal negative potential of a value equal to half the grid voltage required to bring the plate current to zero. This value of normal negative grid voltage should be computed from the curve C-D rather than the static curve A-B. In other words, the best value of negative biasing grid voltage should reduce the plate current to much less than half the value obtained at zero volts on the grid. A negative voltage that reduces it to about one-quarter value is approximately the best.

The foregoing, of course, does not apply to receiving amplifiers or cases where the amount of plate-current fluctuation is small.

The most usual method of modulation employed for vacuum-tube, radio-telephone transmitters is shown in Fig. 15. In this arrangement the output of the oscillator tube is varied above and below its normal amount by variations in plate voltage set up by the amplified microphone voltages. Therefore the peak of plate current in the modulated oscillator tube is considerably higher than in a straight oscillator circuit. More electron emission is therefore required for the modulated tube than for a simple oscillator tube. Very often poor articulation in a radio-telephone transmitter is due to insufficient electron emission in the oscillator tube.

In a radio-telephone transmitter correct wave-length and normal antenna current are not, as in telegraphy, indications that the set is functioning properly. Neither of these factors give any information as to the degree of modulation. The amount of modulation is most satisfactorily obtained by means of an oscilliograph, but this is seldom available for use when desired.

A simple device to indicate modulation is a miniature tungsten filament lamp in the plate circuit of the modulator tube. This should be chosen of such a rating or so shunted that normally it burns at a dull red. When the microphone is spoken into it should flash up and the degree of this brightening soon becomes a very good indication to the operator as to whether the modulation is normal or not. This arrangement is shown in Fig. 16.

There are so many things that may prevent a radio-telephone transmitter from properly functioning while showing full radiation current, that an indicator, as described, is very useful.

Practical Points on Amplifier Operation

By **Bernard Steinmetz**

The amateur or novice frequently stumbles across a phenomenon which interferes with the operation of his set. This is especially the case when he is opcerating a regenerative set and amplifier, as regenerative effects make their appearance in amplifiers and give rise to such annoying disturbances as howling. A discussion of some of these things may not be amiss, therefore, and may be of help to those struggling with the strange manifestations of a sensitive receiver.

About the greatest nuisances that the novice has to contend with are the strange noises which he hears in the phones when adjusting his receiver. Assuming that he is not using an amplifier (the amplifier will be discussed later) these noises will generally be found to be caused by starting and stopping of oscillations which is due to incorrect values of grid condenser and leak. While the receiver is in the oscillating state the grid has an average negative potential, which must be given a path for leaking off or else it will block the passage of the plate current. This leakage path is provided by the grid leak and the rate at which the negative charge on this leaks off depends upon the value of the grid condenser and leak. If the leak has too high a resistance, the charge leaks off too slowly, with the result that oscillations stop. During the period that the oscillations have ceased, the leakage still continues until the grid potential has again assumed a value permitting oscillations. Oscillations then commence until the above performance is repeated. This starting and stopping of oscilations may take place at an audible rate and results in the peculiar noise generally heard in the phones. The rate at which this takes place is what determines the pitch of the noise heard. The rate of starting and stopping of oscillations is determined by the time constant of the grid condenser and leak combinations. The greater the values of resistance and capacity, the lower will be the pitch, and vice versa. By varying the values of leak and condenser, the note can be varied from individual clicks widely separated to a continuous high shrill note and even beyond to the inaudible stage. From this it will appear that it is best to use a variable grid condenser and leak and adjust these values until proper operation is secured. This is much more preferable than using a fixed condenser and leak, since each tube requires certain values for maximum efficency, and these can best be secured by trial.

Frequently it will be found that the above tube noises can be traced to too tight a tickler coupling, and since feedback coupling varies with the wavelength used it often happens that when changing from one to another wavelength no change is made in the tickler coupling. As a result, if the tickler coupling should be lower for the new wave-length and is not, change noises are likely to make their appearance. It is, therefore, best always to alter the feedback coupling when any other change is made in the tuning of the set.

Howling noises in amplifiers are also a source of considerable trouble, and is a case of audio frequency oscillations in the amplifier system caused by regeneration. Naturally the greater the amplifying possibilities of an amplifier the more liable will it be to howling. Many amateurs realizing this, resort to the poor remedy of working their amplifiers at low amplification, as for example reducing the filament currents, in order to eliminate howling. Obviously this is no remedy at all, since an amplifier is designed to amplify and should be worked for all the amplification that it is capable of. In fact an amplifier which shows no tendency to howl may be a very poor one. Elimination of howling should not be obtained by a sacrifice of amplification. By understanding the causes of howling we may be able to arrive at other more desirable remedies.

Oscillations in an amplifier are the result of regeneration due to feedback coupling between plate and grid circuits of the amplifier, exactly as in a regenerative receiver, the difference being that in the receiver the regenerative action is intentional and in the amplifier it is accidental and undesired. This regeneration in the amplifier may be due to either inductive or electro-static coupling between grid and plate of the amplifiers. Thus the electrostatic coupling may be provided by the inherent capacity in the tube itself; or by the capacity between grid and plate leads in the wiring of the amplifier. Inductive coupling may also be due to the coupling between grid and plate leads of the wiring; or to coupling between transformer windings in plate and grid circuits due to interlinking of flux paths and so on. The case of transformer coupled amplifiers may be considered from the point of view of tuned grid and plate circuits. The distributed capacity of the transformer coils in grid and plate acts as the tuning condenser, thus tuning grid and plate circuits and providing the necessary regenerative action. Any of these means provides sufficient coupling between plate and grid to initiate oscillations if there is present a circuit which is able to oscillate, and experience shows that there always is. It is not essential that the plate of one tube be directly coupled to the grid of the same tube. If the plate of any tube is coupled to the grid of any other tube oscillations are bound to occur. The entire amplifier system oscillates at a frequency which is determined by the most favorable constants of the system and at a frequency which gives the least losses.

Not only may the amplifier oscillate at audio frequency, but it may also oscillate at radio frequency and still produce noises in the phones. The noises in the phones when the amplifier oscillates at radio frequency are due to blocking action on the grid exactly as in the case of the receiver above described. Due to very high amplification the grid of a tube may be given a very high negative potential which immediately stops the oscillations. The charge on the grid gradually leaks off until a potential is reached which permits the oscillations to start again. This starting and stopping of oscillations takes place at an audio frequency rate which depends upon the values of leak and condenser.

The problem of preventing howling then is the problem of eliminating the feed-back coupling between the grid and plate of tubes. To put it in other words if we can prevent the electrostatic or electromagnetic fields of the plate circuit from reaching the grid circuit and causing variations in the grid circuit we will be able to avoid howling.

The following methods will be found to be of great assistance in accomplishing this purpose:

1. Proper wiring of amplifiers. This is where a great deal of the trouble experienced generally arises. Wiring should be arranged so that all leads are as short as possible thus giving minimum coupling. Care should be taken that grid and plate leads should be as far apart as possible thus preventing any transfer of energy between the two circuits. Most important of all grid and plate wires *should not be run parallel* to one another as the coupling is thereby considerably increased.

2. Transformers should be mounted so that their cores and coils are at right angles to each other, thus securing minimum coupling between different stages. In order to prevent spreading of the magnetic field the transformers should be encased in an iron shell thus concentrating the lines of force around the transformer. In order to prevent electric lines of force from spreading the metal case and core of the transformers should be grounded, thus putting these shields at earth potential, and preventing transfer of energy.

3. If possible each tube and its associated apparatus should be mounted in a separate chamber which is lined with copper gauze or foil and grounded. Any energy which may be transferred from other circuits to the shielded circuits is absorbed in the shield and run to ground.

4. A common source of coupling between different circuits is due to the use of a common "B" and common "A" battery. It is of course too expensive to use different batteries for each stage although this is the best way of eliminating this source of coupling. However by shunting the "B" battery with a high capacity the coupling may be considerably reduced.

5. Finally there is that disturbing source of coupling due to the operator wearing headphones whenever he moves his hand in the vicinity of the set or makes adjustment. Two remedies for this may be suggested. The first is that the panel of the receiver and amplifier should be lined with a copper shield and grounded. Thus any variations due to the operator's body will be effectively absorbed by the eddy currents in the shield and run to earth. The second is that the leads of the telephones should also be sheathed in copper gauze tubing and grounded to the case of the telephones, if metallic, and then grounded to earth.

The above precautions apply specifically to prevention of audio frequency oscillations. They also apply to the prevention of radio frequency oscillations which may cause howling and which always reduces the efficiency of the amplifier system. A further precaution in the case of radio frequency oscillations is in the use of very small choke coils of a few turns in the grid leads of the amplifiers, or a small resistance in the grid leads. These act to prevent the circuits from oscillating.

Stray fields which spread out and cause coupling and transfer of energy between different parts of circuits depend upon the size and shape of coils used in the set. Naturally large coils will spread the electric and magnetic fields considerably farther than small coils. Hence small coils should be used wherever possible. This will explain why radio frequency transformers are gradually being more and more reduced in size. The coils on them are becoming smaller and smaller so that the electric and magnetic fields are concentrated in the space around the coils themselves. The shape of the coil often influences coupling. Certain types of coils have very little leakage and the lines of force are concentrated in the coil itself. Of these types the toroidal coil is the best example. In this type of coil the external field is reduced to a minimum and hence coupling and transfer of energy is in a minimum. Wherever this type of coil can be effectively used it will be found to help considerably in reducing howling.

There are other types of noises, not due to regeneration and coupling, which often cause considerable annoyance. These are due to causes which result in small variations in plate current which are considerably magnified by the amplifier before they reach the telephones. Some of these causes are:

1. Bad "B" batteries and run down storage batteries. Any variations in battery voltage naturally make themselves felt either as lower filament current or lower plate voltage, hence the final result is a varying plate current which produces noises. A rundown storage battery is apt to do this and an old "B" battery. If but one cell of the "B" battery is bad it will make itself felt in harsh and grinding noises in the phones. Hence the solution is to watch your batteries and see that they are always in good condition.

2. Noises due to microphonic contacts. Anything which causes a variation in plate current will cause a noise in the phones. Poor contacts which vary and thereby alter the resistance in the circuit ultimately cause a variation in plate current and hence noises. All contacts should be firmly and securely soldered to avoid any such occurrence.

3. Noises due to gas and ionization. The presence of gases always results in somewhat erratic operation. Any variation in voltage may produce abnormal changes in currents due to presence of gas and ionization of the gas. These cannot of course be guarded against. However by careful operation of the tube a good operator can secure excellent results by operating with proper potential.

4. Mechanical vibration of the tube. Whenever the tube is jarred or vibrates, noises are heard. This is due to the fact that the elements in the tube are also jarred and hence the relative distance between the elements varies and the plate current varies in accordance. The best way to avoid noises due to mechanical vibration is to mount the tube either on springs which take up the vibration or on heavy rubber bases.

These are the principal causes of howling and tube noises and for best results should be eliminated as far as possible. The methods here outlined will yield satisfactory results if carefully observed.

Vacuum Tube Facts

By **M. Wolf**

The importance of properly taking care of the vacuum tubes in a set is so great that it is surprising so little is said on the subject. Tubes cost much and they burn out easily for one reason or another. The tube is the weakest element of the set. The average incandescent lamp in a house lasts much longer than the average tube. Since they are both burned to give a maximum life the vacuum tube should last as long as the incandescent lamp. Actually it does not. What is the secret?

The operator of a set tries to take as good care of the tube as he possibly can, but the trouble is he does not seem to be aware of what is actually happening to the tungsten wire of the filament. He knows that too much juice will decrease the life of his tube. Hence he tries to keep his filament current as low as good operation of his set will permit. Not only that, but when he quits operating his set he throws in all of the resistance in his filament rheostats so that when he starts his set working the next time he must gradually cut out his resistance, thus making the filament current go through low values gradually, before reaching the operating value. The reason he does this instead of leaving his rheostats in the operating position is this: He figures if he leaves his rheostat in its operating position there will be a rush of current into the filament due to the storage battery having recovered some of its lost voltage, thus endangering his tube.

The trouble with this point of view is that it is incomplete and inaccurate and based on an insufficient knowledge of the properties of tungsten filament wire. It is true that storage batteries recover some of the lost voltage, but this recovery is relatively very small and not enough to endanger the life of the tube. The only time this danger is likely to occur is just after charging the storage battery. At this time the above precautions should be carefully observed. Of course occasional adjustments of the rheostat are always necessary, but apart from this there should be no fear of the battery recovering sufficientl to burn out the tube.

Otherwise it is most beneficial and advantageous to the life of the vacuum tube to keep the filament rheostat at its operating point all the time and to flash the bulb instantaneously at its operating temperature when throwing the set into commission. This principle has been verified by the latest researches on the subject and the basis for this will be clear from the following data.

Microscopic examination of tungsten wire generally used in lamps and vacuum tubes shows that it may appear in two forms: (1) the ductile form, in which the wire appears to be made up of a continous mass of small grains firmly welded together; (2) the brittle form in which the wire appears to be made up of fairly large blocks with definite boundary or cleavage lines. The ductile form of the wire may be bent without harming it, but if the brittle form is bent the wire immediately and easily breaks at these boundary or cleavage lines. These cleavage lines where the separate blocks of the wire seem to be joined are the weak links in the filament, and the brittle form is therefore apt to burn out or be damaged more easily at these points.

Now what makes an ordinarily ductile tungsten filament wire brittle? The filament as it comes from the factory is usually in the ductile form, as shown by microscopic examination. Now experiment shows that if this ductile filament is taken and heated at its proper operating temperature, or over, it still retains its ductile form. This is shown both by mocroscopic examination and by bending the wire after burning as above, when the wire does not break, but bends easily, thus showing that it still is in ductile form. Now if this very ductile filament is burned at red heat or below its proper operating temperature, a great change will take place. Bend the wire now and it breaks easily. Examine it under the microscope and the wire is shown to be now in the brittle form with its blocks and definite boundary and cleavage lines. Still another experiment performed proves this. Take a ductile filament wire and gradually increase the current by cutting out your rheostat as so many operators do, and thus raise the temperature to its proper operating value. Examination and test again show that the wire has changed from the ductile to the brittle form. In other words these tests have shown that operating filaments made of tungsten, at temperatures below their operating values will result in deterioration of the filament due to formation of a brittle or crystalline structure.

Thus these researches have definitely proved that far from increasing the life of the tube, operation at low temperatures has the effect of decreasing the life due to fundamental changes which take place in the structure of the wire. These facts are apparently well known to the electric lighting companies. For when one turns on the electric lights in one's house the entire lighting current is flashed on the lamp, and no resistance is varied. And in spite of this, incandescent lamps last a pretty long time. If the same procedure were followed in operating vacuum tubes a marked increase in tube life would result. Once you have adjusted your filament rheostat at the proper operating position, it should be left there and the current simply applied whenever the set is started up. The only time the filament rheostat should be varied is for necessary fine adjustments which have to be made from time to time, and for compensation of any battery voltage variation. But otherwise the rheostat should be left at the last operating position.

Stress is laid on this particular point in vacuum tube operation because it is generally neglected and has not been brought out very much in publications. The operator is liable to lay too much stress on not overloading his tube filaments, meanwhile overlooking the equally important fact that underloading the filament is equally injurious and detrimental to long tube life.

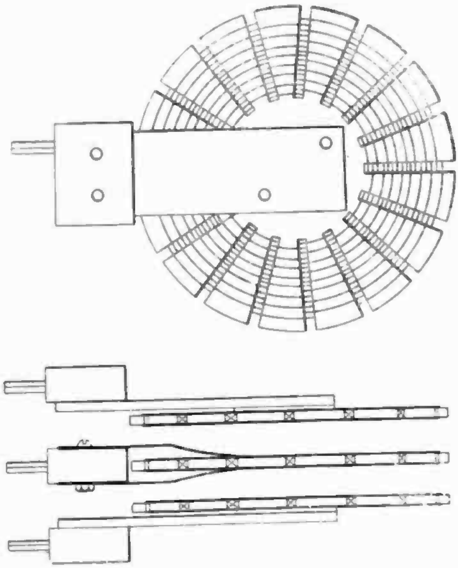
Basket-Wound Coils

***By* Paul G. Watson**

Having experimented for about a year on the best type of coil, for 200 to 450 meter work, to use in a receiving tuner with honeycomb coil mountings and having tried honeycomb, plain wound, bank wound and other types of winding, I found the following type coil to be most efficient for short-wave work.

The most important details are brought out by the drawings.

The winding form was cut from 1/16" black bakelite. To cut the 17 slots for winding, careful work is necessary, and the piece should be placed between two small boards, the edges of each placed parallel, and about 1/16" back from the line to which the cut is to be made. When placed in this manner, the whole thing should be clamped in a vise. A ⅛" drilled hole should form the bottom of each slot, and the cutting should be done with a fine hack-saw.



These Spider Web Inductances, Which May be Easily Constructed, can be Plugged Instead of Honeycomb Coils in a Standard Three Coil Mounting.

After cutting down each slot, the actual winding is the next step. The placing of the wire is very simple, ordinary basket weave, back of one section and in front of the next. About 25 to 30 turns on each coil will be sufficient wire, but in case this gives too great a wave-length, several turns can be removed from each coil. Number 24 D.C.C. was used in the original, and well shellacked, after winding. To fasten the wire ends, it should be passed through the small holes in the form, and then led to the plug terminals, when ready to mount.

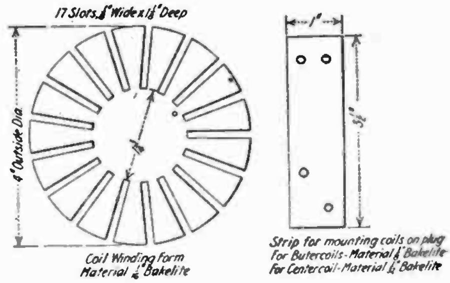
The actual method of mounting is not important, but the method shown here has given complete satisfaction for some time and is recommended as being O.K.

The actual plugs for fitting in honeycomb mountings are available at low prices, so that this item can be bought cheaper than it can be made. Plugs for these coils must have parallel sides, the tapered plug being useless in this case.

In mounting the outer coils, a right- and a left-hand coil should be made, the reasons for which can be clearly seen in the assembly drawing. The bakelite strip should be fastened to the plug by two flat head (countersunk) machine screws and nuts. It is much better, however, to thread the holes in the plugs and then place the screw directly in the plug; many are unable to thread bakelite, hence the other method.

To fasten the coil form and winding to the strip, it should be placed so a 1/16" space is between the coil edge and the plug end. A spacer, the width of the strip and 1¼" long should be placed between the coil center and the strip to allow space for the winding. It will be noticed in the assembly drawing that the coupling is loose between the coils. If tighter coupling is desired, thicker spacers should be used, placing the outer coils nearer to the center one. The coupling shown in the drawings was satisfactory in the original set of coils. The coil form is fastened to the bakelite strip and spacer by means of two soft copper rivets which should be countersunk on both sides.

The middle coil mounting is considerably different from either of the outer coils; it is mounted by two strips of celluloid 1" wide and 3½" wide, respectively, the coil ends being riveted under washers and the



Here is Given the Size of the Form on Which the Wire is Wound with the Dimensions of the Bracket Supporting the Coil in the Mounting.

plug end being fastened with a round head machine bolt and washers. If suitable fiber is available, it will do, but the celluloid is obtainable in any automobile supply store.

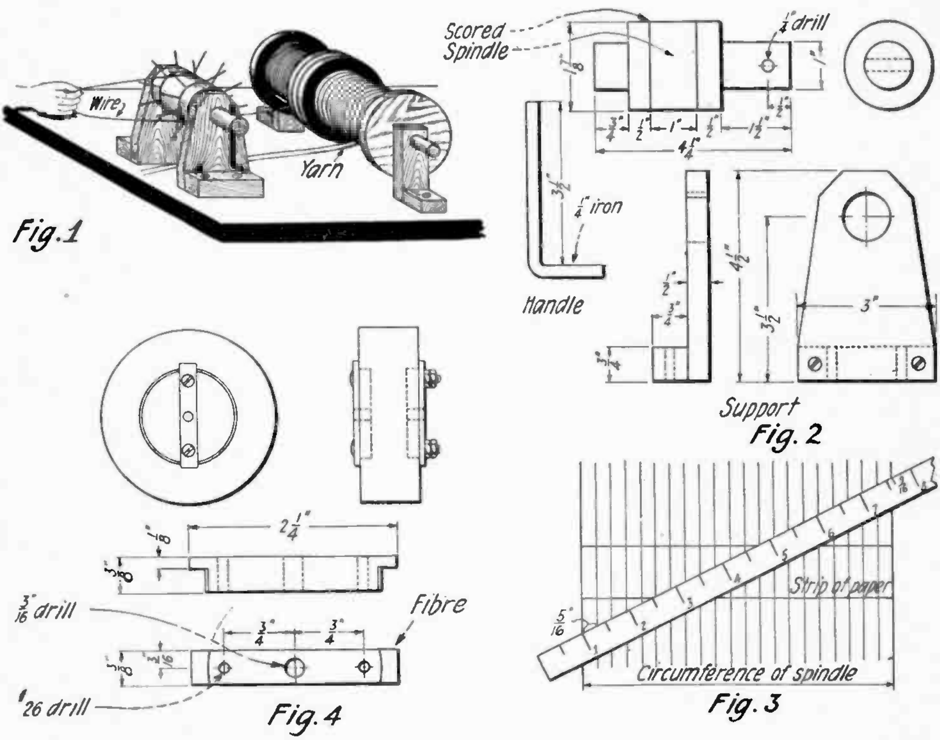
Coils mounted in this manner worked fine in the honeycomb coil tuner, but in connecting the ends of the windings to the plugs, it will be found necessary, in some cases, to reverse the wires to get maximum results. After this is done, the ends should be soldered.

Winding G-R Solid Wire Coils

By T. Morse Lloyd, B. Sc.

To wind the new type of solid wire inductance coils, make a winding device as shown in Fig. 1. The individual parts of the device are shown in Fig. 2. The winding device will take a little time to construct, but once built, it will serve for any number of coils. The spindle consists of a turned piece of close grained hardwood dimensions of which are given in Fig. 2. (A dowel forced over a ½-inch shaft can be used in lieu of a turning, but will not be found as satisfactory.) Lay out two parallel markings 1 inch apart around the circumference of the spindle. Wind a strip of paper 15/16 inch wide around the spindle to get its true circumference and divide this length into 21 equal parts.

This can most easily be done by pinning the strip of paper to a larger sheet of paper thumb-tacked to a board. At the ends of the strip draw two lines, as shown in Fig. 3. Across the lines lay a rule so that the 1-inch division and the 7 9/16-inch division coincide with the lines, then lay off every 5/16 inch along the rule. Draw lines parallel to the end lines through the points and across the paper.



The Constructional Details of G-R Coils.

Re-wind the strip of paper on the spindle and prick point the 21 divisions on the two parallel lines. Drill at each of these points to a depth of ¾ inch with a 1/16-inch or smaller drill. Insert pieces of steel wire 2¼ inches long. The diameter of the wire should be such as to fit tightly in the holes. Before inserting the second row slip a piece of 1/16-inch fibre or cardboard tubing 2 inches in diameter and 15/16 inch wide over the spindle. Place the spindle in its supports and insert the handle.

The size of wire used depends upon the size of coil. For coils of 25 to 150 turns use No. 24 S.C.C.; for coils of 200 to 500 turns use No. 25 S.C.C.; and for coils 600 to 1,500 use No. 28 S.C.C. Obtain a spool of untwisted or just slightly twisted strand cotton yarn, commonly called electrical yarn, and mount, as shown in Fig. 1, beside the spool of wire. For all coils over 150 turns wind a full layer of wire on the tubing and fasten the end of yarn under the last turn by looping the yarn around one of the pins. For coils of 150 turns or less start the wire and yarn at the same pin.

Now have an assistant hold the wire and guide it in its proper place. With the right hand turn the spindle and with the left hand loop the yarn around the eleventh pin on the opposite side of the coil from the pin at which the yarn started. At the end of the next half revolution throw the yarn around the twelfth pin from the last which brings the yarn to a pin two spaces removed from the start pin. Continue the process using every 11th and 12th pin. It will be noticed that the wire weaves in and out of the yarn, and also that when all pins have a loop of yarn around them, the second layer (first layer in small coils) is only partially full.

Continue the process until the layer of wire is full, at which time there will be several layers of yarn between the two layers of wire at the start side of the coil and all the layers of yarn will be on top of the wire at the opposite side of the coil. The end of the 22d turn of yarn should fall midway between two turns already placed. The third and succeeding layers of wire are wound in the same manner until the total number of turns are put on. Either use an automatic counter or count each revolution of the handle to determine the number of turns.

When the last turn has been put on, fasten the wire with a bit of sealing wax. Withdraw the pins and slip the coil off the spindle. Give the sides and top of the coil a thin coat of shellac. Mount in the usual way. If the coils are to be used in a fixed circuit in which the coils will not be changed, a mounting composed of fibre strips across the center of the coil, as shown in Fig. 4, will be found advantageous.

The value of the assistant is that the turns of wire tend to separate considerably if not manually guided back into their proper locations. In conclusion don't attempt to wind the coils unless you possess considerable patience and also count your free time less valuable than the cost of the coils at a radio supply house. Approximately 250 turns can be wound an hour.

A rough estimate of the amount of wire required can be made beforehand by means of the following formula:

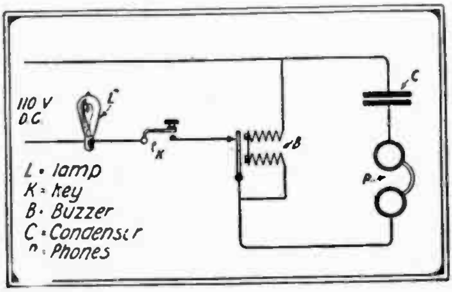
$$\text{Wt.} = \frac{3.14 \times N \times (D - d)}{24000} \times K$$

Where Wt = weight of wire
N = number of turns
D = Approx. outside diameter
= 2.3+.0015xN.
d = inside diameter. (2" in this case)

K = 1.3 for No. 24 S.C.C.
= 1.03 for No. 25 S.C.C.
= .54 for No. 28 S.C.C.

An Arc Buzzer Practice Set

The apparatus needed for my practice set is a small buzzer set, consisting of a high-tone buzzer and a key mounted on the same base, such as is sold by any wireless supply house, a 25-watt lamp, a telephone condenser, and a source of 110 volt direct current. Connect as shown in the diagram.



The Buzzer is Connected In Series With a 25-watt Lamp.

Adjust the buzzer so it gives a rather ragged, high-pitched note and screw the key down tight. Then to transmit signals, instead of pressing on the bakelite knob, touch the metal part of the key.

When you touch the key your body acts as a condenser in the phone circuit and so varies the frequency and therefore the note in the phones perceptibly. This sounds just like a station with a singing arc operating through heavy static. With a scheme like this you get very fine practice in receiving through static and interferences.

R. E. MATHES.

A Storage Battery for 1½ Volt Vacuum Tubes

The popularity of the Westinghouse one and one-half volt tube, type H is steadily increasing, and a great many owners of this tube are using dry cells with which to light the filament. The disadvantage of dry cells can easily be seen in the cost and noises produced by the deterioration of the cell.

The discomforts produced by the dry cell can easily and cheaply be overcome by building a two volt storage battery of the type here described.

First secure a bottle or jam jar, six and one-half inches high, the mouth of which

A Neat Little Storage Battery for the 1½-Volt Tube. All the Necessary Parts Are Easily Obtainable and May Be Purchased for Next to Nothing. The Plates Are Cut from Those of a Large Storage Battery. Any Garage Can Furnish Them.

should be one and one-half inches wide. Procure a positive and negative plate of an old storage battery and cut each plate so as to include two sections of pasted grid, the plates can be easily cut with a hack saw. Next is a rubber stopper in which three holes are bored, one for the vent and two for the lugs. The vent is a piece of glass tubing about two inches long.

Lugs should be burned or soldered on each plate, and led through the holes in the stopper, and a binding post soldered to each one.

A battery of this type can easily be recharged at home by using a chemical rectifier. J. A. Barlock.

Amplifier Trouble

After operating a single-tube regenerative set for some time, I decided to add a one-step audio frequency amplifier. When all was ready I sat down to listen for an amateur radiophone, expecting to hear it fine and loud. The amplifier would not work.

On the detector alone everything was O. K., but as soon as I switched to the amplifier the set would not oscillate and signals were mushy and only one-fifth as loud as on the detector alone.

Thinking it must be the transformer, I had an electrical engineering firm test it; in fact, so sure was I that the transformer was defective that I asked for a quotation for repairing it! However, they found nothing wrong with it. As I had been looking for the trouble for close on three weeks, I was getting pretty disgusted.

It only then occurred to me that my phones had the usually high resistance of 8,000 ohms, while the resistance of the primary of the amplifying transformer was only 900 ohms. My detector tube, a soft one of Dutch manufacture, was marked for a plate voltage of 25 to 30, and I had always used a 30-volt battery. Now the phones would drop the voltage quite considerably by reason of their high resistance, but the drop across the transformer would be very little (on account of its lower resistance) and consequently the plate voltage on the detector would be higher with the transformer in the circuit.

An excessive plate voltage paralyzes a tube and could thus render the entire apparatus inoperative. I accordingly cut open a portion of the cardboard covering of my 30-volt "brick" and with a drop of solder fixed a lead to the side of the third cell from the positive end, this giving me about 26 volts. I hooked up my 26 volts, and the set worked perfectly right away.

K. McLean

Notes on Crystal Detectors

In this day, just as of old, the layman goes through the period of his apprenticeship using the crystal detector in preference to the more expensive and complicated vacuum tube.

He is favored less, however, than the "Bug" of other days, inasmuch as the ground that he must cover is but occasionally touched upon by the substance of the current press.

The aim of this explanation is to bring out a few points of construction in a general way with a word or two anent the safeguarding and operation of crystal detectors.

As the jarring out of adjustment is a consideration that should be anticipated in designing of the device, it will be considered first. Briefly speaking, a design which best overcomes the effects of jarring and all ordinary vibration is one in which those parts not rigid with the base are so light as to be carried freely with the slightest motion given the device.

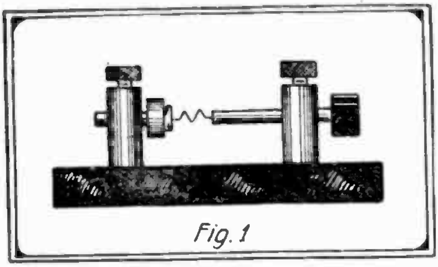


Fig. 1

A Very Efficient Galena Detector Design. Note the Rigid Construction.

These qualities are instantly apparent in the galena detector shown in Figure 1. There is nothing new about this particular form, but it illustrates the point in question very well as all the parts are rigid except the fine wire contact, which is so light as to offer practically no resistance to any vibration transmitted to it. The smooth

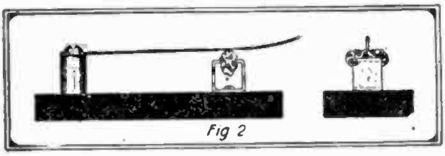


Fig 2

This Type of Construction is Best Adapted to a Silicon Detector.

surface of galena is adaptable to this form, as it permits the contact points being moved over it with the point of a pencil. The rod holding the wire being tightened at a point that gives approximately the best working pressure.

Another style that involves the same principles is shown in figure 2. This pattern is a variation of the so-called "catwhisker," and as the length of the spring wire contact requires some size and moderate pressure, it is a very satisfactory mount for silicon which ranks a close second to galena for sensitivity.

Either of the foregoing types will remain in adjustment for days at a time where they are subject to the ordinary jarring that works havoc with the setting of many other types. Though they are but two of many ideas that embody the same virtues, they will give very good results when mounted on receiving panels, on bases with tuners or other apparatus, in portable sets or, in fact, any location where the processes of tuning impart vibration to the whole.

By way of contrast an opposite extreme is shown in Figure 3. Here the contact carrying arm will rebound with vertical vibration and undergo tortion with sudden motion on a horizontal plane resulting in microphonic noises in the headset and loss of setting.

Detectors that employ comparatively heavy pressures, such as carborundum and zincite-bornite couples, do not require much delicacy of design, and nearly any type of stand will suffice for their use.

Another annoyance common to crystals is the burning out of a sensitive spot through strong signals or the effects of the local transmitter. A very common error in correcting this evil lies in "shorting" the detector while sending. A glance at Fgure 4 will show that this procedure defeats the purpose intended as the detector then forms a closed circuit in itself, the size of which depends on the physical arrangements of the parts that make up the loop.

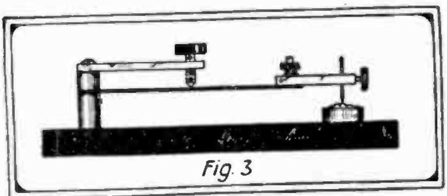


Fig. 3

Carborundum and Other Minerals Requiring Heavy Pressure Should be Used in a Stand of This Type.

When in proximity of the transmitting circuit this loop is traversed by a current that is governed by the plane of the loop in relation to the conductor of the transmitter and its nearness to them.

The best procedure in safeguarding the detector while sending is to disconnect

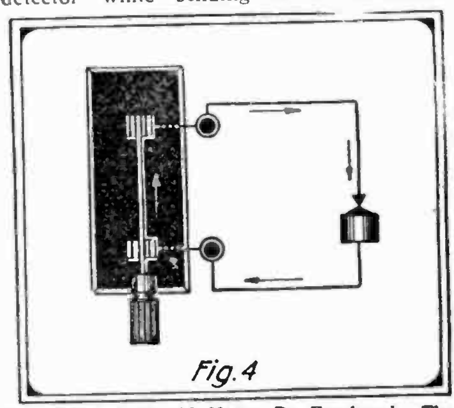


Fig. 4

This Method Should Never Be Employed. The Shunting or a Detector With a Switch Forms an Oscillating Circuit.

both sides of it from the circuit as close to the device as is found practicable. It is also well to cover it with a metal box or a non-metallic cover lined with tinfoil, which may be set gently over it after adjusting. This cover will also preserve the mineral by shielding it from grease and dirt.

C. H. Bixon

Practical Pancake Coils

The coils described may be arranged on honeycomb-coil plugs or, they may be connected with flexible leads. The construction is quite simple and the results are generally good.

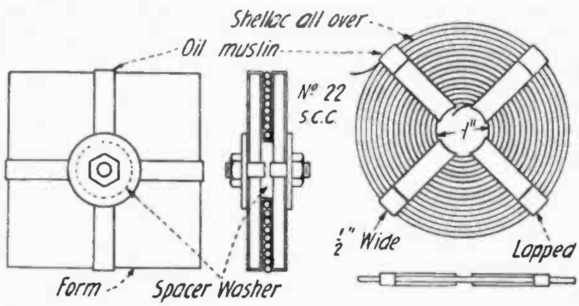


Fig. 1 Fig. 2

How the Pancake Coil is Made and Assembled.

Two perfectly flat surfaces of wood or sheet metal for a form as shown in Fig. 1 are bound together with a bolt having two outside washers for holding free ends of oil muslin, and a spacing washer the thickness of wire to be used.

In the case of the writer 30 turns were wound in pancake (helix) form of No. 22 S. C. C. wire.

Half-inch strips of oil muslin were arranged as shown in Fig. 2, and as wire is wound, sticks to muslin which had previously been coated with heavy shellac. When allowed to dry and removed, the coil was coated with shellac and again allowed to dry, presenting a rigid article.

Two such coils were used, one as a primary in the antenna circuit with a variable condenser in series and the other (secondary) in the grid circuit.

The two coils when laid flat upon the table one on the other may be made to produce any degree of coupling by sliding horizontally.

Later a third coil of similar construction, but of fewer turns, was connected in the plate circuit for regeneration.

With 50 feet of lamp cord laid on the hallway floor as an antenna in conjunction with a detector tube and one stage of amplification, excellent results were obtained.

Such coils may also be used as primary and secondary of radio-frequency transformers which work very well. The ratio of turns may be made 2 to 1 and the proper number of turns wound so as to cover any desired band of wave lengths.

E. J. Pilkington

A Sensitive Detector

The material necessary can be found among the junk of any radio bug.

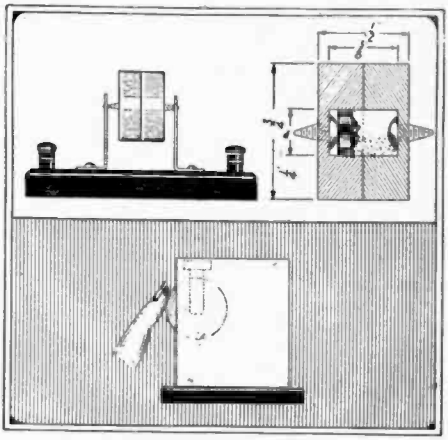
The material required is as follows:

1. A piece of hard rubber or fibre rod ¾" in diameter and ½" long.
2. Two small brass wood scews about ¼" long.
3. A small piece of tested galena.
4. A small piece of scrap aluminum.

Directions for assembling:

Saw your piece of hard rubber or fibre rod in half.

In each half counter base a ¼" hole about 3/16".



A Very Clever Scheme—A Revolving Unit Makes a Very Sensitive Detector.

Then bore two small holes in the center of each half and fasten the small wood screws in.

Secure your piece of galena against one of the brass screws with woods metal.

Make enough aluminum filings to fill half the space and fasten the two halves together with a good grade of furniture glue.

Your detector is now complete and you may place it in a stand as in the diagram or any other way suitable to you.

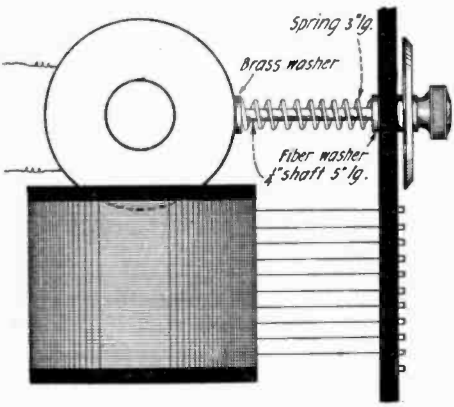
To adjust the detector turn with the finger until the most sensitive spot is found.

This detector, owing to its small size is very suitable for pocket and portable sets.

C. ANCHILOWITZ.

Simple Mounting for Vario-Coupler Secondaries

Having to build a variocoupler and wishing to use, as a primary, an inductance which was already wound, and on which I could not mount the necessary bearings, I decided to fix the secondary as shown in the sketch.



A Simple and Clever Mounting for the Secondary of a Variocoupler.

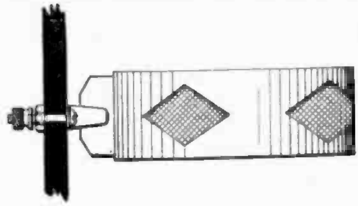
The form on which the secondary is wound is mounted on a shaft passing through a bearing mounted on the front panel. To this shaft is affixed the dial in the usual manner, and a spring which should be strong enough, pressing between two washers, holds the secondary in the correct position over the primary inductance.

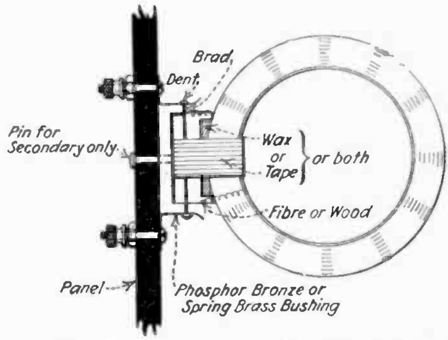
BY HARRY KENNEDY.

A Method of Mounting Coils

For the benefit of those who wind their own D-L or H-C coils and cannot suitably mount them, I give the following suggestions. No dimensions are given, because they can be made to fit any coil.

Possibly the illustration will make it clearer than an explanation in writing, but I will suggest a few things. Either red sealing wax or tape, or both, may be used, adding greatly to the strength. If only a dent is made in the spring bearings, the brass brads should have the heads left on for large contact surface. If a hole is





If a Mounting is Too Expensive for You, You May Make This One Yourself.

made, the heads should be cut off and a washer soldered on. Solder the leads from the coil to the pins also. Back of the secondary drill a hole in the panel big enough to admit a pin, as shown by the dotted lines. Fasten it in with glue. In the plug of the secondary coil, drill a hole to correspond, and large enough to readily slide into place; this will hold the secondary in place. The springs should have good tension so as to insure good contact and hold the coils in adjustment when placed there. The binding posts hold the coil mount as well as serving for binding posts.

This is neater than the methods used by most amateur coil winders though it does not compare with the regular method.

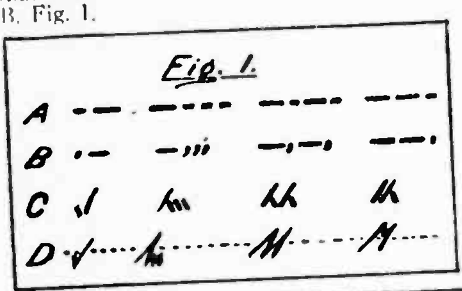
ROBERT HALE

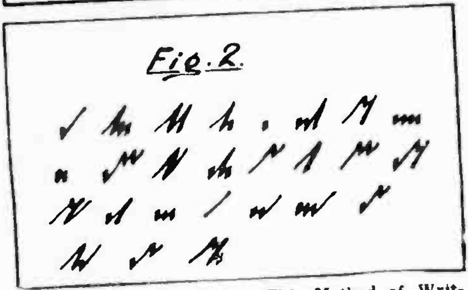
A Practical Method for Writing Code

Most Radio beginners are so situated as to be able to practice the code with someone else who is learning, but many find this impossible and are forced to resort to the use of mechanical senders, or to picking up what they can from the messages intercepted by their simple sets, it being well known that practice at sending alone will never make one proficient in receiving.

A mechanical sender represented in my own case, as in many others, too great an expenditure, and I soon found that the messages I picked up were entirely too fast to be of any help to an absolute novice.

A friend in the same predicament finally suggested a correspondence by mail, in Morse code, and this proved to be the solution of our problem. At first we wrote out the dots and dashes in the regular fashion as shown at A, Fig. 1, but this was so slow that we soon adopted the style shown at B, Fig. 1.





For Practicing the Code. This Method of Writing is Ideal and Simple to Read and Write.

One day while reading of the old Needle System in an English book, I got an idea that helped us tremendously, making the writing of Morse by hand much less tedious. In this system a magnetized needle was used, a movement of the point of which, to the left, indicated a dot, to the right, a dash. The symbols were represented in print as shown at C, Fig. 1.

This was adapted to our needs by making all the dashes with an up stroke of the pencil, and the dots with a down stroke, the dots being entirely below an imaginary center line and the dashes extending above it, as shown at D, Fig. 1. All the parts of each letter are written without lifting the pencil from the paper. An entire alphabet is shown so as to make the idea perfectly clear, see Fig. 2.

This method proved to be very practical. Messages are easily and rapidly written, and after sufficient practice, can be read almost as rapidly as if written in longhand.

We were soon able to read fast enough to take down parts of the messages intercepted, and after that all was plain sailing, but we still find it very convenient to be able to read and write in Morse legibly and rapidly.

P. B. CROUSE

Form Wound Coils

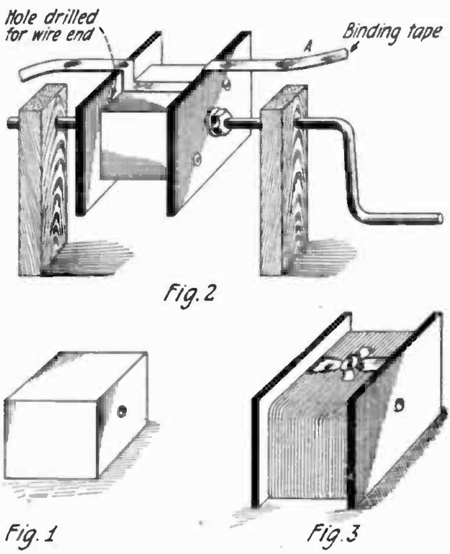
Practically every amateur has occasion at various times to use form wound coils of special dimensions. In the construction of plain magnets or open core apparatus, the wire is usually wound in place directly upon the core. With dynamo or motor fields and closed core apparatus, it is usually impracticable, and, in some cases, impossible, to wind the wire in this way. Consequently, the coils must first be wound upon a form, after which they are removed, tapped, and slipped in place in the apparatus. Square or rectangular coils are needed more often than round ones, but the process of winding is the same in any case.

For the average job a form should be made of exactly the same length as is desired for the finished coil, making due allowance for the necessary insulation to be added later. Each of the other two dimensions should be about 1/8 inch greater than the corresponding dimensions of the core upon which the coil is to be placed. A block of wood planed to the oversize dimensions indicated above, and sawed to the desired length is the most convenient kind of core form. A 1/4-inch hole is bored through the longitudinal axis of this block and receives the axle used in rotating the form. The appearance of the finished block is shown in Fig 1.

Two end pieces of suitable size are made from thin board and a 1/4 inch hole is bored in the center of each. One end piece is screwed to each end of the core, its center hole coinciding with that in the core. The spool thus formed is slipped on to a 1/4-inch rod which has one end threaded for several inches, and the other end bent in the form of a crank. A tap is screwed up tightly to each end of the spool, and the whole is mounted as shown in Fig. 2. The bearings are simply wooden uprights with holes for the axle. If all work has been done with reasonable accuracy, the spool should show no tendency to wobble when the crank is turned

The first step before winding the coil is to be sure that it will slip off the core readily when it is finished. Wind on the core a single layer of small hard-twisted cord. This layer must be wound perfectly smooth and the ends should be brought out through small holes in the end pieces. Wrap upon this layer two or three thicknesses of thin, stiff paper, just wide enough to come flush against both ends. Glue both tabs of the paper slightly, just enough to hold it in place.

On each side of the core, and parallel to the axis, glue a strip of narrow cloth tape as shown at A, Fig. 2, allowing each end to come up from the core along the end pieces, and fasten temporarily upon the outside. The tape ends must be of sufficient length to tie over the coil when it is wound, thus providing a method of binding it tightly in the process of removal. If the coil is to be a large one, two or more pieces of tape should be placed on each side of the form. After these binders are in place, paint the core with shellac or insulating paint.



The Above Illustration Shows Clearly the Method of Constructing the Form and the Means of Winding the Coil.

Pass one end of the wire to be wound through a small hole drilled through one end-piece. Draw several inches of the wire through and fasten securely by wrapping around the shaft. Wind the required number of turns on the spool, laying each turn as closely as possible against the preceding one. Paint each layer, as it is wound, with a liberal coat of insulating paint, and allow it to partly dry before putting on the next layer. Wire—especially enameled wire—may be placed much more satisfactorily if it is wound on a bed of paint which has been allowed to dry just to the point of tackiness. When all the winding is in place paint the last layer, release the tab ends and tie each piece of tape firmly across the coil, as shown in Fig. 3. Allow time for the paint to harden before removing the coil. Passing just sufficient current through the coil to warm up the wire will hasten the drying.

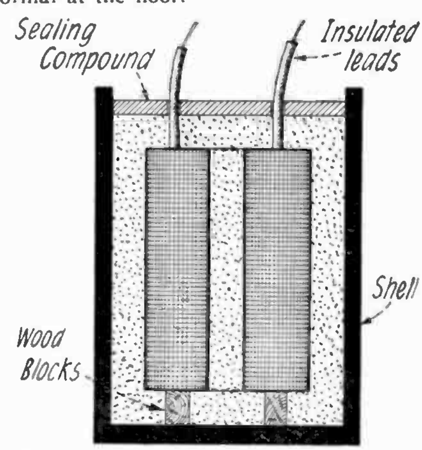
Take the form from the axle, remove one of the heads, and grasp the end of the layer of string. By pulling in the direction parallel to the axis, the string may be removed, thus leaving a free space between the coil and the core. Remove the coil from the —, tape it and it is finished.

In the final taping the binding tabs should be removed, but it is not necessary to remove the paper. Narrow tape is best, and makes a much neater job on small coils. Each turn should overlap the preceding one by half its width. Going once around the coil with tape in this way gives two thicknesses at every point, and this is usually sufficient. S. E. Watson.

Cores for Transformers

I have found that in building transformers and chokes, the core often causes more trouble than the windings. Whatever material is at hand must be used or expensive electrical sheet bought and cut. If ready-made core is used the windings must be made to "go in the space," often at a sacrifice of capacity. When used in radio work sheet or wire cores can also cause troub!• strong lines of force traveling between transformers or chokes.

The solution of most of these difficulties is the use of powdered iron cores. This suggestion may at first sound preposterous, because of the apparent impossibility of obtaining the powdered iron for such a core; but in reality it is a simple matter, an excellent substitute for the unobtainable powdered iron being found in any machine shop, structural iron shop or garage, this being the fine grindings from the abrasive wheels. While this material may be ground from hard steel it is really very soft due to cooling from white heat at the wheel to normal at the floor.



A Transformer with a Closed Core Composed of Powdered Iron. This Helps to Simplify the Matter of Construction.

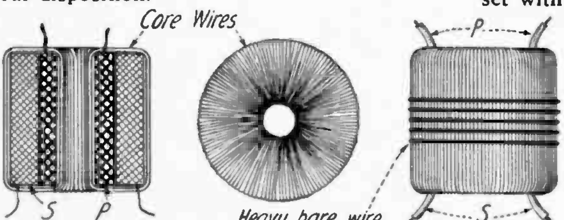
This material has all the advantages of powdered iron and is far superior to sheet and wire core with the added advantage of low cost, most shops throwing it out as scrap. But above all, it is efficient, it fits the space meant for it, and it prevents stray flux

To make use of this type of core it is only necessary to see that the coils wound about a fair sized central opening are of a size to leave at least ¼" space between them and the case on all sides, that they are firmly wound, well taped and impregnated with well insulated leads brought out. This unit is then placed in the shell, the end resting on two small blocks of wood which provide space for the core to completely enclose the coil. The shell can be a small tin can or a hard rubber, bakelite or fibre tube plugged at one end. The filings, which have been previously dried to remove all oil and moisture, are then tamped in around and on top of the coil, entirely surrounding it with a perfect path for the magnetic circuit. When the core has been well packed, melted paraffin or other sealing compound, is poured on and allowed to soak in, which completes the assembling of the transformer or choke.

This type of core adapts itself readily to any kind of coil that the amateur may have occasion to build, and has been tried out successfully on radio chokes and transformers, and even on small welding transformers, living up to expectations in every case. CHARLES B. NEILL.

An Inexpensive Amplifying Transformer

This transformer is distortionless, squeal-less and ultra-efficient. In order to build this transformer, two articles are required; an old Ford ignition coil and a patient careful disposition.



A Transformer from a Spark Coil Secondary.

The Ford coil may be purchased at a local garage very cheaply (mine cost 25 cents). Remove the secondaries and find both leads to one of them. Decide what ratio your transformer is to be. (The ratio should be 4 to 1 or lower.) Count the layers on the coil and mark off a proportionate number of layers on the center of the coil for your primary. At this point push back the coil with a pocket-knife, exposing the winding. Lift up and break the last turn on this winding. Upon the ends now made solder larger wires and insulate with rubber tubing. Push back the primary coil and cover the entire unit with hot paraffin. The coil is now completed and ready for the iron core which consists of a bundle of iron wires. These wires are so bent around the coil that the ends meet. The same amount of wire as was contained in the original coil should be used. Around the outside of the transformer a few turns of heavy bare wire are placed to hold the core tightly and to improve appearances.

The diagrams show the necessary details clearly.

If desired this transformer may be mounted upon a panel with four terminal posts. ARTHUR VANCE.

A Silver Dial

Secure a sheet of stiff brass, cut it to the shape desired with whatever diameter is wished, and clean it top and bottom with steel wool until it is bright. Having drilled the shaft and supporting screw holes for the knob, make a solution of sulphuric acid and rain water, using three parts of acid to one of water. Pour the acid into the water slowly employing a porcelain bowl as container. Dip and wash the disc in this solution. Melt some tinfoil in a clean pan and, when the foil has completely melted, dip the brass disc in it, allowing it to remain for about 15 seconds. Place it in a pan of water to cool.

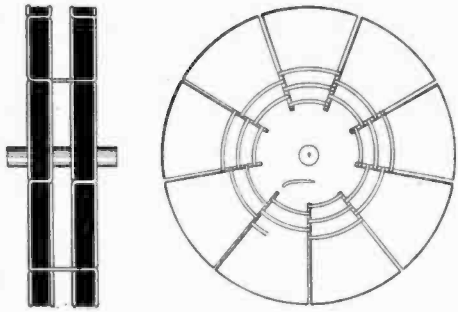
The finish is made by rubbing surfaces with a small piece of clean cloth until the "silver" shines up brightly. The marking may be done with a pen and good ink, or indentations may be stamped in the brass disc before silvering. This treatment may be applied to all the brass work on the set with a resulting neatness in appearance. It would be well to give each part a heavy coat of lacquer or good varnish to prevent tarnishing. W. C. UTZ.

Duo-Vertical Coil Winding

In making a three-coil spider-web tuner, amateurs have often been dissuaded from completing the job because of the great size of form needed for the coil with the greatest number of turns. Take a tuner, for example, in which the primary has 35 turns, the secondary 50 and the tickler 80 turns. Using No. 22 S. C. C. copper wire, the radio amateur finds that he can get 25 turns to the inch, measuring at right angles to the direction of the winding; 80 turns means a little over 3" of winding which in turn require a form over 7½" in diameter.

This is too large to handle and to mount conveniently, and in searching for a better way to wind the tickler coil, a radio experimenter hit upon a novel plan, details of which are here described and illustrated.

Instead of providing on extra-large disc



Method In Which the Duo-Vertical Coil Is Wound.

for the tickler winding, he made two small discs and put them side by side on a temporary shaft, as shown in the diagram. For uniformity's sake he made this double form the same size as the primary and secondary forms. Then he made what is described as a "duo-vertical" winding. That is to say, he wound identical coils side by side in a vertical line, doing it in such a manner that the inductance effect is the same as with one coil.

Winding clockwise, he first completed one full turn on the disc nearest him as he held the double form in his left hand. He wove the wire in one slot and out the next, alternately crossing in front of and behind the various sections. Then, instead of continuing on for the second turn on the first disc, he crossed over to the second disc and completed the first full turn on that. Then he came back and made another turn on the form nearest him, crossing to the rear to do the same to the disc in back. Back and forth, in and out, first a turn on this disc, then a turn on that, until the required number had been made.

This duo-vertical winding is not hard. The only thing about which to be careful is to see that the winding on both halves of the double form goes in the same direction. This direction, incidentally, should be the same as that of the primary and secondary windings.

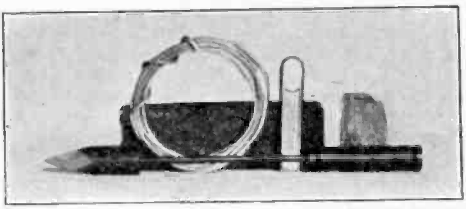
The result of this novel method of coil construction is a compact and efficient coil, which can be readily handled and which gives better results than the cumbersome 7½" "solo-vertical" winding.

AURTHUR S. GORDON

How to Solder Connections

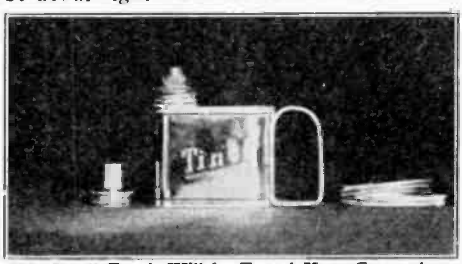
It is of great importance to the working of radio sets, that a clear path for the electrical energy (which at its best is very weak, owing to distances traveled) should be provided so that no buzzing sounds due to loose connections are heard along with the signals, there being enough trouble encountered in the radio field without adding any from this source. Therefore, it is absolutely necessary that all connections should be firmly soldered.

Soldering wires on variometers and other parts is easy once the knack of handling a soldering iron is learned. It is better for those who have never done work of this kind to try it on some spare pieces of copper wires twisted together, which will enable them finally to do a neat job. Soldering irons, or coppers as they are termed, range in weight from a few ounces to several pounds; they can be either made or bought. The lighter ones are easier to handle, but they lose their temperature very quickly when compared with the heavier variety. The ability to retain heat as long as possible allows of a number of joints to



A Complete Soldering Outfit Which Should Be in the Possession of the Amateur Desiring to Do Good Work.

be fastened together, thus rapid work can be done. One weighing about ¾ or one pound (shank and handle not included) will be about right for most radio work.



This Small Torch Will be Found Very Convenient.

The one shown in the photograph weighs close to one pound, and was made by the writer from a one-inch copper bar, the shank being from a poker and wooden handle obtained from an old broom. In order to do good work in soldering, five things are essential. The point of a soldering iron has to be coated with solder or "tinned" as it is termed by men who make a living doing this work. The portions to be united together must be made very clean either by scraping with a piece of a sharp knife blade kept for this purpose and filed or rubbed with emery cloth—whichever need soldering ought to be heated above the melting point of solder. In ordinary classes of small work, such as soldering one wire to another, or sheets of metal to other sheets, the heat of a soldering iron itself must be sufficient not only to melt the solder, but also to raise the temperature of the metal to be fastened together, so that firm joints are made.

Do not let your iron become too hot, that is, red-hot; it will not take up any solder at all. Lastly, it is always essential to keep the iron well tinned at all times, so that when a person desires to use it, the device is always ready, and thus save time by not having to re-tin it. As new irons sold in a hardware store are in the rough state with no tinning upon their points, most of them also have no handle, which has to be bought separately. It is necessary after one is put on, to smooth its four-sided face with a medium coarse file so as to make the tin stick to it. To tin these sides, put the iron in a clear, red coal fire, which is not giving off any smoke. Heat it until nearly red-hot. When it has the right degree of heat, the solder will melt instantly when it is applied to the iron. At this stage if it is held about 3" away from the palm of the hand, the heat given off from the hot metal may be felt. This will serve as a guide for future heatings instead of touching solder to the tool.

Have some powdered rosin together with solder on a board; quickly brighten one face of the soldering iron with a file or a piece of sandpaper tacked on a block of wood and then rub it rapidly into the rosin and solder mixture. The surface of the copper bit will be found to have taken a shiny coating of solder. Repeat this process with the other sides until they are tinned. If it should happen that a soldering iron refuses to take a tin coat, heat the copper a bit more, but not red-hot; file its face and rub it on a lump of sal-ammoniac to remove any grease, then plunge into the rosin and solder flux. A few trials will enable any novice to do good tinning work.

Once a nose of an iron is "tined," it will remain so, provided it has not been overheated so as to burn off the solder or cause it to become alloyed with the copper; this can be easily seen by its surface turning black. In cases of this kind, file and re-tin.

Having coated the tool with tin, the next thing is to use it on wires of radio outfits, it being presumed that the amateurs have practiced soldering other pieces of wire before trying this work on their instruments. A description of fluxes and their action will be gone into, as fluxes play a most important part in soldering work. The main reason for using fluxes in order to make firm joints that will not become loose, exists in the fact that a thin film of oxide always forms upon all brightened surfaces of metals; this oxide being caused by action of the air. Fluxes dissolve and prevent any further oxide forming and by thus preventing the formation of oxides, allow the solder to stick directly to a metallic body, instead of an oxide film which, sooner or later allows the joints to come apart.

To solder twisted wires on vario-couplers, untwist them and scrape the insulation off the ends and brighten with emery or sandpaper, also coat them with rosin flux, taking care not to get any of the latter on the insulation. Heat the iron in a gas or coal fire until it has acquired the right temperature, when the solder on its tinned surface will be observed to melt; this shows it to be hot enough. Remove it from the fire, give a quick rub on a piece of old carpet and touch it to a bar of solder. A drop of the latter will adhere to the iron and can be conveyed to the wires that need uniting. Hold the hot copper on the junction and as soon as they are hot enough, the solder will leave the iron and flow over the wires. Remove the iron but do not disturb the joint until the solder has set, which will be shown by a sudden dulling of its surface. It may be necessary to add more solder to the joint. In this case, add more flux and put on another drop of metal.

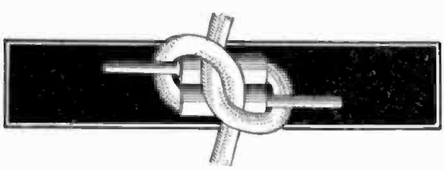
Some radio fans use aluminum wires for aerials and try to solder the joints with ordinary "half-and-half" tinners' solder and then wonder why it does not stick to them. Aluminum has an oxide on its surface which reforms as quickly as removed. For this reason a special solder is needed. If possible, a radio enthusiast who desires to use an aluminum wire aerial should have a wire of such length that it will reach the binding posts of his set without any soldered connections in it. Should this be impracticable, then resort will have to be made to a soldered lead-in wire. If this work is done with a solder and flux of formula given, aluminum wires may be united with the least amount of trouble. The formula for aluminum solder is 80 per cent. tin, 20 per cent. zinc and 1 per cent. aluminum. Place a dry grooved board with a slot cut in it the thickness of a lead pencil. Stop up both ends and pour the hot metal from the iron ladle into it. The flux is composed of equal parts stearic acid and rosin, melted and well stirred together. A bar of common yellow laundry soap melted up with a sufficient amount of rosin so as to make a mixture that can be spread on with a stick, will also make a good flux.

Heat the place on the wire with a blowpipe until it is hot enough to melt the solder (which differs from the ordinary variety in that it flows more sluggishly) then quickly rub the hot surface with flux and tin well with the solder, pushing the latter backward and forward. This removes the oxides and prevents any more from forming. When both wires are thoroughly "tinned," wind one over the other in the usual manner. Heat joint again and apply more flux and solder so as to cover both parts well. In aluminum soldering it is better to have each wire well covered with a plentiful supply of solder so as to exclude moisture. This solder will impart a strength to a joint nearly equal to the metal itself. An aluminum soldering bit will be found to work better than a copper one, although the latter can be used successfully for aluminum work. Joints on outside, aerials should be painted with several coats of a spar varnish, so as to keep out the moisture.

W. S STANIFORD

Connecting Phones

One often desires to connect two or more pairs of phones in series for the benefit of visitors who would like to "listen in." It is usually the case that nothing is handy for this purpose. The illustration herewith



If You Are In a Hurry to Connect Up Two or More Pairs of Phones, Do It Like This. It's Simple.

shows a quick as well as practical method for doing this. The cord tips are held in firm contact by an over hand knot. Care must be taken to make the knot tight, otherwise, stray noises and scratches will be produced. The drawing is self-explanatory.

S. H. EMMES.

How to Wind Duo-Lateral Coils

As is well known, the difference between honeycomb coils and duo-lateral coils is in their winding. In winding honeycombs, consecutive layers are spaced so that the turns of the second layer fall directly over the turns of the first layer, while in the duo-lateral wound coils the turns of the second layer fall over the space between the turns of the first layer. The turns of the third layer then fall directly over those of the first layer and those of the fourth layer over those of the second and so on. Like honeycombs these coils may be wound around pins fixed in a tube, but in the case of the duo-laterals twice the number of pins must be used.

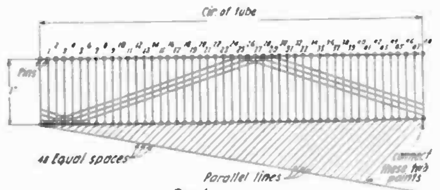


Fig. 1

For the Ham Who Builds His Own, But Has No Winding Machine, Here is How to Wind D. L. Coils by Hand.

First purchase a two-inch mailing tube from a bookstore. Make a wooden dowel to fit into the tube or, if the tube has fairly thick walls, this will not be necessary as the pins will be held firmly enough by the tube. Next determine the position of the pins.

For a tube 1⅞ inches in diameter 96 pins are needed, 48 on each side. An easy method of dividing the circumference into the desired number of spaces is shown in Fig. 1. Draw a rectangle whose length is the exact circumference of the tube and whose width is the width of the coil to be made. In this case it is one inch. From one corner draw a line as shown and mark off 48 equal spaces on it with a ruler or compass. Connect the last mark with the corresponding corner of the rectangle. When lines parallel to this line have been drawn from the equally spaced marks to the bottom of the rectangle and lines continued from these marks have been drawn across the rectangle as shown in the figure it will be found that the rectangle has been divided into 48 equal parts. This method will serve for any size rectangle to be divided into any number of parts.

The drawing is then placed on the tube and the pins put in their places. By winding the coil at one end of the tube the remainder will serve as a handle while winding. Start the winding by taking a turn around one of the pins. Then lead the wire around the 25th pin on the opposite side, then back to the second pin on the first side, then to the 24th pin on the other side and so on. Only the first three turns are shown in the figure. Wind the first layer in this way omitting every other pin all the way around. When the second layer has been reached take the next pin to the last one for one turn only around the tube and then start omitting every other pin again. Thus the second layer will be wound on an entirely different set of pins and this will bring the turns of the second layer exactly over the space between the turns of the first layer. When the third layer has been reached switch back to the row of pins the first layer is wound upon, and so on for all the rest of the layers. On the top row of pins shown in the figure the odd numbered layers will be wound on the odd numbered pins and the even numbered layers on the even numbered pins. There will be a slight irregularity on one turn of each layer, but this is not objectionable as it is only one turn in twenty-five and cannot be noticed.

When finished, the coil is shellacked, cut off the tube, the pins pulled out and is ready for mounting. If the coil has been appearance.

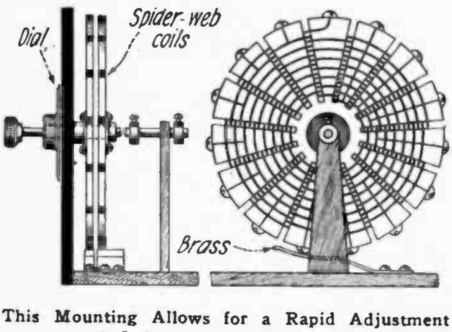
WM. T. PRATHER.

in the form and wound with 195 turns of No. 22 S. C. C. wire. Each coil is tapped every 13 turns so there is a tap on each slot. A disc of brass is then soldered on the axle of the movable coil and fastened to the form by four screws. The other coil is fixed on the tube in the same way. The large knob with the 360° dial as well as the small one, were made of hard wood. The stroke of the main shaft is limited by two collars placed on each side of the end support. Contact strips are made of brass and are fixed to the cabinet by screws. The contact strip corresponding to the movable coil is wider in order to keep contact through the total variation of the movable correctly made.

ROBERT SERRELL.

A Spider-Web Coil Mounting

The new mounting shown in the accompanying sketch makes use of two coils of spider-web construction and permits variation of their coupling. One of these coils, wired as usual, is fixed in the center of the wooden form and a tube attached to a knob. The other is also fixed in the center on a shaft which can slide in the tube. This coil is attached to another knob as shown in the sketch. Each coil is tapped every several turns. Tapped points made of screws are fastened on the periphery of the coil. Brass strips under these give a good contact. Turning each coil changes its corresponding inductance; in pulling or pushing a little knob, the coupling may also be varied. Connections to the end of each coil are made of flexible wire. The two induc-

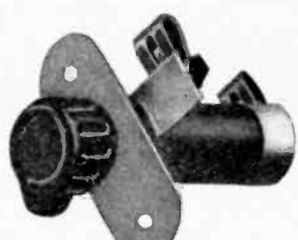


This Mounting Allows for a Rapid Adjustment of Inductance and Coupling.

tances can be coupled in series or used as primary and secondary of a loose coupler. The model employed in my receiving set had the following constructional details: Spider-web coil forms were made of thin, hard wood 8" in diameter; 15 slots were cut

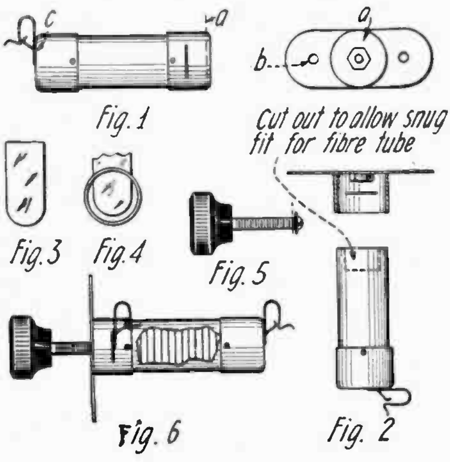
A Carbon Disc Rheostat

In constructing a receiving set for experimental purposes the writer had a desire to use a carbon disc rheostat for filament control. Not wishing to purchase one of the numerous types on the market, the following idea was conceived and a rheostat constructed accordingly, which was tested very rigidly and gave excellent results.



The Carbon Disc Rheostat As It Appears When Finished.

A non-refillable fuse of the cartridge type (30-60 amp.), with the ferrules secured to the fibre tube by small brass tacks was procured and one end sawed off as in Fig. 1-a. The filling material and remaining parts of the fuse link were next removed and a Fahnestock connector soldered on, as in Fig. 1-c. After cutting off ferrule 1-a, the ferrule had best be removed for subsequent soldering, etc., as the heat used will burn and char the tube. A saw cut is made ½" long. (Fig. 1-b), to admit flat spring pieces (Figs. 3 and 4). This was made out of a piece of brass socket shell nicely flattened and cut to shape. Solder in as shown in Fig. 4. A piece of brass (Fig. 2) 2½" long x ⅞" wide and about ⅛" thick is next secured. The ends can be rounded or squared as desired and three holes drilled, all to clear an 8/32 brass screw. One is drilled in the exact center, the other two, ¼" each away from the center hole. An 8/32 brass nut is now centered over center hole and sweated on. The ferrule is next placed on this piece centrally located and



Constructional Data On the Carbon Disc Rheostat. All Measurements Conform To the Size of the Fuse Cartridge Used.

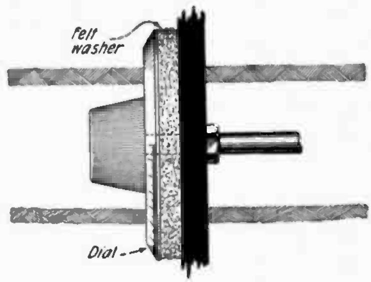
soldered fast with the nut inside. Another Fahnestock connector is soldered to a flat spring piece, Fig. 3, also shown in Fig. 4. One side of the fibre tube is cut out on the end as shown in Fig. 2, to allow the fibre tube to fit up over the brass spring. Next a knob from an old rotary snap switch is secured and an 8/32 screw is put in as tightly as possible and the head is cut off, see Fig. 5. This should be left long enough to pass through your panel and work against the spring piece, Fig. 4.

A number of discs about ⅛" or 3/32" thick are cut from a ½" hard round carbon such as are used in arc lights, and these discs are nicely sanded and worked to uniform thickness. Cut and finish enough to fill the tube so that with the tension relieved the brass spring will make contact with the carbon discs when the front ferrule is replaced. One or two discs may have to be cut slightly thicker to make up properly. A little experimenting in this particular detail will soon determine the proper number of discs to be used. After assembling, the brass tacks are cut off to just fit through holes in the ferrule and into the fibre tube and the unit is ready for mounting. Fig. 6 shows a sketch of the complete assembly. As is generally known, the more pressure on the discs the smaller the resistance offered and vice-versa. The writer tested this piece of apparatus in every conceivable way and it is now giving service equal to, if not better than most of the rheostats on the market. A little care and patience will well reward anyone who wishes to construct this rheostat, and the cost should not be more than a few cents. The writer is an electrical engineer, afflicted with the radio bug of course, and had access to a quantity of discarded fuses, sockets, carbons, etc., and the only cost was just what he would consider his labor. Almost anyone can secure enough material around home or from the this little instrument.

C. E. Mooney.

A Device to Eliminate Dial Scratch

The amateur who has been annoyed by noise originating from his dial scraping on the panel, when he finds it necessary to turn same, will find this hint valuable. By simply gluing a piece of felt ⅛" thick, on the inside of the dial this nuisance will be abated. It is wise to make this washer about ½" smaller in diameter than the dial itself. This will prevent the felt from being seen from the front. By making use of such a washer it is also possible to prevent the condenser or anything else, from moving out of place.



The Noise of Dials Scratching Against Panels Is Very Annoying. Here Is a Good Means of Preventing It.

When attempting this trick, first take the dial off the panel. Glue on the washer, put the dial back on the panel and after seeing that it fits tight against the panel, make it fast by screwing down the little set screw, incorporated in the dial for this purpose. It will be surprising how smoothly and noiselessly the dial may be revolved. The revolving of the dial will not cause the felt to loosen and become annoying. It is a practical idea and the one who is interested enough to try it out, will wonder how he ever got along without it, and it will mean but a hardly noticeable expense.

C. A. Reberger.

INDEX