Radio Broadcast's Data Sheets

190 Radio Data Sheets

Convenient---Accurate---Useful

WE commend this book of Laboratory Information Sheets to the attention of all radio fans who desire authentic technical data presented to them in a clear, concise and convenient form.

The experimenter and technical radio man will find in it a wide range of radio information. These Radio Data Sheets have been compiled by the Technical Staff of Radio Broadcast Laboratory.

1928 **Price, $1.00**

See Dollar Back Offer on pages 28 & 29

Doubleday, Doran & Company, Inc.
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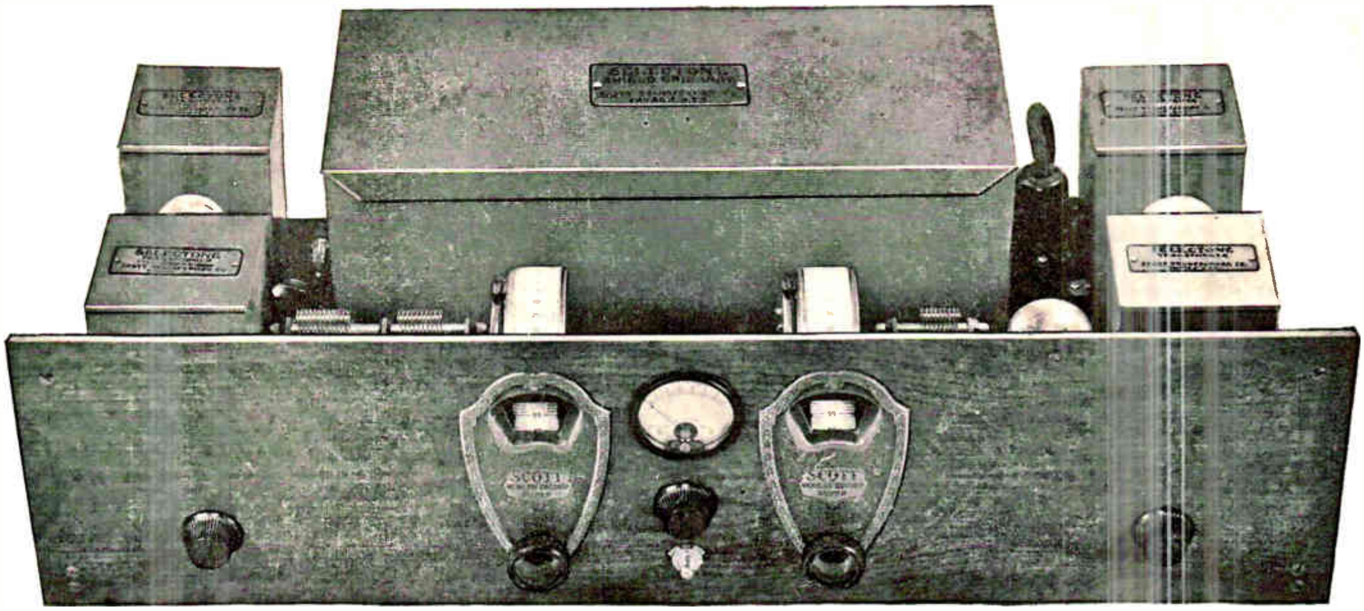


The *NEW* Scott Shield Grid 9

Radio's Most Powerful Receiver!

FOR those who want radio reception at its highest development, this is the set to build! Even more powerful than the preceding Scott receivers that established four world's records for DX reception. More selective. More superbly toned!

In range, the new Scott Shield Grid Nine is practically *unlimited*—the only range limit being the atmospheric noise level.

New Shield Grid Tubes in improved circuit

The *new* Scott uses shield grid tubes in an improved circuit with *new* power pack and amplifier. Through the greater efficiency of the new tubes and circuit, many times the amplification obtainable with the ordinary circuit using 201A tubes is secured. The Scott Power Pack and Amplifier makes it possible to obtain enormous volume—yet so completely is this volume under control that the simple turning of one knob covers the entire range from merest whisper to full auditorium strength.

Perfected matching of parts

Not only is the Scott Receiver new in design, but it represents new ideals in accuracy of radio building. All parts are designed especially for this set and are *matched* with absolute precision. The extreme care taken in testing and matching the transformers is one of the reasons why the *new* Scott out-performs in competitive DX tests.

Maximum efficiency from highest to lowest wavelengths

Transformers as well as tubes are perfectly shielded in the *new* Scott. The efficiency of the R.F. stage ahead of the first detector is increased through the use of a special Selectone Two-Gang Condenser and regeneration in the first detector. The Two-Gang Condenser matches the inductances of the antenna and R.F. coils so perfectly that they line up throughout the entire scale, affording *razor-edge* selectivity with maximum amplification all the way from the lowest to the highest wave lengths.

One spot reception

All stations come in at one point only on the dial in this "one spot" super. A further improvement is evidenced in the fact that both dials track practically together—making tuning particularly easy.

Costs little to operate

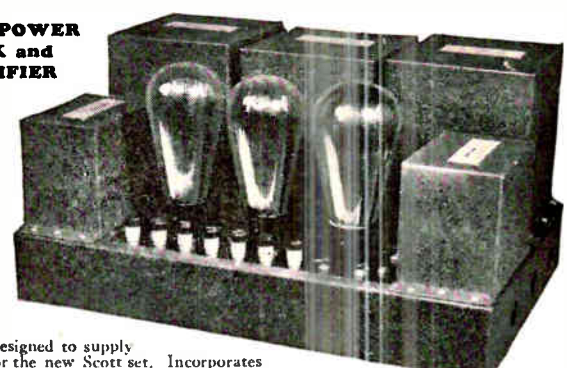
The Scott Shield Grid Nine can be economically operated with dry batteries if desired and will give ample volume for the average home. The eight tubes incorporated in the receiver draw only 29 mils. Maximum volume is obtained by the use of the Scott Power Pack and Amplifier, incorporating the ninth tube for the second stage of audio. This is the latest 250 power tube, a new radio development that gives tremendous volume with perfect tone quality.

Build the new Scott in four hours RESULTS GUARANTEED

New and highly developed as the Scott receiver is, anyone can build it—*easily*—and in four hours! Panel and sub-panel are drilled to receive each part; and the shielded grid amplifier unit comes fully tested and wired, ready for hook-up into the circuit. No adjustments whatever are needed. No possible chance for errors in the assembly.

We positively guarantee that you will get the same results with the Scott Shield Grid 9 that we obtain from our laboratory models.

SCOTT POWER PACK and AMPLIFIER



Especially designed to supply B current for the new Scott set. Incorporates the second stage of audio, using 250 power tube.

FREE Circuit Diagram and Particulars

Write at once for particulars! Get the facts about this amazing new world's record set—its low cost—limitless range—tremendous power—10 kilocycle selectivity. Build this set *now* and enjoy radio at its best! FREE circuit diagram. Also copies of 6000 and 9000 mile reception verifications. Write today. NOW!

SET BUILDERS! We offer an unusual plan that will triple your custom set business. Ask your jobber, or write us direct.

Clip this and mail today

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Please send me FREE circuit diagram, records, and full particulars of the new Scott Shield Grid Nine.

( ) I am interested in your proposition to professional set builders.

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Street ....

Town .... State ....

SCOTT TRANSFORMER COMPANY
4456 Ravenswood Ave. Chicago, Ill.

The Radio Broadcast

LABORATORY INFORMATION SHEETS

Prepared by
HOWARD E. RHODES
Radio Broadcast Laboratory

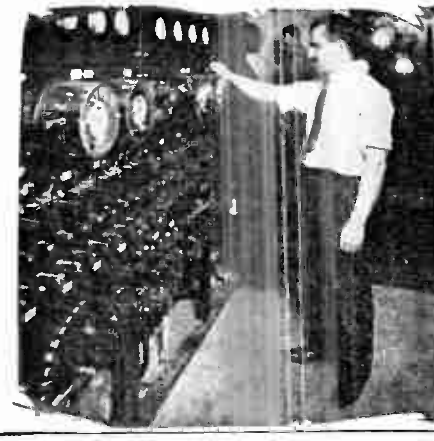
Numbers 1--190

With Index On Page 70

FIRST EDITION

Doubleday, Doran & Company, Inc.
Garden City, New York

I Will Train You at Home to Fill a Big-Pay Radio Job



If you are earning a penny less than $50 a week, send for my book of information on the opportunities in Radio. It's FREE. Clip the coupon NOW. A flood of gold is pouring into this new business, creating hundreds of big pay jobs. Why go along at $25, $30 or $45 a week when the good jobs in Radio pay $50, $75 and up to $250 a week. My book "Rich Rewards in Radio" gives full information on these big jobs and explains how you can quickly become a Radio Expert through my easy, practical home-study training.

Salaries of $50 to $250 a week not unusual

Get into this live-wire profession of quick success. Radio needs trained men. The amazing growth of the Radio business has astounded the world. In a few short years three hundred thousand jobs have been created. And the biggest growth of Radio is still to come. That's why salaries of $50 to $250 a week are not unusual. Radio simply hasn't got nearly the number of thoroughly trained men it needs. Study Radio and after only a short time land yourself a REAL job with a REAL future.

You Can Learn Quickly and Easily in Spare Time

Hundreds of N. R. I. trained men are today making big money—holding down big jobs—in the Radio field. Men just like you—their only advantage is training. You, too, can become a Radio Expert just as they did by our new practical methods. Our tested, clear training makes it easy for you to learn. You can stay home, hold your job, and learn quickly in your spare time. Lack of education or experience is no drawback. You can read and write. That's enough.

Many Earn $15, $20, $30 Weekly on the Side While Learning

My Radio course is the famous course "that pays for itself." I teach you to begin making money almost the day you enroll.

My new practical method makes this possible. I give you SIX BIG OUTFITS of Radio parts with my course. You are taught to build practically every type of receiving set known. M. E. Sullivan, 412 73rd Street, Brooklyn, N. Y., writes: "I made $720 while studying." Earle Cummings, 18 Webster Street, Haverhill, Mass., "I made $375 in one month." G. W. Page, 1807 21st Ave., S., Nashville, Tenn., "I picked up $935 in my spare time while studying."

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I'll give you just the training you need to get into the Radio business. My course fits you for all lines—manufacturing, selling, servicing sets, in business for yourself, operating on board ship or in a broadcasting station—and many others. I back up my training with a signed agreement to refund every penny of your money if, after completion, you are not satisfied with the course I give you.

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J. E. SMITH, President
Dept. 8-O
National Radio Institute
Washington, D. C.

RADIO NEEDS TRAINED MEN!

Here's the PROOF

Made $185 in Three Weeks Spare Time

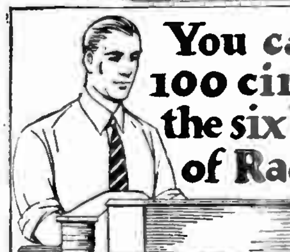
"I have met with continued success. For instance, recently I realized a profit of $185 in three weeks, $1.50 an hour. I have been making good money almost from the time I enrolled. The N. R. I. has put me on the solid road to success."—Peter J. Dunn, 901 N. Monroe St., Baltimore, Md.

Made $588 in One Month

"The training I received from you has done me a world of good. Some time ago during one of our busy months I made $588. I am servicing all makes of Radio receiving sets. My boss is highly pleased with my work since I have been able to handle our entire output of sets here alone."—Herbert Reese, 2215 So. E St., Elwood, Indiana.

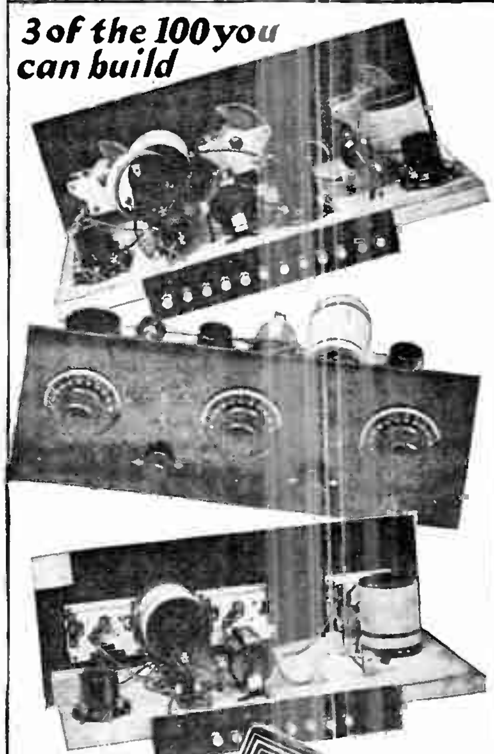
Earns Price of Course in One Week Spare Time

"I have been so busy with Radio work that I have not had time to study. The other week, in spare time, I earned enough to pay for my course. I have more work than I can do. Recently I made enough money in one month spare time to pay for a $375 beautiful console all-electric Radio. When I enrolled I did not know the difference between a rheostat and a coil. Now I am making all kinds of money."—Earle Cummings, 18 Webster St., Haverhill, Mass.



You can build 100 circuits with the six big outfits of Radio parts I give you

3 of the 100 you can build



Find out quick about this practical way to big pay

Mail This FREE COUPON Today

J. E. SMITH, President,
Dept. 8-O, National Radio Institute,
Washington, D. C.

Dear Mr. Smith: Kindly send me your big book "Rich Rewards in Radio," giving information on the big-money opportunities in Radio and your practical method of teaching with six big outfits. I understand this book is free, and that this places me under no obligation whatever.

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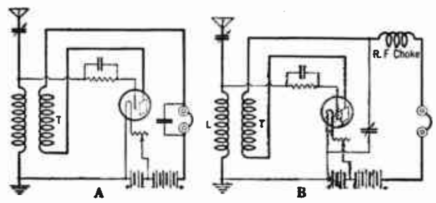
No. 1 RADIO BROADCAST Laboratory Information Sheet

Regeneration

METHODS OF CONTROL

WHEN radio waves of the frequency to which the antenna circuit is tuned are being received the high frequency currents flowing in the coil produce high frequency variations in the grid potential which, in turn, produce high frequency currents (of considerably greater energy) in the plate circuit. If we could "feedback" some of this plate energy to increase the original potential applied to the grid, it might help to increase the original potential applied to the grid. This can be done in several ways. A very common method is shown in A.

The essential addition to the circuit is the coil in the plate circuit. This is called the "tickler" coil, and upon being brought up near the antenna coil its mutual inductance, or transformer action, affords a means by which energy from the plate circuit is fed back into the antenna circuit. The tickler must be connected the right way too, for if the connections are reversed its effect will be to reduce the antenna current instead of increasing it. If the coils are brought too close together, a point will be reached where more power is being fed back to the antenna circuit than is being dissipated therein. The tube is then said to be oscillating, and will continue to oscillate even if the radio waves cease coming in. The loudest signals are obtained just before the tube "breaks into oscillation." Signals can be received even while the tube is oscillating if the oscillation frequency is kept exactly the same as the carrier-wave frequency.



There are several methods of controlling feedback, either by a variable tickler as in A or by a variable resistance shunted across a fixed tickler coil. Another method is by the use of a variable condenser, as illustrated in B.

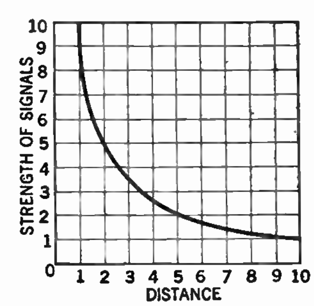
No. 2 RADIO BROADCAST Laboratory Information Sheet

Factors Governing Radio Receiving

HOW THEY AFFECT DISTANCE

THERE are three main factors governing the distance that can be satisfactorily covered between a given transmitting station and a given receiving set. These can be stated as follows:

1. The amount of interference.
2. The inverse distance effect. As the radio waves spread out in all directions from the transmitting station their strength naturally decreases. At twice the distance, their amplitude is halved; at four times the distance, it is only one quarter, etc. This same fact could also be expressed by saying that the strength of the signals is inversely proportional to the distance. A curve illustrating this is shown in the accompanying diagram. The curve is based on ideal conditions, and neglects absorption by buildings, fading, etc.
3. The attenuation, which is quite a different thing. It acts simultaneously with the inverse distance effect to reduce the amplitude of the waves. Attenuation of the waves is due to their being dissipated in the form of heat. Whenever the waves strike any object in which they can produce electric currents, the currents are produced at the expense of the energy of the waves and heat up, to a minute degree, the material in which they flow. In the case of ordinary telephony over land wires, the attenuation is such that the current is about one third, at the end of every ten miles, of what it was at the beginning of those ten miles, and a little calculation shows that to talk across the continent without any amplifiers inserted along the line would require an immense amount of power. Yet, by the insertion of fifteen amplifiers or relay stations along the line, the attenuation law is prevented from "getting under way," and a ridiculously small power is enough for proper transcontinental land line telephony.



No. 3 RADIO BROADCAST Laboratory Information Sheet

The Browning-Drake Receiver

ON SHEET No. 4 is shown a diagram of the popular Browning-Drake receiver, which, in its improved form, was fully described by Glenn H. Browning, one of the designers, in the December 1925, RADIO BROADCAST. The first article appeared in this magazine for December, 1924. Three stages of impedance-coupled audio amplification are employed in this circuit. The constants of the circuit as shown, are as follows:

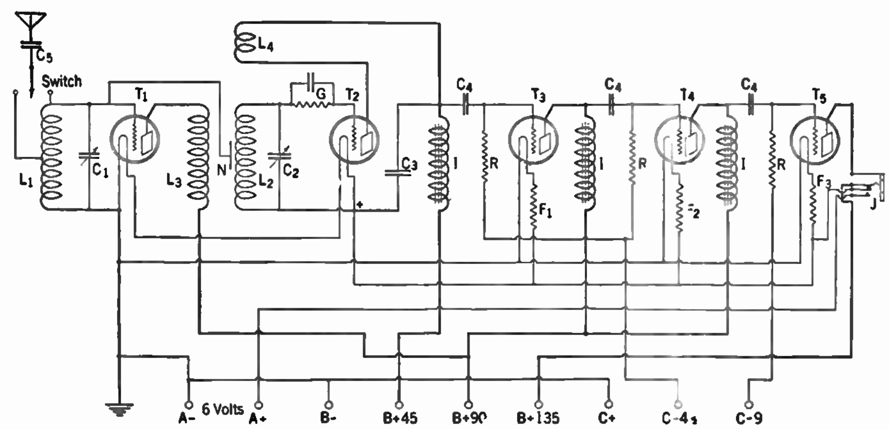
C_1—.0005-mfd. variable condenser.
C_2—.00025-mfd. variable condenser.
C_3—.00025-mfd. fixed condenser.
C_4—.0.1-to 1.0-mfd. fixed condenser.
C_5—.0001-mfd. fixed condenser.
L_1—46 turns No. 20 d.s.c. wire on a form 3 inches in diameter, with a center tap.
L_2—75 turns No. 20 d.s.c. wire on a 3-inch form.
L_3—24 turns No. 28 d.c.c. wire wound in a groove and placed under the filament end of the secondary.
L_4—20 turns No. 28 d.c.c. wire wound on a 2½-inch form to fit in grid end of secondary (L_2).
I —100-henry choke coils.
R —1-megohm grid leaks.
N—Neutralizing condenser, consisting of a small brass disc about an inch in diameter, mounted so as to make its position, in relation to L_2, variable.
F_1, F_2, F_3,—Fixed filament control resistances to match the type of tubes employed.
J —Single-circuit filament control jack.
G —.00025-mfd. grid condenser and leak (6-megohm).
T_1, T_2,—Two UV-199 tubes.
T_3, T_4,—Two UV-201-A or High-mu tubes. If the latter are used, F_1 and F_2 may be omitted.
T_5,—Semi power tube.

Although choke-coupled amplification is shown in the diagram, the circuit may be used just as well with transformer or resistance-coupled audio stages. If the transformer-coupled form of amplification is desired, only two stages will be necessary for average requirements.

The center tap is employed on the antenna coil for use when one's antenna is in excess of 100 feet in length, but it is advisable to employ a single-pole double-throw switch at this point so that either antenna connection may be used without undue changes being necessary. The reason for this is that the capacity of the antenna has to be taken into consideration as well as its length.

No. 4 RADIO BROADCAST Laboratory Information Sheet

The Browning-Drake Circuit



Complete data, on the sizes of the various units, used in this circuit appear in Sheet No. 3

No. 5 RADIO BROADCAST Laboratory Information Sheet

Transformers

PRIMARY–SECONDARY RATIOS

THE ordinary commercial iron-core transformer consists simply of two coils of wire wound on the same core. So long as the secondary of such a transformer is open circuited, or connected to something with an impedance so high that not much current flows, we have a very simple relation between the voltage delivered by the secondary and that applied to the primary. This relation states that the ratio of these two voltages is the same as is the ratio between the primary and secondary turn numbers. A ten to one step-up transformer would be one with ten times as many turns on the secondary as on the primary.

A transformer corresponds to gears in mechanics. If by an arrangement of gears or levers we increase a mechanical force ten times, we know instinctively that we must expect the part of the arrangement that is exerting the "stepped-up" force to move ten times as slowly as the part where the original force is being applied. If we choose to gain in force, we lose correspondingly in speed, or else we could get "something for nothing." The electrical transformer is not a source of power. It merely changes the power put into it at one voltage into the same power (with a small percentage loss) at a different voltage. Hence, just as the speed went down in the mechanical case, so the current is less in the high tension or high voltage side of the transformer. The primary current is related to the secondary current as the secondary voltage is related to the primary voltage. An auto transformer is no different except that the winding having the fewest turns is merely a part of the other winding. Thus only one coil is required.

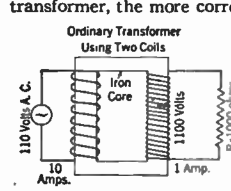
There are several simple formulas regarding transformers that are quite useful:

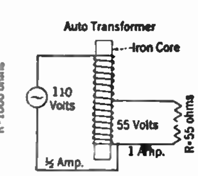
$$\frac{\text{Primary Turns}}{\text{Secondary Turns}} = \frac{\text{Primary Voltage}}{\text{Secondary Voltage}}$$

$$\frac{\text{Primary Turns}}{\text{Secondary Turns}} = \frac{\text{Secondary Current}}{\text{Primary Current}}$$

$$\frac{\text{Primary Voltage}}{\text{Secondary Voltage}} = \frac{\text{Secondary Current}}{\text{Primary Current}}$$

Values obtained by the use of the above relationships will serve as fairly close approximations. In general, the smaller the load being supplied by the transformer, the more correct this data will be.





No. 6 RADIO BROADCAST Laboratory Information Sheet

Dielectric Constant

ITS EFFECT ON CONDENSER CAPACITY

THE capacity of a condenser depends upon several different factors, the most important of which are:—1. Area of plates; 2. Number of plates; 3. Distance between plates; 4. The dielectric or insulating material between plates.

The effect of the first three quantities on the capacity is easily calculated by means of formulas the larger condensers, of one or two microfarads capacity, oiled paper is generally used. Its use helps to reduce the cost and the break-down voltage of such a condenser will be greater than if plain paper is used.

Solid dielectrics have the disadvantage that if they are once broken down and punctured, due to excessive voltage, they are rendered useless. However, if a liquid dielectric is used, this disadvantage cannot exist, and for this reason laboratory con-

Vaseline	Ebonite	Glass	Mica	Paraffin Wax	Porcelain	Quartz	Resin	Shellac	Castor Oil	Olive Oil	Petroleum Oil
2.0	3.0	7.0	6.0	2.5	4.0	4.5	2.5	3.5	5.0	3.0	2.0

based on theory, but in order to determine the effect of the dielectric, it is necessary to conduct actual tests using different materials.

The commonest dielectric used in variable condensers is air, and its dielectric constant, or specific inductive capacity, is unity. For fixed condensers, one of the best dielectrics is mica, and it is used on practically all small fixed condensers for radio use, because of its low losses. When a voltage is impressed across a condenser, a certain amount of energy is consumed in the dielectric, and the smaller this energy loss, the better is the condenser. For densers of fairly large capacity quite frequently use castor oil as the dielectric. In this way it is not only possible to obtain variable condensers with a fairly large capacity (the capacity of any given condenser by the use of castor oil is made five times as great as it would be if air were used), but it is also possible to apply greater voltages without sparking between plates. The capacity of any given condenser is proportional to the constant of the dielectric that is used.

Some of the most common materials used as dielectrics are listed in the table given herewith.

No. 7

RADIO BROADCAST Laboratory Information Sheet

The New Tubes

Type	A Battery Volts Supply	Filament Terminal Volts	A Battery Current (Amperes)	B Battery Volts, Detector	B Battery Volts, Amplifier	Negative C Battery	Plate Current (Milli-amperes)	Output Resistance (Ohms)	Voltage Amplification Factor
199	4.5	3.0	.06	45	90	4.5	2.5	15,000	6.25
200	6	5	1.0	15 to 25	—	—	—	—	—
201-A	6	5	.25	45	90 135	4.5 9.0	3 4	12,000 11,000	8 8
12	1.5	1.1	.25	22½	90	4.5	2.8	14,000	5.6
112	6	5	0.5	22½ to 45	157 135 112 90	10.5 9.0 7.5 6.0	7.9 5.8 2.5 2.4	4800 5500 8400 8800	8.0 7.9 7.9 7.9
120	4.5	3.0	.125	—	135	22.5	6.5	6600	3.3
210	8 6	7.5 6.0	1.25 1.1	— —	425 350 250 157	35 27 18 10.5	22 18 12 6.0	5000 5100 5600 7400	7.75 7.65 7.5 7.5

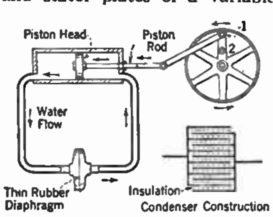
No. 8

RADIO BROADCAST Laboratory Information Sheet

Condensers

A SIMPLE EXPLANATION OF CONDENSER ACTION

THE accompanying diagram shows the construction of a condenser, and also a simple analogy for its action. The crank and piston arrangement, when rotating, produces an alternating current of water which fills the system. A thin rubber diaphragm prevents any direct circulation, but, by bending back and forth, allows alternating motion of the water. The greater the area of the diaphragm, the thinner it is, and the more flexible it is, the easier it will be to turn the crank to operate the piston. If (refer to the diagram) the piston connecting rod is hitched to point No. 2 on the drive wheel instead of No. 1, only half the force will be required to turn the crank, as the diaphragm will only be stretched half as much. Also, the current will be only half as great. But if, then, the crank be turned twice as fast, the speed of the water will be doubled so that the current is the same as before. This establishes a relation that holds good in the electrical case, namely, that if the frequency be doubled, or trebled, etc., the electromotive force required to produce the same current will be only one half, or one third, etc., as great. In the electrical case, corresponding to the diaphragm we have a sheet of some insulating material (dielectric) separating the two sheets, or sets of sheets, of the condenser. By increasing the area of the metal plates, thinning the insulating material (this corresponds to decreasing the spacing between the plates), or employing dielectric with a high "constant" (see Laboratory Sheet No. 6), the value of the applied voltage to produce a given current is proportionally decreased. Fixed condensers usually consist of metal foil cut up into small pieces which are connected together, and separated with mica or some other dielectric. There are two distinct sets of plates, corresponding to the rotor and stator plates of a variable condenser. The "capacity" of condensers used in radio circuits is usually expressed in microfarads, and if air is used as the insulating substance between the plates, the capacity in microfarads is approximately equal to the area of one of the plates (measured in square centimeters) divided by 11,300,000 times the distance between the plates (measured in centimeters). If other insulating material is used, it is necessary to multiply by its dielectric constant. The dielectric constant of mica, for example, is about 6.



From this explanation it is evident that current never actually flows through a condenser, but that it merely, we might say, collects on the condenser plates, and then returns back to the starting point.

No. 9

RADIO BROADCAST Laboratory Information Sheet

Data on the Roberts Four-Tube Receiver

COIL DETAILS, ETC.

ON SHEET NO. 10 is shown a diagram of the popular four-tube Roberts receiver. It is quite an easy matter to wind coils for this receiver, and there are given below complete data regarding their construction.

L_1 = 40 turns No. 22 d.c.c. wire wound on a 3" cylindrical form. The coil is to be tapped at every 10 turns.
L_2 = 45 turns No. 22 d.c.c. wire wound alongside L_1, on the same form. The spacing between L_1 and L_2 should be a quarter of an inch.
L_3, L_4 = 40 turn bunch-wound coil of No. 26 d.c.c. wire tapped at the center and wound over the filament end of the secondary winding, L_5.
L_5 = 45 turns No. 22 d.c.c. wire on a 3" form.
L_6 = Tickler, 20 turns No. 26 d.c.c. wire wound on a 1¼" cylindrical form and mounted at the grid end of the secondary winding, L_5.

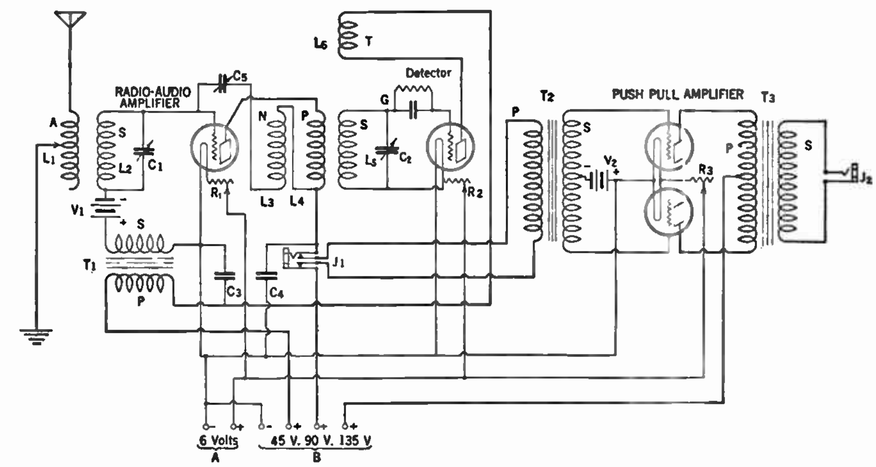
Besides the coils, it is necessary to have the following additional apparatus in order to construct the receiver.

T_1 Audio transformer; ratio about 4:1.
T_2 Input push-pull transformer.
T_3 Output push-pull transformer
C_1 Variable condenser 0.0005-mfd. capacity.
C_2 Variable condenser 0.0005-mfd. capacity.
C_3 0.0025-mfd. fixed condenser.
C_4 0.005-mfd. fixed condenser.
C_5 Midget variable condenser.
V_1 4½-volt C battery.
V_2 9-volt C battery.
J_1 Double-circuit jack.
J_2 Single-circuit jack
R_1 10-ohm rheostat
R_2 10-ohm rheostat
R_3 10-ohm rheostat
G Grid leak and condenser, 0.00025-mfd. condenser and a 4-megohm grid leak.

After the receiver has been completely built, it should be neutralized. The following method of doing this will, in general, be found the simplest. First, tune-in some local station that is broadcasting with a frequency of about 1000 kc. (300 meters). Advance the tickler until the detector begins to oscillate. Now, by varying the setting of the first condenser, it will be found that the pitch of the whistle will change. The variation of the pitch of the whistle is due to the fact that the radio frequency stage is oscillating and heterodynes the oscillations in the detector stage. When the receiver is properly neutralized, oscillations will not take place in the radio frequency amplifier, and the pitch of the whistle will not change. The problem is, therefore, to so adjust the neutralizing condenser as to bring about this condition. When the receiver is properly neutralized, the tuning of the first condenser will have no effect on the tuning of the second condenser.

No. 10 RADIO BROADCAST Laboratory Information Sheet

The Four-Tube Roberts Circuit



Complete data on the sizes of the various units used in this circuit appear on sheet No. 9

No. 11 RADIO BROADCAST Laboratory Information Sheet

The Type 200-A Tube

A STABLE SOFT DETECTOR TUBE

A NEW detector tube now made by several leading manufacturers has recently been placed on the market. It is called the 200-A, and in so far as its operation is concerned, it is similar to the old type 200, since its efficiency as a detector depends upon the presence of a gas in the tube. The major difference in appearance between this new tube and the type 201-A, is the absence of the silver coating on the bulb. The type 200-A has a bluish smoky color due to the special gas content.

The characteristics of this new type, as given by the manufacturers, are as follows:

Design................Same as standard 201-A
Base..................Same as standard 201-A
Filament Voltage....................5 Volts.
Filament Current..............0.25 Amperes.
Plate Voltage ....45 Volts Maximum
Plate Current................0.2 Milliamperes
Plate Impedance...............28,000 Ohms
Grid Leak......................2.0 Megohms
Grid Consender............0.00025 Microfarad

It might be of interest if the action of a gas-filled detector tube is reviewed, and an attempt made to show why such a tube can be made very sensitive for detecting signals.

The gas contained in the tube is composed of innumerable atoms, each of which consists of a nucleus surrounded by electrons, which are negatively charged. Normally, the positive charge on the nucleus exactly equals the negative charges on the electrons, and the atom is in a stable condition. When the filament is heated, it emits a great many electrons which are projected from its surface at very high speed. As they pass through the space between the filament and the plate, they frequently collide with some of the gas atoms, disrupting them and causing one or more of the negative electrons to be torn away from the atom, leaving what is called an ion, which is an atom that has lost one or more of its negative electrons. As soon as the negative electron is separated from its atom, it moves toward the positively charged plate with the other electrons emitted from the filament, and the plate current is thereby increased. Now, this breaking down of the atoms is called ionization, and it usually occurs at some particular value of grid and plate voltage. At the point of ionization, large changes in plate current occur with only small changes in grid potential, and if the tube can be operated at this point on the plate current curve, it will be very sensitive. In the old style type 200 tube the various voltages required very accurate adjustment in order to make the tube operate at the critical point of the characteristic, and this fact more or less detracted from its increased sensitivity. With a type 201-A tube, however, very stable operation can be obtained over a wide range of voltages. As with the type 200, operation of the type 200-A is accompanied by a slight hiss, not unlike escaping steam, but it is not sufficiently loud to become bothersome.

No. 12 RADIO BROADCAST Laboratory Information Sheet

The 112-A and 171-A Type Tubes

OPERATING CHARACTERISTICS

TWO new power tubes have recently become available; they are designed especially for use in the output of a receiver. These new tubes employ an improved type of filament which gives high emission at a filament current of 0.25 amperes at 5 volts. They are exactly similar to the older 112 and 171 type tubes with the exception that the filament consumption is only half that of the older types. The filament of the corresponding 112 and 171 type tubes is 0.5 amperes at 5 volts. The other characteristics of these new tubes remain the same as those of the 0.5 ampere filament tubes. These characteristics are given below.

The type 112-A may be satisfactorily used as a detector, general-purpose tube, or as a power tube in the last stage of a receiver. When used as a detector, the plate voltage should be 45 volts. The 171-A must only be used in the last stage of a receiver, and a choke-condenser combination or output transformer should be used in the plate circuit to keep the plate current out of the loud speaker.

The advantage of these new tubes is in their greater efficiency. Under the same condition of plate voltage they produce the same plate current as the corresponding 0.5-ampere tubes with only half as much filament current.

These tubes must not be substituted for the 112 or 171 types in a receiver without changing the values of fixed filament control resistances or rheostats if they are used. Since they take the same filament current as a 201-A type tube, it follows the filament control resistances designed for the latter tube may be used in conjunction with these new tubes.

TYPE	FILAMENT VOLTS	FILAMENT CURRENT	PLATE VOLTAGE	NEGATIVE BIAS	PLATE IMPEDANCE	AMP. CONSTANT	PLATE CURRENT	OUTPUT MILLIWATTS
112-A	5	0.25	90	6	8800	8	2.5	40
			135	9	4800		6	120
			157½	10.5	5500		8	195
171-A	5	0.25	90	16.5	2500	3	10	130
			135	27	2700		16	330
			180	40.5	2000		20	700

No. 13 RADIO BROADCAST Laboratory Information Sheet

Charging Storage Batteries on Direct Current

NECESSARY RESISTANCES, ETC.

IF ONE has a convenient source of direct current, it is a comparatively simple matter to charge storage batteries. Although such charging will necessarily be done rather wastefully, it will nevertheless be cheaper and much more convenient than having it done at a charging station.

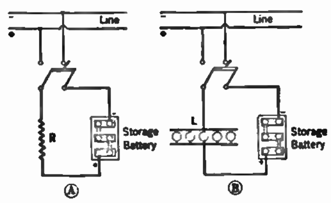
The charging may be accomplished by either of the two methods illustrated in the diagram. In A, the charging rate is determined by the value of the resistance R. Most of the power companies supply 110 to 120 volts, and for this line voltage, the following values of resistance should be used. The values are approximate and based on an average voltage of about 115.

CHARGING RATE	RESISTANCE	POWER DISSIPATED IN RESISTANCE
1 Amp.	110 Ohms	110 Watts
2 Amps.	55 "	220 "
3 "	37 "	330 "
4 "	28 "	440 "
5 "	22 "	550 "

The last column is given so that if a resistance unit is purchased care can be taken in choosing one that is capable of dissipating the power given in the table.

In place of the resistance units we can substitute a bank of electric lights as is illustrated at L, in B. The charging rate will be determined by the total wattage of the entire bank of lamps, and this total will equal the sum of the individual wattages of the lamps. If five 40-watt lamps are used, the total will be 200 watts. If the bank consisted of one 40-watt lamp, one 150-watt lamp, and one 60-watt lamp, the total would be 40+150+60=250 watts. By reference to the table, the total power (wattage) required, for any value of charging rate, can be found in the last column.

There are several precautions to be taken. In the first place, be sure to connect the positive side of the line to the positive side of the battery. If the battery is wrongly connected in the circuit, it is likely that it will be seriously damaged. Secondly, be sure that none of the leads touch any metal surfaces, such as water pipes, for if this occurred a short-circuit might result. Thirdly, be certain that the charging rate is not too high. Information regarding this is generally given on the name plate of the battery. However, if this information is lacking, the charging rate should be determined by the heating of the electrolyte. As the battery charges, the temperature of the solution gradually increases, and no damage will result if the temperature is not allowed to exceed 110 degrees Fahrenheit.



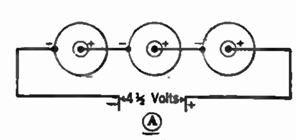
No. 14 RADIO BROADCAST Laboratory Information Sheet

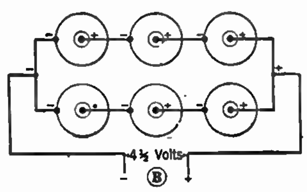
A Batteries

THE DRY TYPE

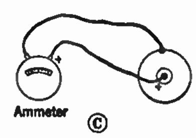
FOR the majority of receivers using type 199 tubes, a bank of dry cells can be used to supply the filament current. For portable sets such an arrangement is very convenient, and although, in general, the operation of these tubes will be found somewhat more expensive than storage battery tubes, their added convenience usually more than compensates for the greater cost of upkeep.

The common type of dry cell usually consists of a zinc container (which also acts as one element of the battery) in which is placed the active material. The active material is usually a mixture of powdered carbon and manganese dioxide moistened with a solution of sal ammoniac. Between the zinc container and the active material, there is usually placed a layer of blotting paper. The layer of paper acts, not only as an absorbent of some of the electrolyte but also as a separator which prevents the manganese dioxide from coming into contact with the zinc. If such contact does occur, an internal short-circuit takes place and the cell becomes useless.





The zinc case of the cell forms the negative terminal, and the positive terminal is a carbon rod that is placed in the center. This carbon rod is insulated from the zinc shell and does not react chemically with any of the other substances used.



The current from any one cell should not exceed one-quarter ampere. In the case of portable sets, it is not always possible to use that number of cells which would give greatest efficiency. In an installation in the home, arrangements should be made to use sufficient cells for most effective operation.

For any receiver using up to four 199 tubes, only three dry cells are necessary, connected as is shown in A on the accompanying diagram. If the receiver uses more than four tubes, two banks of dry cells should be used connected as shown in B.

Dry cells can be tested most easily by means of an ammeter. The instrument should be capable of reading up to about 50 amperes, and in testing the cell, it should be connected as in C. The cell should be thrown away if it reads less than five amperes.

No. 15 RADIO BROADCAST Laboratory Information Sheet

Loop Antennas

THEORY OF OPERATION

A LOOP antenna is quite commonly used in connection with multi-tube receivers, especially super-heterodynes. The action of a loop is not quite as simple to understand as is the action of a simple antenna.

The theory of the operation of a loop is commonly explained in the following manner. Suppose we have two vertical wires separated by a distance of 200 meters, both of them insulated from each other and from the ground. Now, if a wave approaches from a direction perpendicular to the plane of the two wires, the wave will reach each wire at exactly the same time, and the voltages induced will be exactly in phase. If the wave approaches from some other direction, it will reach the two wires at different times and, therefore, the induced voltages will be out of phase with each other. If the wave approaches in the direction of the plane of the two wires and has a wavelength of 400 meters, the two induced voltages would be 180 degrees out of phase. Therefore, the voltage at the top of one wire will be a positive maximum when the voltage at the upper end of the other wire is at a negative maximum. Now, if the upper ends are connected together and the input to a receiver is connected across the lower ends, current will flow around the circuit, and if the circuit is tuned by a condenser, the currents will become comparatively large. The induced voltages will be greatest when the wave and the loop are both in the same plane, since this will result in maximum phase displacement between the voltages induced in the front and rear wires of the loop.

With regard to the design of loops, it will generally be found that the current induced in the loop varies directly as the area, directly as the number of turns, inversely as the resistance, and inversely as the length of the wave being received.

The common type of loop antenna consists of several turns of wire wound on a rectangular form. The turns should be spaced about one-half or one inch from each other, so as to keep the capacity low. The distributed capacity of a loop also increases with the number of turns. This capacity increases rapidly with the first few turns, and then the rate of increase becomes slower. A very satisfactory loop for use with a 0.0005 mfd. condenser can be made by constructing a four-foot square form and winding on it six turns of No. 22 wire. Such a loop would have a range of from 1500 kc. (200 meters) to 600 kc (500 meters).

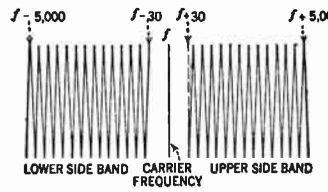
Generally, for satisfactory operation, no connection to ground is necessary. However, somewhat louder signals can usually be obtained if the low potential end of the loop is connected to ground. When such a connection is made, it is likely that the loop also acts as a small antenna by reason of its capacity to ground. In this connection, it should also be pointed out that the inner end of the loop should always be at the lowest potential.

No. 16 RADIO BROADCAST Laboratory Information Sheet

Carrier Wave Analysis

HETERODYNE INTERFERENCE

RADIO waves travel with the speed of light—300,000,000 meters per second. Now, in any wave motion, the frequency, or number of waves passing a given point per second, multiplied by the wavelength, gives the speed with which the waves are traveling. If a train of railroad cars passes a given point at the rate of two cars per second and each car is fifty feet long, the speed of the train is obviously one hundred feet per second



Quite similarily, if the frequency of passing radio waves is one million per second, then the length of each wave must be 300 meters to make the speed come out the value stated above. Broadcasting stations have a frequency separation of 10 kilocycles to prevent heterodyning, and no uniform wavelength separation can be given that will be applicable throughout the broadcasting band. If we work with wavelengths, we must calculate anew the width of channel expressed in meters for every different wavelength. Thus a 10-kilocycle channel at three-hundred meters wavelength is only a three meter channel, while at three thousand meters wavelength, it is a three hundred meter channel. There are about nine times as many 10-kilocycle channels available between the wavelengths 30 and 300 meters as there are between 300 and 30,000 meters.

For very high quality music, all tones between about 30 and 5000 vibrations per second should be transmitted with equal efficiency. To transmit the former, we must transmit a frequency 30 cycles greater than the carrier and another 30 cycles less than the carrier, in addition to the carrier itself. To transmit the 5000-cycle note we must use the frequencies 5000 greater and 5000 less than the carrier, and to transmit all the intermediate tones, we must use the two bands of frequencies (called the upper and lower side bands) shown in the accompanying diagram.

The whole range of frequencies used is called a "channel." In the case just described, the width of the channel is 10,000 cycles. The important thing about all this is that broadcasting stations do not use only a single frequency or wavelength as might be supposed from the figure given at the top of the newspaper radio programs (that figure is the frequency of their carrier wave in kilocycles per second), but they each require a channel of definite width, and hence only a rather small number can work at once without their channels overlapping. Overlapping results in a continuous whistling sound (of high pitch if the channels overlap only slightly, and of lower pitch if the overlapping is greater).

No. 17 RADIO BROADCAST Laboratory Information Sheet

Inductance of Single-Layer Solenoid Coils

CALCULATION FORMULA

IT IS possible to obtain quite a close approximation of the inductance of a solenoid coil by the use of the Bureau of Standards formula, which is as follows:

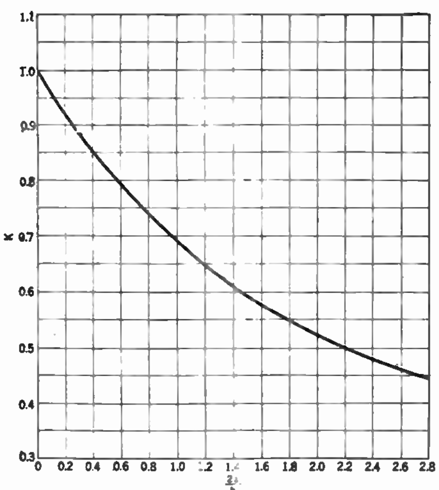
$$L = \frac{a^2n^2}{10b}K$$

in which—
L = Inductance of coil in microhenries.
a = Radius of coil in inches, measured from the center of the coil to the center of any wire.
b = Length of coil, in inches.
n = Number of turns.
K = A constant, depending upon the ratio of $\frac{2a}{b}$.

The constant K in the formula can be obtained from the accompanying curve.

This formula can be used very well in determining the approximate inductance of any particular coil, or can be used to determine the number of turns necessary in order to give certain inductances.

It does not take into account the shape or size of the wire, nor does it consider the effect of the capacity of the coil. However, since the coil capacity is usually negligible in comparison with the capacity of the tuning condenser, it is not especially important in so far as the tuning range of the coil is concerned.



No. 18 RADIO BROADCAST Laboratory Information Sheet

Volume Control

CORRECT METHOD TO USE

A GREAT many of the present receivers now in use are not equipped with any really satisfactory means of volume control. The most common method used on these receivers is to control volume by means of one or more filament rheostats. Usually these rheostats control the audio frequency tubes and, when such is the case, the quality is sure to suffer when the volume is reduced by lowering the filament current. Under such conditions, the quality will be impaired due to the two following causes.

In the first place, lowering the filament temperature will increase the plate impedance. Now the frequency characteristic curve of any audio transformer depends to a great extent upon the impedance of the plate circuit. If this impedance is high, the quality will be poorer than if the impedance was low and, for best results, the impedance of the transformer primary should be at least three times the impedance of the plate circuit. Lowering the filament temperature will destroy this ratio, and the quality thereby becomes poorer.

In the second place, lowering the filament temperature has the same effect as increasing the negative grid bias. If the temperature is lowered to any great extent, the tube will operate on the lower bend of its characteristic curve and distortion of the signals will then take place because a certain amount of detection will occur. Detection should only take place in the detector circuit, and if it occurs at any other point, it will invariably cause distortion.

If volume control is at present being accomplished by filament rheostats in the audio amplifier, it will be wise to revise the set so as to permit the use of some other system.

Volume can be controlled quite satisfactorily by means of a potentiometer across the secondary of the first audio transformer. This resistance will, actually, somewhat better the quality, since, if a rather poor transformer is being used, it will smooth out the amplification curve and make it quite flat. This unit should have a maximum resistance of about 500,000 ohms, and should always be placed across the first audio transformer. It is then possible, on strong signals, to cut down the volume and incidentally prevent overloading of the audio tubes. However, if the resistance were connected across the second transformer, it would not be possible to prevent overloading of the first tube. Connection across the first transformer is, therefore, advisable.

It is also possible to control volume very nicely by means of the filament rheostat controlling the radio frequency tube, without getting into any of the difficulties that occur if filament variation of the audio tubes is used to control volume. This is due to the fact that variations in the plate impedance of the radio frequency tube merely tend to cut down the overall amplification, but there is no possibility of frequency distortion since we are working with what is practically a single frequency.

No. 19

RADIO BROADCAST Laboratory Information Sheet

Learning to Read Code

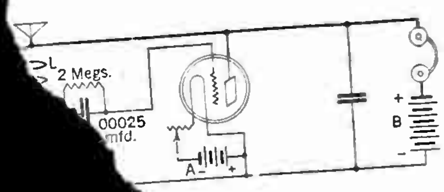
novice simple

Therefore, the energy radiated into the air consists of a series of high frequency impulses. These signals are not audible until they are heterodyned by the oscillations that take place in the receiver. Therefore, in using this receiver, the filament rheostat should be advanced until the set oscillates.

A copy of the International Morse Code is shown on Sheet No. 20.

The following table gives the coil sizes for L to cover the various wavelength bands commonly used—

600-meter traffic,	L =	100 to 150-turn coil
1200– 2600 " "	, L =	300 to 400 " "
2600– 5000 " "	, L =	750 " "
5000–15,000 " "	, L =	1500



heet

No. 22 Radio Broadcast Laboratory Information

A Simple Loop Receive...

GENERAL DATA

IT IS possible to make up a very simple yet quite efficient loop receiver using condenser feedback for the control of regeneration. Such a receiver will be useful for local reception when sufficient audio frequency amplification is added. If the receiver is made up in the form of a portable set, it will also be found extremely valuable in locating sources of interference.

The circuit diagram of such a receiver, using two stages of audio amplification, is given herewith.

L_1 = Any standard loop designed for operation with a 0.0005-mfd. variable condenser.
C_1 = 0.0005-mfd. variable condenser.
R = 5-megohm grid leak.
C_2 = 0.00025-mfd. grid condenser.
C_3 = 0.00025-mfd. variable condenser used to control regeneration.
K = Radio frequency choke coil. This coil may consist of about 300 turns of No. 30 d.s.c. o... other fine wire, bank wound on a 1-inch tub...
T_1 and T_2 = Audio frequency transformers.
J = A single-circuit filament control jack.
R_1, R_2, and R_3, = filament ballast resista... type satisfactory for the kind of t... ployed.

If the set is to be designed for portable ... tubes are recommended and, in this c... best to supply the filaments with th... batteries in series. The tuning of ...

is quite simple ... ting of the co... receiver, ma... the det... slightl... n... d...

No. 23 Rad...

DETERMINING CORREC...

ON THIS sheet are given ... amount of resistance no... rheostat in order to control... tubes. The values of resista... just sufficient to reduce the ... necessary amount, and if it i... tubes at somewhat below th...

Number of Tubes in Para... Type of Tubes ↓
201-A—With 6-Volt Supp...
199—With 4½-Volt Supp...
199—With 6-Volt Suppl...
12—With 1½-Volt Suppl...
12—With 2-Volt Suppl...
112—With 6-Volt Sup...
120—With 4½-Volt Su...
120—With 6-Volt Su...

No. 2...

No. 19

RADIO BROADCAST Laboratory Information Sheet

Learning to Read Code

A GOOD CIRCUIT TO USE

ONE of the best methods for use by a novice in learning the code is to construct a simple receiver capable of receiving the long wavelengths ranging from 600 to 15,000 meters (500 to 20 kc.). Practically all of the transatlantic stations operate on these low frequencies, and usually the transmitting is done at a fairly low speed, so that it is possible for anyone with just a rudimentary knowledge of the code to decipher quite a few letters. In a comparatively short time it will be found possible to receive whole words—and then sentences.

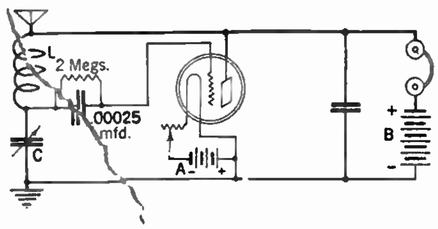
The circuit diagram of a long-wave receiver that can be used to receive code signal is shown in the accompanying diagram. L is a honeycomb coil, the size of which depends upon the wavelength it is desired to receive. Condenser C is an ordinary 0.001-mfd. variable condenser. Forty-five volts of B battery is sufficient. This receiver is regenerative, and feedback is controlled by variation of the 20-ohm filament rheostat.

The receiver should be connected to an antenna about 100 feet in length, and a good ground should be used. Most of the long-wave stations operate on pure c. w. which means that the antenna at the transmitter is fed from a high frequency oscillator, the output of which is controlled by the key. When the key is depressed the set breaks into oscillation, and when the key is raised the set stops oscillating. Therefore, the energy radiated into the air consists of a series of high frequency impulses. These signals are not audible until they are heterodyned by the oscillations that take place in the receiver. Therefore, in using this receiver, the filament rheostat should be advanced until the set oscillates.

A copy of the International Morse Code is shown on Sheet No. 20.

The following table gives the coil sizes for L to cover the various wavelength bands commonly used—

600-meter traffic, L =	100 to 150-turn coil
1200–2600 " " , L =	300 to 400 " "
2600–5000 " " , L =	750 " "
5000–15,000 " " , L =	1500 " "



No. 20

RADIO BROADCAST Laboratory Information Sheet

The Morse Code

A	· —
B	— · · ·
C	— · — ·
D	— · ·
E	·
F	· · — ·
G	— — ·
H	· · · ·
I	· ·
J	· — — —
K	— · —
L	· — · ·
M	— —
N	— ·
O	— — —
P	· — — ·
Q	— — · —
R	· — ·
S	· · ·
T	—
U	· · —
V	· · · —
W	· — —
X	— · · —
Y	— · — —
Z	— — · ·

Ä)German)	· — · —
Á or Å Spanish-Scandinavian	· — — · —
CH (German-Spanish)	— — — —
(É French)	· · — · ·
(Ñ Spanish)	— — · — —
Ö (German)	— — — ·
Ü (German)	· · — —
1	· — — — —
2	· · — — —
8	· · · — —
4	· · · · —
5	· · · · ·
6	— · · · ·
7	— — · · ·
8	— — — · ·
9	— — — — ·
0	— — — — —

Period	· · · · · ·
Semicolon	— · — · — ·
Comma	· — · — · —
Colon	— — — · · ·
Interrogation	· · — — · ·
Exclamation Point	— — · · — —
Apostrophe	· — — — — ·
Hyphen	— · · · · —
Bar indicating fraction	— · · — ·
Parenthesis	— · — — · —
Inverted Commas	· — · · — ·
Underline	· · — — · —
Double dash	— · · · —
Distress Call	· · · — — — · · ·
Attention call to precede every transmission	— · — · —
General inquiry call	— · — · — — · —
From (de)	— · · ·
Invitation to transmit (go ahead)	— · —
Warning-high power	— — · · — —
Question (please repeat after ______) interrupting long messages	· · — — · ·
Wait	· — · · ·
Break (double dash)	— · · · —
Understand	· · · — ·
Error	· · · · · · · ·
Received (O.K.)	· — ·
Position report (to precede all position messages)	— · — ·
End of message (cross)	· — · — ·
Transmission finished (end of work)	· · · — · —

No. 21

RADIO BROADCAST Laboratory Information Sheet

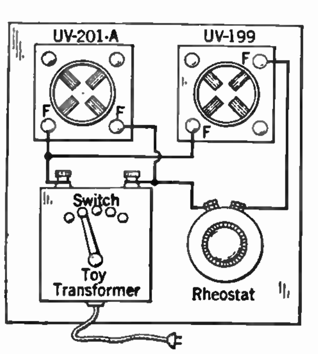
Rejuvenating Tubes

CONSTRUCTION OF A SUITABLE UNIT

IT NOT infrequently happens that, with tubes having thoriated filaments, the emission gradually decreases after considerable use so that the tube is rendered useless, even though the filament still lights. Under such conditions, it is usually possible to subject the tubes to a treatment that will put them once more in usable condition. This treatment is called reactivation, or rejuvenation, and is quite easily accomplished by the home experimenter with a few fairly cheap parts that can easily be assembled into a suitable instrument for reclaiming apparently useless tubes. Many tubes will, after reactivation, give off as much emission as they did when new.

The parts needed to assemble a rejuvenator are a toy transformer of the type usually employed to operate small electric trains, two tube sockets, one for 199's, and the other for 201-A's, a 30-ohm rheostat, and some odd screws, nuts, etc. The connections are clearly shown in the accompanying diagram.

Practically all toy transformers have on the top of the case a small switch by means of which the secondary voltage can be raised or lowered. Voltages from six to twelve can usually be obtained.



Suppose we desire to reactivate a 201-A. The tube is placed in the 201-A socket (which is the left hand socket in the diagram) and the plug connected to the 110-volt alternating current supply. The tap switch is set for twelve volts and the tube is allowed to burn at high voltage for about one minute. The voltage is then reduced to six or seven volts, and the tube is permitted to "cook" for about one-half hour. It can then be removed and, generally, when placed in a receiver, it will be found to give entirely satisfactory operation.

The procedure to be followed in treating a 199 tube is practically the same. At first the tube is "flashed" at eight volts for half a minute. The switch is then placed at the lowest voltage, which is usually about six volts, and then the rheostat is used in order to reduce the voltage to 4½ volts. With this applied voltage the tube is cooked for half an hour, when the treatment is complete.

The voltages given above are only approximate and need not be followed exactly. The rheostat for 199's is not essential, and if it is dispensed with, the tube should not be cooked as long at the higher voltage.

No. 22 RADIO BROADCAST Laboratory Information Sheet

A Simple Loop Receiver

GENERAL DATA

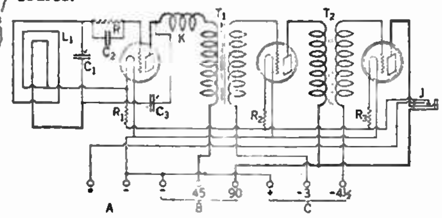
IT IS possible to make up a very simple yet quite efficient loop receiver using condenser feedback for the control of regeneration. Such a receiver will be useful for local reception when sufficient audio frequency amplification is added. If the receiver is made up in the form of a portable set, it will also be found extremely valuable in locating sources of interference.

The circuit diagram of such a receiver, using two stages of audio amplification, is given herewith.

- L_1 = Any standard loop designed for operation with a 0.0005-mfd. variable condenser.
- C_1 = 0.0005-mfd. variable condenser.
- R = 5-megohm grid leak.
- C_2 = 0.00025-mfd. grid condenser.
- C_3 = 0.00025-mfd. variable condenser used to control regeneration.
- K = Radio frequency choke coil. This coil may consist of about 300 turns of No. 30 d.s.c. or other fine wire, bank wound on a 1-inch tube.
- T_1 and T_2 = Audio frequency transformers.
- J = A single-circuit filament control jack.
- R_1, R_2, and R_3, = filament ballast resistances of type satisfactory for the kind of tubes employed.

If the set is to be designed for portable use, UV-199 tubes are recommended and, in this case, it will be best to supply the filaments with three 1½-volt dry batteries in series. The tuning of such a receiver is quite simple and depends entirely upon the setting of the condenser C_1. As in any regenerative receiver, maximum volume will be obtained when the detector tube is adjusted so as to operate slightly below the oscillating point, this adjustment being controlled by variation of condenser C_3.

Particularly in interference investigations the directional effects of the loop will be found very valuable, the loudest interference being received when the plane of the loop is pointed toward its source.



At all times during the operation of the receiver, care should be taken so as to keep the detector tube below the oscillating point since, if this tube does oscillate, a certain amount of radiation will take place which will produce interference with other receivers. Since a loop is being used, this radiation will not be very great, however.

No. 23 RADIO BROADCAST Laboratory Information Sheet

Rheostats

DETERMINING CORRECT VALUES

ON THIS sheet are given data regarding the amount of resistance necessary in a single rheostat in order to control various numbers of tubes. The values of resistance that are given are just sufficient to reduce the battery voltage by the necessary amount, and if it is desired to operate the tubes at somewhat below the rated voltage (not altogether a good practice), rheostats with about 50 per cent. more resistance than specified, should be used.

In any case, it will generally be found impossible to obtain rheostats with the exact resistance given in the table, and it will be necessary to use the next larger size. It should be noted that two lines are given to both the 199's and 12's to cover the use of either dry cells or a storage battery.

NUMBER OF TUBES IN PARALLEL → / TYPE OF TUBES ↓	1	2	3	4	5	6	7	8
				RESISTANCE IN OHMS				
201-A—With 6-Volt Supply	4	2	1.5	1	.8	.7	.6	.5
199—With 4½-Volt Supply	25	13	9	7	5	4.5	4	3
199—With 6-Volt Supply	50	25	17	13	10	9	8	7
12—With 1½-Volt Supply	1.6	.8	.6	.4	.4	.3	.25	.2
12—With 2-Volt Supply	4	2	1.2	.9	.75	.6	.55	.45
112—With 6-Volt Supply	2	1	.7	.5	.4	.35	.3	.25
120—With 4½-Volt Supply	12	6	4	3	2.5	2	1.7	1.5
120—With 6-Volt Supply	24	12	8	6	5	4	3.5	3

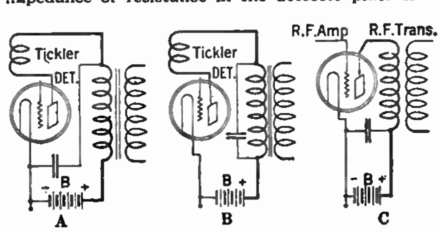
No. 24 RADIO BROADCAST Laboratory Information Sheet

Bypass Condensers

RULES FOR LOCATION

AT SEVERAL locations in a receiver it is essential that bypass condensers be used and, at several other points, their use is advisable.

In practically all receivers, a bypass condenser is necessary across the primary of the first audio transformer, which is, of course, connected in the plate circuit of the detector tube. In those cases where transformer coupled amplification is not used, the condenser should be placed across the impedance or resistance in the detector plate circuit, depending upon whether an impedance- or resistance-coupled amplifier is used. In any event, the method of connection shown in A, is to be preferred to the method shown in B.



With the former method of connection, the radio frequency currents are returned, by the condenser, directly to the filament and do not need to pass through the B battery. The condenser used at this point should not be larger than is necessary to give good results. Usually a 0.00025-mfd. condenser is large enough, and a 0.001 one should not be used unless it is found necessary.

It is frequently wise to place a large bypass condenser across the B battery. This condenser, which should have a capacity of about 1 mfd., bypasses the audio currents around the B battery.

A condenser connected as shown in C, will usually be found of value in obtaining more stable operation from a radio-frequency amplifier. If this condenser is not used, the r. f. currents, in returning to the filament, must pass through various leads and then through the B battery and, quite possibly, there will be sufficient coupling to other parts of the circuits to prevent accurate neutralization. This condenser should have a value of not less than 0.1 mfd.

The function of any bypass condenser is to return certain currents, by as short a path as possible, to the tube where they originated. A bypass condenser is practically worthless if connected to any part of the circuit without giving regard to this rule. Therefore, whenever possible one side of the bypass condenser should connect to the filament terminal of the socket containing the tube to which the currents are to be returned.

No. 25 RADIO BROADCAST Laboratory Information Sheet

Modulation

THE HEISING METHOD

THE process of impressing audio frequency current on the radio frequency output of a transmitter is called "modulation."

The simplest case of modulation occurs when a pure note of single frequency, such as is produced by a tuning fork, is transmitted. If the tuning fork is struck and is placed near the microphone, the sound produced by the fork will be transmitted by the microphone to the radio transmitter. These audio-frequency currents will cause the radio-frequency wave to vary in amplitude and also in frequency. If the radio wave without any modulation had a frequency of 500,000 cycles, and a 1000-cycle note was produced by the tuning fork, the radio-frequency wave would change in frequency and would be composed of three frequencies; one equal to the original frequency of 500,000 cycles, another equal to 499,000 cycles; and another equal to 501,000 cycles.

These latter two frequencies are equal, respectively, (1.) to the difference between the original, or carrier frequency, and the audio frequency, and (2.) the sum of the carrier and audio frequency. In actual transmission, we are not dealing with a single 1000-cycle note but are dealing with the entire band of frequencies between approximately 50 and 5000 cycles, so that all of these various frequencies are impressed on the carrier wave during modulation.

The most common method of modulation used by broadcasting stations is the Heising method, and it is shown in its elementary form in the diagram on laboratory Sheet No. 26. Here tube No. 1 is the oscillator, and No. 2 the modulator. Choke coil L is sometimes called the Heising choke. The oscillatory circuit is the familiar Hartley type using an inductively coupled antenna coil.

The voice signals are impressed on the grid of the modulator tube as is shown in the diagram. Actually, between the microphone and the modulator tube, it would be necessary to use several stages of additional amplification. These audio signals impressed on the modulator cause its plate current to vary and produce a corresponding plate-current variation in the oscillator tube.

The total current supplied to the circuit by the battery supply, marked B on the diagram, does not vary appreciably as the modulation is impressed on the grid of the modulator tube No. 2, due to the fact that the choke coil has a very high inductance and, therefore, offers considerable impedance to any variation in the current flowing through it. This Heising choke coil is an essential part of a radio transmitter using this type of modulation.

If a radio wave is completely modulated, the power transmitted will be about one and a half times as much as an unmodulated wave having the same average current. However, in ordinary broadcasting, it is not advisable to completely modulate the carrier and, therefore, it can be said that the power transmitted when the wave is being modulated is about the same as the power transmitted when the wave is not being modulated.

No. 26 RADIO BROADCAST Laboratory Information Sheet

The Three-Electrode Tube

ITS VARIOUS FUNCTIONS

THE three-electrode tube can be used in a great many ways, but its use in connection with radio transmission and reception is confined almost exclusively to the following:

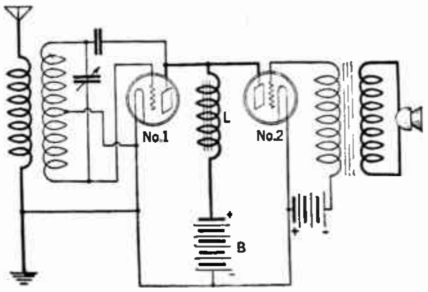
1 MODULATION: Vacuum tubes are used in this connection in all the large radio broadcasting stations throughout the world. Modulation can be defined as the process of varying the amplitude of the transmitted radio waves in accordance with the variations of air pressure that constitute the voice or music. The actual process of modulating the power of a high-power station, in general, requires considerable essential auxiliary apparatus. However, modulation can be accomplished using a single circuit such as that shown in the accompanying diagram, where tube No. 2 is the modulator. A careful analysis of modulation appears on Sheet No. 25.

2. DETECTION (also called RECTIFICATION and DEMODULATION): This is the process of converting modulated radio-frequency alternating currents into direct currents varying in strength in accordance with the original voice or music.

3. REGENERATION: The process of neutralizing some of the unavoidable resistance in the receiving circuits, resulting in greater currents being produced by the incoming waves.

4. AMPLIFICATION: Increasing the energy of either radio- or audio- (voice and music) frequency currents, without changing their form. The tube itself is an amplifier, the ordinary type giving an output voltage about seven times greater than the input voltage. The tube may function in conjunction with a transformer, in which case an even greater overall amplification is obtained.

5 OSCILLATION: The production of high-frequency alternating currents. At the transmitting stations it is high frequency current flowing in the antenna that radiates energy in the form of electromagnetic waves (in this case, radio waves). Tube No. 1 is an oscillator in the diagram shown.



No. 27 RADIO BROADCAST Laboratory Information Sheet

A Voltmeter Made From a Milliammeter

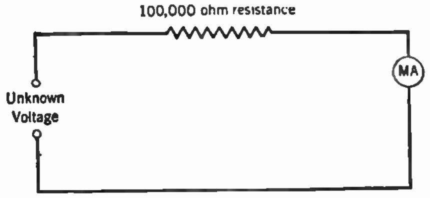
CALCULATING THE NECESSARY RESISTANCE

IN THE course of their experiments, most home constructors acquire one or more d. c. milliammeters for use in measuring the plate current of tubes. These instruments are comparatively cheap and are essential in making general tests on radio parts.

Another very useful instrument is the d. c. voltmeter for use in measuring the voltage of all kinds of batteries and line supply devices. It is possible to make up a very useful and fairly accurate voltmeter using a milliammeter and a good fixed resistance, and thereby make unnecessary the purchase of a voltmeter. Actually, a voltmeter consists of a sensitive milliammeter in series with a high resistance. In calibrating, such a meter, in series with the resistance, is placed across known voltages, and its scale marked off in volts instead of milliamperes.

Suppose we have a meter with a full-scale reading of 2 milliamperes (.002 amperes), and we want to use it as a voltmeter for use on line supply devices which supply voltages up to 200. To determine the required resistance necessary in series with the meter, we divide 200 by .002, and the quotient, 100,000, is the required resistance in ohms. If we place the milliammeter in series with the 100,000-ohm resistance across an unknown voltage, as shown in the diagram, the needle will deflect an amount proportional to the voltage. We have made our voltmeter so that if the meter reads 2 milliamperes the voltage is 200. Now, if the meter reads 1½ milliamperes, the voltage is 150; if it reads 1 milliampere, the voltage is 100, etc.

It is not always possible to obtain accurate resistance units so that it is, in general, wise to calibrate the voltmeter so as to allow for errors in the fixed resistance. On Sheet No. 28 is given information regarding the calibration of a home-made



voltmeter, and if the calibration is done carefully, it should be possible to obtain readings which will be accurate within a few per cent. For rough measurements, no calibration is necessary since, if good fixed resistances capable of passing several milliamperes are purchased, their marked resistance value can be depended upon within about ten per cent., and usually the per centage error will be even less than this.

No. 28 RADIO BROADCAST Laboratory Information Sheet

Calibrating a Home-Made Voltmeter

PLOTTING THE CURVE

On Laboratory Sheet No. 27 were given data regarding the construction of a simple voltmeter from a milliammeter. Information is given here for the calibration of such a meter.

First determine the required resistance in series with the milliammeter by the following formula:

$$R = \frac{E \times 1000}{I}$$

where E is the maximum voltage it is desired to read, I is the full scale reading of the meter in milliamperes, and R the unknown resistance.

Examples:

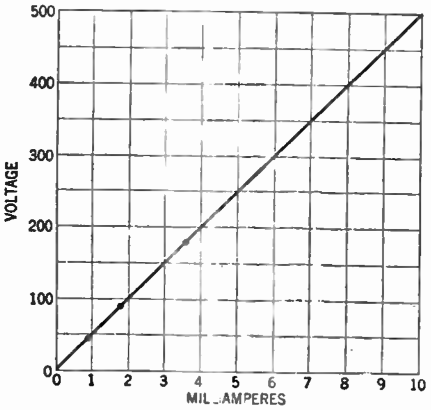
1. It is desired to read 500 volts using a 10-milliampere meter.

$$\text{Then } R = \frac{500 \times 1000}{10} = 50{,}000 \text{ ohms.}$$

The calibration is performed by placing the fixed resistance and meter across different known voltages and plotting a curve showing the deflection of the meter for different values of voltage.

By making such a calibration, it will be possible to compensate for any inaccuracy in the fixed resistance. If no voltmeter is available whereby the applied voltages for calibrating purposes can be measured, it will be possible to use new B Batteries, since the marked voltages will then be quite dependable. First 22½ volts could be placed across the combination and the meter reading taken, then 45 volts, etc., until several points are obtained.

It will not be necessary to calibrate the full scale of the meter since the calibration will be a straight line. The abscissa, or horizontal axis, of the curve should be plotted in milliampere deflections, and the ordinate, or vertical axis, should be plotted in the corresponding voltages. Such a curve is illustrated on this Sheet.



No. 29 RADIO BROADCAST Laboratory Information Sheet

Tubes: Miscellaneous

213

This is a full-wave rectifier for use with line supply devices. Its filament voltage is 5, and it takes a filament current of 2 amperes at this voltage. The maximum value of the a.c. input voltage is 220 volts (effective value), and the maximum rectified current the tube can deliver is 65 milliamperes.

216-B

This tube is a half-wave rectifier for use in line supply circuits. Its filament voltage is 7.5, and current is 1.25 amperes. The maximum value of the a.c. input voltage is 550 volts (effective value). The maximum rectified current is 65 milliamperes.

874

This tube is used as a voltage regulator and, when correctly connected in a circuit, it functions to maintain a constant voltage. The voltage drop is 90 volts d.c., and the starting voltage is 125 volts d.c. The maximum current is 50 milliamperes d.c. The positive lead is connected to the rod and the negative lead connects to the cylinder. This tube is used in the line supply device manufactured by the Radio Corporation of America and also in their Model 104 loud speaker.

876

This is a ballast tube and when correctly connected in a circuit it functions to maintain constant current. It has a current rating of 1.7 amperes, and the voltage drop is 40 to 60 volts. This tube is designed for use on units using 105 to 125 volts supply at from 50 to 75 cycles.

886

This tube is practically the same as the model UV-876 except that it is for use on from 40- to 45-cycle current. It has a current rating of 2.05 amperes, and the voltage drop is from 40 to 60 volts.

877

This is a protective tube, and is used in the B battery circuits of receivers to prevent damage to tubes or wiring, if the B batteries are accidentally short-circuited. The voltage drop across half the filament is 2.5 volts at 20 milliamperes d.c., and rises to 45 volts at 90 milliamperes d.c. Across the entire filament, the voltage drop at 20 milliamperes is 5 volts. With 90 milliamperes flowing through it, the voltage drop is 90 volts. From these figures it is evident that, if the B batteries are accidentally short-circuited, practically all the voltage will be consumed by this tube, and the current definitely limited to a safe value.

No. 30 RADIO BROADCAST Laboratory Information Sheet

Measuring the Output Voltage of a Line Supply Device

REQUIREMENTS OF A SUITABLE METER

Considerable care must be taken in measuring the output voltage of a line supply device if an accurate reading is to be obtained. The output voltage of such devices depends to a great extent upon the current being drawn from them, and if any considerable amount of current is also drawn by the voltmeter which is used in determining the output voltage, the reading will not be accurate and cannot be used.

Also, if true results are to be obtained, the output voltages must be measured when the instrument is connected to the receiver and a normal load is being drawn from it, since, if these conditions do not exist at the time of the test, the voltage read with the voltmeter will be considerably higher than would actually be applied to a receiver during operation. A reading taken without any load on the line supply device will sometimes be 100 volts higher than the reading taken with load.

The voltmeter used to measure the output voltage must have a very high resistance in order to prevent large currents from flowing through it. On Sheet No. 27 is given information regarding the construction of a home-made voltmeter which can be used.

It is also possible to purchase suitable units for use in measuring the output of B eliminators. In any event, the voltage cannot be at all accurately read if one of the cheaper low-resistance type of meter is used.

A numerical example might make more evident the errors which will be introduced in the reading, if the incorrect type of voltmeter is used. As an example, suppose that we desire to measure the output voltage of a Raytheon B line supply device such as was described in the December, 1925, RADIO BROADCAST. If the receiver was drawing from the eliminator 20 milliamperes, the output voltage would be about 120 volts. However, if this output was measured with a low resistance meter, itself drawing about 20 milliamperes, the voltage read would be 75, an actual error of 38 per cent. However, if a high-resistance meter is used, such as is described on Laboratory Sheet No. 27, only about 2 milliamperes will be required by the voltmeter, and then the voltage read would be practically the same as the actual voltage, and a truer indication of the voltage being supplied to the set would be obtained.

The care which is necessary in measuring the output voltages of B line supply devices is not necessary in measuring B batteries, since a drain of 20 or 30 milliamperes will make very little change in the voltage of a B battery. Therefore, it becomes possible to read the voltages of these units with an ordinary voltmeter whether it have a low resistance or not.

No. 31 Radio Broadcast Laboratory Information Sheet

Distortion in Receivers

SOURCES AND REMEDIES

THERE are several points in a receiver where distortion can occur. In the first place, if the radio-frequency amplifier or detector circuits are tuned too sharply, distortion will occur due to the fact that the side bands of the radio frequency waves which carry the voice or music will not be equally transmitted by the tuned circuit, and in this way unequal amplification is obtained.

If a grid leak and condenser system of detection is used, it is not at all impossible to overload the detector tube on strong local stations. If this occurs, the various frequencies will not be properly amplified by the detector tube and serious distortion will occur. For real quality on local stations, a C battery detector is advisable since it can handle comparatively larger amounts of signal strength without overloading.

Distortion can occur in the audio frequency amplifier. To prevent this, good transformers should be employed, if this form of coupling is used, and a C-battery bias should always be placed on the grids of all the audio amplifiers in order to prevent the tubes from overloading. If overloading does occur, the peaks of the voice waves will be cut off, and serious distortion results. Also, if the wiring of the audio amplifier is rather poorly done, it is not at all impossible that the audio amplifier will begin to oscillate, sometimes at inaudible frequencies and sometimes at audible frequencies. If the oscillation is audible it can be fairly easily checked up and corrected, but if it is inaudible, it is sometimes quite a while before we realize just what the trouble is. The only practical method that can be used to detect these inaudible oscillations, is to place a milliammeter in the plate circuit of the tube of the suspected circuit. After putting this meter in the plate circuit, the input to the tube is short-circuited (if a transformer-coupled amplifier is used, a lead would be connected between the G post and the F post on the transformer) and no change should take place in the reading of the plate milliammeter. If a change in the reading does occur, it is a fairly good indication that the circuit is oscillating. Of course, during this test, no signals whatsoever should be received.

The final point at which distortion might occur is in the reproducing device. In order to obtain best reproduction from a cone speaker, it is necessary to use a semi-power tube in the output stage, with sufficient voltage to prevent overloading. It is also essential that the impedance of the loud speaker be fairly closely matched with the plate impedance of the output tube. If any discrepancy between the two impedances does exist, the tube should be preferably of a lower impedance than the speaker.

No. 32 Radio Broadcast Laboratory Information Sheet

Matching Tube and Loud Speaker Impedances

THE USE OF AN OUTPUT TRANSFORMER

MANY recent articles dealing with quality amplification have stressed the point that an endeavor should be made to approximately match the impedance of the output tube with the impedance of the loud speaker. This fact is important from two standpoints; first, from the standpoint of quality and, secondly, from the standpoint of efficiency.

Regarding the first point, if a low-impedance cone speaker is used with a high-impedance tube, such as the 201-A, the low frequencies will be lost and undue prominence will be given to the high frequencies. In order to eliminate this drawback, and at the same time make it possible to obtain a considerably greater amount of undistorted power, the new type 112 and 171 tubes have been developed; both of these have quite a low plate impedance. The characteristics of these two tubes were printed on Laboratory Sheets Nos. 7 and 12 respectively. By the use of such tubes, the frequency distortion (produced when a high-impedance output tube is used) is practically eliminated.

When we use a low-impedance tube and thereby better the quality output of our receiver, we at the same time increase the efficiency with which the power developed by the tube is delivered to the loud speaker. Maximum power will be delivered to the output when its impedance is equal to the tube impedance, so that, for best results, the loud speaker impedance at a medium frequency, say 1000 cycles, should match fairly well the output impedance of the tube.

A simple method whereby tubes and loud speakers of different impedances may be used together, is by the inclusion in the circuit of a suitable output transformer, several of which are now on the market. When this plan is resorted to, it is necessary for the impedance of the transformer primary to approximately match that of the tube. The secondary should have an impedance similar to that of the loud speaker. In this way, it becomes possible to use a low-impedance speaker with a high-impedance tube, although it is not particularly advisable since the high-impedance tubes are not capable of handling any great amount of power and will very likely overload, if they are used to supply a loud speaker.

If a semi-power tube is used in the output, it is not generally advisable to connect the loud speaker directly into the plate circuit of the tube since, if this is done, the d. c. plate current will pass through the loud speaker windings and will harm the magnets used in the loud-speaker unit. In order to eliminate the d. c. from the loud speaker windings, either an output transformer or a combination of a choke and condenser should be used.

No. 33 Radio Broadcast Laboratory Information Sheet

Tandem Tuning

EQUALIZING THE CIRCUITS

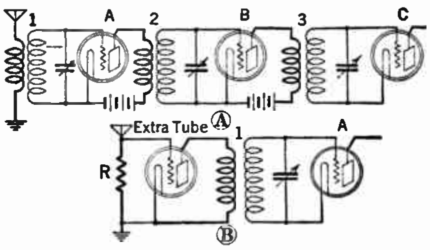
TANDEM tuning of condensers, to decrease the number of separate controls, has become quite common. There are some fundamental facts concerning tandem tuning which must be considered if satisfactory results are to be obtained.

The output and input characteristics in which the tuned circuits work must be the same in each stage. In A of the accompanying diagram, the tuned circuit No. 2 works out of the plate circuit of one tube and into the grid circuit of the following tube. The same thing is true of circuit No. 3. Therefore, if the coils and condensers are exactly similar, the two condensers in these circuits may be coupled together and operated from a single control. The tuned circuit No. 1, however, is coupled to an antenna, and for this reason its condenser will not tune in exact step with the other two condensers and, therefore, it cannot be "ganged" with the other two circuits even though the coil and condenser have the same characteristics.

One method which will permit the ganging of all three condensers is shown in B. Here, tuned circuit No. 1 has been coupled to the plate circuit of an additional tube. It is now similar to the other two tuned circuits, and the three can be all tied together. The antenna then feeds through a resistance coupled directly to the grid of the additional tube.

It is, of course, possible to so construct circuit A so as to permit ganging of all three units without an additional tube. It would require, however, very accurate cutting of the condenser plates so as to compensate any effect of the antenna circuit. This is a difficult job and it is preferable to either retain two controls or to use an extra tube.

Many so-called single-control receivers are equipped with some compensating device which



permits exact tuning of each circuit to resonance. In some cases this device consists of a small midget condenser connected in parallel with one of the main tuning elements; sometimes the stationary plates of one of the condensers are mounted on a pivot so as to permit more accurate tuning. But no receiver that has such an adjustable feature can accurately be called a single-control set.

No. 34 Radio Broadcast Laboratory Information Sheet

Series Connection of Filaments

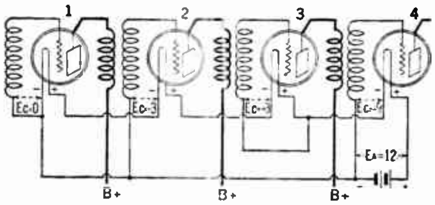
BIAS FROM VOLTAGE DROP

ALTHOUGH the practice of connecting filaments in series has been common in telephone work for some time, it has only lately come into use among radio set builders.

When filaments are in parallel, the battery voltage must be the voltage that one tube requires. For a 201-A type tube this is five volts. When the tubes are in series the battery voltage must be the sum of the voltages, that is, for five 201-A type tubes, 25 volts is required. In the parallel case, the total current is the sum of that taken by each tube; in the series case, the current is that taken by one of the tubes.

In the diagram are four 199 tubes in series with a 12-volt battery to supply them with current. There is a three-volt drop in each filament and, taken from the positive end of the battery, the total drop increases in three-volt steps. This voltage drop can be used as a negative bias for amplifier tubes. It is only necessary to connect the grid return of the amplifier in question to the place along the line where the voltage—with respect to the negative side of the amplifier filament—is that required for proper bias.

For example, in the diagram, tube No. 1 has its grid return connected to the negative side of the filament. This represents zero bias. Tube No. 2 is also connected to the same place, but between the negative side of the filament of tube No. 2 and the point where its grid return is connected, is a three-volt drop caused by the preceding tube. In the same manner, tube No. 3 has its grid biased positively three volts since in this case there is a difference of voltage of three between the positive and negative sides of this filament. Tube No. 4 has a



negative bias of 9 since between its negative filament lead and the point where its grid return is connected is the voltage drop caused by three preceding tubes. In the diagram, Ec represents grid volts. In the article entitled "An A. B. C. Line Supply Device" in the October, 1926, Radio Broadcast, diagrams are given of receivers with filaments in series.

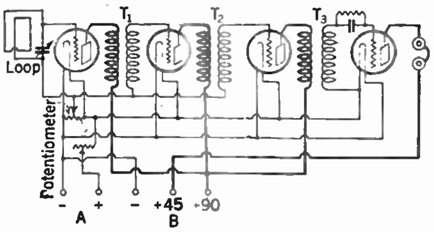
No. 35 Radio Broadcast Laboratory Information Sheet

Radio Frequency Transformers

TUNED AND UNTUNED

RADIO frequency transformers are classified as "tuned" or "untuned." A tuned transformer must be tuned to the frequency that is to be amplified. Thus, for a particular setting of the condensers, the amplification would be great for a narrow band of frequencies but negligible for frequencies even slightly outside of this band. Untuned transformers, despite the fact that they are called "aperiodic," work best at some particular frequency. However, they are supposed to work over a wide range of frequencies. The wide range is due to the introduction of resistance, or, if iron cores are used, by a combination of the advantage of the iron core with the effective resistance introduced into the transformer by the losses that occur in iron at high frequencies. In general, it may be said that, when there is much resistance or anything else that causes losses, the amplification will be less than that theoretically obtainable by the use of tuned transformers. A few stages of tuned transformer-coupled amplification have the advantage of giving great selectivity, that is, amplifying only one frequency (strictly speaking, only a very narrow band of frequencies) but have the disadvantage that as each stage must be carefully tuned, it is complicated to change from one frequency to another and difficult to pick up weak signals unless the proper setting for each tuning condenser is known in advance. In the super-heterodyne system, this disadvantage disappears because the intermediate-frequency amplification is done at a fixed frequency, irrespective of the wavelength of the station being received.

The diagram shows a typical three-stage untuned transformer-coupled r. f. amplifier with potentiometer stabilization. The transformers are marked



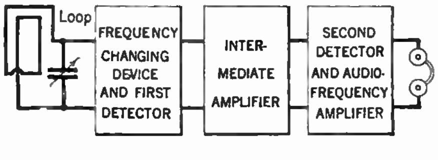
T_1, T_2, and T_3. Receiving sets of this type are not very selective as there is only one tuned circuit to do the "selecting," but they are easy to operate as the tuning condenser and the potentiometer are the only controls. Unless an arrangement for plugging-in different transformers is provided, the range over which best amplification is obtained is usually only about two hundred meters.

No. 36 Radio Broadcast Laboratory Information Sheet

The Super-Heterodyne

ACTIONS AND PRINCIPLES

ESSENTIALLY, the super-heterodyne consists of a receiver constructed to receive on one single frequency (whatever frequency it is most efficient to work with), ahead of which is a frequency changing device in combination with a detector tube (known as the first detector) designed to change the frequency of the incoming signals to that of the fixed frequency receiver. The receiver designed to receive on one single frequency consists



of several r. f. stages (known as the intermediate-frequency amplifier), a detector (the second detector), and the usual audio amplifier.

The tuning controls consist of two variable condensers, one to tune the loop to receive the incoming signals (which are passed to the grid of the first detector), and the second to tune the frequency changing device (known as the local oscillator).

It is a well-known fact that two frequencies, if superimposed, will produce a third frequency, its value equalling the difference between the two superimposed frequencies. The object of the local oscillator is to produce locally a frequency which may be superimposed upon the incoming frequency. The frequency of the locally generated wave must be such that when it heterodynes (is superimposed) with the incoming signal, the third frequency will equal that which is capable of being received by the fixed frequency unit of the super-heterodyne. This third frequency may be 30 kc. Thus we hear mention of a 30-kc. super-heterodyne, which means that its intermediate amplifier is designed to pass signals of only that frequency.

A very realistic example of the super-heterodyne principle may be obtained any night these days by listening-in to the shorter wave broadcasting stations. Often the program is marred by a constant howl which may vary slightly in pitch. This is caused by two broadcasting stations straying from their allotted frequencies and heterodyning with each other, thereby causing an audible howl. This is known as "beating." The third frequency produced by the heterodyne action in such a receiver is known as a "beat" note.

The accompanying diagram makes clear the sequence of units in the super-heterodyne. In some receivers of this pattern, r. f. amplification is resorted to ahead of the first detector and frequency changing unit. Further details of the super-heterodyne appear on Sheet No. 41.

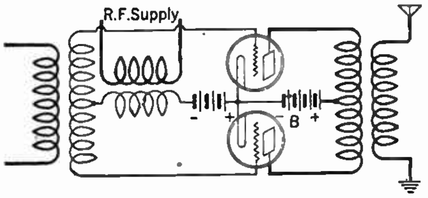
No. 37 RADIO BROADCAST Laboratory Information Sheet

Single Side Band Transmission

A SIMPLE EXPLANATION

THE carrier wave plays no important rôle in the actual conveyance of intelligence. It is required only for the purpose of modulation at the transmitting station and of demodulation at the receiving end. For actual transmission it may be left out entirely, only the modulated component being transmitted, provided that a local oscillator tube is used at the receiving end to supply current of the same frequency to take its place. The "balanced modulator," used to get rid of the carrier, is shown in the diagram. Analysis of this circuit (which consists merely of two tubes, each acting as an oscillator) shows that the two side bands generated by each tube act additively in producing current in the antenna, but the carrier frequency current in the plate circuit of one tube just cancels the effect of the carrier current in the other tube, as far as producing current in the antenna is concerned. Much power is wasted transmitting the carrier, but for most purposes it is best to do so because it is difficult to make the local oscillator at the receiving station supply just exactly the same frequency. Another advantage in suppressing the carrier is that the locally generated carrier frequency at the receiving end is not subject to variations in strength, and hence there is a reduction in the amount of fading of the received signals.

Furthermore, only one of the side bands is required to convey the speech or music, and, therefore, the channel required will only be one half as wide, which is an important feature if the ether is crowded with transmitting stations. Also, the receiving set can be made to receive only one half as wide a band of frequencies and hence offers only one half as much chance for interference to get in. If both the carrier and one side band are suppressed, the local oscillator at the receiving end can be as much as fifty cycles different in frequency from the original carrier without serious interference with



intelligibility of speech. However, the harmonic ratios in music would suffer. For the reasons mentioned above, the American Telephone and Telegraph Company is using single side band transmission in its transatlantic telephony tests. This system is not now practicable for short-wave work as it is too hard to "filter out" the side band that is not wanted when the width of these bands is only a small fraction of the carrier frequency.

No. 38 RADIO BROADCAST Laboratory Information Sheet

Neutralization

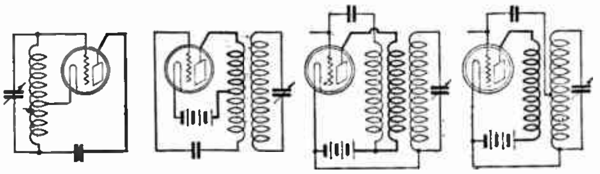
WHAT IT ACCOMPLISHES

THE best way to prevent oscillation in an r. f. amplifier is by the "bridge," or "capacity neutralization" method. When this system is used, the variations of plate potential which are caused by the grid variations (which, in turn, may be caused by the incoming signal impulses) do not react upon the grid circuit and cause feedback. The method will be better understood if prefaced by a brief statement of what happens when the bridge is *not* used. The alternating current in the plate circuit flowing through the impedance, or "load," (such as a transformer primary) in the same circuit, produces an alternating potential-difference between plate and filament. This potential difference cannot exist without causing currents to flow from plate to filament by every possible path. One such path is from the plate to the grid through the grid-plate capacity of the tube, thence from the grid to the filament through the grid circuit. Now, this current flowing through the impedance of the grid circuit produces an alternating potential difference between grid and filament. As the impedances of both the plate circuit and the grid circuit probably contain inductance, regeneration will result, and if enough inductive reactance is introduced into the plate circuit (for example, by tuning a secondary circuit coupled in any way to the plate circuit), oscillation will take place.

Considering what causes the regeneration or oscillation, it is easy to see that it can be eliminated by connecting a small condenser in such a fashion that the current flowing through it affects the grid to an extent just equal but exactly opposite in nature to the effect of the current flowing through the grid-plate capacity. This may be accomplished in a number of ways, a few of which are shown in the diagram.

In every case, the current flowing through the neutralizing condenser to the filament does away with the effect of current flowing through the grid-plate capacity provided the neutralizing condenser is adjusted to the proper capacity. For the sake of variety, the tuning condenser has been shown in several positions. It can be put across either part of any of the split coils, or across the whole coil, or across a separate coil coupled to the split coil.

The positions shown are the more commonly used ones.



No. 39 RADIO BROADCAST Laboratory Information Sheet

Field Intensity Measurements

HOW THEY ARE MADE

IN A recent report by the Bureau of Standards, the following method of measuring the field intensities of broadcasting stations is suggested.

The method can be used for distances up to about fifty miles, and will give correct results at broadcast frequencies. For greater distances than fifty miles it gives approximately the maximum value of field intensity (not the average value) reached by waves subject to fading. The method makes use of what is termed the radiation constant. This constant is determined by making field intensity measurements at not less than five points distributed fairly evenly around the transmitting station at a distance of about ten miles The radiation constant is then expressed as the average field intensity at ten miles in millivolts per meter.

The radiation constants of several stations are given below:

STATION	RATED POWER, kw.	RADIATION CONSTANT
KDKA	10	43
KFKX	2	28
WEAF	3	32
WHAS	0.5	5
WCAP	0.5	17
WLW	5	31

With the field intensity at ten miles known, the resultant field intensity at any other distances is given by the formula:

$$F = \frac{10}{d} F_{10} \qquad (1)$$

where F_{10} is the radiation constant and F the field intensity at any other distance. This value of F neglects any ground absorption and gives correct results up to about fifty miles, as mentioned above.

To make a measurement a receiver is set up and a milliammeter placed in the output of the detector circuit. The deflection of the needle is observed when signals from the base station—the radiation constants of which are known, are being received, and then the receiver is re-tuned to the station on which it is desired to make the test, and the deflection noted again. The field strength can be determined by substituting in the formula given below:

$$F = \frac{R}{R_B} \times \frac{I}{I_B} F_B \qquad (2)$$

where R is the resistance of the receiving antenna, at a frequency corresponding to the transmitted signals of the station under test; R_B is the resistance of the receiving antenna at a frequency corresponding to the signal from the base station; I, the deflection on the signal from the test station; I_B, the deflection on the signal from the base station and. F_B, the field intensity of the base station determined by formula No. 1. The derivation of formula No. 2 will be found on Laboratory Information Sheet No. 43.

No. 40 RADIO BROADCAST Laboratory Information Sheet

Analysis of Detection

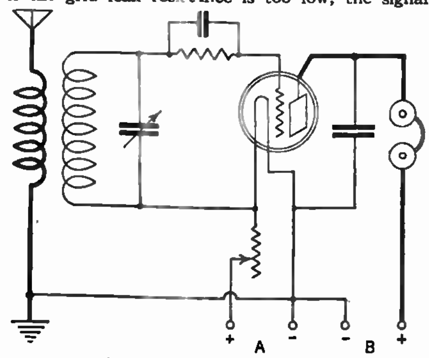
THE REASON FOR THE GRID LEAK

A METHOD of detection commonly used makes use of a grid leak and condenser. The operation of the circuit may be roughly outlined as follows:

In the absence of incoming waves, the potential of the grid is the same as that of the filament. Incoming waves cause the grid to become alternately more positive and more negative than the filament. While the grid is more negative, nothing happens, but while it is more positive it attracts negative electrons. These electrons cannot get off the grid once they are on it (the grid is not hot like the filament) except via the high resistance which is called the grid leak. If, for the moment, we suppose there is no grid leak provided, we can see that after a very few waves have come in, the electrons drawn to the grid will charge it to a steady negative potential equal to the maximum instantaneous potential of the top of the coil in the antenna circuit. This steady negative potential causes a reduction in the plate current. Even if the waves cease coming in, or their amplitude is diminished, the grid retains its negative charge since there is no way for the electrons to get off it. So we put in a very high-resistance path by which they may slowly (compared to the wave frequency) escape so that, if the amplitude of the incoming waves slowly (*i.e.*, at voice frequency) diminishes, electrons will leak off until the grid potential drops to the new maximum value of potential at the upper end of the coil. In this system, the greater the strength of incoming waves the less the plate current.

The connections shown in the diagram are often recommended.

The size of the grid leak is more or less important. If its resistance is too great it is possible that the grid of the tube will block on strong signals, whereas if the grid leak resistance is too low, the signal



strength will be decreased. For the ordinary 201-A type tube, a grid leak of about four megohms resistance will give the best results. If a soft detector tube is used, a somewhat lower resistance leak is generally required; about one half to two megohms being about right.

No. 41 RADIO BROADCAST Laboratory Information Sheet

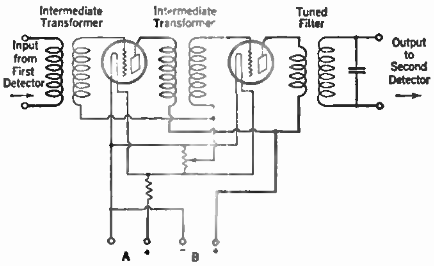
The Super-Heterodyne

INTERMEDIATE-FREQUENCY AMPLIFIER

IN THE super-heterodyne there is a group of apparatus termed the intermediate-frequency amplifier which functions to amplify the beat notes produced by the action of the first detector and local oscillator (See Laboratory Sheet No. 36). Characteristics which a good intermediate-frequency amplifier must possess are discussed below.

In the first place, all of the transformers used in the amplifier must be resonant at the same frequency. Improperly matched transformers are a cause of poor operation of a super-heterodyne, since the overall efficiency of the entire receiver can be considerably lowered if one of the transformers is slightly different in characteristics from the others. Matching of the transformers is not an easy process since the matching must usually be done with very low voltages in order to make the conditions similar in every way to those found during ordinary operation.

The resonance curve must be sufficiently broad so that all side bands which make up the signal are evenly amplified. On the other hand, if the resonance curve is too broad, the selectivity of the system will not be good enough. No trouble should be met with as regards selectivity in the intermediate amplifier when properly matched air-core transformers are used, but these must be carefully designed to prevent some of the side bands being cut off, due to their (the transformers') sharp peaks. Iron-core transformers are often used in super-heterodynes in conjunction with a filter. Since the selectivity obtained from the iron-core transformer is not great enough, it is necessary to improve this characteristic by placing, either before or after the amplifier, a tuned circuit known as the filter, designed to pass only those frequencies for which the transformers give the maximum amplification.



Regeneration in the intermediate-frequency amplifier will considerably improve the selectivity and sensitivity by sharpening the resonance curves of the transformers.

The common method of connecting together intermediate-frequency amplifiers is illustrated in the diagram, in which potentiometer control of regeneration is used.

No. 42 RADIO BROADCAST Laboratory Information Sheet

Super-Regeneration

THE THEORY EXPLAINED

WHERE loud signals are required from a loop, and the number of tubes is limited to one or two, super-regeneration can be used. Super-regenerative circuits are not very selective and hence are not very good for working through interference. The principle of super-regeneration is simply explained by a mechanical analogy. Suppose a clock to be wound up and the pendulum placed carefully in its lowest position and left there. The clock will not start itself. But now, suppose strong puffs of air come along at the proper interval to start the pendulum swinging slightly. Once it starts ever so slightly an ideal spring and escapement mechanism would cause its swinging to increase even if the puffs of air stop coming in. The oscillations of the pendulum "build up" and in due time the amplitude of swing reaches a limit determined by friction, air resistance, etc. But if we confine our attention to a sufficiently short period of time after the swing starts to build up, we will find that the amplitude attained during this time is proportional to the strength of the incoming puffs of air. At the end of this period, let the pendulum be stopped and set again at its lowest point so that the whole operation may be repeated. A great deal more swinging is done by the pendulum if the clock is wound up and the puffs of air are playing on it, than if the clock were not wound up, in which case the pendulum would only swing the very small amount caused by the air puffs.

In the electrical sense, in super-regeneration, we have a circuit all set to oscillate, *i.e.*, wound up and balanced, so to speak so that some incoming ether wave is required to start it oscillating. This is similar to our analogy, in which the puff of air is necessary in order to start the pendulum swinging. In the super-regenerative receiver, the oscillations started by the incoming waves are permitted to build up very rapidly in the same manner that they would be built up in an ordinary regenerative receiver if the coupling was greatly increased beyond that necessary to make the detector oscillate. However, before the circuit can break into continuous oscillation the entire oscillation is automatically extinguished by another oscillation (generally about 10,000 cycles) which opposes the incoming oscillations every 20,000th of a second. This 10,000-cycle oscillation may either be generated in the same tube or in another tube coupled to the detector. During half of each cycle, that is, every 20,000ths of a second, the 10,000-cycle oscillation has no effect upon the incoming signal and during the other half of the cycle its effect is to prevent the production of any high frequency oscillation in the detector circuit.

Consequently the signal energy is very large during half of each 10,000 cycle oscillation, and on the whole there is very much more energy in the detector grid circuit than would be present under ordinary conditions. A comparatively large voltage is therefore impressed on the grid, which makes a correspondingly large amount of energy available in the plate circuit.

No. 43

RADIO BROADCAST Laboratory Information Sheet

Field Intensity Measurements

DERIVATION OF THE FORMULA

ON LABORATORY Sheet No. 39 were given some data regarding the measurement of the field intensity of broadcasting stations. Further information concerning this subject is given on this sheet, with regard, especially, to the derivation of the formula which was given on the previous Laboratory Sheet.

With the field intensity of some base station known, from actual measurements at a distance of ten miles, it is possible to calculate the field intensity of the base station at any other distance up to about fifty miles, by the formula given below:

$$F_b = \frac{10}{d} F_{10}$$

Where F_b=field intensity of base station at distance d; d=distance from station in miles; F_{10}=radiation constant of base station.

The field intensity, F, of the station under test, is determined by the relative deflections of a meter in the plate circuit or the detector tube when signals from the base station are being received and when signals from the test station are being received. The two field intensities will be proportional to the meter deflections; the greater the deflection, the greater the field strength. Therefore we can write:

$$F = F_b \frac{I}{I_b}$$

Where F=field intensity of station under test; I=meter deflection when signals from test station are being received; I_b=meter deflection when signals from base stations are being received.

If the total amplification in the receiver is held constant, the only other factor that would influence the results would be the antenna resistance, and we can take account of it by placing in the formula the ratio of the antenna resistances at the two wavelengths (it is always best to use as a base station one which is transmitting on a wavelength quite close to that being used by the station under test). Putting this ratio in the formula we have:

$$F = F_b \frac{I}{I_b} \times \frac{R}{R_b}$$

which is the same as the formula given in the former Laboratory Sheet.

A great deal of work has been done on this subject and some very interesting data were given in the August, 1926, issue of RADIO BROADCAST by Mr. Albert F. Murray, who recorded the work done by Doctor Pickard. The methods used by Doctor Pickard must be used if the station whose field intensity is to be determined is located at any distance over about fifty miles. For distances less than fifty miles, practically all the energy is received by what is commonly called the ground wave, but for distances very much greater than fifty miles, energy is also received by other paths, so that a formula which only takes into consideration that energy received by the ground wave cannot be used for very great distances.

No. 44

RADIO BROADCAST Laboratory Information Sheet

The R. B. "Local" Receiver

NECESSARY EQUIPMENT

IN THE August, 1926, issue of RADIO BROADCAST, there was described a high-quality local receiver by Mr. Kendall Clough. This receiver was designed particularly for local reception and consists of a stage of radio frequency amplification coupled to a non-regenerative detector and the usual audio amplifier. Both of the tuned circuits are contained in shields. The C battery form of detection is used since this method of detection permits the handling of loud signals without distortion. All tuning is accomplished by varying the two condensers. The only other controls are a filament rheostat and a volume control. The following apparatus was used in the original model:

1 7 x 18 x 3/16-Inch Bakelite Front Panel.
1 7½ x 17 x 3/16-Inch Bakelite Sub-Panel.
1 Pair Mounting Brackets.
1 3-Ohm Rheostat. R_3.
1 25-Ohm Rheostat, R_2.
1 Open-Circuit, Jack, J_1.
1 Filament Switch.
2 0.00035 Condensers, C_1 and C_2.
2 4-inch Dials, Zero Left.
2 Stage Shields.
2 Coil Sockets.
2 No. 115A coils, 1578–545 kc. (190–550 Meters).
4 Sockets.
1 1.0 mfd. Condenser, C_3.
1 0.002 Condenser, C_4.
2 Audio Transformers T_1 and T_2.
1 Output Transformer, T_3.
1 Coil Flexible Hook-Up Wire.
6 ¼ x ¼-Inch Lengths Brass Tube for Mounting Coil Sockets.
1 Filament Resistor 35 ohms, R_1.

An Assortment of 6/32" Round Head Screws and Nuts, together with Lugs.

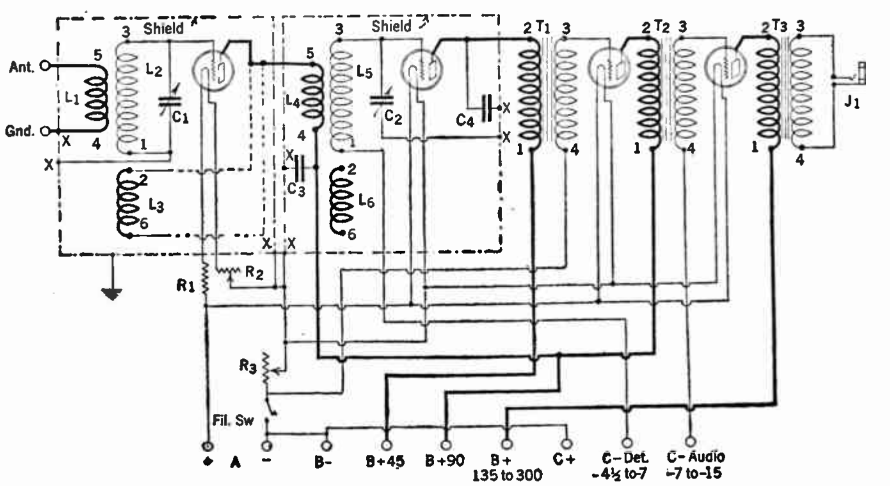
Home-made coils may be made up in accordance with the following specifications:

For the secondaries marked L_2 and L_5 on the diagram, Laboratory Sheet Number 45, wind ninety turns of number 22 d.c.c. wire on a 2-inch tube. The primaries, L_1 and L_4, consist of 13-turn windings wound over the centers of the secondaries. The primary and secondary windings are separated from each other by layers of cambric tape or other insulation. If a 201-A tube is to be used in the r. f. stage, an additional winding is necessary on the first coil. This additional winding, marked L_3 on the diagram, should consist of five turns of number 26 d.c.c.wire. The winding, L_6, can be ignored. It is merely shown since it is to be found on the manufactured coils if they are purchased. It is not, however, connected into the circuit in any way. Shields should preferably be used and are indicated in the diagram by a dot-dash line. The "Xs" of the diagram indicate parts of the circuit that are connected to the shields. The shielding may consist of aluminum cans made to fit over the apparatus. Numbers on the diagram correspond to those to be found on the manufactured coil sockets.

No. 45

RADIO BROADCAST Laboratory Information Sheet

The R. B. "Local" Receiver



Data on the R. B. "Local" Receiver appears on Sheet No. 44

No. 46 RADIO BROADCAST Laboratory Information Sheet

Loud Speakers

SOME GENERAL CONSIDERATIONS

IT IS easy enough to fix a megaphone to a telephone receiver to produce a loud signal, and some loud speakers are merely refinements of this idea. The horn concentrates the sound in one direction, and the tapered column of air within the horn that fills the space about the small receiver diaphragm at the small end, and swells gradually out to join the open air at the flared end, supplies something for the diaphragm to work against. The diaphragm is caused to set more air in motion just as if a bigger diaphragm were used, thus increasing the volume of sound produced. But inasmuch as the best reproducers are only about 2 per cent. efficient (that is, of 100 units of electric energy entering them only about 2 leave in the form of sound energy), only small efficiencies are likely to be obtained even when good horns are coupled to the diaphragm. The great sensitivity of the human ear tends to make up for the inefficiency with which energy is converted from mechanical to acoustical by means of vibrating bodies. In ordinary speech only about one erg (the erg is the physicist's unit of energy) per second is converted into sound energy. How little this is can be seen from the following calculation: Reckoning that the average human being talks the equivalent of two hours steady talking per day, and that the average population of the United States since the Revolution is forty millions, and that power is worth two cents per kilowatt hour, then, from the energy point of view all the talking that has been done in the history of our country is only worth $8.59!

In addition to the low efficiency of the conventional loud speaker, there is also distortion introduced in this method of making radio signals audible by the horn. An excellent method of mitigating this is by the use of two or three separate horns, each with its own diaphragm. In the case where three are used, for example, one is a very long horn that responds well to low tones; the second is an ordinary-sized loud speaker responding fairly well over the middle range; and the third is a very small horn giving the very high-pitched notes. The three horns, all working at once, combine to give a satisfactory uniform response over the whole audible range. The three horns, of course, are combined in a single box. The long horn can be coiled to save space, if necessary.

Another type of loud speaker avoids such distortion as is due to the horn by using no horn at all. This type of speaker usually, but not necessarily, has a large, light, stiff paper cone for a diaphragm, and this alone is sufficient to give it a good "grip" on the air. At present only a few commercial types of loud speakers give any sort of an approach to the goal of quality, which is to have all frequencies transmitted from speaker to listener with equal efficiency.

No. 49 RADIO BROADCAST Laboratory Information Sheet

Trickle Chargers

DIFFERENT TYPES AVAILABLE

IT HAS been customary in general to operate a radio receiver from a storage battery having a very large capacity. However, during the last year or so there has come into rather common use the combination of a storage battery with a trickle charger. This combination consists of a small storage battery which is directly connected to the trickle charger. The trickle charger, connected to the a.c. mains, serves to keep the battery in a constantly charged condition.

There are several types of rectifiers which have been used in trickle chargers. In the bulb type of rectifier, with which we are all familiar, a small vacuum tube is used which rectifies the alternating current and supplies it to the battery. This type is more familiarly known as the Tungar or Rectigon trickle charger, and is very satisfactory and dependable.

The second form of rectifier is the electrolytic type which consists of two electrodes suspended in an electrolyte. It is very simple to construct and works very satisfactorily. It is probably more efficient than the above type since it does not require any energy to light a filament.

The third type, which has only recently come into prominence, uses a crystal. We are all familiar with the crystal detector used in a radio receiver which functions to rectify the small radio frequency currents, and since the trickle charger need only supply a small current it seems quite possible to use a number of crystal detectors in parallel. Several models using this system are now on the market.

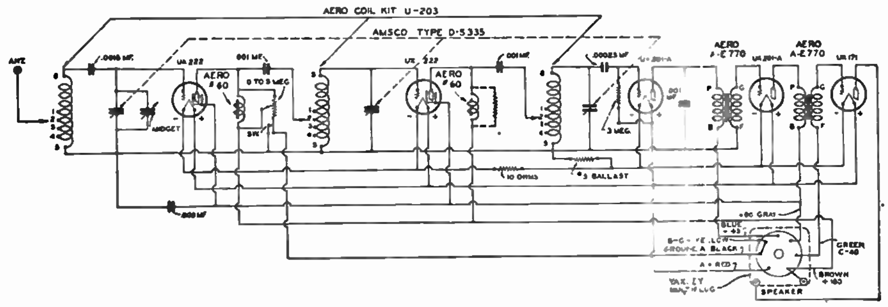
The battery used in conjunction with a trickle charger need not be very large since, under normal operation, it need only be large enough to operate a receiver for one day, after which it may immediately be charged. However, it is wise to use a fairly good size battery—a unit having a capacity of about 40 ampere hours should give quite satisfactory operation. With such a battery in use, it will be possible to operate the receiver for several days without charging, and in this way preparation is made for any emergencies that might occur.

When the storage battery is operated in conjunction with a trickle charger the only attention required is to see that the water in the battery is kept above the plates. It will be best to examine the battery about once a month. The rate of charge should be adjusted so as to keep the battery fully charged. This means that, when the charger is first purchased, frequent hydrometer readings should be taken to determine the condition of the battery. If the battery begins to run low the rate of charge should be increased; if the battery gases considerably when on charge, it is an indication that the battery is full and it will then be best to reduce the rate at which the trickle charger supplies current, so as to prevent excessive charging.

ADVERTISEMENT ADVERTISEMENT

AERO PRODUCTS DATA SHEET

"Chronophase" Shield Grid Broadcast Receiver



LIST OF PARTS

1—Aero Foundation Unit No. 20, including Cabinet. 1—Aero Coil Kit No. 203. 2—Aero C-60 Noskip R. F. Chokes. 1—Aero Special Centralab Resistance, AE-250. 2—Aero AE-770 Audio Transformers. 1—Amsco DS-335 Triple Condenser, .00035. 1—Amsco No. 132 Midget Condenser, .00005. 1—Aerovox Mica Condenser, .00025. 3—Aerovox Mica Condensers, .001. 1—Aerovox Mica Condenser, .0015. 1—Aerovox Mica Condenser, .003. 1—No. 669 Yaxley Cable Connector. 1—No. 810 Yaxley Resistance. 1—No. 5 Daven Ballast. 1—Type E. National Dial. 2—Carter Shield Grid Connectors, No. 342. 1—Eby Binding Post.

Data Sheets Nos. 47 & 48 originally contained an index and were purposely omitted.

No. 50

RADIO BROADCAST Laboratory Information Sheet

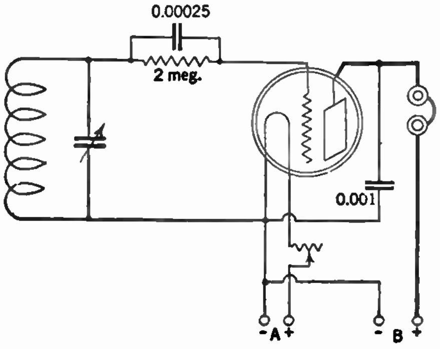
Hard and Soft Vacuum Tubes

SOFT TUBES FOR DETECTOR USE

IF A vacuum tube, during manufacture, has left within its bulb a small amount of gas, or if a small amount of gas is introduced into the tube, it is known as a soft tube. If every particle of gas is removed, the tube is known as a hard tube. Soft tubes are particularly suited for use as detectors. They generally require somewhat critical adjustment of the filament and plate voltages but, once these potentials are found, the soft tube makes a very sensitive detector.

Recently some progress has been made in designing sensitive detector tubes, such as the 200-A, which do not require especially accurate adjustment of the operating voltages. The action of a soft tube depends upon the fact that, at certain critical voltages, the gas in the tube is practically in a state of ionization. Then, when a signal is impressed on the tube, the plate current is caused to change, due to the increase in the flow of electrons from filament to plate and due to the increase in the number of ionized gas particles which also flow to the plate. The plate current is therefore increased by these two effects, so that the total change in plate current is greater than it would be if no ionization occurred. When a soft tube is used for a detector, the grid return must connect to the negative end of the filament instead of the positive, as is done when a 201-A tube is used for detection. Therefore, when changing over from a 201-A to a 200-A, be sure to alter the connections so as to have the return connected to the negative filament.

Hard vacuum tubes are generally used as amplifiers, and structurally, are the same as the soft tubes, the only difference being that they have no gas content. Amplifier tubes do not require any critical adjustment and will operate on from 40 volts up to the maximum that can safely be placed on the tube.



A diagram of connections of a 200-A detector tube is given herewith.

No. 51

RADIO BROADCAST Laboratory Information Sheet

Overtones (Harmonics)

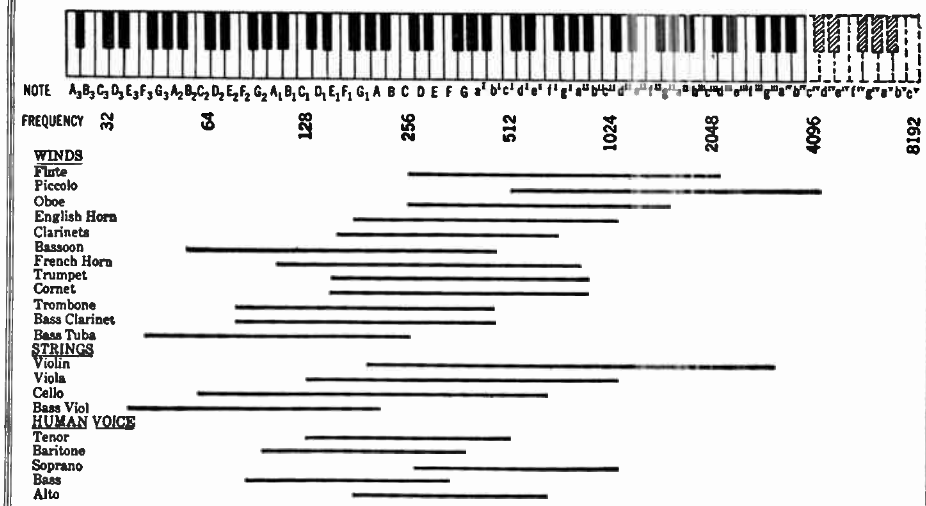
THEIR IMPORTANCE IN RADIO

A GREAT many of the fundamental notes used in speech lie below a frequency of 1000 cycles, but it is the overtones (or harmonics) which determine the quality and timbre of the sound. In order to obtain perfect quality, the characteristics of all the amplifiers and reproducers used in a radio receiving system must be absolutely flat, *i.e.*, they must transmit all frequencies with equal fidelity.

The overtones which were mentioned above are harmonics which are produced by all instruments, including the human voice, and the correct transmission of the harmonic frequencies is essential if the characteristics of the original sound are to be maintained. In many cases it is the prominence of certain harmonics which distinguish the different instruments from others. Quite frequently overtones are confused with octaves. An example will distinguish the difference between these two units. The fundamental sound of, say, 500 cycles has an octave corresponding to 1000 cycles, another octave at 2000 cycles and another one at 4000 cycles, etc.—each octave being double in frequency to the one preceding it. If two octaves are sounded at the same time, it is rather difficult to distinguish between them. On the other hand, the fundamental note of 500 cycles has overtones, or harmonics, corresponding to 1000, 1500, 2000, 2500 cycles, etc. In this case, the various tones are separated by an amount equal to the fundamental frequency. Whereas the difference between two octaves is rather difficult to detect, it is quite easy to distinguish between various overtones. From the above, it is evident that some octaves are also overtones; for example, the octave at 1000 cycles corresponds to the 2nd overtone of the fundamental note of 500 cycles. However, the next overtone is 1500 cycles, but there is no octave corresponding to this pitch. It is evident that, starting with a certain note, all octaves correspond to certain overtones but that all overtones are not octaves. On Laboratory Sheet No. 52 there is reproduced a diagram showing the fundamental frequency range of various instruments. In the diagram given, it will be noted that an extra octave is shown at the high frequency end of the piano keyboard. As experience has shown that at least one harmonic must be provided for when amplifying a signal near the top of the audible frequency scale, to obtain true fidelity, the extra octave is included to indicate the frequency range requirements of an amplifier to successfully reproduce the highest note of the piano, which has a fundamental of 4096 cycles.

No. 52 RADIO BROADCAST Laboratory Information Sheet

Frequency Ranges of Musical Instruments

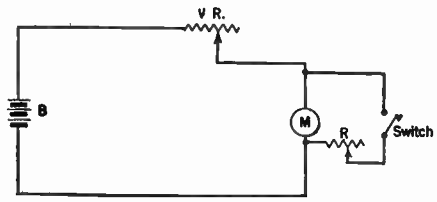


No. 53 RADIO BROADCAST Laboratory Information Sheet

Shunts

DETERMINING THEIR VALUE

SHUNTS, as used in an electrical laboratory, consist of an electrical conductor placed in parallel with an indicating meter so as to increase the range of currents that can be read with this meter. We might have a 10-milliampere meter and desire to read a current of, say, 50 milliamperes; with the aid of a shunt, this can easily be done. The method of calibrating a shunt is indicated in the diagram.



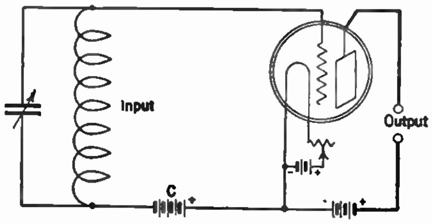
Suppose we desire to calibrate a 10-milliampere meter so that it will read 50 milliamperes. We would connect a battery, B, as indicated on the diagram, in series with a variable resistance, V.R., so as to limit the current passing through the meter (without a shunt) to 10 milliamperes. The resistance would be varied until the meter read exactly 10 milliamperes and then the rheostat R (the shunt) would be switched across the meter and its resistance altered until the meter read two milliamperes. Under such conditions (with the shunt connected), a reading of 2 milliamperes on the meter would mean that 10 milliamperes were flowing through the circuit. Likewise, full scale deflection would indicate a 50-milliampere flow although the needle pointed only to 10 milliamperes. The same procedure would be followed in shunting any instrument, *i. e.*, setting up a circuit which will pass sufficient current to give a maximum deflection on the meter, then shunt the meter and reduce it a definite amount such as one half, one third, or one fifth, then, in order to determine the actual current flowing in the circuit with the shunt connected, it is merely necessary to multiply the meter reading by 2, 3, or 5, depending upon how much the original deflection of the meter was reduced by the shunt.

No. 54 RADIO BROADCAST Laboratory Information Sheet

C Battery Detector

FORM OF PLATE CURRENT

IN THIS Laboratory Sheet we are going to discuss some points regarding the operation of a C battery type detector. We are going to consider, in particular, the form of the plate current of this detector tube.



When no signals are being received, the plate current is constant and depends on the adjustment of the C battery. For best operation of a detector of this type, about four volts of C battery should be used on the 201-A when 45 volts are used on the plate. When a signal is received, the plate current varies and is then made up of two components; one of these components is the pure d.c. current that flows in the plate circuit when no signals are being received and the other component is an alternating current which is produced by the audio frequency modulation in the carrier-waves that are being received. Although the detector is a rectifier, the current in the plate circuit is not in the form of a pulsating current as might be obtained from such a unit as a B line supply device, which is also a rectifier.

When the signal is being received, the voltage is impressed across the input on the accompanying diagram. This voltage causes the grid to become alternately more positive and then more negative than the voltage due to the C battery. However, the C battery voltage is such that a greater change of plate current takes place when the grid becomes more positive than it does when the grid becomes more negative; therefore, the current variations in the plate circuit increase more than they decrease and the result is that the average current in the plate circuit is higher than when no signal is being received. These current variations in the plate circuit can be detected if they are permitted to pass through a telephone. Also, if a transformer primary is placed in the plate circuit, the current variations will produce a varying flux in the core and will cause corresponding voltages in the transformer secondary, and these, in turn, can be impressed on a further tube and the signal amplified.

No. 55 RADIO BROADCAST Laboratory Information Sheet

Tuning the Antenna Circuit

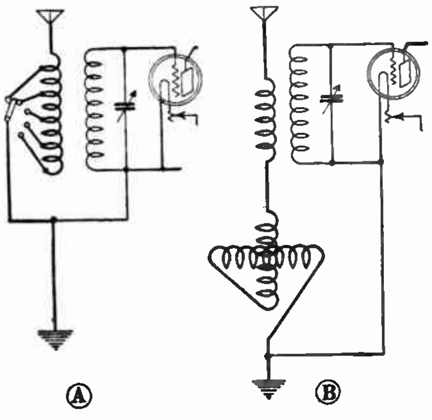
POSSIBLE METHODS TO USE

IN PRACTICALLY all receivers described to-day no tuning is used in the antenna circuit. Generally the antenna circuit is of fairly high resistance and therefore rather broad in tuning and, consequently, it is seldom worth while to accurately tune the circuit. However, some increase in signal strength can be obtained by approximately tuning the circuit to resonance. This tuning can be accomplished in several ways. The simplest method is to use a tapped inductance as shown in sketch A. The taps should be so designed that the antenna circuit is tuned to approximately 1500 kilocycles when the fewest numbers of turns are included in the circuit, and resonant at about 500 kilocycles when the total number of turns are in the circuit.

The antenna circuit may also be tuned with a variometer, as shown in B. The variometer must be capable of being varied in inductance sufficiently to cover the broadcast band of frequencies.

The disadvantage of tuning the antenna circuit is that it adds another control when the trend in design is toward the elimination of controls. Evidently, then, the solution is to design an antenna tuning device that can be automatically controlled, perhaps by attaching some device to the shaft of the variable condenser, such as is done in the "Equamatic" system, to vary the coupling of coils between tubes in an r.f. amplifier.

It should be understood that movements of the condenser across the secondary winding has a tuning effect on the antenna circuit if the coupling between the coils is close. As an example, the coil used in the antenna circuit of a Browning-Drake receiver has a tap at the center for connection to the antenna. Consequently, the antenna capacity (possibly reduced somewhat if a series condenser is used) is across half of the coil and has a decided effect on the tuning of the secondary circuit.



No. 56 RADIO BROADCAST Laboratory Information Sheet .

Radio Telegraph Transmission

DIFFERENT TYPES OF WAVES

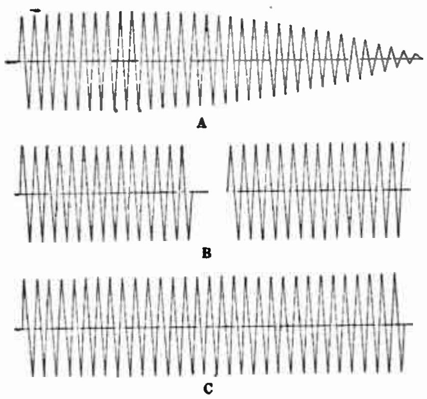
IN TRANSMISSION work by telegraph there are several different types of waves used, these being illustrated in the accompanying drawing.

The drawing A represents the type of wave radiated by a spark transmitter. This form of wave is known as a damped wave since it gradually decreases in amplitude. One of these wave trains is radiated each time that a spark takes place across the electrodes of the spark transmitter. Generally the spark frequency is about 500 per second, so that, if the transmitter was turned on, there would be 500 of these wave trains radiated every second. This type of transmitter is gradually being replaced by apparatus using vacuum tubes for the generation of the high frequency oscillations.

The second form of radiated energy is illustrated in B, and is known as I. C. W., meaning Interrupted Continuous Wave. In this system, the energy is radiated in a series of wave trains similar to the radiations obtained from a spark transmitter, the difference being that the amplitude of the radiated wave is constant and does not decrease as shown in A.

Energy of this form could be obtained by supplying a transmitter from a plate battery in series with which there was arranged some form of interrupter which opened the circuit, say, 500 times per second.

The third type of transmitted wave is known as C. W. or Continuous Wave and in this system, energy is radiated all the time that the key is pressed and it is not broken up as was shown in the two instances given above. This form of transmission is a very common one and is used by the majority of the high-powered transmitter stations and in amateur work.



No. 57 RADIO BROADCAST Laboratory Information Sheet

What is Resonance?

AN ELECTRICAL ANALYSIS

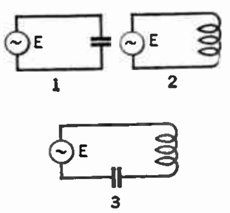
IT HAS frequently been said that, in order to receive any particular station, we must tune the various circuits of our receiver to resonance with the incoming frequency. We shall endeavor, in this sheet, to explain what is meant by resonance.

In the accompanying sketch, first refer to "A." Diagram No. 1 is a simple circuit consisting of some source of alternating voltage, marked E, in series with a condenser. The reactance or impedance offered by the condenser to the flow of current depends upon the frequency, and, if we plot a curve showing the change of reactance with frequency, we will get a curve similar to that marked C, in "B." As the frequency increases, the reactance of the condenser decreases, and the curve approaches the zero line. Capacitive reactance is usually considered negative, as shown, in order to indicate that it is opposite in effect to the inductive reactance.

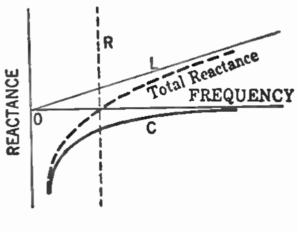
If the condenser in the circuit is replaced by a coil of wire, or inductance, as shown in No. 2, "A," we find that the inductive reactance increases with an increase in frequency which is shown by the curve marked L on "B."

Now, if we connect both a condenser and an inductance in a circuit as shown in No. 3, "A," we will have a combination of the effects produced by both of them. Remembering that the effective resistances or impedances are opposite in sign, we may add the two curves together and the result will be a curve such as that marked "Total Reactance" in "B." At one point we notice that the line passes through zero, this point being indicated by the dotted line marked R. In other words, at this point, the total reactance in the circuit is zero, the reactance which is due to the condenser cancelling out the reactance due to the inductance.

When a circuit is tuned to resonance, the capacity and inductance are so proportioned that their effect in the circuit are nullified, and, as more current will flow in a circuit of least resistance or reactance, the combination will offer very little opposition to the currents having a frequency of R in the diagram but will offer considerable resistance to any other currents having a different frequency



-A-



-B-

No. 58 RADIO BROADCAST Laboratory Information Sheet

Type 171 and 210 Tubes

A COMPARISON

BOTH of these tubes are suitable for use in the last stage of audio amplification, but under certain conditions one tube is to be preferred over the other.

By glancing at the table, it will be seen that the output resistance is lower for the 171 than the 210 for all values of plate voltage. The greatest transfer of energy occurs between a tube and a speaker when their impedances are matched. As most loud speakers have very little impedance at low frequencies, it is advantageous to use a tube such as the 171 which has a very low plate impedance. This compensates to some extent the low amplification factor of 3. From the figures given for the maximum undistorted output, it can be seen that, with 180 volts on the plate, the 171 will deliver to the load 700 milliwatts of power. This is about the same power as can be obtained from a 210 with about 300 volts on the plate. However, at 425 volts, the 210 is capable of delivering more than twice the undistorted power of a 171. It is quite evident then, that the 171 is somewhat to be preferred for ordinary signal strength such as is needed in the home, and that for unusual volume, such as concert work in large halls, the 210 would prove more satisfactory.

TUBE	GRID VOLTS	PLATE VOLTS	OUTPUT RESISTANCE	MAXIMUM UNDISTORTED OUTPUT (MILLIWATTS)	AMPLIFICATION FACTOR	PLATE CURRENT
171	16.5	90	2500	130	3	10
	27	135	2200	330	3	16
	40	180	2000	700	3	20
210	4.5	90	9200	18	7.5	3
	9	135	8000	65	7.5	4.5
	10.5	157.5	7400	90	7.5	6
	18	250	5600	340	7.5	12
	27	350	5100	925	7.6	18
	35	425	5000	1540	7.7	22

No. 59 RADIO BROADCAST Laboratory Information Sheet

What are Harmonics?

THEIR ELECTRICAL CHARACTERISTICS

PRACTICALLY none of the sounds that we hear can be said to be pure, in the sense that they contain only one frequency. Several different persons could all sing the same note and yet the different voices would be easily distinguishable. A violin and a flute might play the same note, but they would sound entirely different.

The factor which causes this difference is the existence in practically all sounds of various harmonics, or overtones, about which something has been said in Laboratory Sheet No. 51. In the present Sheet, we will explain, from an electrical standpoint, what harmonics are.

Acoustically, the difference between a fundamental note and, say, its fifth harmonic is that the pitch of the harmonic is five times as high as the pitch of the fundamental. Electrically, the difference is that, for every time that the fundamental note goes through one cycle, the fifth harmonic goes through 5 cycles. This relation between a fundamental and any of its harmonics always is true, *i. e.,* while the fundamental passes through one cycle, a harmonic passes through a number of cycles, depending upon what harmonic it is; the second harmonic passes through two cycles, the third harmonic passes through three, the fourth through four, and so on.

A cycle comprises one complete alternation of the wave and, therefore, to produce one cycle the wave must start at zero, rise to a positive maximum, decrease to zero, rise to a negative maximum and again decrease to zero.

The sounds created by instruments are practically always very complicated and contain many harmonics. The violin, as an example, produces a very complex note containing a very prominent third harmonic, and many other harmonics as well, while some of the notes produced by a flute are perhaps the purest of any sounds that are generated by musical instruments

Many amplifying systems are not capable of amplifying the low notes but fortunately a considerable decrease in amplitude in these low frequencies is hardly noticeable to the ear. It is also generally true that the harmonics of these low notes will have the same effect on the ear as the fundamental note. Consequently, if an organ sounded a chord which contained a 30-cycle note and only the second harmonic, 60 cycles, of this note was heard, it would give the same effect to the ear as the fundamental note of 30 cycles. This characteristic, combined with the fact that these low notes are very seldom used, makes it hardly worthwhile to go to any great expense to set up apparatus capable of giving exact amplification of these low frequencies.

No. 60 RADIO BROADCAST Laboratory Information Sheet

Filter Circuit Data

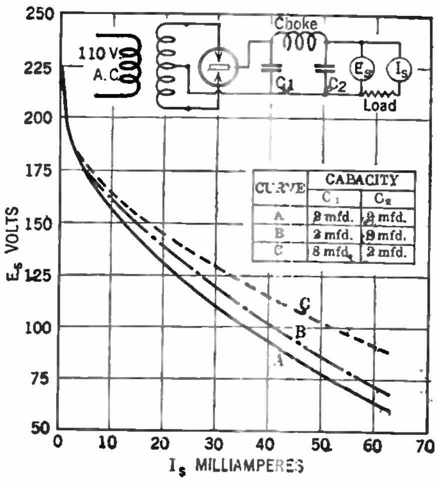
CONDENSER VALUES

SOME interesting data were given in the General Radio *Experimenter* of July, 1926, regarding the characteristics of filter circuits for use with B-current-supply devices.

In the diagram, the condenser marked C_1 may be called a reservoir condenser as its function is to store up energy during the peak of the wave and feed it back into the circuit at the lower values of the wave. This condenser is especially valuable in keeping the voltage more nearly constant with varying loads. A small condenser at this point will cause the voltage to drop off very readily with increasing load.

The condenser marked C_2 is placed across the output, and is especially valuable in eliminating any ripple. The curves given on this sheet indicate the effect obtained with different values of condensers in the two positions. It should be noted that an increase in either one of these condensers improves the regulation (curve B and C both showing a decrease over A in voltage drop), due to increasing the size of the load. Curve C shows the best regulation where C_1 is the larger. This indicates that an increase in C_1 is more effective in improving the voltage regulation than C_2. An oscillograph would show that an increase in either condenser would tend to eliminate the ripple, but that less ripple would be obtained by increasing C_2 rather than C_1.

Both experiment and theory seem to indicate that, with a certain total capacity in the current, the best regulation and the least ripple are obtained by making both of the condensers of the same value.



The curves shown are for a single section filter using the Raytheon tube as a rectifier. A multi-section filter would, however, give the same type of curves.

No. 61 RADIO BROADCAST Laboratory Information Sheet

The Intermediate Frequency Amplifier

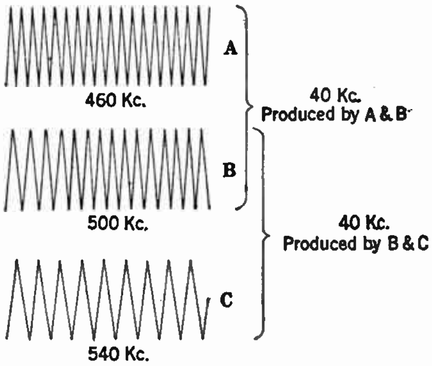
CHOOSING THE BEST FREQUENCY

THE best operating frequencies for intermediate-frequency amplifiers are, 45, 55, 65, etc. rather than 40, 50, or 60. kc.

At the present time, broadcasting stations are supposed to be separated by a frequency of 10 kilocycles. Consequently, it is quite possible for any two stations to be separated, by, say, 40 kilocycles. If two stations, one strong and the other weak, are separated by this amount, it may be quite difficult to completely separate them by means of a single tuned circuit such as a loop. Therefore, both of these frequencies will be present in the loop circuit, and will beat with each other to produce a frequency equal to the difference between their respective frequencies. That is, a station on 500 kilocycles would heterodyne a station on 460 kilocycles to produce a 40-kilocycle note.

Should the intermediate-frequency amplifier happen to be tuned to this frequency, both stations will be heard in the output, even though the oscillator is removed from the circuit. If, on the other hand, the intermediate frequency amplifier is tuned to 45 kilocycles, only the heterodyne beat between the station wanted and the oscillator would be amplified.

We have endeavored to show this idea in the diagram where a 40-kc. intermediate amplifier is used: "A" is the interfering station, "B" is the station desired, and "C" is the wave produced by the oscillator. C is tuned to 540 kilocycles and produces a 40-kc. beat note or heterodyne with the desired signal B which is fed to the intermediate-frequency amplifier. However, at the same time, we will suppose that there is a powerful local station operating on 460 kilocycles (indicated at A), and the interaction between A and B also produces a 40-kilocycle beat note. The result is, that the station broadcasting on 460 kilocycles will also be heard through the amplifier. When stations whose frequencies are multiples of 10 heterodyne, they naturally produce a beat note which also is a multiple of 10. By designing the intermediate amplifier for a frequency which is not divisible by 10, it will, therefore, exclude beat notes of two heterodyning stations if such are divisible by 10. Hence the desirability of a 45-, 65-, or 65-kc. intermediate amplifier.



No. 62 RADIO BROADCAST Laboratory Information Sheet

Antenna Power Dissipation

DISTRIBUTION OF ENERGY

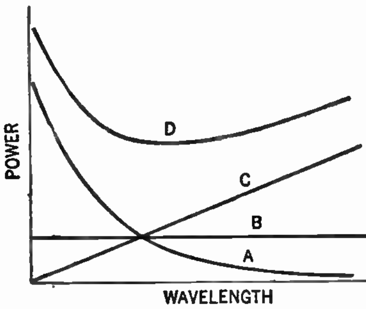
THE power supplied by an oscillator to a transmitting antenna, is dissipated in three ways: First, in the form of radiation; second, in the form of heat due to resistance of the wires in the circuit; third, in the form of heat due to dielectric absorption.

Only the first of these factors represents a useful dissipation. This radiation is the power which travels out from the antenna in the form of electromagnetic waves (as signals). Curve A in the accompanying drawing shows how the radiated power varies with the wavelength, it being proportional to the square of the antenna current, and inversely proportional to the square of the wavelength.

Curve B represents the power used up in the resistance of the wires. This is a straight line and does not vary with the wavelength. In actual practice, the eddy current loss and skin effect might be slightly greater at the lower wavelengths, but the variation is so small that it may be neglected.

Curve C illustrates the variation with wavelength of the power absorbed in the dielectric, and, since this absorption is proportional to wavelength, the curve is a straight line. This loss is due to trees, buildings, masts, or other objects in the vicinity of the antenna which absorb power.

Curve D represents the total power in the antenna, and is equal to the sum of the three separate curves. In taking curves such as this on an antenna, it is quite possible to obtain humps at certain wavelengths. This generally indicates the presence of some circuit in the vicinity of the antenna with a natural period of oscillation at that wavelength.



No. 63 RADIO BROADCAST Laboratory Information Sheet

Line Power-Supply Devices

CALCULATION OF RESISTANCE VALUES

IN ORDER to obtain four output voltages from a line power-supply device we will place four resistances, R_1, R_2, R_3, R_4, in series across the total output of the device. One end of R_1 will connect to the negative B and one end of R_4 will connect to the maximum voltage terminal of the device.

The positive voltage tap, E, for the detector (22½ or 45 volts) will be taken off between R_1 and R_2. The voltage, E_2 (generally 90 volts), for an r.f. amplifier, will be taken off between R_2 and R_3. Voltage E_3, with a value of, say, 135 volts, will be obtained from a tap connected between R_3 and R_4. E_4 is the maximum voltage of the unit.

In order to calculate these resistance values, we must assume that a certain amount of current flows through the resistance R_1. An average value that can be assumed is 5 milliamperes, or 0.005 amperes. If we assume this current to flow through R_1, and that we desire 22½ volts for the detector, then $R_1 = 22.5 \div 0.005 = 4500$ ohms. If the voltage required is to be 45, then $R_1 = 45 \div .005 = 9000$ ohms.

The voltage across R_2 is 90 — 22½ = 67½, and as the detector plate current at 22½ volts is usually about 0.0005 amperes, this current, plus the 0.005 amperes loss current, flows in R_2, hence $R_2 = 67.5 \div 0.0055 = 12,300$ ohms approximately. In the case of 45 volts on the detector the R_2 voltage would be 45 (90 — 45) but the detector plate current at 45 volts is now about 0.001 amperes, hence $R_2 = 45 \div 0.006 = 7500$ ohms.

To determine the current in R_3, we must know the plate current taken by all the tubes operating at 90 volts. Assuming there are two r.f. tubes (UV-201-A) only, the current taken by each when biased at 4.5 volts is 0.002, or 0.004 for both. The voltage across R_3 is 135 — 90 = 45, and the current flowing in R_3 is 0.005 + 0.0005 + 0.004 (for a detector plate voltage of 22½), therefore $R_3 = 45 \div 0.0095 = 4750$ ohms approximately. In the case of 45 volts on the detector plate, with 0.001 amperes flowing, we have $R_3 = 45 \div 0.01 = 4500$ ohms.

The current in R_4 is the sum of all the currents plus the current in the plate of the first audio tube (UV-201-A). The plate current in an UV-201-A at 135 volts with 9 volts negative bias is 0.0025 amperes and, in the case of 22½ volts detector, the total current in R_4 is 0.0005 + 0.005 + 0.004 + 0.0025 or 0.012 total. The voltage across R_4 is 400 — 135 = 265. Hence, $R_4 = 265 \div 0.012 = 22,000$ ohms approximately.

CASE 1.

1 UV-201-A Detector, 22½ volts.
2 UV-201-A R. F. 90 volts, Neg. bias 4½.
1 UV-201-A A. F. 135 volts, Neg. bias 9.
1 UX-210 A. F. 400 volts, Neg. bias 30.
$R_1 = 4500$, $R_2 = 12,300$, $R_3 = 4750$, $R_4 = 22,000$

CASE 2.

Same as above except 45-Volt Detector.
$R_1 = 9000$, $R_2 = 7500$, $R_3 = 4500$, $R_4 = 21,200$

No. 64 RADIO BROADCAST Laboratory Information Sheet

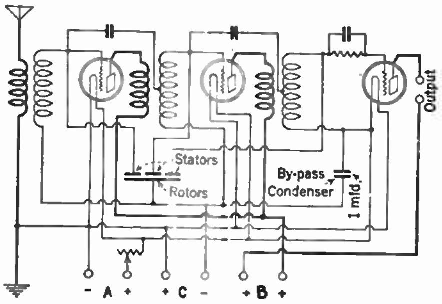
The Gang Condenser

CORRECT CONNECTIONS

SINCE the appearance on the market of gang condensers, that is, condensers having a common shaft and working in unison, many readers have requested information as to how they should be connected. The difficulty in connecting them usually arises from the fact that all of the rotor plates are connected together, thus making it impossible to get a positive return lead for the detector tube, while the radio frequency tubes of necessity must be negatively baised.

By looking at the diagram, it will be noticed that the filament return of the detector tube coil does not connect to the variable condenser but to the positive filament lead. A path for the radio frequency current is provided through the bypass condenser, as shown, to the tuning condenser. An alternative way of connecting is to allow the coil to be connected to the condenser, making the grid positive by connecting the grid leak directly between the grid of the tube and the positive filament. The grid condenser prevents the short circuiting of the batteries.

When a gang condenser is used, the coils must be carefully matched in order to minimize any inequalities between them. In spite of careful matching, there are bound to be some discrepancies, and it is frequently necessary to use a separate condenser in the antenna circuit, as outlined in Laboratory Sheet No. 33. Some gang condensers are provided with small condensers in parallel with the main condensers, which may be used to bring each circuit into exact resonance.



No. 65 RADIO BROADCAST Laboratory Information Sheet

The Vacuum-Tube Voltmeter

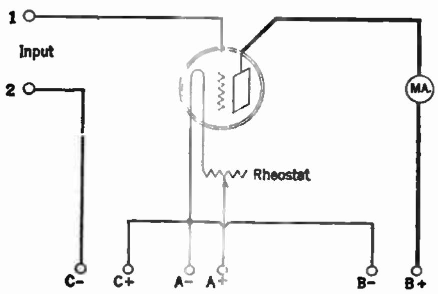
HOW IT FUNCTIONS

THE vacuum-tube voltmeter is a very useful instrument and it finds wide use in an electrical laboratory. The simpler type is not at all difficult to make up, and with it some interesting measurements can be made. For best results it should be calibrated, but even without calibration it is still possible to make many measurements with it that will give a general indication of the comparative merits of different coils, amplifiers, and other units, etc.

The circuit diagram of a vacuum-tube voltmeter is given on this Sheet. The B-battery voltage need not be more than 22½ volts, and the indicating instrument in the plate circuit should have a maximum scale reading of not more than 1½ milliamperes. The C-battery voltage should be adjusted until the meter reads about $\frac{1}{10}$th of a milliampere when the terminals 1 and 2 are short-circuited.

The tube is now being operated on the lower bend of its characteristic curve, similar to the condition under which a C-battery detector operates. Now, if any voltage, whether it be direct or alternating, is impressed across the input terminals, the plate current will change. If a calibration is to be carried out, it is accomplished by impressing various known values of voltage across the input terminals and reading the corresponding deflections of the plate milliameter. Then, if the input terminals are connected across any unknown voltage it is possible to determine the value of this voltage by noting the deflection of the plate milliameter. The actual voltage is obtained from the previously made calibration curve.

As mentioned, even if instruments are not available with which a calibration can be made, it, is possible to make comparative tests. For instance, by placing the same input on two amplifiers under test and then connecting the vacuum-tube voltmeter across the output of each, readings may be obtained. Obviously, the amplifier which produces the greatest deflection has the greatest amplification.



No. 66 RADIO BROADCAST Laboratory Information Sheet

A Radio Frequency Oscillator

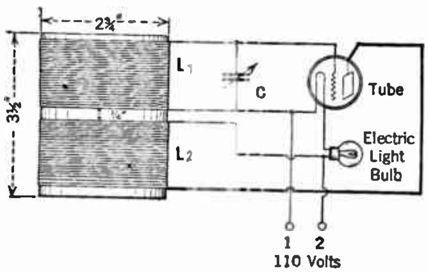
ITS USE AND CONSTRUCTION

A DIAGRAM of a simple oscillator that takes all of its energy from the power mains is given on this Laboratory Sheet. A unit such as this is quite useful to the home-constructor in making many tests on receivers. It sends out energy in much the same way as any broadcasting station, and it can be tuned to deliver this energy at any frequency between 500 and 1500 kc. (600 and 200 meters). It makes use of a 201-A tube and will operate on either 110 volts a.c. or d.c. If the latter is used, the device will only function when terminal No.2 is connected to the positive side of the line.

The coils, L_1 and L_2 may be wound on a single piece of tubing 3½ inches long, having an outside diameter of 2¾ inches. L_1 consists of 50 turns of No. 26 d.c.c. wire, and L_2, spaced ¼ inch from L_1, consists of 40 turns of the same size wire. Both coils are wound in the same direction.

The condenser, C, should have a maximum capacity of 0.0005 mfd. An ordinary electric light bulb of 25 watts rating is shown in the circuit. If by any chance the oscillator is to be used on a 220-volt circuit, the electric light bulb should be replaced by one suitable for use on this voltage, and should be rated at 50 watts.

If this oscillator is supplied with alternating current and is placed within a few feet of a receiver, it will be possible to tune-in the signal generated by it if the receiver is in good condition. The note heard will be a low-pitched hum. If the unit is supplied with direct current it will not be directly audible. However, if the receiver is of the regenerative type it will be possible to produce a heterodyne whistle, when the set is oscillating.



No. 67

RADIO BROADCAST Laboratory Information Sheet

171 Tube Characteristics

PLATE IMPEDANCE

THIS Laboratory Sheet will explain how to determine the plate impedance, or output resistance, of a tube by using figures that can be obtained from the static characteristics. Specifically does it deal with the 171 type tube. The plate impedance is equal to the change in plate voltage divided by the corresponding change in plate current. We will calculate the plate impedance of a 171 tube using the static characteristic curves given on Laboratory Sheet No. 68.

EXAMPLES:

No. 1. What is the plate impedance of a 171 tube with 180 volts on the plate and a negative grid bias of 40.5 volts?

See curve 5 on Sheet No. 68. The X indicates that point on the curve corresponding to the condition given in the example (*i. e.*, 180 volts on the plate). The impedance is determined by first of all reading from the curve two different plate currents corresponding to two different plate potentials, with the same grid bias in each case. Any plate voltages may be taken provided we stay on the straight portion of the curve. Therefore, we might take plate voltages of 170 volts and 190 volts, corresponding to plate currents of 15.8 mA. and 26 mA. The change in plate voltage is 190–170 = 20 volts, and the change in plate current is 26 - 15.8 = 10.2 mA. Therefore, the plate impedance of the 171 is equal to the change in plate voltage (20), divided by the change in plate current (10.2 mA., or .0102 amperes) which equals 1961 ohms. This value corresponds very closely to that given for the UX-171 (2000 ohms) in Laboratory Sheet No. 58, in the January issue.

No. 2. What is the plate impedance of a 171 tube with 135 volts of B battery and a grid bias of minus 27 volts?

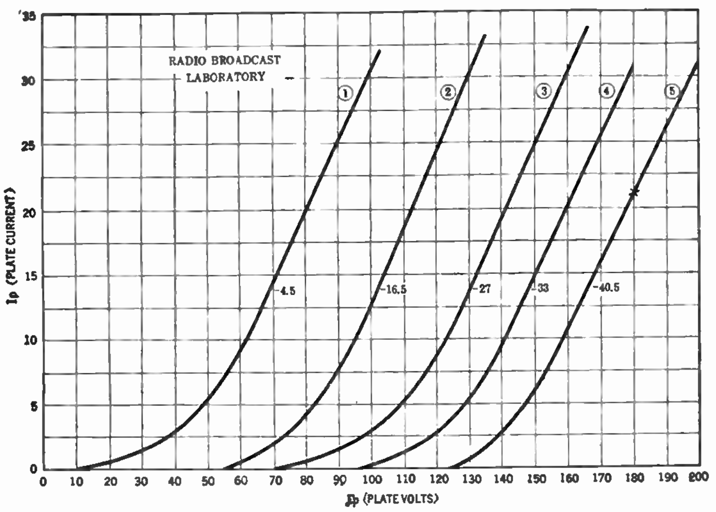
Refer to curve No. 3 and take any two plate voltages in the straight position of the curve, say 130 and 160 volts. The corresponding plate currents are 13.8 mA. and 30.3 mA. The plate-voltage change is 160 - 130 = 30 volts, and the plate-current change is 30.3 - 13.8 = 16.5 mA. Therefore, the plate impedance is 30 volts divided by 16.5 mA., or 0.0165 amperes, which gives 1818 ohms as the plate impedance.

Mathematically, it is evident that what we are determining is the reciprocal of the slope of the curve. The plate impedance is constant over the straight position of the curve. It is also apparent from an inspection of the curves that the output resistance or plate impedance is practically the same for all values of plate voltage, the slope of the curves being nearly the same.

No. 68

RADIO BROADCAST Laboratory Information Sheet

Curves for the Type 171 Tube



No. 69

RADIO BROADCAST Laboratory Information Sheet

Sources of Electrons

THE HEATED FILAMENT

THE commonest source of electrons with which the home-constructor is familiar is the filament of an ordinary vacuum tube. Present theory regarding metals indicates that they are made up of atoms, which are, in turn, composed of electrons. These electrons are in violent motion and it might be expected that some of them would leave the metal, but there is an opposing force which holds them in position at ordinary temperatures. If the metal is made hot, however, the velocity of the electrons increases to a very great extent, and some of them do leave the metal. The easiest way to heat the metal is to make it in the form of a wire and send an electric current through it. This creates an excellent source of electrons. It is unquestionable that, by far the most important way, of obtaining electrons commercially, is through the heating of a wire. This method is used to obtain a source of electrons in vacuum tubes.

The vacuum tube was not a very useful instrument at first until it was found that by placing a metal grid between the filament and the plate, the number of electrons passing to the plate could be controlled. Some years after this first discovery, it was found that the vacuum tube would act as an amplifier of weak electric impulses, such as telephone currents. The three-element tube, as it is called, has opened up an entirely new field of research and is doubtlessly one of the most important tools in the hands of science.

There are, however, other sources of electrons which are used to a considerable extent in scientific practice. It has been found that some metals will give off electrons if they are placed in a strong light. This is true of zinc, as an example. Under ordinary light zinc does not give off many electrons, but under the influence of light of very short wavelength, such as ultra violet light, it will give off electrons quite rapidly. This effect is known as the photo-electric effect. Other metals, such as potassium, are very sensitive to light in the visible part of the spectrum. Potassium is, therefore, used in some photo-electric cells where its function is to control electric currents in proportion to the amount of light that is permitted to fall on it. The photo-electric cell is one of the most important units used in a picture transmitting system. The effect produced in the cell is of interest to physicists because of the information it can give them regarding the nature of the electron.

No. 70 — RADIO BROADCAST Laboratory Information Sheet

Soldering

ESSENTIALS FOR GOOD WORK

IF A receiver is to operate efficiently and quietly it is essential that all of the soldered joints be securely made. Soldering is an exceedingly important operation in wiring a receiver and poor soldering is doubtlessly a frequent cause of trouble.

The ordinary solder consists of a combination of lead and tin, the percentages generally being 50 per cent. lead and 50 per cent. tin. In order to make a good joint, the surfaces to be soldered should be entirely free from oxides. Soldering flux will prevent the formation of oxides while the heat is being applied. The metal parts which are to be soldered should be scraped clean before the flux is applied and, under proper conditions, the solder will flow very easily around the joint when the parts have been heated sufficiently.

If the soldering is correctly done, the solder will appear bright after the joint is made, but a poor joint made with a cold iron will generally leave the solder with a somewhat crystaline structure. Some fluxes should be used very sparingly in making the joint, as they will conduct electric currents and will also have a very detrimental effect on any insulation with which they come in contact. Rosin is a very excellent flux to use, although it is somewhat more difficult to work with than the ordinary soldering paste. It is standard practice in most large electrical companies to use rosin flux almost exclusively, since it has no bad effects on insulation. When rosin is the flux it is important that a very hot iron be used, otherwise, what is called a rosin joint may be produced, in which case there is a thin layer of rosin left between the two metal surfaces. This makes the electrical conductivity of the joint very poor if it does not completely prevent the flow of current.

As mentioned above, it is essential that the iron be sufficiently hot if a good job is to be done. A hot iron will also, in many cases, prevent other troubles. If soldering is attempted with an iron that is not hot enough, it is necessary to hold the iron on the metal for a long time before the solder becomes sufficiently hot to melt and, during this procedure, much of the heat energy is wasted. With a hot iron, the heat, although more intense, is confined to a smaller space because the job is completed quickly. This is important when we are, as an example, soldering a lead to a lug on a transformer. In such a case it is essential that the job be done quickly so as to prevent heating the lug to such an extent that the lead from the winding which connects internally to the other end of the lug will not come unsoldered and thus cause the circuit to be broken.

No. 71 — RADIO BROADCAST Laboratory Information Sheet

Push-Pull Amplification

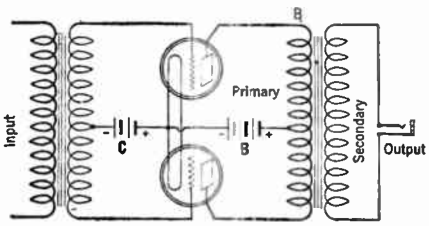
WHY IT IS USED

TRANSFORMERS are not the only source of loss of quality in audio amplifiers. The tube itself can introduce a certain amount of distortion, although this distortion is generally quite small.

The effect of the curvature of the tube characteristic is to introduce in the plate circuit, for each frequency applied to the grid, a new current of twice that frequency. The relative strength of these double frequency currents must be kept small, otherwise the quality will suffer. In order to keep them small, a large impedance must be used in the plate circuit, which will tend to straighten out the tube characteristic. It is also essential that there be enough C battery always to keep the grid negative, and then again, enough B battery must be used to permit operation on that portion of the characteristic curve which has the least curvature. It should be obvious that, as each successive tube in an amplifier has to handle more current than the one before it, the tubes in the last stage must be rated at, or must be capable of, handling greater power than the earlier stages of amplification.

The effect of the curvature of the plate characteristic can be canceled out by using the so-called push-pull transformers. The sketch on this Sheet indicates the scheme of connections of a push-pull amplifier. Briefly, its usefulness is due to the fact that the phase relations of the double frequency currents produced by the tube characteristic are such as to cause them to cancel out in the transformer primary and not to appear across the transformer secondary.

The design of a push-pull transformer is important, and unless the same care is taken in designing as with an ordinary transformer, the actual results obtained will not make the push-pull arrangement worth while. It is essential that a push-pull transformer have a very high impedance primary and that the frequency characteristic of the transformer be reasonably flat.



No. 72 — RADIO BROADCAST Laboratory Information Sheet

A. C. Operated Power-Supply Devices

TROUBLE SHOOTING

THIS Laboratory Sheet will give briefly possible sources of trouble in line power-supply devices (B-battery eliminators).

Quite frequently it is found that a hum is audible in the output of the receiver when it is operated from a power device. This hum need not necessarily indicate poor design, and may be due entirely to mechanical vibration. It can be eliminated by moving the device further from the receiver, or by placing the receiver on top of several layers of soft cloth.

Trouble in the power-supply unit may be the result of breakdown of one of the filter condensers, the breakdown of one of the resistances controlling the intermediate voltage taps, a defective rectifier, or to open connections. In testing the device, a voltmeter is essential. It should be connected between the negative post and the various taps, and if one of the taps gives no reading, the trouble is probably due to a defect in the resistance unit supplying that tap. This is not an uncommon cause of trouble and, therefore, good resistances, capable of carrying the required current without excessive heating, must be used.

Defective resistances are also capable of creating home-made "static." If reception is accompanied by considerable noises when using the power-supply device, the antenna should be disconnected and, if the noise persists, and the connections and joints should be carefully examined. Be sure that the A-battery terminals are not corroded. If possible, substitute for the power unit good dry B batteries, and if there is no noise, it is a good indication that the line power-supply device is causing the trouble. Defective resistances are the commonest cause of this noise and they should be carefully examined.

If no voltage readings can be obtained on any terminals, the rectifier tube should be examined. Make sure that the filament has not burned out, or, if the rectifier is of the electrolytic type, be sure that it contains sufficient solution. The filter condensers, if possible, should be tested with phones and B battery to make sure they have not broken down. The same test can also be made on the choke coils to be sure that they have not been burned out, and in this way an open circuit created.

If all the connections appear to be complete and the apparatus in good condition it will be best to try a new rectifier tube in the correct socket. Rectifiers in which a filament is used are constructed in the same manner as are ordinary receiving tubes, and the fact that they light does not necessarily indicate that they are functioning in a satisfactory manner. Rectifier tubes are counted upon to supply comparatively large currents and must be extremely well made with very sturdy filaments if they are to last any great length of time.

The fact that we are powering our receiver from a line power-supply device does not mean that it does not require attention, or that the parts are going to last forever. The rectifier device may wear out after considerable use, and the condensers will sometimes break down as they become old.

No. 73 Radio Broadcast Laboratory Information Sheet

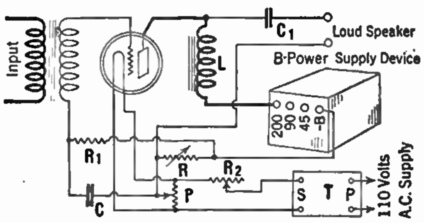
An A. C. Operated Power Amplifier

CONNECTION TO AN ORDINARY RECEIVER

MANY standard a.c. operated power-supply devices available at present are capable of supplying sufficient voltage for the proper operation of a 171 type tube. When this tube is used in conjunction with such a device in an ordinary receiver, the filament is usually lighted from a storage battery, and a dry cell is used to bias the grid of the tube. A few slight changes, however, will make it possible to light the filament of the 171 from an a.c. source and to obtain the necessary grid bias by means of a resistance in the plate circuit of the tube.

The following parts will be required:
T—An ordinary bell transformer giving about 6 volts on the secondary.
P—200-ohm potentiometer.
R—500- to 5000-ohm variable resistance.
R_1—25,000-ohm fixed resistance.
C_1—2- to 4-mfd. bypass condenser.
C—1-mfd. bypass condenser.
R_2—10-ohm rheostat.
L—Output choke coil.

A circuit arrangement such as is shown makes the one-stage power amplifier entirely independent of any local supply of energy, since all the necessary voltages are now being drawn from the a.c. power lines. In the operation of the unit, the potentiometer, P, should be adjusted to that point at which the hum in the output circuit is at a minimum. Generally it will be found that the center point of the potentiometer will give minimum hum.



The variable resistance, R, controlling the grid bias, should not be lowered to a value less than 1000 ohms. It should be adjusted to that value (something above 1000 ohms) which gives the best quality of reproduction.

No. 74 Radio Broadcast Laboratory Information Sheet

Resistance-Coupled Amplifiers

GRID LEAK-CONDENSER COMBINATIONS

SOME information regarding resistance-coupled amplifiers is to be found in an article by Sylvan Harris published in the December, 1926, issue of the *Proceedings of the Institute of Radio Engineers*, and, incidentally, the data given in the proceedings confirm some calculations and measurements made by the Laboratory of Radio Broadcast about a year ago.

When a mathematical analysis is made of the resistance-coupled amplifier, it becomes evident that a very large coupling condenser need not necessarily be employed. It is the combination of the coupling condenser and the grid leak which determines the quality that can be obtained from such an amplifier. If the coupling condenser is made large, the grid leak resistance may be made small, and if the coupling condenser is small, the grid leak resistance can be increased a proportional amount, and the same frequency characteristic will be obtained in each case.

In the article in the Institute's organ, some curves were given showing the relationship between the value of the grid leak resistance and the size of the coupling condenser for a 201-A type tube. From these curves we can easily determine what value of coupling condenser must be used in conjunction with any particular grid leak, in order to obtain a certain definite frequency characteristic.

If a 100,000-ohm resistance is used in the plate circuit, the following combinations of grid leaks and coupling condenser may be used to obtain a practically flat characteristic curve down to 50 cycles:

GRID LEAK	COUPLING CONDENSER
0.2 megohm	0.06 mfd.
0.5 megohm	0.025 mfd.
1.0 megohm	0.012 mfd.
2.0 megohms	0.006 mfd.

The greatest trouble with resistance amplifiers is due to the blocking of the tubes which sometimes takes place. It is unlikely, however, that this blocking will occur unless one of the tubes is being overloaded. This makes it essential that the proper C-battery bias be used on the grids of the various tubes. It is possible to calculate the required value of the grid bias if the characteristics of the circuit and the amplification constants of the tubes are known. These calculations indicate that for a 20-mu tube the C battery bias on the first high-mu tube should not be more than 1 volt, and that 4 volts is about right on the grid of the second high-mu tube. These values are high enough to handle a grid swing of 40 volts peak value on a 171 type power tube in the last stage.

No. 75 Radio Broadcast Laboratory Information Sheet

Interference Finder

A PORTABLE RECEIVER

ON LABORATORY Sheet No. 76 is given a circuit diagram of a small portable receiver for use in locating sources of interference. In order to make up this receiver, the following apparatus is necessary:

L—Any standard loop, tapped at the center.
C_1—Variable condenser designed for operation with the loop that is used. Any value between 0.00025 mfd. and 0.0005 mfd. is satisfactory.
R_g—4-megohm grid leak.
C_2—0.00025-mfd. grid condenser.
C_3—Midget condenser, 0.00015 mfd. max.
T_1, T_2—Audio-frequency transformers.
J—Single-circuit filament control jack.
R—20-ohm rheostat.
L_2—Radio-frequency choke coil which may consist of 400 turns of No. 32 or smaller wire wound on an ordinary spool.

To operate this receiver the following accessory equipment is necessary:

Three ordinary dry cells for the filament circuit; one small 45-volt battery for the plate circuits of all three tubes.

Three 199 tubes.

The receiver is of the ordinary regenerative type. The condenser, C_1, controls the tuning, while condenser C_3 controls the amount of regeneration. When C_3 is advanced near to its maximum position the detector tube will oscillate so that stations may be picked up by a heterodyning whistle.

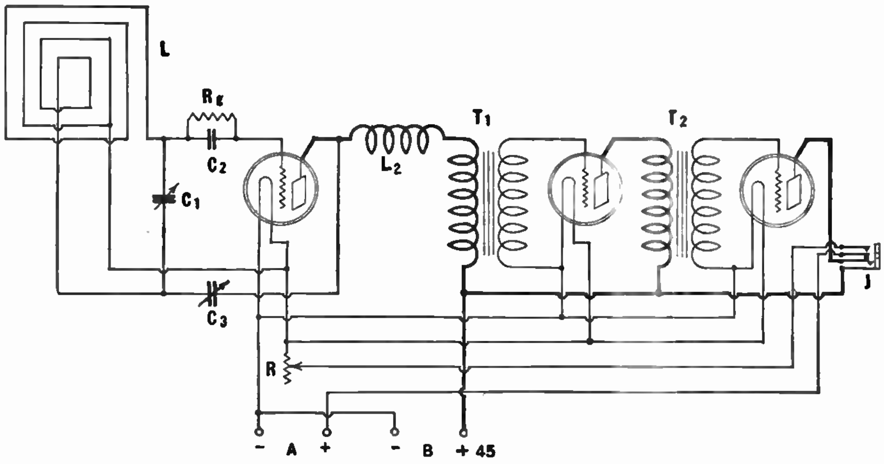
The loop should be mounted so that it can be turned in any direction. It will be found that the loop is very directional and that, therefore, in interference investigations, the interference will be picked up loudest when the loop is pointing toward the source. In this way the actual source of interference can often be located.

The receiver should be made extremely portable and, for this reason, it is preferable to enclose the batteries and loop, as well as the receiver, in a small carrying case that can be easily handled. The receiver should be equipped with a jack into which a separate loop unit may be plugged, or the loop may be wound inside the case itself. The filament rheostat controlling the tubes should not be advanced further than necessary to obtain satisfactory reception since excessive filament voltage on the 199 tube is very detrimental. It will be found that three ordinary dry cells used for filament lighting will last for many months.

No. 76

RADIO BROADCAST Laboratory Information Sheet

Interference Finder



No. 77

RADIO BROADCAST Laboratory Information Sheet

Interference Elimination

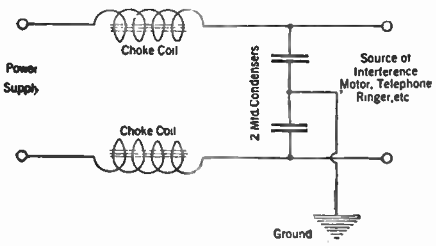
USE OF CONDENSERS AND CHOKES

WHEN interference is experienced from motors, telephone ringers, or other similar apparatus, it may frequently be eliminated by using some such circuit arrangement as is illustrated on this Sheet.

This circuit is called a filter, and can easily be connected to practically any piece of apparatus that is causing interference. If, for example, a motor is found to be causing the interference, such may be eliminated by connecting two condensers across the line terminals of the motor with the mid point grounded, as illustrated in the sketch. The values of the condensers should, in general, not be less than 2 mfd., although smaller size condensers will sometimes give satisfactory results.

In extreme cases of interference, where it is found that the condensers shunted across the line with their mid point grounded do not remedy the trouble, the inclusion of choke coils in series with the line is necessary. These choke coils must be fairly large and wound with wire large enough to carry the full current in the line. The shunting condensers and the choke coils, if they are used, should always be placed as close to the source of interference as possible. The source of interference is not always obvious, and, for that reason, it is advisable first to make some simple tests to make certain of the cause. In such an investigation the small portable receiver described on the Laboratory Sheets Nos. 75 and 76 will be found very useful.

Before installing any condensers, one should make certain that they have a rating sufficiently high enough to withstand the voltages under which they



must operate. There will be little difficulty in obtaining satisfactory condensers for use on direct-current circuits since there are many on the market rated at as high as 1000 volts d.c. Frequently these same condensers are not satisfactory for use on a. c. circuits, however, and consequently, if the device to be shunted is operated from a.c., make sure that the condensers used have a satisfactory a.c. rating.

No. 78

RADIO BROADCAST Laboratory Information Sheet

The Volt, Ampere, and Ohm

DEFINITIONS

WE ARE giving below an explanation and meaning of the common terms, the volt, the ampere, and the ohm. Hydraulic analogies will be used in explaining the first two of these terms.

AMPERE: A current of water in a pipe is measured by the amount of water that flows through the pipe in a second, such as 1 gallon per second, or 10 gallons per second, etc. Electricity is measured by the amount of current that flows along a wire in one second. This quantity is known as the coulomb, and if this term is used we would express the current as 1 coulomb per second or 10 coulombs per second, etc. In electricity, however, we have a special name for the rate of flow of 1 coulomb per second which we call 1 ampere. Thus, 8 amperes is the same as 8 coulombs per second. Ampere, then, is a term defining the quantity of current that is flowing per unit of time.

VOLT: The number of gallons per second of water flowing in a pipe, or the number of amperes flowing in a wire, depends upon the pressure under which it flows. The electrical unit of pressure is the volt. A volt means the same thing in speaking of a current of electricity that a pound pressure means in speaking of a current of water. It follows then that the greater the pressure (voltage at the supply, the greater will be the flow of current.

OHM: There is no hydraulic unit which corresponds to the ohm, which is a measure of the resistance of a wire to the flow of current. A wire is said to have 1 ohm of resistance when a pressure of 1 volt will cause a current of 1 ampere to flow through it. If the resistance were doubled, the current would be halved, etc.

According to the definitions given on this Sheet, then, we see that amperes represent the amount of current, volts the pressure causing this current to flow, and ohms the resistance impeding the flow of current. These three units bear a definite relation to each other. This relationship, named after the scientist who discovered it, is known as Ohm's Law, which states that the number of amperes flowing in a circuit is equal to the voltage of the circuit divided by its resistance. An explanation of Ohm's Law is given on Laboratory Sheet No. 81.

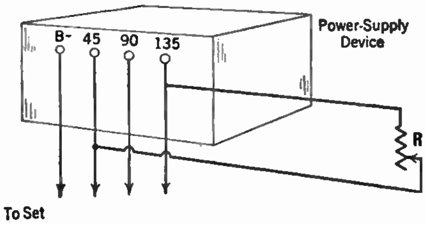
No. 79 RADIO BROADCAST Laboratory Information Sheet

Regulating Voltage on B Power-Supply Device

USE OF RESISTOR

MANY commercial a. c. operated power-supply devices are equipped with taps for supplying different voltages suitable for use in conjunction with the detector, amplifier, etc. The voltage obtained from any tap on such a device is not constant but varies with the amount of current that is drawn from it. If an unusually heavy load is drawn from any one of the taps, it will generally be found that the voltage is somewhat less than the specified amount. In such a case, it is possible to increase the voltage on the particular tap which is low by connecting an external resistance between the tap whose voltage is low and the maximum voltage tap on the device. The proper connections for this resistance are indicated in the diagram, and, by the proper variation of this resistance unit, it will be found possible to obtain any value of voltage that might be required. This method of increasing the voltage on any tap is very simple, since it does not require that the power-supply device be opened and the internal resistances varied.

It should be noted that the resistance does not connect between the two adjacent taps but that it is connected between the 45-volt tap and 135-volt tap which, in this particular case, is supposed to be the maximum voltage tap on the device. This method of increasing the voltage on any tap was suggested



in the December issue of the General Radio *Experimenter*.

The resistance should be variable between 5000 and 50,000 ohms, and must be of a type satisfactory for use in power-supply devices.

No. 80 RADIO BROADCAST Laboratory Information Sheet

Characteristics of Tubes

MEASURING THE AMPLIFICATION CONSTANT

LABORATORY Sheet No. 68 (February, 1927) gave some characteristic curves of the 171 type tube, and Sheet No. 67 explained how the plate impedance of the tube might be calculated using these curves. The present Sheet will explain how to calculate the amplification constant.

The amplification constant is the measure of the effect of the grid voltage on the plate voltage. Stated as a formula, the amplification constant equals:

$$\frac{\text{CHANGE IN PLATE VOLTAGE}}{\text{CORRESPONDING CHANGE IN GRID VOLTAGE}}$$

We are giving two examples below which will make simple the calculation of the amplification constant of any tube provided its characteristic curves are available.

EXAMPLE 1: Calculate the amplification constant of a 171 using the curves given on Laboratory Sheet No. 68. In this example we shall use curves Nos. 2 and 3. Locate some point on curve No. 2; in this example we are taking the point corresponding to 100 volts, although any point might be taken provided we stay on the straight portion of the curve. We find that at this point, corresponding to 100 volts, the plate current is 12.5 milliamperes. Following across the horizontal line corresponding to this plate current until we come to curve No. 3, we find that the corresponding plate voltage on this curve is 128. We now have two voltages, 100 and 128, corresponding to two different grid biases, 16.5 and 27. Both of these values are for the same value of plate current. These values can be substituted in the above formula as follows:

$$\frac{128-100}{27-16.5}=\frac{28}{10.5}$$

Solving this formula, we get a value of 2.67, which is the amplification constant of this particular 171 type.

EXAMPLE 2: Find some point on curve No. 4, taking that point corresponding to 160 volts as an example. In this case a plate current of 20.3 milliamperes is obtained. Following across to the corresponding plate current on curve No. 5 we find that the plate voltage is 179. The difference in plate voltage between these two points is 19 and the difference in grid bias is 40.5 minus 33, or 7.5. Dividing these two, we obtain a value of 2.54, the amplification constant of the 171.

It should be noted that this latter result is somewhat different from that given in the preceding example due to the fact that the tube was considered to be operating under different voltages. The amplification constant varies slightly for different plate voltages, but the variation over the operating range of plate and grid voltages is not usually more than 10 per cent.

No. 81 RADIO BROADCAST Laboratory Information Sheet

Ohm's Law

SOME EXAMPLES

IF A tube's filament has a resistance of 20 ohms and five volts are applied to it, a current of ¼ ampere will flow. If the filament resistance is one half this figure (10 ohms), then the current, for the same applied voltage, will be twice as large, or ½ ampere.

To determine these currents, we have used a fundamental relationship regarding the current, voltage, and resistance of any circuit, known as Ohm's Law, which states that the current in a circuit is always exactly proportional to the voltage and inversely proportional to the resistance. Therefore, in the above example, halving the resistance doubled the current, and doubling the resistance would have halved the current. Inversely, doubling the voltage doubles the current, and halving it gives half the current.

These facts can be expressed in the form of a simple algebraic equation as follows:—

$$(1).\quad I=\frac{E}{R}$$

in which I is the current in amperes, E the voltage, and R the resistance in ohms.

The equation shows that the current is equal to the voltage divided by the resistance. It can be rearranged so as to make it easy to solve for voltage or resistance as well as current.

To determine an unknown voltage, use the equation in the following form:

$$(2).\quad E=I\times R$$

For determining an unknown resistance:

$$(3).\quad R=\frac{E}{I}$$

Let us take up a few simple examples in which these equations are used.

EXAMPLE 1:

A tube's filament has a resistance of 20 ohms, and its rated voltage is 5. What current does it require?

In the problem the voltage and resistance are given and we can substitute in equation number 1 as follows

$$I=\frac{E}{R}\ \therefore\ I=\frac{5}{20}=0.25 \text{ Amperes}$$

EXAMPLE 2:

If a 199 tube filament takes 0.06 amperes at 3 volts, what is its resistance?

Using formula No. 3.

$$R=\frac{E}{I}\ \therefore\ R=\frac{3}{0.06}=50 \text{ Ohms}$$

EXAMPLE 3:

A filament is designed with a resistance of 4 ohms, and its rated current is 1.25 amperes. What voltage must be placed across the tube to make the rated current flow?

Using formula No. 2, we have:

$$E=I\times R\ \therefore\ E=1.25\times 4=5 \text{ Volts.}$$

No. 82 — RADIO BROADCAST Laboratory Information Sheet

Oscillation Control

A COMPARISON OF TWO COMMON METHODS

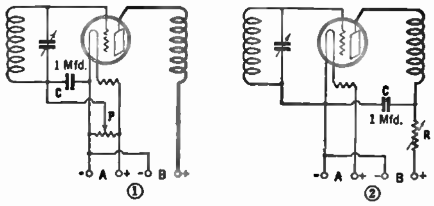
IT IS the purpose of this Laboratory Sheet to compare two methods commonly used to control oscillations in the radio-frequency amplifiers of receivers.

The first method to be discussed is that using a potentiometer to vary the bias on the grid of the tube. This method is illustrated in Fig. 1, in which P is the potentiometer, and C is a bypass condenser functioning to bypass the radio-frequency energy directly to the negative filament.

When the potentiometer arm is connected to the negative side, the amplifier operates most efficiently and the result is that it oscillates. To prevent the oscillations from occurring, the potentiometer arm is moved toward the positive side and this makes the grid positive, lowers the efficiency of the circuit, and thereby prevents oscillations.

The second method is indicated diagramatically in Fig. 2, in which case the oscillation control is a variable resistance, R, in the plate circuit of the tube. In this case a bypass condenser is again used to bypass the radio-frequency energy to the negative filament. This oscillation control functions by lowering the value of voltage impressed on the plate of the tube. In this manner the plate impedance of the tube is increased and oscillations prevented.

The second method is to be preferred over the first since it has several distinct advantages. In the first place the plate current consumption, using the second method, is quite low, whereas, in the first method, in order to prevent oscillations it is necessary to make the grid positive, which causes the plate current to increase to comparatively large values. The second method does not lower the



selectivity of the receiver. This is not true of the first method because, when the grid becomes positive, a load is placed on the tuned circuit, and the resistance of the circuit is thereby increased. The result is that it tunes broadly, or, in other words, the selectivity of the receiver is lowered.

In practice, the resistance used in Fig. 2 generally has a maximum value of about 500,000 ohms.

No. 83 — RADIO BROADCAST Laboratory Information Sheet

Tube Characteristics

MUTUAL CONDUCTANCE

ON LABORATORY Sheet No. 84 is given a group of curves for a 120 tube, while on this Laboratory Sheet we will calculate the mutual conductance of the 120 tube with the aid of these curves.

The mutual conductance is a measure of the effect of a varying grid voltage on the plate current for a constant plate voltage. Stated as a formula, the mutual conductance equals:—

$$\frac{\text{CHANGE IN PLATE CURRENT (AMPERES)}}{\text{CORRESPONDING CHANGE IN GRID VOLTAGE}}$$

We are giving below some examples that will make simple the calculation of the mutual conductance of any tube provided its characteristic curves are available:

EXAMPLE 1

Calculate the mutual conductance of a 120 type tube using the curves given on Laboratory Sheet No. 84. Locate any point on curve No. 3, as for example, that indicated by the cross. This point corresponds to a plate current of 3.4 milliamperes, a plate voltage of 120, and a grid bias (E_g) of minus 25 volts. Follow along on the 120-volt line to curve No. 2, and we find that the plate current is 5.4 milliamperes for a grid bias of minus 22½ volts. We now have two values of grid voltage and two values of plate current for the same plate voltage. Changing the milliamperes to amperes, and substituting in the formula, we have:

$$(0.005 - 0.0034) \div (25 - 22.5)$$
$$= \frac{0.0016}{2.5} = 0.00064 \text{ mhos} = 640 \text{ micromhos}$$

EXAMPLE 2

Calculate the mutual conductance of the 120 tube for a lower value of plate voltage, say 95. To do this we will locate the point on curve No. 2, corresponding to 95 volts on the plate, and this point, indicated by a cross, gives a plate current of 3.2 milliamperes for a grid bias of minus 22½ volts. This same voltage on curve No. 1 gives a plate current of 4.7 milliamperes for a grid bias of minus 15 volts. Substituting these values in the formula:

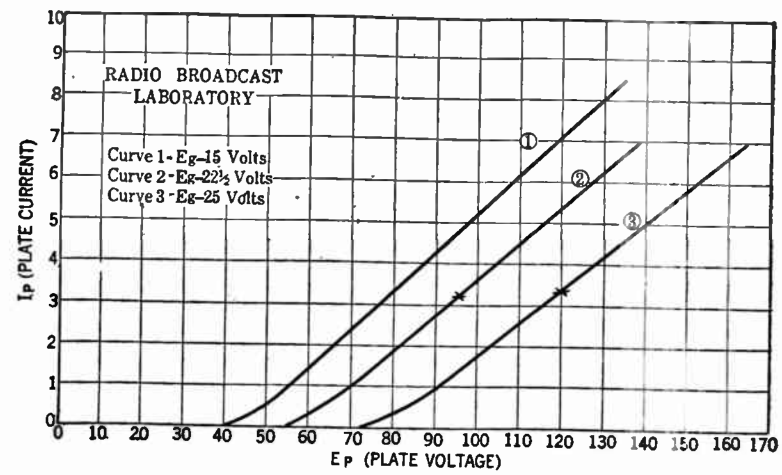
$$(0.0047 - 0.0032) \div (22.5 - 15)$$
$$= \frac{0.0015}{7.5} = 0.0002 \text{ mhos} = 200 \text{ micromhos}$$

It is evident from these two values of mutual conductance that the 120 give very low values when low plate voltages are used. Practically the only voltages which can be used on the 120 tube with satisfactory results are 135 volts on the plate and minus 22½ on the grid.

Readers interested in calculating the other constants of a tube are referred to Laboratory Sheets No. 67, February, 1927, and No. 80, March, 1927.

No. 84 — RADIO BROADCAST Laboratory Information Sheet

The Type 120 Tube Characteristic Curve



No. 85 Radio Broadcast Laboratory Information Sheet

C Voltages

FACTORS DETERMINING VALUE

THE C-battery voltage that can be placed on any tube indicates the amplitude of the signal voltage that the tube can handle without seriously overloading. For example, the 171 tube with 180 volts on the plate requires a 40.5-volt C battery. Any signal can be impressed on this tube, therefore, whose peak value does not exceed 40.5 volts.

Ordinarily we do not talk of the maximum values of alternating current voltages but speak instead of the effective values, which are equal to 0.707 times the maximum or, so called, peak value. In other words, a voltage with a peak value of 40.5 has an effective value of 28.6. If signals greater than this are impressed on the tube, the grid voltage will swing until at times it becomes positive and it will then draw a small amount of grid current, which it does not do when negative. Even very small grid currents flowing through the secondary of a transformer have a very serious effect on their operation. Consequently in amplifier work it is an axiom that the grid voltage must never be permitted to swing an amount exceeding the value of the C battery.

The handling capacity of a tube can be increased by increasing the grid voltage up to a certain point. Beyond this point an examination of the tube characteristic would indicate that the signals will cause the grid to operate on the lower curved portion of its characteristic. The manufacturers' C-battery ratings are generally the highest that can be used and still operate the tube on the straight portion of the characteristic. As an example, when the 201-A tube is used in an amplifier with 90 volts on the plate it is recommended that the C-battery voltage be 4½, and this can be taken as the value of C-battery which will permit the tube to handle the greatest amount of undistorted power.

The C-battery voltage used on the last tube of an amplifier determines what C battery is required on the other amplifier tubes because it will take a certain definite value of signal voltage on the grid of the preceding tube in order to place the maximum allowable signal voltage on the grid of the last tube. See Laboratory Sheet No. 88. Consequently, the voltage on the grid of the tube preceding the last tube need only be sufficiently great to prevent its grid from going positive on the maximum signal necessary to give maximum voltage on the grid of the second tube

No. 86 Radio Broadcast Laboratory Information Sheet

A Double Impedance-Coupled Amplifier

THE NECESSARY PARTS

A SCHEMATIC diagram of a double-impedance amplifier is shown on Laboratory Sheet No. 87. The material required to build such an amplifier is described below:—

L_1—Impedances designed for use in the plate circuit of an impedance-coupled amplifier. Four of these coils are necessary. They should have an inductance of at least 60 henrys; somewhat better results will be obtained if the inductance is about 100 henrys, however. The exact value of inductance is not very important so long as it be at least 60 henrys. The choke coil in the plate circuit of the power tube, T_3, must be capable of carrying the plate current drawn by this tube. For a 171 tube with 180 volts, the plate current will be as high as 20 milliamperes.

L_2—Grid impedances. These should have a value of inductance of about 100 henrys. Three of these coils are required.

C—Coupling condensers, having a capacity of 0.1 mfd. These condensers must be well constructed since, if poor units are used, a certain amount of leakage occurs across the condensers. Well-constructed paper condensers are quite satisfactory.

C_1—4-mfd. output condenser.

R—Fixed filament control resistance of a type depending upon the kind of tubes used. It must be capable of passing the total filament current of the three amplifier tubes.

J—Single-circuit jack.

S—Filament switch.

T_1, T_2—Two high-mu tubes. Two 201-A's may be used but the amplification will not be as great.

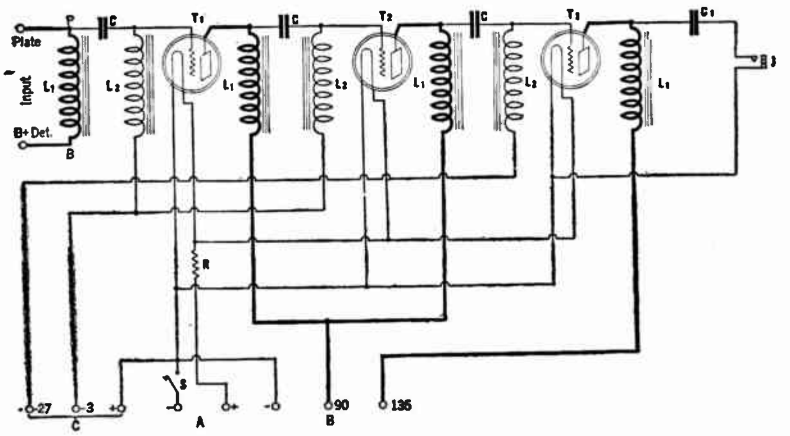
T_3—Power tube of either the 112 or 171 type. The C-battery voltage on the last stage will depend upon the type of tube and the plate voltage that is used.

It will be found that an amplifier of this kind will give excellent quality. It can be used in conjunction with any receiver, it merely being necessary to connect the input of the amplifier circuit to the detector circuit of the receiver. The terminal marked plate on the input connects to the plate of the detector tube and the B plus det. terminal connects to the plus 45-volt B battery terminal. In those receivers using a tickler, the B+ detector terminal would connect to one end of the tickler winding instead of directly to the plate of the detector tube.

People frequently ask if the primaries or secondaries of old audio transformers might not be used as impedances in an amplifier of the type under discussion. This is not feasible, for the characteristics which cause old-style transformers to give poor quality, also make them unsuitable for use as impedances. High inductance windings and well-designed cores are not to be found in old transformers, and it is desirable that an impedance unit have both of these.

No. 87 Radio Broadcast Laboratory Information Sheet

A Dual-Impedance Coupled Amplifier



No. 88 RADIO BROADCAST Laboratory Information Sheet

Audio Amplifying Systems

NO. 1, TRANSFORMER AMPLIFIERS

THE conventional transformer-coupled amplifier consists of two stages. The over-all amplification of such a system is generally around 300, and this is sufficiently high to give loud speaker reproduction with a moderately strong signal available at the output of the detector. The transformer-coupled system has the advantage that only two stages are required and can, therefore, be made quite compact.

The plate current consumption of such an amplifier is fairly low and only moderately high voltages are necessary on the first stage. The quality of the results obtained depends primarily upon the transformers used and for this reason a certain amount of care is necessary in choosing the transformers that are to be incorporated in such an amplifier.

The transformer feeding out of the detector stage should have a primary impedance that is somewhat higher than is necessary for that transformer used in the second stage. The higher impedance is necessary in the transformer feeding out of the detector tube due to the fact that the detector place circuit generally has a somewhat higher impedance than the plate circuit of a tube used as an amplifier.

If two transformers of different ratios are to be used, the rule is almost invariably to place the low-ratio transformer in the first stage and high-ratio transformer in the second stage. For commercial reasons, most manufacturers put a fixed number of turns on the secondaries of their transformers irrespective of the ratio required. The different ratio values are then obtained by winding on the necessary number of primary turns, this latter figure of course varying proportionally with the ratio. Thus, the lower the ratio, the greater the number of primary turns and likewise, the greater the primary impedance.

Proper C battery on the amplifier tubes is absolutely essential if good quality is to be obtained. The C battery voltage on the first stage should not be higher than is necessary to prevent overloading. Placing an unnecessarily high bias on the first tube increases the plate impedance of the tube, and it is essential that the plate impedance be kept low.

If a 171 tube is used in the last stage with a 40 volt C bias, we can impress signals on the grid of this tube which have a peak value up to 40 volts. If the transformer has a ratio of 4:1, the peak value of the voltage in the primary will be 10 volts. If a 201-A tube is used in the interstage, we can obtain the value of peak voltage on its grid by dividing the voltage in the plate circuit, 10, by the amplification constant of the tube, 8, which gives 1¼ volts. It follows then, that a C battery bias of 1¼ volts on the first tube will be sufficient to prevent overloading.

No. 89 RADIO BROADCAST Laboratory Information Sheet

Short-Wave Coils

SOME DATA ON THEIR RESISTANCE

THERE are, at present, a great many excellent coils on the market for use in short-wave receivers. They are generally of the "plug-in" type so that different coils are used to obtain the various ranges required.

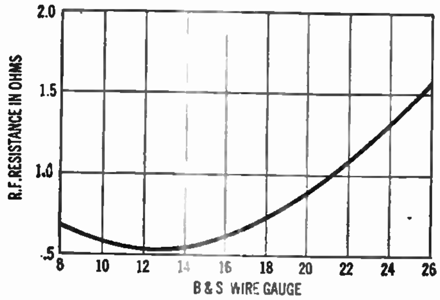
These coils should have as low a radio-frequency resistance as is possible, consistent with a construction sufficiently rugged to prevent their being damaged if they are handled somewhat roughly. It would be preferable if the coils could be wound on some solid form but the question then arises whether or not a form can be used without increasing the resistance of the coil to a considerable extent.

The General Radio Company has conducted some experiments along this line to determine just how much the form used affects the coil's resistance and also to determine what size wire is best to use. Tests were made using a standard bakelite form having a diameter of 2¾". The curve given on this Sheet indicates how the radio-frequency resistance of the coil varies with the size of the wire used. Evidently, from the curve, the wire size is not especially critical but best results are obtained with a wire size of about No. 12 or 14 gauge.

It was found that the use of good binders to hold the turns in place has no appreciable effect upon the resistance. A coil was wound in such a manner that a form could be slipped in and out of it without disturbing the wire. Measurements on the coil with and without the form indicated that the difference in efficiency was negligible.

Tests were also made with regard to shielding and it was found that the shielding could be placed very near the coil and have no appreciable effect. The result of the tests may be summed up as follows:

When designing a coil for use on the 40-meter



(7500-kc.) short-wave band (all these tests were made at this frequency), it is well to (1.) use about No. 12 to 14 wire; (2.) use a coil form if desired; (3.) use any good dope as a binder; (4.) use any reasonable amount of shielding where advantageous; (5.) keep the form factor (diameter divided by length) around 1 to 2.5.

These data are taken from the February, 1927, issue of the General Radio *Experimenter*.

No. 90 RADIO BROADCAST Laboratory Information Sheet

Loop Antennas

SOME OF THEIR ADVANTAGES

THE operation of a transformer is usually explained by saying that the current flowing in the primary sets up an alternating magnetic field which in turn causes a current to flow in the secondary. This is also the simplest way to explain the operation of a loop antenna, the only difference being that the alternating magnetic field that causes the current to flow in the loop is in the form of radio waves.

The number of volts induced in a loop by the passage of radio waves is:

$$2 \pi f n A H \times 10^{-8}$$

where H is the amplitude of the wave, f the frequency, n the number of turns in the loop, and A the area of the loop. The voltage calculated from this formula is only correct when the plane of the loop is vertical and perpendicular to the direction of the magnetic field. That is, the loop must be pointing toward the transmitting station. If rotated about a vertical axis only a quarter of a turn, no voltage will be induced.

This feature is the most important advantage of a loop, for two stations using exactly the same wavelength may often satisfactorily be separated (provided they do not lie in the same or exactly opposite directions) by simply turning the loop at right angles to the interfering station. Loops are coming into greater use as transmitting stations become more powerful, and they will probably ultimately be used almost exclusively on account of the small space required, ease of installation, portability, lack of necessity to safeguard against lightning, and the improvement of the ratio of signal strength to interfering noises, due to their directional properties.

If a loop is compared in size to an antenna of the ordinary type it would appear that the amount of energy intercepted by the loop would be exceedingly small indeed. The fact is, however, that a good loop antenna, tuned with a condenser having low insulation losses, will pick up signals much better than might be expected from a comparison of its size to that of an outdoor antenna. This is due to the fact that the loop has a very much lower resistance than an elevated antenna.

The loop type antenna has been used most frequently in conjunction with super-heterodynes because, with this type of receiver, it is easy to obtain a large amount of radio-frequency amplification. During the last year, however, several receivers of the neutrodyne type have been placed on the market designed for use with a loop. These receivers are generally completely shielded so as to prevent interaction between the loop and the coils in the receiver.

No. 91

RADIO BROADCAST Laboratory Information Sheet

A Simple Tube Tester

HOW TO GET CHARACTERISTICS OF TUBES

CONTRARY to the opinion of many experimenters, a set-up of instruments to measure the characteristics of vacuum tubes is not excessively costly nor is it complicated. The diagram of connections of a tester is shown on Laboratory Sheet No. 92; this Laboratory Sheet will explain how to measure tube characteristics using the tester. The procedure can be explained most easily by taking an actual example.

Suppose we desire to measure the characteristics of a 201-A tube. We would first place the tube in the socket and then, with switch No. 2 in position B and switch No. 3 in position A, the rheostat would be adjusted until the filament voltage, as read on the voltmeter, is correct. In this case the correct voltage would be 5. Then, with switch No. 3 in position B the plate voltage is adjusted to 90 volts. The grid bias is next adjusted to 4.5 volts by throwing switches Nos. 1 and 2 to the A positions and adjusting the potentiometer P. The milliammeter will now read about 0.002 amperes (2 m A.). Note down the plate voltage, the grid voltage, and the resulting plate current.

Now adjust the potentiometer until the grid bias is, say 3.5., and read the plate current. It should read about 0.003 amperes (3 mA.). Leaving the grid bias at 3.5, next adjust the switches to read the plate voltage. Reduce the plate voltage so as to make the milliammeter read exactly the same as before (2 mA.). The new reading of plate voltage may be 82. We now have all the necessary data to calculate the constants of the tube.

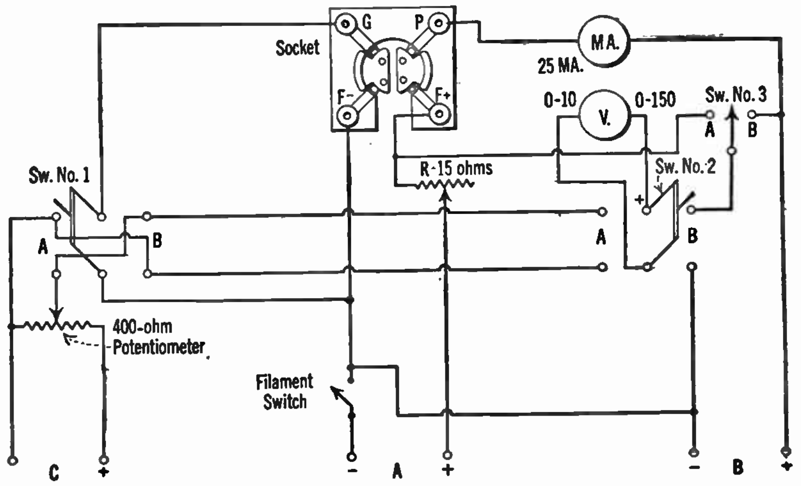
The amplification constant will be equal to the difference of the two plate voltages, 90-82, or 8, divided by the difference of the two grid voltages, 4.5—3.5 = 1. The amplification constant is therefore 8. The plate impedance is equal to the difference of the plate voltages divided by the difference in the plate currents, or 8 divided by 0.001. The quotient is 8000, which is the plate impedance. The mutual conductance is the plate current difference divided by the grid voltage difference, or 0.001 divided by 1 = 0.001 mhos or 1000 micromhos.

In measuring tube factors with this apparatus, care must be taken that the actual changes in voltages—and the corresponding current changes—are small. If the plate-current meter, and the grid-voltage meter, can be read with sufficient accuracy, very small changes should be made—say a plate voltage change of 5 volts. This, however, would make it necessary to read grid bias changes of less than a volt. The investigator, then, is between two fires in his endeavor to measure his tubes accurately. If he takes plate current readings resulting from large voltage changes, he gets a factor which represents working the tube over a large part of its characteristic curve. On the other hand, if he uses small voltage changes, the accuracy depends upon the accuracy of his meters and his ability to read them.

No. 92

RADIO BROADCAST Laboratory Information Sheet

Circuit Diagram of Tube Tester



No. 93

RADIO BROADCAST Laboratory Information Sheet

Audio Amplifying Systems

DUAL-IMPEDANCE COUPLED AMPLIFIERS

ON THIS Sheet we give some facts regarding dual-impedance coupled amplifiers. A circuit diagram of such an amplifier will be found on Laboratory Sheet No. 87 (April, 1927).

Double-impedance amplifiers are capable of giving excellent results if care is taken in the selection of the apparatus and in the layout of the parts. The plate impedances should have an inductance around 100 henries; if the inductance is much less, the low frequencies will be lost. Well-made 0.1-mfd. blocking condensers are essential to prevent leakage.

The amplification of each stage is generally equal to about nine tenths of the amplification constant of the tube. If we lose one tenth on each stage, then the total amplification in three stages will be equal to 0.9 x 0.9 x 0.9 = 0.73 times the product of the amplification constants of the three tubes concerned. Suppose two 201-A's, each with an amplification of eight, and one 171 with an amplification of three, are used. Then the total amplification will be equal to 8 x 8 x 3 x 0.73 = 140.16. This value is rather too low for best results, and for this reason high-mu tubes, having an amplification constant of anything up to about thirty, are generally used in this type of amplifier.

From some tests made in the Laboratory, it appears possible to overload the power stage of an impedance amplifier to a considerable extent, without introducing very objectionable distortion. This comes about in the following way.

In a transformer-coupled amplifier the maximum signal that can be placed on the grid is limited by the fact that, if the signal voltage is too large, grid current will flow in the grid circuit of the power tube. This current flowing through the secondary of the transformer saturates the core and prevents the transformer from properly amplifying the signal. In an impedance amplifier there are no transformers, and the grid current only has the effect of slightly lowering the inductance of the impedance unit in the power tubes's grid circuit. Slight overloading is therefore less noticeable in an impedance amplifier than in a transformer-coupled one.

As stated above, the amplification obtained at low frequencies depends upon the use of high-inductance impedances in the plate and grid circuits. There has however been a recent development in the design of double-impedance amplifiers by which it is possible to obtain very good low-note amplification without using very large coils. This design feature consists in so determining the inductance of the plate and grid coils and the capacity of the coupling condenser, that the entire combination tunes or resonates at about 30 cycles, with the result that the amplification of these low frequencies is unusually good.

No. 94 — RADIO BROADCAST Laboratory Information Sheet

The Principle of Reflexing

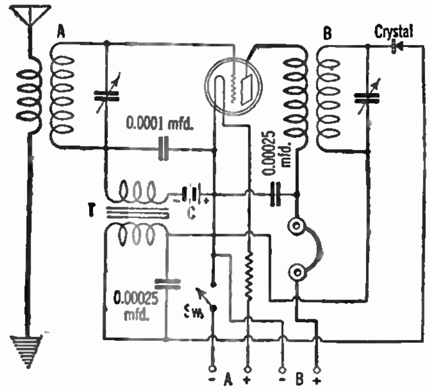
AN EXPLANATION OF THE ACTION

WHEN a tube capable of amplifying a fairly strong signal is used to amplify a very weak one, it is evident that its power amplifying ability is not being made use of to the fullest possible extent.

"Reflexing" is a system for getting more out of a tube by making it amplify two things—the incoming signal, which is a radio-frequency current, and the detected signal, which is an audio-frequency current. The accompanying diagram indicates a simple receiver using one stage of reflexed amplification.

In this receiver, the radio-frequency current enters the receiver via the antenna and is impressed on the tube by the tuned circuit, A. It then passes through the tubes and into the tuned transformer, B, the output of which is impressed on a crystal detector. The audio-frequency currents resulting from the detecting action of the crystal pass through the primary of the audio transformer, T. The voltage induced in the secondary of this transformer is impressed on the grid of the tube and is amplified. A pair of phones is used in the plate circuit of the tube for receiving the signal.

So long as the variations of potential due to these two different signals do not cause the tube to overload, neither interferes with the other. Some circuits use a reflex principle consisting of several stages of radio-frequency amplification and several stages of audio-frequency amplification. In such sets it is advantageous to use the system due to David Grimes and known as the Inverse Duplex system. In this system, the tube handling the smallest amount of radio-frequency energy is made to handle the largest amount of audio-frequency energy and, vice versa, the tube handling the greatest



amount of radio energy handles the smallest amount of audio energy. In this way the point of overloading is not reached as quickly, and it is possible to obtain high efficiency from such a receiver.

No. 95 — RADIO BROADCAST Laboratory Information Sheet

Storage Batteries

NECESSARY CARE

THE storage battery has been developed to a remarkable degree of perfection so that it will function over a long period of time with only a small amount of attention. Such attention consists more than anything else in keeping the battery properly filled with pure distilled water and correctly charged at all times. The efficiency and the life of the battery will decrease considerably if these two points are not carefully watched. The charging rate should be as close as possible to that recommended by the manufacturer, this information generally being given on the name plate of the battery. Although the state of charge of a battery can be measured with some accuracy by means of a voltmeter if the proper precautions are taken, the readings made in this way are not generally to be relied upon. A better method for use in testing a storage battery is to determine the state of charge by means of a hydrometer. The specific gravity, which is what the hydrometer measures, will be found to increase the reading of the hydrometer as the battery is charged, up to a certain point. The specific gravity reading for full charge is not the same for all batteries. For this reason, an endeavor should be made to obtain from the manufacturer of the battery information regarding the hydrometer reading which should be obtained using his battery when it is fully charged and when it is fully discharged. Frequently, but not always, these same data will be found on the name plate. In the event that this information cannot be obtained, it is a safe rule to charge the battery until the hydrometer reading does not change during a period of one hour. When this condition holds true, the battery has absorbed all the charge possible. It will generally be found also that, when this condition of constant specific gravity reading throughout an hour is reached, the electrolyte will also begin to gas or bubble.

Care should be taken in charging the battery to make certain that its positive terminal is connected to the positive terminal of the source being used for charging purposes. If the battery is charged in the opposite direction the plates will be reversed in chemical character, and if the charging is continued for any great length of time, the battery will be destroyed. If a battery has only been charged in the wrong direction for a short length of time it can generally be brought back to normal by charging in the right direction for a very long time at a low charging rate.

No. 96 — RADIO BROADCAST Laboratory Information Sheet

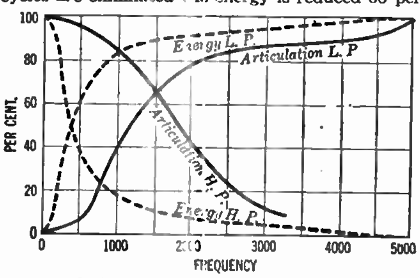
Analysis of Voice Frequencies

RELATIVE IMPORTANCE OF LOW AND HIGH FREQUENCIES

MANY investigations have been made to determine the relative importance of the various frequencies that are found in the human voice. For these investigations a high-quality audio amplifying system must be employed over which it is possible to hear equally as well as by direct transmission through the air.

Tests have been made by the Western Electric Company using such an amplifying system to determine the relative importance of different frequencies in the voice frequency range, and the results of these tests are shown in the curves on this sheet. These curves were obtained by inserting in the circuit low-pass (L.P.) filters, which will only pass low frequencies, and high-pass (H. P.) filters designed to pass no frequencies below a certain point. First of all let us consider the curve marked "Articulation H. P." The curve shows that the articulation was 40 per cent. when a high-pass filter was used that eliminated all frequencies below 2000 cycles. The articulation rises to 70 per cent. when a high-pass filter was used to cut off all frequencies below 1400 cycles. The curve marked "Energy L.P." shows that 60 per cent. of the total energy in the voice remained when a low-pass filter was used to cut off frequencies above 500 cycles.

These curves indicate then, that the lower frequencies furnish most of the energy in the voice and that the higher frequencies are most important for proper articulation. If frequencies below 500 cycles are eliminated the energy is reduced 60 per



cent., and the articulation is only reduced 2 per cent. Eliminating all frequencies above 400 cycles leaves remaining 60 per cent. of the total energy but the articulation is only about 5 per cent.

The curves on this sheet were traced from an excellent book by K. S. Johnson entitled: *Transmission Circuits for Telephone Communication.*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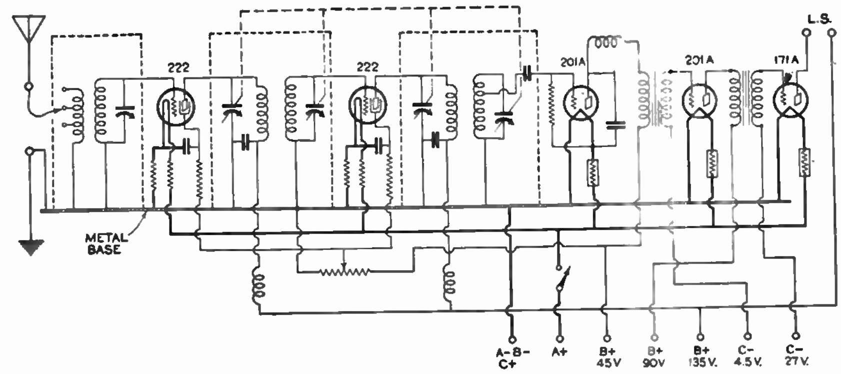

Circuit Diagram of the Hammarlund-Roberts Hi-Q 29. Master Model for Battery Operation

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2 Hammarlund No. SDW Knob-Control Drum Dials (Walnut).
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  Hammarlund Mfg. Co., Inc.
5 Benjamin Cle-Ra-Tone Sockets, No. 9040.
  Benjamin Electric Mfg. Co.
1 Sangamo .00025 mfd. Fixed Mica Condenser.
1 Sangamo .001 mfd. Fixed Mica Condenser.
  Sangamo Electric Co.
1 Carter No. 11-S "Hi-Pot" Potentiometer with switch, 100,000 ohms.
  Carter Radio Co.
2 Thordarson No. R-300 Audio Transformers.
  Thordarson Electric Mfg. Co.
4 Parvolt .5 mfd. Series 200 By-Pass Condensers
  Acme Wire Co.
1 Durham Metallized Resistor, 1½ megohms.
  International Resistance Co.
1 Yaxley No. 660 Cable Connector and Cable.
1 pr. Yaxley No. 422 Insulated Phone Tip Jacks.
  Yaxley Mfg. Co.
2 Amperites No. 1-A.
1 Amperite No. 112.
  Radiall Co.
2 Eby Engraved Binding Posts.
  H. H. Eby Mfg. Co.
1 "Hi-Q 29" Master Foundation Unit (containing drilled and engraved Westinghouse Micarta panel, three complete aluminum shields, drilled steel chassis, shafts, binding post strips, Fahnstock clips, fixed resistance units, resistor mounts, brackets, clips, wire, screws, nuts, washers, and all special hardware required to complete receiver).
  Hammarlund Mfg. Co., Inc.

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Hammarlund-Roberts "Hi-Q 29" Master A. C. Model

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3 Hammarlund No. RFC-85 Radio Frequency Chokes.
  Hammarlund Manufacturing Co., Inc.
6 Benjamin Cle-Ra-Tone Sockets, No. 9040.
  Benjamin Electric Mfg. Co.
1 Sangamo .00025 mfd. Fixed Mica Condenser.
1 Sangamo .001 mfd. Fixed Mica Condenser.
  Sangamo Electric Co.
1 Carter No. 11 "Hi-Pot" Potentiometer, 100,000 ohms.
  Carter Radio Co.
2 Thordarson No. R-300 Audio Transformers.
1 Thordarson No. R-196 Choke Coil.
1 Thordarson No. R-171 Power Compact.
1 Thordarson No. T-2610 Filament Transformer. 15 Volt.
  Thordarson Electric Mfg. Co.
6 Parvolt .5 mfd. Series 200 By-Pass Condensers.
1 Parvolt 4 mfd. Series 200 By-Pass Condenser.
1 Parvolt 3 mfd. By-Pass Block.
1 Parvolt 1 mfd. Series 200 Filter Condenser.
1 Parvolt 2 mfd. Series 200 Filter Condenser.
1 Parvolt 4 mfd. Series 200 Filter Condenser.
1 Parvolt 2 mfd. Series 400 Filter Condenser.
  Acme Wire Co.
1 Durham Metallized Resistor. 1½ megohms.
2 Durham Metallized Resistors, ½ megohm.
  International Resistance Co.
1 Yaxley No. 612 Cable Connector and Cable.
1 pr. Yaxley No. 422 Insulated Phone Tip Jacks
  Yaxley Mfg. Co.
1 Electrad "Truvolt" "Hi-Q 29" type Resistor.
  Electrad, Inc.
2 Eby Engraved Binding Posts.
  H. H. Eby Mfg. Co.
1 "Hi-Q 29" Master Foundation Unit (Containing drilled and engraved Westinghouse Micarta panel, three complete aluminum shields, drilled steel chassis, shafts, binding post strips, Fahnstock Clips, fixed resistance units, resistor mounts, brackets, clips, wire, screws, nuts, washers, and all special hardware required to complete receiver).
  Hammarlund Mfg. Co., Inc
2 Arcturus Tubes No. 22 A-C Shield Grid.
1 Arcturus Tube No. 46 A-C Detector.
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For example, the various parts, accessories and supplies mentioned throughout the information sheets in this book are all available to the trade from the W. C. Braun Co.

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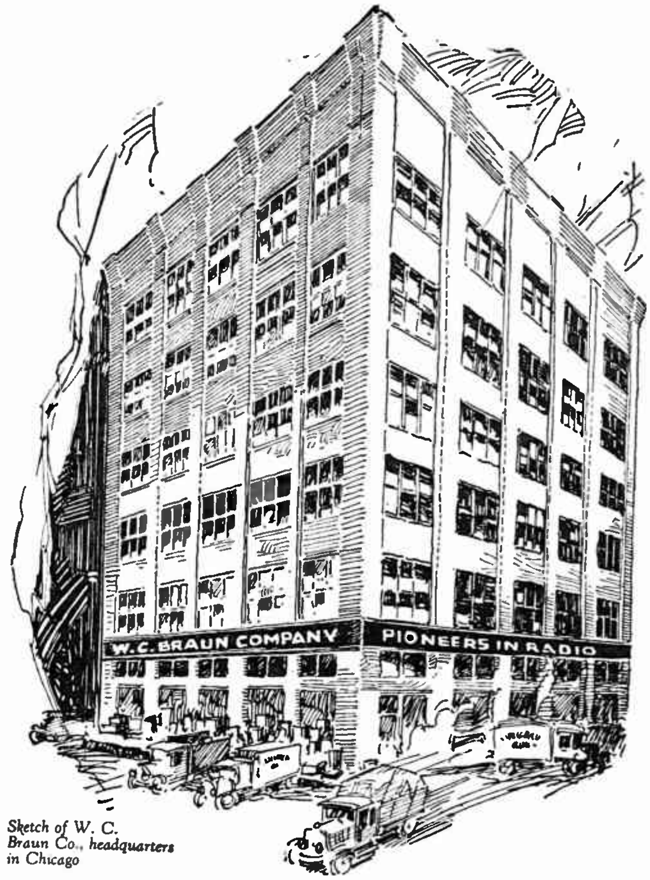

Sketch of W. C. Braun Co., headquarters in Chicago

Selections—Variety—Service

The list of well-known radio lines shown at the right includes practically all the famous names in the radio industry. Besides carrying large selections of varied lines of products of leading parts, equipment and accessory manufacturers, we distribute well-known lines of radio sets and co-operate with our dealers in advertising, window and store displays and in furnishing proper sales aids to insure successful business. In the small-town field as well as in larger radio centers, Braun service means much to the dealer and professional radio man.

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We are headquarters for the parts of the country's ten leading parts manufacturers' products, used in the Hammarlund Hi-Q circuit. Parts and supplies for any published radio circuit, whether short wave or broadcast, are immediately available from our stock.

Manufacturers desiring a distributing outlet furnishing world-wide service, are invited to take up their problems with us. Dealers and custom set builders will find here an organization keyed to fill their needs promptly and efficiently and a request on their letterhead will bring a copy of the Braun's Radio Buyers' Guide—the bible of the radio industry.

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Sonatron
Magnaformer
Cunningham
R. C. A. Tubes
Monroe Sets
Elkay
Kursch-Kasch
Trav-Ler
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Kodel
Marco
Balkite
Micamold
Baldwin
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Hoyt
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Signal
Ultradyne
Stevens
Madison-Moore
Precise
Eagle
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And Many Others

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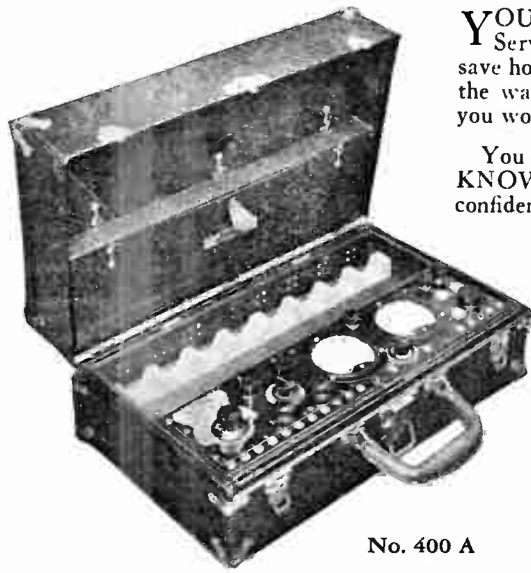


No. 400 A

No. 97 RADIO BROADCAST Laboratory Information Sheet

Methods of Generating High-Frequency Energy

THE ARC

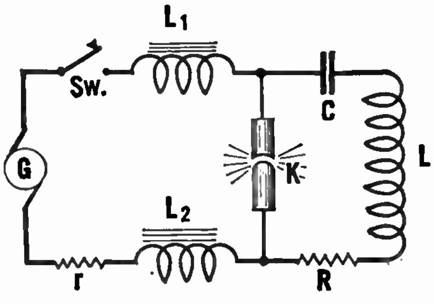
BEFORE the invention of the three-electrode tube, and its subsequent use as a source of large amounts of high-frequency energy, the arc was a common type of continuous wave generator.

In the drawing on this Sheet is given the circuit diagram of a simple arc. The ordinary arc light used for street lighting might be used, but much more efficient operation is obtained from an especially designed arc. The elementary theory of the arc is given below.

The drawing indicates the simplest arrangement of the apparatus. "G" is a direct current generator, "r" is a resistance to control the current, L_1 and L_2 are two choke coils to keep the r. f. energy out of the generator and to keep the current practically constant, "K" is the arc, and "C," "L," and "R" are respectively, the capacity, inductance, and resistance of the oscillating circuit.

The arc, which consists of two electrodes, is different from ordinary electrical conductors in one important respect, which is that its resistance is not a constant quantity but a variable one, depending on the current flowing through it. At high current values the resistance is low and at low current the resistance is high. Consequently, an increase in current will produce a decrease in resistance.

Now, when the switch is closed, certain currents flow and the condenser begins to charge, and, therefore, part of the current is diverted from the arc. Since the current through the arc is decreased by this action, the voltage across the arc must rise, and it continues to rise as long as the condenser continues to charge. As soon as the condenser becomes fully charged, the arc voltage stops rising and the condenser begins to discharge itself through the arc.



When the discharge is complete, the cycle of charge and discharge repeats itself with a frequency determined by the constants of the inductance L and the capacity C. By carefully choosing these values, large amounts of high-frequency energy can be obtained.

No. 98 RADIO BROADCAST Laboratory Information Sheet

Audio Amplifying Systems

RESISTANCE-COUPLED AMPLIFIERS

A VERY satisfactory method of audio amplification is that employing resistance coupling. The usual resistance-coupled amplifier requires three stages of amplification in order to obtain sufficient overall gain to satisfactorily operate a loud speaker. The introduction, however, of a new tube with a very high amplification constant, makes it possible in some cases to obtain sufficient amplification using only two stages. This new tube is known as the type 240 and data on it will appear on Laboratory Sheet No. 106 (July, 1927).

Several factors must be given attention if satisfactory results are to be obtained from a resistance-coupled amplifier. The mere fact that it is resistance coupled will not insure good quality. A poorly designed resistance-coupled amplifier is capable of creating as much distortion as can be obtained from a poorly designed amplifier of any other type. Some data regarding the constants of a resistance-coupled amplifier were given on Laboratory Sheet No. 74 (March, 1927). The constants given were for an ordinary tube for use in the resistance-coupled amplifier with an amplification constant of about 20. For the new type high-mu tube, however, with an amplification factor of about 30, it is necessary to use somewhat different values of resistance. See Laboratory Sheet No. 106.

The coupling condenser is a very important factor, and it is essential that this condenser have a very high insulation resistance, otherwise some of the B voltage will leak through the condenser to the grid circuit, and the amplifier will no longer function satisfactorily. In building up a resistance-coupled amplifier the best condensers should be used.

It is essential that high-quality plate and grid resistances be used to prevent noise in the amplifier. Also, the plate resistor should be capable of carrying the plate current of the tube without overheating.

Another important point is the amount of plate voltage used. It should be realized that most of the plate voltage supplied to the amplifier is lost in the resistance in series with the plate circuit of the tube. For this reason, it is necessary that fairly high voltages be available in order that there will be sufficient voltage left at the plate of the tube to obtain satisfactory operation. At least 135 volts should be used, and it should preferably be 180. The C-battery voltages should be kept as low as possible. It will generally be found that in an ordinary resistance-coupled amplifier a C-battery voltage of about 3 volts will be necessary on the grid of the tube preceding the last tube, if the latter is of the 171 type. The C voltage on the first tube of the ampifier need not be more than one volt.

No. 99 RADIO BROADCAST Laboratory Information Sheet

Data on the "Universal" Receiver

PARTS REQUIRED

ON LABORATORY Sheet No. 100 is given the circuit diagram of the new "Universal" receiver which was described in the December, 1926, issue of RADIO BROADCAST. In constructing this receiver, the following parts are necessary:

L_1—Antenna coil consisting of 13 turns of No. 26 d. s. c. wire wound at one end of a 2¾-inch tube.

L_2—Secondary coil consisting of 50 turns of No. 26 d. s. c. wire wound on the same tube as L_1. The separation between L_1 and L_2 should be ¼ inch.

L_3—Primary of interstage coil constructed in same manner as L_1 and tapped at the exact center.

L_4—Secondary winding constructed in same manner as L_2 and tapped at point No. 9, the 15th turn from that end of L_4 which is nearest to L_3

C_1, C_2—Two 0.0005-mfd. variable condensers.

C_3—Neutralizing condenser, variable, 0.000015 mfd.

C_4—Regeneration condenser, 0.00005 mfd.

L_5—R. F. choke coil, made by winding 400 turns of No. 28 wire on an ordinary spool.

T_1, T_2—Two audio-frequency transformers.

J_1—Interstage double-circuit jack.

J_2—Single-circuit filament-control jack.

R_1—30-ohm rheostat.

R_2—Fixed filament-control resistance for two 201-A tubes.

R_3—Fixed filament-control resistance for one power tube. One 0.00025 grid condenser with 3-megohm grid leak.

Four Sockets.

Eleven Binding posts.

In operation, condensers C_1 and C_2 will control the tuning, and C_4 will control the amount of regeneration. Various values of voltage should be tried on the plate of the detector tube, and that voltage used which gives smoothest regeneration. Frequently 22½ volts is more satisfactory than 45. Make certain that excessive C-battery voltage is not used on the grid of the r. f. tube, since the amplification obtained will be decreased considerably under such conditions. If there is any tendency toward regeneration or howling in the audio-frequency stages, reverse the connections to the primary of the transformer, T_2.

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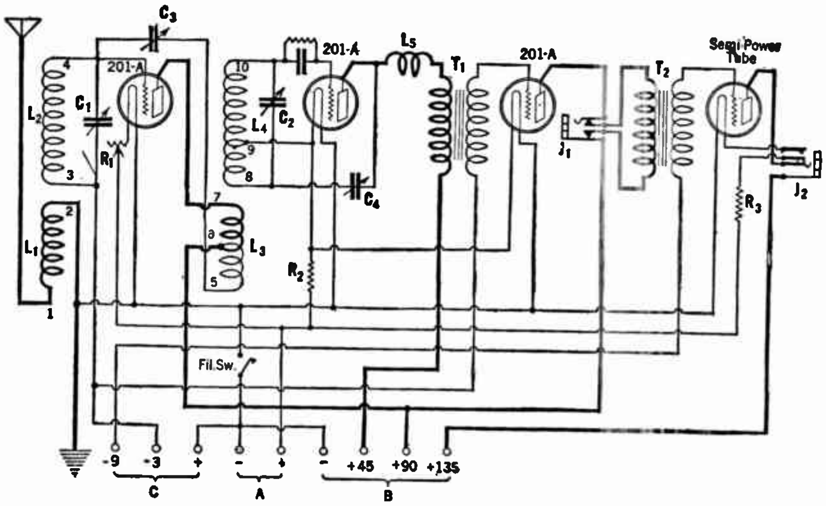
No. 100 RADIO BROADCAST Laboratory Information Sheet

Circuit Diagram of the "Universal" Receiver



No. 101 RADIO BROADCAST Laboratory Information Sheet

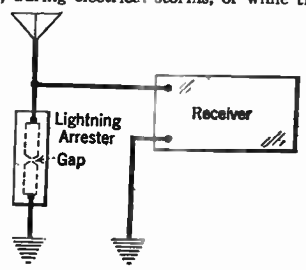
Lightning Arresters

HOW THEY WORK

AN ESSENTIAL part of any radio installation is the lightning arrester, which should be connected in the circuit as indicated in the diagram.

The arrester should preferably be located outside of the building at that point where the antenna lead-in enters the building. One terminal of the lightning arrester connects to the antenna and the other terminal connects to a good ground. A lightning arrester is a very simple device and actually consists of two metal electrodes which are spaced to within about five thousandths of an inch of each other. A radio-frequency current is too weak and too low in voltage to jump across these points which form the gap in the arrester and hence there is no path for the signal except that through the antenna to the receiver and thence to ground. The receiver is therefore actuated by this radio-frequency current and a signal is produced in the telephones, or the loud speaker, as the case may be. Suppose, however, that a high-potential atmospheric electrical discharge takes place near the antenna. Such discharges are always erratic in character and of high frequency. The antenna coil of the set therefore exerts a powerful choking action upon them even though the coil is quite small. For this reason, and also due to the very high voltage of the lightning discharge, it jumps across the small gap in the arrester and passes to ground without causing any more effect on the set than a loud static crash which will possibly drown out the signal for a moment.

Also, during electrical storms, or while they are



approaching, there is a considerable amount of static electricity present in the atmosphere which tends to accumulate on the antenna system until such time as the voltage is high enough to jump across the small gap in the arrester. This discharge voltage is generally about 500 volts.

No. 102 RADIO BROADCAST Laboratory Information Sheet

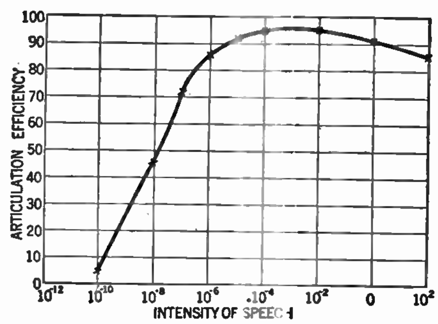
Efficiency of Amplifying Systems

ARTICULATION

IN AUDIO-amplifying systems, efficiency must be judged from two standards. One of the standards is, in the terminology of telephone engineers, the "volume efficiency" of the system, which tells us how much increase in loudness of sound is produced by the system. The other standard is known as "articulation efficiency." The "articulation efficiency" of any system is a measure of its effectiveness in the transmission of detached speech sounds. In these tests, sounds are grouped into meaningless monosyllables and the efficiency is measured by the percentage of sounds which are correctly received.

In actual tests on a system the monosyllables are spoken into the input of the system and listeners at the output record what sounds they think were spoken. In very high quality systems it is possible to obtain an articulation efficiency of almost 100 per cent.

The articulation efficiency depends upon the frequency distortion in the system, the amount of noise, and the volume efficiency. On this Sheet is an interesting curve the data for which were taken from a paper by Mr. R. L. Jones in the April, 1924, issue of the *A. I. E. E. Journal*, which shows how articulation varies with variations in intensity of sound. At the zero point the intensity of the received speech is equal to the intensity of the speech as it leaves the mouth and the articulation is about 91 per cent. With an intensity 100 times greater (10^2), the articulation falls to 87 per cent. If the intensity is decreased to a million times less than when it leaves the mouth, (10^6) the articulation is still very



good, being 85 per cent. These tests were made under quiet conditions and, of course, under noisy conditions the results would have been somewhat different.

No. 103

RADIO BROADCAST Laboratory Information Sheet

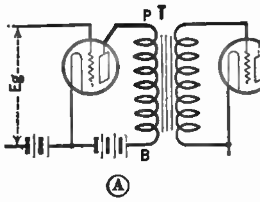
Audio Transformers

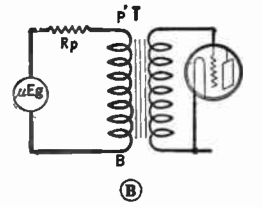
HIGH-IMPEDANCE PRIMARY NEEDED

THIS Sheet will explain why better quality is obtained from transformers with high-impedance primaries.

Drawing A shows how a transformer is connected in the plate circuit of a tube. Now, a voltage, Eg, on the grid of a tube is equivalent to a voltage of µEg (amplification constant times Eg) in the plate circuit of the tube. Also, the plate circuit of a tube acts like a resistance equal in value to the plate impedance of the tube (12,000 ohms for a 201-A type tube). These two facts were used in drawing the equivalent circuit diagram, B. In this diagram µEg indicates the voltage acting in the plate circuit and Rp represents the plate impedance of the tube. It is evident that the total voltage, µEg, available in the circuit, must divide itself between Rp and T, the transformer, and therefore the percentage of the total voltage across the transformer, increases with increased impedance in the transformer. Now, the impedance varies with the frequency, becoming greater as the frequency rises and decreasing as the frequency becomes lower. It is evident, then, that the percentage of the total voltage across the transformer will also vary with frequency, and if this variation is very great it will be a source of distortion. Practically, the result will be that, at the low frequencies where the transformer impedance is low, very little of the total voltage will be across the transformer, most of it being across the tube. As a result, the low frequencies will not receive as much amplification as do the moderate and high frequencies. The problem then is to so design the transformer that this variation of amplification with frequency is as small as possible consistent with economy of manufacture. The problem evidently comes down to one of designing a transformer to have as large an impedance as possible at the low frequencies for, since the impedance increases with frequency, there is no difficulty in obtaining high impedance at other than the low frequencies.

The impedance at low frequencies depends upon the inductance. The larger the inductance the greater the impedance. In order to get a large inductance, a large number of primary turns are required. It is also essential that the core of the transformer be very efficient so that the turns will have as much inductance as possible.





No. 104

RADIO BROADCAST Laboratory Information Sheet

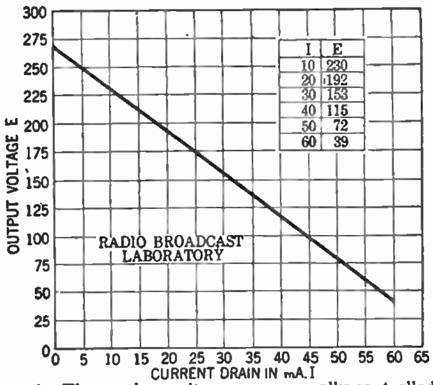
Socket Power Units

VOLTAGE OUTPUT CURVES

AT THE present time, it is common practice in rating B power units, to specify the voltages at various current drains which the unit will deliver from the high-voltage tap. These data are obtained by connecting a variable resistance, in series with a milliammeter, between the negative B and the terminal giving the highest voltage, and then measuring the output voltage with different values of current through the resistance. The data may be collected in the form of a table or a curve may be plotted. It is best to plot a curve for, from it, we can determine the voltage at any current drain. Also, the slope of the curve gives us visually an idea of how constant the voltage is.

If full benefit is to be obtained from such curves, it is essential that we thoroughly understand what they signify. We must first determine the total plate-current drain of our receiver. This information can be obtained by connecting a milliammeter in series with the negative B lead, where it will measure the total plate current. Suppose the reading to be 35 milliamperes. This value of current is now located on the curve and we find that the corresponding plate voltage is (in this particular case) 135 volts. This is the maximum voltage that the socket-power unit will supply at 35 milliamperes. If you require a maximum of 135 volts for your receiver, then the unit is satisfactory. If you cannot use as much as 135 volts and there is no adjustment on the device to lower this voltage, then the unit is not satisfactory; or you might want to use a 171 type tube with 180 volts and in this case also the unit will be unsatisfactory for it can only deliver 135 volts at the requisite current drain.

The curve tells us nothing concerning the voltages supplied by the other terminals on the power



unit. These other voltages are generally controlled by variable resistances so that any voltages from zero to maximum can be obtained.

No. 105

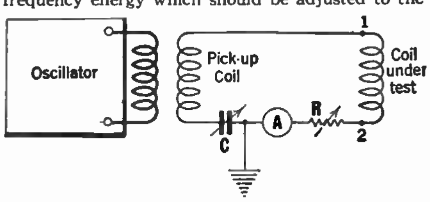
RADIO BROADCAST Laboratory Information Sheet

Measuring R. F. Resistance of a Coil

NECESSARY EQUIPMENT AND PROCEDURE

THE job of measuring radio-frequency resistance is not an especially difficult one, although it requires considerable apparatus. The circuit diagram of the test circuit is given on this Sheet. The apparatus used should have the following characteristics:

OSCILLATOR—This represents a source of radio-frequency energy which should be adjusted to the frequency at which the measurements are to be made. It should have plenty of power. In the Laboratory a 210 tube with at least 300 volts on the plate is generally used, but it is doubtlessly possible to use a 201-A as an oscillator with about 100 volts on the plate. The important point is that adjustments in the test circuit should produce no change in the energy delivered by the oscillator.



A—This is a radio-frequency milliammeter with a range of about 200 milliamperes or preferably somewhat less. It may be a hot-wire or thermocouple meter, or an ordinary crystal detector used with a low-range d. c. milliammeter.

C—The condenser should be a very carefully constructed one because it is essential that its resistance be low and constant. It should preferably be a laboratory type instrument although a well made receiving condenser can be used.

R—This resistance must be continuously variable and must be non-inductive. A decade resistance box is well suited for this purpose.

PICK-UP COIL—The pick-up coil functions to pick up energy from the oscillator and feed it into the test circuit. It may consist of just a few turns of wire coupled just close enough to the oscillator so as to give a good deflection on the meter, A.

The procedure in making a test is quite simple. Start with zero resistance at R and once the test has started make no changes at all in the oscillator or in the position of the pick-up coil. The oscillator should be turned on and the condenser varied until the circuit is in *exact* resonance, this condition being indicated by a maximum reading noted on meter A. Points 1 and 2 are now short circuited and the condenser readjusted so as to again bring the circuit into resonance. The reading of the meter will now be greater than before because the resistance of the coil under test is no longer in the circuit. Now add resistance to the circuit at R until the meter reading is decreased to the same value as was noted above, and under such conditions the resistance R is equal to the r. f. resistance of the coil under test.

No. 106 — RADIO BROADCAST Laboratory Information Sheet

The 240 Type Tube

GENERAL CHARACTERISTICS

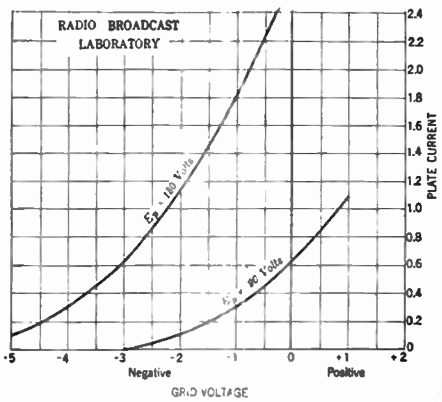
THE 240 type tube is designed for use in resistance-coupled amplifiers and under proper conditions will give an effective amplification of about 20 per stage. The plate resistor used with this tube should have a value of 250,000 ohms and the B and C voltages should be 180 volts or 135 volts and 3 or 1.5 volts respectively. The coupling condensers should have a value of 0.05 mfd. and the grid leak resistance should be of 2 megohms. these values are correct when the tube is used as an amplifier. It can also be used as a C-battery type detector in which case the C voltage should be 3 volts for a plate voltage of 135 or 4.5 volts for a plate voltage of 180. The plate resistor, coupling condenser, and grid leak should have the same values as given above.

The general characteristics of this tube are as follows:

Filament Voltage	5.0 Volts
Filament Current	0.25 Amperes
Maximum Plate Voltage	180 Volts
Amplification Constant	30
Plate Impedance	150,000 Ohms
Plate Current	0.2 Milliamperes

This tube can be used in any existing resistance-coupled amplifier provided the resistances used are of the proper value and the tubes are supplied with the proper A, B, and C voltages.

It is not possible to use this new tube in a transformer-coupled amplifier because its high plate impedance will cause the transformer to have a rather sharp peak at some frequency. This fact, however, makes the tube very satisfactory as an amplifier for c. w. reception in short-wave receivers where we are interested in obtaining high amplification around 1000 cycles and very poor amplification at all other frequencies. The tube can also be used as a detector in a short-wave receiver.



No. 107 — RADIO BROADCAST Laboratory Information Sheet

Neutralization

EFFECTS OF MALADJUSTMENT

AT THE present time there is only one known way whereby a very high-gain high-frequency amplifier can be obtained, and that is by using several well-designed tuned radio-frequency amplifiers with each stage properly neutralized. Manufactured receivers are neutralized at the factory and consequently the problem of neutralizing a receiver or the effect of improper neutralization does not generally concern those who buy their receiver ready made. The home constructor, however, must neutralize his own receiver, and for this reason it is rather important that the effect of improper neutralization be known.

The first and most obvious manifestation of incorrect adjustment of the neutralizing device is oscillation in some or all of the radio-frequency circuits. These oscillations as a general rule become more severe as the frequency is increased, and a loud squeal or whistle will be heard as the tuning controls are adjusted to receive some station that is transmitting.

Such an effect will make it difficult for the user of the receiver to obtain satisfactory reception and the oscillations will be radiated from the antenna attached to the receiver and cause interference on other receivers located in the neighborhood. Such oscillations can be prevented by correct adjustment, and it is essential that the proper setting be determined in order to make it possible to obtain best results from the receiver.

A second detrimental effect of maladjustment of the neutralizers is poor quality, which is generally due to the existence of too much regeneration. The quality under these conditions will generally sound drummy, indicating that the various frequencies in the carrier are being unequally amplified by the radio-frequency amplifiers. To preserve good quality, the radio-frequency amplifiers must amplify without distortion a band of frequencies extending about 5000 cycles above and 5000 cycles below the carrier frequency, and this condition does not exist unless proper neutralization is obtained.

Another effect of improper neutralization is to cause one or more of the tuned circuits in a single-control receiver to be thrown out of synchronism so that the set loses a great deal of its sensitivity, and as a result it is not possible to tune-in distant stations with satisfactory volume.

These three major effects of improper neutralization indicate how essential it is that neutralization be always carefully and completely accomplished. There are several satisfactory methods of neutralizing a receiver, and information regarding them can be found on Laboratory Sheet No. 38, published in the October, 1926, issue

No. 108 — RADIO BROADCAST Laboratory Information Sheet

High Voltage Supply for 210 Type Tube

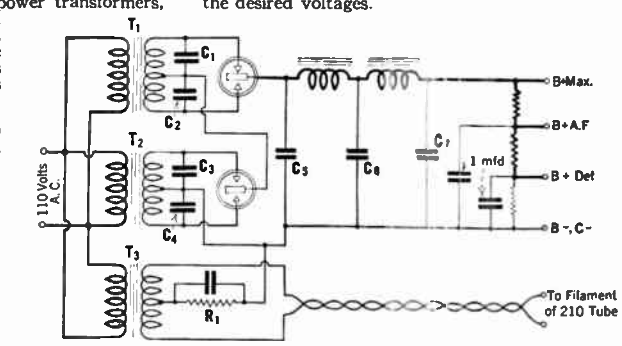
THE DOUBLE TRANSFORMER METHOD

IF HIGH voltages up to 400 volts are required for operation of a 210 type power tube, it is generally best to use a B power unit incorporating a 216-B single-wave rectifier tube. This tube is capable of operating satisfactory at the high transformer voltages which must be used. It is possible, however, by using a somewhat complicated arrangement, to obtain the high voltage by using low-voltage rectifiers such as the Raytheon and Q. R. S.

An arrangement whereby 400 to 450 volts can be obtained using two gaseous rectifiers is shown in the drawing on this Sheet. Two power transformers, T_1 and T_2, are necessary, each supplying about 220 volts each side of the center tap. They are connected into the circuit as shown and supply two rectifiers which in turn feed a common filter system. The maximum permissible current drain is 20 milliamperes using Raytheon type B tubes and 35 milliamperes using type BH tubes. Condensers C_1, C_2, C_3, and C_4 each have a capacity of 0.1 mfd; C_5 and C_6 are of 2 mfd. capacity, and C_7, 8 mfd. All the condensers should have a working voltage of 750 volts d. c.

Filament current for the 210 tube should be obtained from a separate filament transformer T_3 capable of supplying 1.25 amperes at 7.5 volts. The transformer should be tapped at the center as shown and a 1500-ohm resistance, R_1, connected between it and the negative B of the filter system. This resistance will supply C bias to the tube. Its bypass condenser should have a value of 2 mfd.

A 50,000- or 100,000-ohm resistance should be connected from B+ to B− if the unit is only to supply B potential to the 210, but if it is also to be used to supply B voltage to other tubes in a receiver the output should be shunted by several fixed resistors with taps at various points to obtain the desired voltages.



No. 109 — Radio Broadcast Laboratory Information Sheet

The Threshold of Hearing and Feeling in the Ear

ENERGY REQUIRED FOR AUDIBILITY

A GREAT many important experiments in sound have been made in the various large laboratories. An interesting experiment is to determine how much energy is required by the ear in order to just hear tones of various frequencies between about 30 and 5000 cycles. Data of this sort can be plotted on a curve, a typical one being given on this Sheet. Such a curve is called a curve of "threshold audibility" because it indicates the amount of sound energy required to just produce an audible sound.

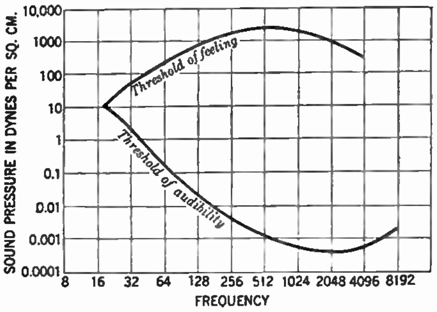
At 32 cycles a sound pressure of somewhat more than one dyne per square centimeter is required to produce an audible response, while at 2000 cycles only about 0.0003 dynes per square centimeter are required to produce an audible sound. The sound pressure required to produce a sound of minimum intensity is fairly constant between about 500 and 5000 cycles. Good speech articulation can be obtained within a frequency range of 250 and 2500 cycles; this band can, in fact, be narrowed to exclude all frequencies below 500 cycles and good articulation will still be retained. In the reproduction of music, however, it is necessary to include a much wider band having an upper limit of 5000 or 6000 cycles and a lower limit of about 32 cycles.

There is also an upper limit of sound pressure at which there is produced a sensation of feeling in the ear and it serves as a practical limit to the range of auditory sensation. At low frequencies the two curves of feeling and hearing meet each other, which indicates that these frequencies give a sensation of feeling which is difficult to distinguish from a sensation of hearing.

The power in microwatts in each square centimeter of the sound wave under average conditions is related to the effective value of the pressure in dynes as follows:

$$\text{Power} = \left(\frac{\text{Pressure in Dynes}}{20.5}\right)^2$$

Using this formula we can calculate the average power required to produce a minimum audible sound at frequencies between 2000 and 4000 cycles, which will be found to be about 4 x 10 $^{-10}$ microwatts per square centimeter.



No. 110 — Radio Broadcast Laboratory Information Sheet

Dry-Cell Tubes

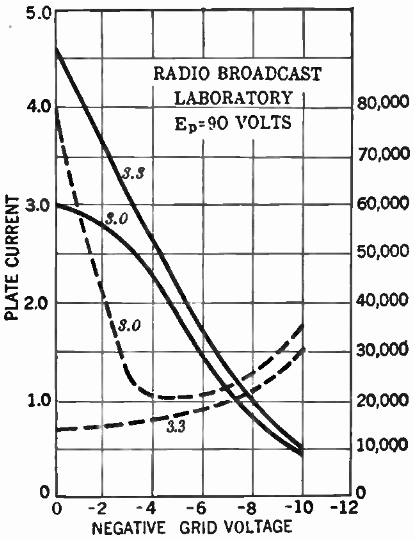
BEST FILAMENT VOLTAGE

ALTHOUGH dry-cell tubes are generally operated with 3 volts on the filament, somewhat better results can be obtained if 3.3 volts is used instead.

The two solid curves on the accompanying diagram are obtained by measuring the plate current at various values of negative grid bias with 3.0 and then 3.3 volts across the filament. If the tube is functioning properly this curve will be a straight line over most of its length. The 3.0-volt curve slopes off at low values of grid bias and this indicates that the filament emission is too low and a signal would be distorted. The 3.3-volt curve, however, is straight over a large portion of its length and therefore this same tube with somewhat higher filament voltage is capable of amplifying without distortion.

The two dotted curves show the plate impedance of the tube first with 3.0 volts and then with 3.3 volts on the filament. With 3.0 volts, and therefore a low filament emission, we obtain an erratic plate impedance curve, which rises to values as high as 80,000 ohms at zero grid voltage. The plate impedance curve taken with 3.3 volts again indicates the value of using this voltage, for it shows the plate impedance to be comparatively constant and low over a greater part of its length, and this is as it should be.

This recommendation that 3.3 volts be used on the filament is the result of many tests made in the Laboratory, and the Cunningham Tube Company has also recommended that this voltage be used.



Data Sheet No. 111 originally contained an index and was purposely omitted.

No. 113 RADIO BROADCAST Laboratory Information Sheet

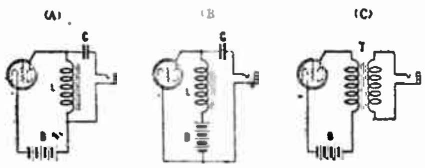
Output Circuits

THREE POSSIBLE CIRCUITS

IN THE sketch on this Sheet are shown three output arrangements that can be used to couple a loud speaker to a power tube in order to prevent the direct current in the plate circuit of the power tube from passing through the windings in the loud speaker and affecting its satisfactory operation. In sketches "A" and "B," the inductance of the choke coil, "L," should be at least 60 henrys and these coils should have a low resistance so as to prevent any great loss in voltage which would occur if the resistance was very high. A good unit should not cause a loss in voltage of more than 15 or 20 volts and this means that its d.c. resistance must not be greater than 750 ohms. The blocking condensers, "C," should have a capacity of from 2 to 4 mfd. The larger size theoretically gives somewhat better reproduction but practically little difference will be noticed with most loud speakers whichever size is used.

The arrangement shown at "A" has the advantage that, if the condenser breaks down, it will not result in any damage to the loud speaker because a breakdown in the condenser will merely cause the loud speaker to be shunted across the output choke "L" whereas, with arrangement "B," a breakdown of the condenser will cause the B battery to be short-circuited through the loud speaker and it is possible that the latter will be burned out. A disadvantage of arrangement "A" is that the a.c. current flowing through the loud speaker must flow through the B supply in order to return to the negative filament, and a comparatively small amount of resistance in the B supply will frequently cause a howl in the amplifier. In the arrangement shown in "B," the a.c. currents in the loud speaker return directly to the negative filament and do not have to traverse the B power unit; consequently, with this latter arrangement, there is less danger of oscillation in the audio amplifier.

In one particular case, during experiments in the



Laboratory, a resistance of 37 ohms in the B power unit, using circuit "A," produced continuous oscillations, whereas a resistance of 600 ohms was necessary in circuit "B" before oscillations were produced.

The arrangement at "C" shows an output transformer which is also a satisfactory method of coupling a loud speaker to a tube. It is essential, however, that the transformer be very carefully designed to prevent magnetic saturation because it must carry comparatively large direct current.

No. 114 RADIO BROADCAST Laboratory Information Sheet

The Transmission Unit

DEFINITION

ANY electrical system having anything to do with the transmission of electrical energy which is finally to be changed into sound energy should have its performance rated in some manner which bears a relation to the sensitivity of the ear. Two audio amplifiers might give power outputs of 800 milliwatts and 1000 milliwatts, and it appears from these figures as though the second amplifier would be capable of giving a considerable increase in volume over that obtained from the first amplifier, but actually this would not be so; the difference between the two amplifiers could hardly be detected by the ear. Evidently it would be of advantage to express the relation between the power outputs of the two amplifiers by some unit which would indicate their relative value as measured by the ear. The telephone companies have worked out such a unit, known as the transmission unit, abbreviated "TU." It is possible for the ear to just distinguish the difference between two powers that differ in intensity by 1 TU.

The two powers mentioned above, 800 and 1000 milliwatts, are in the ratio of 1.25 to 1. The TU difference between these two powers is equal to ten times the natural logarithm of the ratio of the two powers:

$$TU = 10 \log_{10} \frac{P_1}{P_2}$$

The ratio in this case is 1.25 and the natural logarithm is 0.097, which, multiplied by ten, gives 0.97 TU. The minimum perceptible change in loudness is 1 TU and therefore the difference between the two amplifiers would not be audible.

The equation given in the preceding paragraph gives the TU when two powers, or their ratio, are known. If instead of powers we deal with voltages, E_1 and E_2, then the formula is:

$$TU = 20 \log_{10} \frac{E_1}{E_2}$$

When using currents, I_1 and I_2, the equation is:

$$TU = 20 \log_{10} \frac{I_1}{I_2}$$

The logarithm of the ratio of two voltages differing by 12 per cent., is 0.05 and 20 times this gives 1 TU. Therefore, if two audio transformers differ in amplification by 12 per cent., they will give equally good results because a 1 TU change is not audible to the ear.

The natural logarithm of numbers can be found by using a slide rule or they can be determined from tables of logarithms which are frequently found in the appendix of text books.

No. 115 RADIO BROADCAST Laboratory Information Sheet

Wave Traps

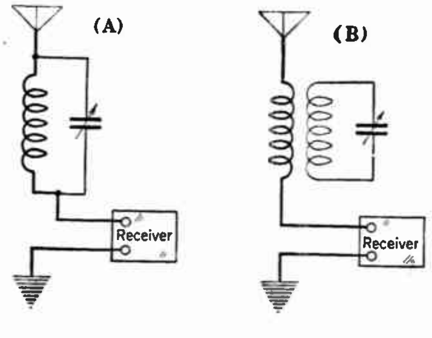
DIFFERENT TYPES

IN MANY cases where difficulty is experienced in eliminating the signals from a nearby powerful broadcasting station it will be found advantageous to use a wave trap in the antenna circuit.

A wave trap is a simple device consisting of a condenser and a coil, the latter with or without a primary, depending upon whether the circuit shown at "A" or "B" is used. In either case the wave trap should be tuned to the frequency of the interfering station. It then offers a very high impedance to the flow of currents of this frequency and in this way reduces their strength.

The circuit shown in "A" will give most complete elimination of undesired signals but has the disadvantage that it will also reduce somewhat the signals from other stations operating on frequencies adjacent to that of the station causing the interference. In cases of severe interference, however, the circuit shown at "A" must be used. The capacity of the variable condenser may be anything from 0.00025 mfd. to 0.001 mfd., and the coil must naturally contain sufficient turns so as to tune the circuit to the frequency of the interfering signals. There is no reason why a standard condenser and coil, designed for reception on the broadcast frequencies, cannot be used and it will then be possible to tune the trap to any frequency in the broadcast band.

The circuit shown at "B" tunes much sharper than the circuit shown at "A" but does not give complete elimination of the undesired signals. This circuit can be used with satisfaction when the interference is not very severe. The coil may be any ordinary tuned radio-frequency transformer.



No. 116 — Radio Broadcast Laboratory Information Sheet

Static

POSSIBILITIES OF ELIMINATION

NATURAL electrical disturbances occurring in the atmosphere are known as "static" or "strays" and frequently cause serious interference during the reception of signals. The subject "static" has been broken up into the following divisions by DeGroot in an article in *The Proceedings of the Institute of Radio Engineers*.

(A)—Loud and sudden clicks occurring intermittently. These do not seriously affect reception and apparently originate in nearby or distant lightning discharges.

(B)—A constant hissing noise giving the impression of softly falling rain or the noise of running water. This form usually occurs when there are low-lying clouds in the neighborhood of the receiving antenna.

(C)—A third form produces a constant rattling noise which sounds somewhat like the tumbling down of a brick wall!

These three forms can be considered as forms of natural static. The problem of the elimination of static is a difficult one upon which a great deal of work has been done and many different schemes have been devised, most of these schemes making use of two receiving antennas feeding a common receiver. The static signals present in the two antennas are made to balance out each other whereas the desired signals are not balanced out. In Morecroft's book, *Principles of Radio Communication*, it is suggested that one of the most promising lines for the development of a static eliminator has to do with a vacuum-tube detector which can only produce a limited response and therefore even with very heavy static the response cannot be more than the definite peak response of the tube.

Reception is also interfered with to a great extent in many localities by sounds produced by electrical apparatus, in which category can be classed the interference caused by various electrical motors and generators, x-ray apparatus, oil burners, precipitators, electrical transmission lines, etc. Their elimination is best accomplished at the source of the trouble by means of filter circuits such as those described in Laboratory Sheet No. 77, in the March, 1927, RADIO BROADCAST.

At the present time it appears that the best method to overcome natural static is to use a receiver in conjunction with a loop or a very short antenna, because with a loop or short antenna a high signal-to-static ratio can be obtained. Also, to prevent serious interference with broadcast programs, high power at the transmitting station is coming into more common use so that even under fairly bad conditions of static satisfactory reception can still be had.

No. 117 — Radio Broadcast Laboratory Information Sheet

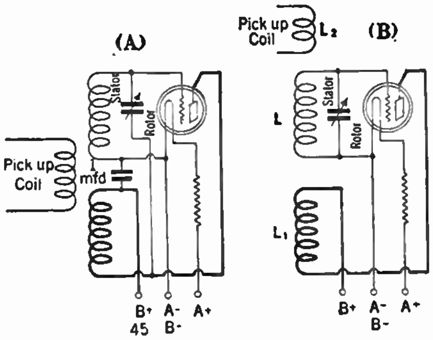
Super-Heterodynes

THE OSCILLATOR

IN A super-heterodyne receiver it is necessary to have one tube acting as an oscillator and functioning to produce radio-frequency energy which, in combination with the incoming signals, will produce a third frequency capable of being amplified by the intermediate frequency amplifier. The amplitude of the locally generated oscillations, in comparison with the incoming signals, has a very definite effect upon the strength of the signal which is finally detected and some care should therefore be taken in adjusting the circuit for most efficient operation, *i.e.*, loudest signals.

In sketch "A" is given the circuit used, probably, in a majority of super-heterodynes. It has the disadvantage that both sides of the variable condenser are at high potential and therefore some hand-capacity effects will be experienced.

In sketch "B" is shown an oscillatory circuit which is not open to the disadvantage of circuit "A" and is capable of giving just as good results in actual practice. In this circuit the rotor plates of the variable condenser connect to the low-potential side of the grid coil instead of across the entire coil. The "low" end of the grid coil connects to the filament and is therefore at ground potential and consequently there is no hand capacity. If a 0.0005-mfd. variable condenser is used, then coil "L" should contain 52 turns of No. 24 wire on a 2½" tube; for a 0.00035-mfd. condenser the number of turns should be 65. L_1, the plate coil, should consist, in either case, of 60 turns of No. 28 wire wound on the same tube and spaced from the coil "L" by ⅛". L_2 is the pick-up coil which should be connected in the circuit of the first detector tube; it should consist of 10 turns of No. 28 wire preferably wound on a tube slightly larger than 2½" so that it can slide over the other form and the coupling be varied in this way. Either a 201-A or 199 type tube may be used in the oscillator without changing the coil constants.



Data Sheet No. 112 originally contained an index and was purposely omitted.

No. 118 RADIO BROADCAST Laboratory Information Sheet

Audio Amplifiers

FREQUENCY AND LOAD CHARACTERISTICS

ANY audio amplifying system has two characteristics, equally important, which determine how well it will function. They are generally known as the frequency characteristic and the load characteristic.

The frequency characteristic indicates the relative amplification of the amplifying system of various frequencies between the limits over which the amplifier is to be operated. The frequency characteristic is generally shown in the form of a curve and, of course, a flat curve indicates equal amplification at all frequencies. Slight rises and depressions in the curve in the order of 10 per cent. can be neglected because they are too slight to be noticeable to the ear.

The load characteristic of an amplifier, while not in such common use, is just as important as the frequency characteristic. The load characteristic will show how the total amplification of the system varies with different input voltages at a constant frequency generally of about 1000 cycles. If the amplifier is a good one the amplification will remain constant over the entire range of input voltages at which the amplifier would normally be worked. If a two-stage amplifier is operated with a 201-A type tube in the output with 90 volts on the plate, it will overload very quickly because a 201-A cannot deliver much power. Consequently, the load characteristic curve of such an amplifier would begin to fall off comparatively quickly, but if a 171 tube with the proper voltages were to be used in place of the 201-A, then the load characteristic would indicate that it was possible to obtain much more power from the amplifier without overloading it.

Both of these characteristics depend upon the type of tubes used and the voltages with which they are supplied, and upon the design of the coupling devices connecting the output of one tube to the input of the next. Frequency and load characteristics can be taken on any part of the complete amplifier but such curves may have very little in common with the characteristics of the complete system. Consequently, although curves on individual units are useful in designing an amplifier, curves on the completed system should always be made to make certain that some factor, such as common coupling in the batteries, is not seriously altering the overall characteristic.

No. 119 RADIO BROADCAST Laboratory Information Sheet

Radio-Frequency Choke Coils

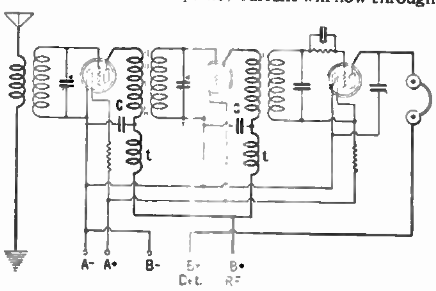
THEIR PLACE IN CIRCUIT

IF A very high-gain radio-frequency amplifier is to be constructed, it is essential that radio-frequency choke coils be used in the amplifier to prevent it from oscillating. Neutralization will prevent the production of oscillations due to feed-back through the tube but will not prevent the production of oscillations due to coupling in the battery leads or in a B socket-power device. To prevent instability due to these effects it is necessary that choke coils, L, and bypass condensers, C, be used in the plate circuits of the radio-frequency tubes, as indicated in the diagram on this Sheet. These choke coils offer a very high impedance to the flow of radio-frequency currents and all these currents therefore flow through the bypass condenser connected between the choke coil and the negative filament, instead of through the plate battery.

What size choke and what size condenser should be used? To keep down the cost they should both be as small as possible whereas their effectiveness becomes greater as their size is made larger.

The plate impedance of a 201-A type tube is about 12,000 ohms and it is essential that the condenser which is incorporated to bypass the r.f. currents does not introduce in the plate circuit any great amount of impedance. A 0.003-mfd. condenser will increase the total circuit impedance from 12,000 to about 12,120 ohms, a negligible amount. This value is correct at 500 kilocycles, the lowest frequency used in broadcasting, and at higher broadcast frequencies the effect of the condenser will be even less.

The choke coil's impedance must be large in comparison with that of the condenser so as to cause practically all the current to flow through the condenser and not through the choke. If the choke coil's impedance is made 1000 times greater than that of the condenser only one-tenth of one per cent. of the total radio-frequency current will flow through



the choke coil and therefore good filtering action will be obtained. If the choke coil's impedance at 500 kilocycles is to be 1000 times greater than the impedance of the condenser then it must be 12,000 ohms. The inductance of a choke coil with an impedance of 12,000 ohms at 500 kilocycles is 38 millihenrys. Most radio-frequency choke coils have an inductance of much more than this.

No. 120 RADIO BROADCAST Laboratory Information Sheet

A-Battery Chargers

TRICKLE VERSUS HIGH-RATE CHARGERS

THERE are many different types of A-battery chargers now available; some of them are satisfactory for use as trickle chargers and others only efficient when used to charge the battery at comparatively high rates of charge. The charger employing an electrolytic type of rectifier, for example, is very well adapted for use in trickle charging. It is very efficient, requires little attention, and has long life.

Another very satisfactory type of rectifier for a trickle charger is the so-called dry crystal, which was developed rather recently. A third type of rectifier that can be used for trickle charging is the Tungar but it is not especially efficient as a trickle charger, because of the comparatively large amount of power required to heat its filament.

There are three types of rectifiers that are satisfactory for use in high-rate charging. They are the Tungar, the Vibrator type, and the new cartridge recently developed by Raytheon. All of these chargers are capable of delivering fairly large amounts of rectified current for charging a battery and are fairly efficient when delivering these currents.

There is little to be said regarding the comparative efficiency of the two methods of charging. Trickle charging has the advantage that it requires somewhat less attention than does high-rate charging but it has the disadvantage that it is somewhat difficult to determine just what the best rate of trickle charge should be in order to prevent the battery from being overcharged or undercharged; also slow rates of charge used in trickle chargers are hard on a battery. With a trickle charger, a low-capacity storage battery can be used because it is not called upon to supply any great amount of current for a long period of time.

With high-rate charging, on the other hand, it is usual to charge the battery every one or two weeks and also a fairly large storage battery is necessary in order that it will have sufficient capacity to supply the receiver between charges. It seems to be generally agreed among battery manufacturers, however, that the high charging rate is somewhat better for the battery in that it makes possible longer life. For best results the charging rate should gradually taper off as the battery becomes charged.

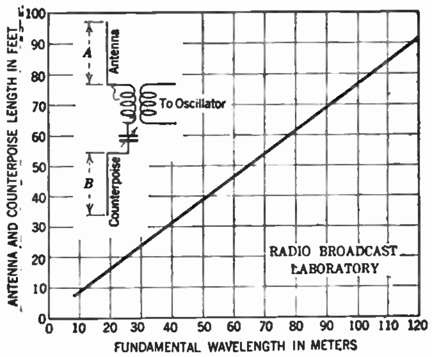
No. 121 — Radio Broadcast Laboratory Information Sheet

The Hertz Antenna

CHA ACTERISTICS

ONE of the commonest antenna systems used by amateurs for transmitting purposes is the Hertz system. This antenna, in its simplest form, consists of two straight wires located diametrically opposite each other as indicated in the drawing on the accompanying curve. The length of the two wires bears a definite relation to the fundamental wavelength at which the antenna system will tune and this relation is indicted by the curve, which is reprinted from *QST* of May, 1926. The relation between the length of the antenna system and the fundamental wavelength is a constant; the length L is equal to the wavelength divided by a constant, 1.3.

It is possible to obtain radiation on any wavelength by using different lengths of antenna and counterpoise. Suppose we wish to transmit on 40 meters (7500 kc.) and the antenna system is to be operated on the fundamental wavelength. Then from the curve the length of the antenna "A" would be 31 feet and the length of the counterpose "B" would also be 31 feet. It would also be possible to transmit on 40 meters using the third harmonic of the antenna, in which case the antenna would be of such a size as to have a fundamental wavelength equal to 40 times 3 or 120 meters. If supplied with energy at a frequency corresponding to 40 meters, however, the antenna would radiate energy at this frequency very efficiently even though its natural wavelength is 120. If such a system of transmission were to be used, the length of the antenna and the counterpoise would each be 93 feet.



No. 122 — Radio Broadcast Laboratory Information Sheet

Testing Radio Receivers

FEATURES TO CONSIDER

IT IS obviously of distinct advantage to test radio receivers in accordance with some standardized test procedure so that the results obtained from different receivers can be readily compared. If such a method is used the manufacturer will be able to have before him information which will tell him definitely just how his product compares with those of other manufacturers and also the buyer of a receiver will have certain definite data upon which to base his decision in buying a receiver. Considerable information on methods of testing radio receiving sets is given in the Technologic Paper of the Bureau of Standards, No. 256. In this paper it is suggested that the following tests be made on a receiver:

(A) Frequency range.

(B) Vibration test, which determines how well the set has been constructed mechanically and whether it will be able to withstand the ordinary shocks obtained in transportation.

(C) Sensitivity.

(D) Selectivity.

These tests are especially effective in indicating how well the set has been engineered from an electrical standpoint. A test should also be made of fidelity, to determine how well the receiver is capable of reproducing voice and music.

From the standpoint of the average user these tests are not conclusive because he is interested in other things besides the electrical efficiency of the receiver or its fidelity of reproduction. In a laboratory test one receiver might show up much better than another in regard to sensitivity and selectivity but the good results might only be obtained with very accurate adjustments. Obviously, a single-control receiver lacking somewhat in sensitivity and selectivity in comparison with another receiver might actually give somewhat better results when operated by an ordinary buyer with little knowledge of the circuit. As is stated in the paper mentioned above, it is really very difficult to judge the performance of any particular receiving set on the basis of any one trial of its operation, largely due to the widely different types of receivers and conditions under which they are best operated. The skill of the operator very largely determines the degree of satisfaction that will be obtained from any given receiver. In practice it will very likely be found best to just make available to the prospective purchaser some figures of merit indicating the sensitivity, selectivity, and fidelity and then to let him determine for himself whether the receiver in his hands gives satisfactory results.

Many letters are received from readers requesting comparisons between different receivers but to give conclusive information of this sort is impossible. The choice of the receiver which one finally purchases after trying out many sets is governed by many factors on which no laboratory measurements can be made.

No. 123 — Radio Broadcast Laboratory Information Sheet

Characteristics of 171 Type Tube

STATIC AND DYNAMIC

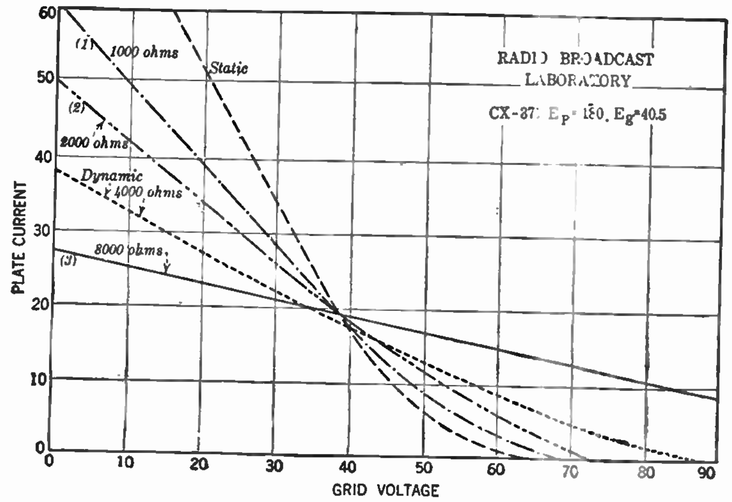
ON LABORATORY Sheet No. 124 are given several curves for the 171 tube. It will be noted that one curve is marked static and another dynamic. The dynamic characteristic is, as its name implies, a curve indicating how the tube will function under actual operating conditions. The static characteristic curve, although valuable in giving an idea of the general characteristics of a tube, gives no indication at all of the tube's actual performance. Under actual operating conditions a tube always operates with a certain load in its plate circuit and consequently a curve taken to indicate the tube's performance should be made with some load in the plate circuit. The curve marked "dynamic" was taken when the tube had 4000 ohms resistance in its plate circuit. The difference between the static and the dynamic curves is considerable.

The curves were taken with 180 volts on the plate and 40.5 volts on the grid. In order that an amplifier may give good quality, its plate-current grid-voltage characteristic must be straight from zero grid voltage to twice the d. c. voltage on the grid. The static characteristic, although straight from 40.5 volts to zero volts, is very curved at voltages greater than 40.5. It might be judged from this curve that the tube's performance would be very poor. However, if a dynamic characteristic is taken, we find that the characteristic remains straight from zero grid voltage down to about 85 volts and consequently the tube would actually give good results.

The other curves on Sheet No. 124 are dynamic characteristics taken with different resistances in the plate circuit. Curve No. 1 was made with 1000 ohms resistance, No. 2 with 2000 ohms, and No. 3 with 8000 ohms. It will be noticed that as the resistances increase the straight portion of the curve becomes greater and greater. The curves all cross at about 40 volts because this grid voltage represents the initial d. c. potential placed on the grid and the curves are made by increasing and decreasing the grid voltage about this average value. It is necessary in taking the curves to adjust the plate voltage each time so that with the different resistances the same plate current is obtained at 40.5 volts on the grid.

No. 124 RADIO BROADCAST Laboratory Information Sheet

Curves of the 171 Type Tube



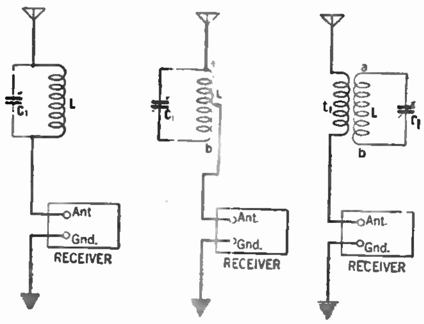
No. 125 RADIO BROADCAST Laboratory Information Sheet

Wave Traps

THREE CIRCUITS

THE trend of broadcasting, for sometime, has been toward the use of high power, and this has made the problem of selectivity a serious one for many listeners located within a few miles of a high-power broadcasting transmitter. When difficulty is experienced in satisfactorily tuning-out such a station, it will be advisable to incorporate a wave trap in the antenna circuit. Wave traps are very easily constructed and cost little. They consist of any ordinary coil and a condenser, connected in the antenna circuit, and adjusted to absorb a large amount of the energy being received from the interfering station. The traps may be connected in several ways, as indicated on the diagram. The arrangement shown at A will give most complete elimination of the undesired signal but may also cause a considerable decrease in volume of stations operating on adjacent channels. The arrangement shown at B is probably the most flexible manner in which to connect a wave trap. If the coil is arranged with several taps an adjustment can be arrived at which gives most satisfactory results. Arrangement C is only useful in case of mild interference. The circuit tunes very sharply and will effectively eliminate interference provided it is not too great.

In constructing a wave trap, coil L may consist of 47 turns of No. 22 wire on a 3-inch diameter form if the tuning condenser C_1 has a capacity of 0.0005 mfd.; with a 0.00035 condenser coil L should consist of 60 turns. With either size, coil L_1 may consist of about 15 turns wound at the b end of the secondary coil. With arrangement B taps should be made at about every 10 turns.



No. 126 RADIO BROADCAST Laboratory Information Sheet

Condenser Reactance

HOW IT IS CALCULATED

IF A condenser is connected in series with an a. c. ammeter to a source of alternating current, a certain amount of current will flow in the circuit, depending upon the size of the condenser and the frequency of the current. If the voltage of the source is divided by the current, the quotient will be the "reactance" of the condenser in ohms. For example, if the frequency of the current being supplied by the source of potential was 60 cycles and the voltage was 110 volts and the size of the condenser was 1 mfd. we would find that 0.412 amperes of current would flow through the circuit. Then 110 volts divided by 0.412 gives 2666, which is the reactance in ohms at 60 cycles of a 1 mfd. condenser. The reactance of a condenser depends upon its size and upon the frequency of the current. It can be calculated by means of the following formula:

$$\text{Reactance} = \frac{10^6}{6.28\ FC}$$

Where F is the frequency in cycles per second and C is the capacity of the condenser in microfarads.

In many calculations it is necessary to know the reactance of a particular condenser at some frequency, and for this reason, on Laboratory Sheet No. 127, is given a table of condenser reactances for capacities between 0.001 and 10 mfd. at frequencies from 60 to 1,000,000 cycles. From the formula given herewith it is evident that the reactance of a condenser is inversely proportional to the capacity of the condenser and inversely proportional to the frequency. Doubling the size of the condenser therefore gives half the reactance, and doubling the frequency of the current also halves the reactance of the condenser. Remembering these two facts it is a simple matter to calculate mentally the reactance of almost any capacity not given in the table on Laboratory Sheet No. 127. For example, a 3-mfd. condenser at 100 cycles has ⅓ of the reactance of a 1 mfd. condenser at 100 cycles. Since the reactance of the latter size at 100 cycles is 1600, then the reactance of a 3-mfd. condenser must be 1600 divided by 3, or 533⅓ ohms. A 0.001-mfd. condenser at 1,000,000 cycles has a reactance of 160 ohms. A 0.0001-mfd. condenser at this frequency therefore has a reactance of 1600 ohms and a 0.01-mfd. condenser likewise has a reactance of 16 ohms.

No. 127 RADIO BROADCAST Laboratory Information Sheet

Condenser Reactance

CONDENSER CAPACITY IN MFDS.	REACTANCE IN OHMS AT VARIOUS FREQUENCIES							
	60	100	250	500	1000	10,000	100,000	1,000,000
0.001	2666000	1600000	640000	320000	160000	16000	1600	160
0.005	533200	320000	128000	64000	32000	3200	320	32
0.01	266600	160000	64000	32000	16000	1600	160	16
0.1	26660	16000	6400	3200	1600	160	16	1.6
0.5	5332	3200	1280	640	320	32	3.2	.32
1.0	2666	1600	640	320	160	16	1.6	0.16
2.0	1333	800	320	160	80	8	0.8	0.08
4.0	666	400	160	80	40	4	0.4	0.04
8.0	333	200	80	40	20	2	0.2	0.02
10.0	267	160	64	32	16	1.6	0.16	0.016

This table shows how the reactance of various capacities varies with different frequencies. The reactance of a condenser varies inversely with its capacity and with the frequency. See Laboratory Sheet No. 126

No. 128 RADIO BROADCAST Laboratory Information Sheet

B Power Units

DESIRABLE CHARACTERISTICS

A B-POWER unit is essentially a device to supply plate voltage to a radio receiver but such a unit has several characteristics besides the ability to supply proper voltages that are important in determining how satisfactorily it will operate. Modern batteries for the plate supply of a receiver can hardly be improved on. Their voltage is constant, they are perfectly quiet in operation, and leave little to be desired as a source of plate potential. The expense of operating a multi-tube receiver using power tubes from batteries is considerable, however, but a B power unit, properly designed, affords an excellent source of high plate potential at moderate cost.

What are the desirable characteristics of such a unit? It must first of all be capable of supplying the proper voltages to a receiver. Either insufficient or excessive voltage will adversely affect the operation of a receiver in many cases and it is therefore essential that some care be taken to make certain that the voltages being supplied are correct.

The power unit must deliver those voltages with a minimum of a. c. hum. Low hum output is only obtained with a properly designed transformer and filter system. The various filter chokes should be shielded so that magnetic coupling between them will not be possible and it is also necessary that some means be used to electrostatically shield the high-voltage secondary windings from the primary winding to prevent any line noise from the power mains getting into the filter system, and making the output of the unit noisy. This shielding between the primary and secondary may be accomplished by means of a grounded copper shield between the primary and secondary windings or the shielding may be accomplished quite effectively by placing the filament winding, supplying the power tube, between the primary and high-voltage windings. The filament winding, being at ground potential, therefore acts as a very effective shield. A noisy plate supply unit generally indicates the lack of proper magnetic shielding, or improper filtering.

A third desirable characterisctic of a power unit is good regulation, which determines how much the output voltage will change with changes in the amount of current being supplied by the unit. A particular plate supply device might give exactly 90 volts at the 90-volt tap with a load of 10 mA. If, however, the regulation was poor and your receiver only required 4 mA. from the 90-volt tap, the actual voltage at this tap might rise as high as 130 volts; if the unit had good regulation the voltage would not be more than 98 at a load of 4 mA. Power units with poor regulation frequently cause receivers to "motor boat" or distort the signal in some other way, and good regulation, *i. e.*, small variation of output voltage with output load, is therefore a very desirable characteristic.

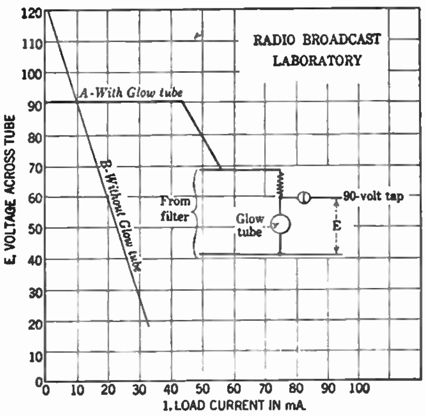
No. 129 RADIO BROADCAST Laboratory Information Sheet

The Type 874 Glow Tube

HOW IT FUNCTIONS

THE type 874 tube is a special voltage regulator designed for use in B power units to maintain the voltages, supplied by the unit, constant. An ordinary B power unit operated without a glow tube has a comparatively poor regulation, *i.e.*, the voltage changes considerably with changes in the amount of current being drawn from the unit. It would obviously be of decided advantage if this voltage could be made to remain practically constant at all loads. The power unit could then be used with any receiver irrespective of the amount of current being drawn by it (within reason) with the knowledge that the actual voltages designated on the binding posts of the B device were being supplied. How the glow tube functions to maintain the voltage constant may be understood by reference to the curve A. This curve is plotted by measuring the voltage across the glow tube with various load currents and it should be noted that the voltage across the tube is practically 90 at all loads up to more than 40 mA. In ordinary operation, when there is no current being drawn from the 90-volt tap, the glow tube current is about 45 milliamperes. Then, if current is drawn for a receiver from the 90-volt tap, which would ordinarily cause the voltage to go down, the current through the glow tube automatically decreases, providing for the current required by the set. The voltage thereby is maintained at exactly 90.

Curve B illustrates the curve of output voltage that might be obtained from a B power unit not using a glow tube. At no load the voltage is 123, while at a load of 10 mA. the voltage drops to 90. If, however, the receiver requires 20 milliamperes, the actual voltage available would be only 60 volts.



No. 130 RADIO BROADCAST Laboratory Information Sheet

Data on Honeycomb Coils

No. of Turns	Inductance, at 800 Cycles, in Millihenries	Natural Wavelength, Meters	Distributed Capacity in Mmfd.	Wavelength Range, Meters	
				0.0005-Mfd. Condenser	0.001-Mfd. Condenser
25	.039	65	30	120 to 245	120 to 355
35	.0717	92	33	160 to 335	160 to 480
50	.149	128	31	220 to 485	220 to 690
75	.325	172	26	340 to 715	340 to 1020
100	.555	218	24	430 to 930	430 to 1330
150	1.30	282	17	680 to 1410	680 to 2060
200	2.31	358	16	900 to 1880	900 to 2700
249	3.67	442	15	1100 to 2370	1000 to 3410
300	5.35	535	17	1400 to 2870	1400 to 4120
400	9.62	656	13	1800 to 3830	1800 to 5500
500	15.5	836	13	2300 to 4870	2300 to 2000
600	21.6	1045	14	2800 to 5700	2800 to 8200
750	34.2	1300	14	3500 to 7200	3500 to 10400
1000	61	1700	13	4700 to 9600	4700 to 13800
1250	102.5	2010	11	6000 to 12500	6000 to 18000
1500	155	2710	13	7500 to 15400	7500 to 22100

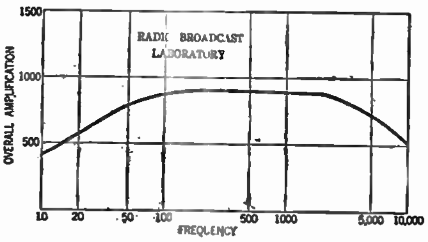
No. 131 RADIO BROADCAST Laboratory Information Sheet

Resistance-Coupled Amplifier

DATA ON CONSTANTS

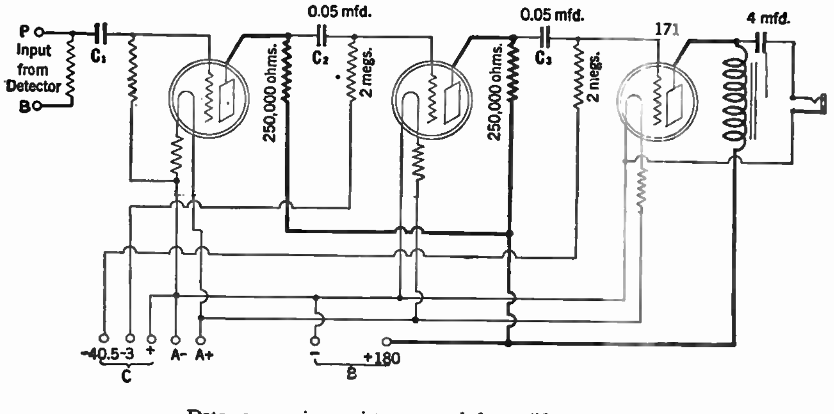
ON LABORATORY Sheet No. 132 is given a circuit diagram of a resistance-coupled amplifier using the new type 240 high-mu tube (Cunningham type 340). To obtain satisfactory operation from such an amplifier it is essential that several points be given careful consideration. In the first place it is essential that excessive C bias is not used on any of the high-mu tubes. The following values should be used in combination with the voltage shown in the circuit diagram to prevent overloading: 1 volt on the first stage, 3 volts on the second stage, and 40.5 volts on the 171 power tube. The second consideration of great importance in the construction of such an amplifier is that the coupling condensers, C_1, C_2, and C_3, be of the best quality that can be obtained. Even a small amount of leakage across the condenser, due to faulty insulation, will permit some of the plate potential to leak through it to the grid of the next tube and this will not only cause distortion but very frequently will make the amplifier absolutely inoperative. Use only the best of mica condensers.

It is, of course, also essential that the plate and grid resistance be noiseless in operation but it is not necessary that they be exactly of the values given in the circuit. A variation of ten or twenty per cent. in these values is quite unimportant. The plate supply for the amplifier may either be a well constructed B power unit or batteries. No trouble whatsoever should be experienced when operating the unit from new batteries, but it is possible that "motor-boating" troubles will develop when the amplifier is used with some B power units. The overall gain is comparatively high and difficulties of this sort become more pronounced as the amplification is increased. Large bypass condensers across the output of the power unit will frequently be necessary in order to prevent the occurrence of "motor-boating." The frequency characteristic of the complete amplifier is shown by the accompanying curve.



No. 132 RADIO BROADCAST Laboratory Information Sheet

Resistance-Coupled Amplifier Circuit



Data concerning resistance-coupled amplifiers appear on Laboratory Sheet No. 131

No. 133

RADIO BROADCAST Laboratory Information Sheet

Care of Power Supply Units

FREQUENT CHECKING NECESSARY

MANY modern radio receiver installations employ a B power unit for the plate voltage, and a storage battery in conjunction with a trickle charger for the filament supply, the entire combination being controlled by means of an automatic relay. If well manufactured units are used throughout, such an installation should require practically no attention other than the addition of water to the storage battery and the trickle charger, if the latter is of the electrolytic type.

In order to make certain that the entire power plant is functioning satisfactorily, it is a good idea to make some simple tests every six months or so. Little can go wrong with the B power unit without it becoming noticeable in the operation of the receiver. If the rectifier tube deteriorates the volume produced by the receiver will be lowered and also the quality will be impaired. A total failure of the power unit will, of course, mean that it will be impossible to hear anything at all on the receiver.

The simplest check to make on the A power unit in order to make certain that it is functioning satisfactorily is to take a hydrometer reading of the storage battery. If the battery reads "fully charged" it is possible that the trickle charging rate is excessive and it will be a good idea to somewhat reduce the rate and then make frequent tests with the hydrometer to determine how the battery is standing up. If the total charge in the battery now gradually decreases it will be best to increase the rate of trickle charge again. If, on the other hand, the battery continues to remain in a fully charged condition, we have a good indication that the previous rate of trickle charge was too high and that very probably the battery was being continually over charged, which is very harmful. If a hydrometer reading of the battery indicates that the battery is very low the trickle charge rate should be increased so that the battery is brought up to practically full charge and then the rate should be adjusted so as to maintain the battery in this condition. The contacts in the relay controlling the installation should be inspected every so often. There is a certain amount of sparking at the contacts which tends to pit them and it might be necessary to smooth them with a piece of emery cloth. Badly pitted contacts in the relay might at times prevent the unit from closing the trickle charger circuit and consequently the battery will not always be charged while the receiver is not being operated.

No. 134

RADIO BROADCAST Laboratory Information Sheet

Loud Speaker Horns

THE EXPONENTIAL TYPE

A CORRECTLY designed horn makes a very good type of loud speaker. The best horn is one which radiates most uniformly over the required range of frequency and it has been proved mathematically that the exponentially shaped horn conforms closely to this requirement. A horn is of the exponential type when its cross section area doubles at equal intervals along its length. For example, a horn would be of the exponential type if at the orifice it had an area of ¼ square inches and an area of ½ square inches, 1 square inch, and 2 square inches, at distances of 1, 2, and 3 feet respectively from the orifice. The rate of expansion determines the lowest frequency of which the horn will be a good sound producer. A horn which doubles in area every foot will reproduce down to about 64 cycles, and a horn which expands twice as rapidly will only reproduce well down to 128 cycles.

A properly designed horn should be free from noticeable resonance, and to prevent this the mouth of the horn should be made large enough to transmit the sounds coming from it without any great amount of back pressure. In the design of loud speaker horns it has been found that, if the mouth is made comparable to ¼ of the wavelength corresponding to the low frequency cut-off point of the horn, the resonance in the horn will be negligible. The wavelength in feet is determined by dividing the velocity of sound in feet per second, which is 1120, by the frequency. For example, a horn whose cut-off frequency is to be 32 cycles, corresponding to a wavelength of 39 feet, should have a mouth of 39 divided by 4, or 9¾ feet. These facts indicate definitely that a horn, to be a good one, must be large. Small horns, whether they are or are not exponential, cannot radiate the low frequencies.

The horn makes it possible for a comparatively small diaphragm to get a good grip on the air and thereby produce a large volume of sound. The small diaphragm and the large horn may be replaced by a large diaphragm, as is done in a cone type loud speaker.

The material of which the horn is made is important. Although a horn may be well designed, and constructed to the correct size, total length and expansion per unit length, it may still fail to give really good results because of resonant effects in the material used in the construction. The material used should have no marked resonant frequency unless it is very low, where it might help to increase the low note radiation.

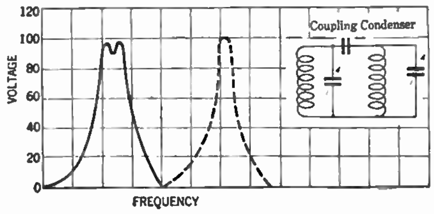
No. 135

RADIO BROADCAST Laboratory Information Sheet

Closely Coupled Circuits

RESONANCE CURVES

IF TWO circuits are coupled together by a condenser, as shown in the sketch, and they are both adjusted so that they are tuned to slightly different frequencies, we will find that a resonance curve of



the combination has the form shown by the solid curve. The resonance curve of either separate circuit alone would have the form indicated by the dotted curve. It is evident from the resultant curve that the combination of these two circuits produces a resultant characteristic curve which is quite broad and flat on the top in comparison with the quite sharp peak of either circuit alone. This double peaked effect is a characteristic of closely coupled circuits and has been used to some extent in radio receivers.

An ordinary resonance circuit consisting of a single coil and condenser has a comparatively sharp resonance curve and therefore frequencies slightly above or below the resonant frequency are not amplified as well as the latter and, therefore, the tuned circuit tends to cut down the amplification of the side bands of the incoming wave and this causes some loss of high frequencies. If a receiver is made up, however, with two coupled circuits, such as we have indicated, this cutting of the side bands will not take place because the flat top of the resonance curve can be made sufficiently broad so as to give equal amplification over a band 10,000 cycles wide and therefore practically equal amplification can be obtained at all frequencies 5000 cycles above or below the carrier frequency. The circuit has not been used in actual practice to any great extent because of the difficult tuning required and because of the careful adjustments necessary.

No. 136 RADIO BROADCAST Laboratory Information Sheet

Carrier Telephony

THEORY AND USES

THE use of power lines for the dissemination of intelligence is becoming increasingly common throughout the country. Large power companies have in many cases installed radio equipment for inter-communication between various power plants; these radio-frequency signals are transmitted over the power lines rather than through the air, and, in this way less interference is encountered. The system has also been used in some communities in order to make it possible to receive musical programs at home by connecting a suitable device directly to the power socket.

For commercial use, this system has certain advantages, such as lack of interference, which make its use valuable, but it is unlikely that the system will ever replace broadcasting. The number of different stations that can be "tuned-in" by a subscriber using the system is naturally limited, and this is a definite disadvantage.

The system actually differs very little from that of ordinary broadcasting, the major difference being that the power of the transmitter, instead of being radiated into the air by means of an antenna, is coupled directly to the power line. The coupling between the transmitter and the power line is generally made through high-voltage coupling condensers and special filter and protective circuits. At the receiving end an ordinary radio receiver can be used to detect the signals. It also must, of course, be coupled in some way to the transmission line. The system is generally operated in duplex so that transmitting or receiving can be accomplished at any of the various terminals of the system.

In carrier telephony it has generally been found best to use carrier frequencies somewhat above 50,000 cycles. For comparatively low radio frequencies, around 10,000 cycles, there is considerable loss in the various power transformers in the line, and at frequencies intermediate between about 10,000 and 50,000 cycles there will very likely be sharp resonance peaks causing excessive loss at particular frequencies. Above 50,000 cycles an ordinary transmission line is fairly satisfactory as a transmitting medium.

No. 137 RADIO BROADCAST Laboratory Information Sheet

Operating Vacuum Tubes in Parallel

METHODS AND RESULTS

IT IS sometimes desirable to operate several tubes in parallel in order to obtain a greater power output, and it is of interest to know how efficiently this may be done.

If two tubes are to be used in parallel in the output of an audio amplifier the two sockets are wired so that the grid of one tube connects to the grid of the other tube and the two plates connect together. The two filaments are also connected together. The result is that from these two tubes we will have only four leads—one from the grids, another from the plates, and two others from the filaments.

The amplification constant of the combination will be equal to the constant of a single tube, provided both of the tubes have the same constant. If one of the tubes had a low amplification constant and the other a high constant the resultant amplification constant of the two would be equal to the arithmetic mean. If the amplification constant of one tube is six and the other four, the resultant amplification constant will be five.

The resultant plate impedance will be equal to one half the impedance of a single tube, and if unlike tubes are used, the total impedance can be calculated by the simple laws governing resistances in parallel. The combined impedance can be stated as follows:

$$\frac{\text{Imped. of one tube} \times \text{Imped. of other tube}}{\text{Imped. of one tube} + \text{Imped. of other tube}}$$

The greatest power output is obtained when the two tubes have identical plate impedances and amplification constants. Fortunately, bowever, a very large fraction of the total power of the two tubes can be obtained even if they differ considerably.

To illustrate, two tubes might be connected in parallel, the amplification constants of which are in a ratio of 2 to 1 and the plate impedances of which are equal, and from the combination we could obtain 90 per cent. as much power as could be obtained if the tubes were operated in separate circuits. If, with equal amplification constants, the plate impedances are in a ratio of 2 to 1, the total power will be about 90 per cent. of the maximum possible value. It is evident, therefore, that the total power will not be decreased by any great amount even if tubes quite widely differing in characteristics are used. From two perfectly matched tubes, feeding into a load resistance equal to their combined plate impedance, we can obtain twice as much power as can be obtained from a single tube feeding into a load resistance equal to its plate impedance.

No. 138 RADIO BROADCAST Laboratory Information Sheet

The Unit of Capacity

CALCULATION AND FORMULAS

THE capacity of a condenser is stated in terms of the quantity of electricity it will hold per volt. When a condenser stores a specific quantity of electricity known as a coulomb and there is an electrical pressure of one volt across its terminals then the capacity of the condenser is one "farad." A condenser must be very large to bave a capacity of a farad and therefore a millionth part of a farad has been adopted as the practical unit and it is called the "microfarad," meaning one-millionth of a farad. Capacities smaller than one microfarad can be expressed in micro-microfarads, corresponding to a millionth of a microfarad.

The capacity of a condenser may be computed from the general equation:

$$C = \frac{2250\ AK}{10^{10}d}$$

where C = capacity of condenser in microfarads
K = dielectric constant
A = total area of dielectric between plates in square inches
d = thickness of dielectric in inches

Example:

What is the capacity in microfarads of a condenser having 2000 plates. The dielectric consists of paraffined paper 0.002 inch thick. The part of each sheet of dielectric actually between the plates has an area of 6.3″ x 8″.

Vaseline	Ebonite	Glass	Mica	Paraffin Wax	Porcelain	Quartz	Resin	Shellac	Castor Oil	Olive Oil	Petroleum Oil
2.0	3.0	7.0	6.0	2.5	4.0	4.5	2.5	3.5	5.0	3.0	2.0

From the table in this sheet it will be seen that the constant of the dielectric is 2.5.

The total area, A, of the dielectric is:—

$$A = 6.3 \times 8 \times 2000$$
$$= 100{,}000 \text{ square inches, approximately}$$

Therefore

$$C = \frac{2250 \times 100{,}000 \times 2.5}{10^{10} \times 0.002}$$
$$= 28.1 \text{ microfarads}$$

No. 139 Radio Broadcast Laboratory Information Sheet

Inductive Reactance

HOW IT IS CALCULATED

If an inductance coil is connected in series with an a. c. ammeter to a source of alternating current, a certain amount of current will flow in the circuit, depending upon the size of the coil and the frequency of the current. If the voltage of the source is divided by the current, the quotient will be the "reactance" of the coil in ohms. For example, if the frequency of the current being supplied by the source of potential was 60 cycles and the voltage was 110 volts and the coil had an inductance of 1.0 henry, we would find that 0.292 amperes of current would flow through the circuit. Then 110 volts divided by 0.292 gives 377, which is the reactance in ohms at 60 cycles of a coil with an inductance of 1.0 henry. The reactance of a coil depends upon its inductance and upon the frequency of the current. It can be calculated by means of the following formula:

$$\text{Reactance} = 6.28\,FL$$

where F = the frequency of the current in cycles per second, and L = the inductance of the coil in henries.

In many calculations it is necessary to know the reactance of some particular coil at some frequency and for this reason on Laboratory Sheet No. 140 is given a table of reactance for inductance coils between 0.01 and 100 henries at frequencies from 60 to 100,000 cycles. From the formula given herewith it is evident that the reactance of a coil is directly proportional to the inductance of the coil and also directly proportional to the frequency. Doubling the size of the coil gives twice the reactance and twice the reactance is also obtained if the frequency is doubled. If these two factors are remembered it is a simple matter to calculate mentally the reactance of any coil not given in the table on Laboratory Sheet No. 140. For example a 10-henry coil has one third the reactance of a 30-henry coil at, say, 100 cycles. Since the reactance of a 10-henry coil at 100 cycles is 6280 ohms, it follows that the reactance of a 30-henry coil at the same frequency must be 18,840 ohms.

No. 140 Radio Broadcast Laboratory Information Sheet

Coil Reactance

Coil Inductance in Henries	Reactance in Ohms at Various Frequencies						
	60	100	250	500	1000	10,000	100,000
0.01	3.77	6.28	15.7	31.4	62.8	628	6,280
0.05	18.8	31.4	78.5	157	314	3,140	31,400
0.1	37.7	62.8	157	314	628	6,280	62,800
0.5	188.5	314	785	1,570	3,140	31,400	314,000
1.0	377	628	1,570	3,140	6,280	62,800	628,000
2.0	754	1,256	3,140	6,280	12,560	125,600	1,256,000
5.0	[illegible],885	3,140	7,850	15,700	31,400	314,000	3,140,000
10.0	3,770	6,280	15,700	31,400	62,800	628,000	6,280,000
20.0	7,540	12,360	31,400	62,800	123,600	1,236,000	12,360,000
30.0	11,310	18,840	47,200	94,200	188,400	1,884,000	18,840,000
40.0	15,080	24,720	61,800	123,600	247,200	2,472,000	24,720,000
50.0	18,850	31,400	78,500	157,000	314,000	3,140,000	31,400,000
100.0	37,700	62,800	157,000	314,000	628,000	6,280,000	62,800,000

This table shows how the reactance of various inductance coils varies with different frequencies. Laboratory Sheet No. 139 explains what inductive reactance is and upon what it depends.

No. 141 Radio Broadcast Laboratory Information Sheet

A. C. Tube Data

"HEATER" AND FILAMENT TYPES

On this Laboratory Sheet are given data on the new a. c. tubes, type 227 and type 226. The former tube is of the heater type whereas the latter is of the a.c. filament type. The heater tube requires a special five-prong socket whereas the type 26 may be used with any standard socket. The filament voltage and current of the type 27 are 2.5 volts and 1.75 amperes respectively. The type 26 requires a filament voltage of 1.5 volts and the filament current is 1.05 amperes. The filament current of these tubes is quite large, especially so in a multi-tube receiver, and for this reason it is essential in wiring the filament leads that heavy wire be used. Determine the total current required by all the tubes and table No. 1 below will tell you what size of wire to use.

Table No. 1

Size (B & S Gauge)	*Current*
12	20 amperes
14	11 amperes
16	6 amperes
18	3 amperes
20	1.5 amperes

Table No. 2 on this sheet gives the characteristics of these tubes under various conditions of plate and grid voltage.

Table No. 2

Type of Tube	Plate Voltage	Negative Grid Voltage	Plate Current	Plate Impedance	Mutual Conductance	Undistorted Power Output in Watts
227	90	5	3	11,300	725	0.020
	135	9	5	10,000	820	0.055
	180	13.5	6	9,400	870	0.140
226	90	6	3.7	9,400	875	0.020
	135	9	6	7,400	1100	0.070
	180	13.5	7.5	7,000	1170	0.160

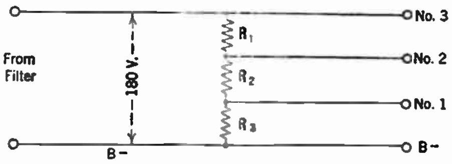
No. 142 RADIO BROADCAST Laboratory Information Sheet

Obtaining Various Voltages from a B-Power Unit

VALUES AND CURRENT-CARRYING CAPACITY

IT IS comparatively simple to calculate the resistance values required in the output circuit of a B-power unit in order to obtain any specific voltages. This Laboratory Sheet will explain how to calculate the values of these resistances.

Consider the fundamental output circuit of a B-power unit as illustrated in the sketch. The diagram of the rectifier and filter has been omitted since they play no important part in the calculation of resistance values. Suppose tap No. 1 is to be 45 volts and is to be used to operate a detector tube. We will assume that the loss current through R_3 is 3 milliamperes, or 0.003 amperes. This is an average figure for the loss current and can generally be used in this type of calculation. If the voltage at tap No. 1 is to be 45, then the voltage drop across resistance R_3 must be 45. The resistance of R_3 will be equal to the voltage across it divided by the current through it or, in this case, 45 divided by 0.003, which gives 15,000 ohms as the value of R_3. The voltage at tap No. 2 is to be 90. Since the voltage drop across R_3 is 45, it follows that the voltage drop across R_2 will also be 45 in order to make the total voltage between the negative B and tap No. 2 equal to 90. The current flowing through the resistance R_2 will be equal to the loss current at 3 milliamperes plus the current drawn by the detector tube, which is 1 milliampere. Therefore the value of resistance R_2 will be equal to the voltage across it, 45, divided by the current through it, which is 0.003 plus 0.001, or a total of 0.004 amperes. This gives a value of 11,250 ohms for R_2. Suppose that the total drain from the 90-volt tap is 10 milliamperes. Then the total current flowing through R_1 will be equal to 10 plus 1 plus 3, or 14 milliamperes. If the maximum voltage available from the power unit is 180 and the voltage at terminal No. 2 is to be 90, it follows that the voltage drop across R_1 must be 90. Ninety volts divided by 0.014 amperes gives 6400 ohms as the value of R_1.



Resistance units for B power units are usually rated in watts and it is essential that the resistances used be capable of carrying the necessary load without overheating. The load in watts being handled by a resistance can be determined by multiplying the resistance in ohms by the square of the current in amperes. In this particular example:

Watts through R_3 = 15000×0.003^2 = 0.135 watts
Watts through R_2 = 11250×0.004^2 = 0.18 watts
Watts through R_1 = 6400×0.014^2 = 1.25 watts

No. 143 RADIO BROADCAST Laboratory Information Sheet

Solenoid Coil Data

UNITS FOR THE BROADCAST BAND

THIS Laboratory Sheet gives the data necessary to wind the secondaries of solenoid type coils for use with 0.0005-mfd., 0.00035-mfd., or 0.00025-mfd. variable condensers. The wavelength range of the coil will be approximately 200 to 550 meters. The coils may be wound on hard rubber or bakelite tubing, or some type of self-supported winding may be used.

DIAMETER OF TUBE IN INCHES	SIZE OF WIRE	NUMBER OF TURNS OF D.C.C. WIRE REQUIRED WITH VARIOUS SIZES OF TUNING CONDENSERS		
		0.0005 mfd.	0.00035 mfd.	0.00025 mfd.
3½	28	28	38	50
	26	31	42	54
	24	34	46	58
	22	38	50	64
	20	42	55	72
3	28	35	48	62
	26	39	52	67
	24	43	56	73
	22	47	61	81
	20	51	67	88
2¾	28	42	54	63
	26	45	58	73
	24	48	63	80
	22	51	70	90
	20	53	78	98

No. 144 RADIO BROADCAST Laboratory Information Sheet

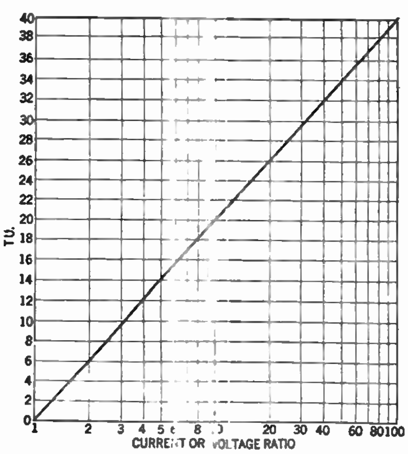
The Transmission Unit

CORRECTION OF LABORATORY SHEET NO. 114

TWO errors occurred in LABORATORY SHEET No. 114 published in the August, 1927, RADIO BROADCAST. In the last line in the first column, the word "natural" should be changed to read "common," and in the first line in the second column, the same change should be made.

The chart on this sheet makes it possible to determine easily the number of telephone transmission units if the current or voltage ratio is known. For example, from the curve it is evident that if two voltages or two currents are in a ratio of 5, then the TU difference between them is 14. If we are dealing with powers rather than currents or voltages, it is merely necessary to divide the number of TU obtained from the curve by 2 in order to determine the TU difference of any two powers. For example, two powers in the ratio of 8 to 1 have a TU difference of 9. To determine this value we look up the number of TU corresponding to a ratio of 8 which gives 18 and then divide by 2.

To illustrate the use of the curve we might take an audio amplifier requiring a tenth of a volt input to produce three volts at the output. If we wanted to know the overall gain in TU we would divide three by 0.1, which gives 30. This ratio on the curve corresponds to a 29.5 TU voltage gain.



No. 145 RADIO BROADCAST Laboratory Information Sheet

Loud Speakers

GENERAL CONSIDERATIONS

IT HAS been realized for some time that a large diaphragm type of loud speaker is capable of giving somewhat better frequency response than can be obtained from a short horn. These large diaphragm loud speakers have generally been called cones because the large diaphragm in most cases takes the form of a right circular cone.

There are certain essential characteristics which must be striven for in designing a loud speaker of this type. What we desire in the diaphragm is to obtain a large surface of great stiffness or rigidity and, at the same time, extreme lightness. If such a material can be obtained, a very satisfactory loud speaker could be made consisting simply of a sheet of the material freely supported at the edge. Such a material having a high ratio of stiffness divided by mass is difficult to obtain, and it has been necessary to devise diaphragm shapes which will give the necessary stiffness and which will still be light. This is the reason why a cone shape has generally been used, for it will give the necessary characteristics.

Recently there was described in RADIO BROADCAST the Balsa wood loud speaker, which represents an attempt to obtain a large flat diaphragm using a light material, with the required stiffness obtained through the use of slats radiating from the center. Because of the extreme lightness of Balsa wood it is possible to obtain in this way a very high ratio of stiffness to mass.

It is, of course, essential that any loud speaker, if it is to radiate sound effectually, be made as light as possible so as to require only a small amount of energy to move it. It is desirable that the entire diaphragm shall move and that the major resistance it encounters in moving should be that due to the energy required to move the air about the diaphragm and set up sound waves in the air. Any of the available energy that is used for other purposes represents a loss.

An excellent book, *Wireless Loud Speakers*, is published in England by Iliffe and Sons and written by N. W. McLachlan. The author says, in speaking of cone type loud speakers:

"There is a wide field for mathematical and experimental work regarding the behavior of diaphragms of various shapes and sizes. By exact measurement, coupled with analysis, it will be possible to pave the way to better reproduction and to evolve a diaphragm with qualities superior to those now used. Until this is done we must remain in ignorance of the action of diaphragms at various frequencies. The human ear may judge one diaphragm to be better than another, but it cannot give exact data."

No. 146 RADIO BROADCAST Laboratory Information Sheet

B Power Device Characteristics

TYPICAL CURVES

ON THIS Laboratory Sheet are given a group of curves, supplied by the Raytheon Manufacturing Company, which show how the output voltage of a typical B power unit varies with the transformer voltage. The circuit diagram of the rectifier and filter system used in making these tests is given on the curve. The curves apply when a type BH or similar tube is used as the rectifier.

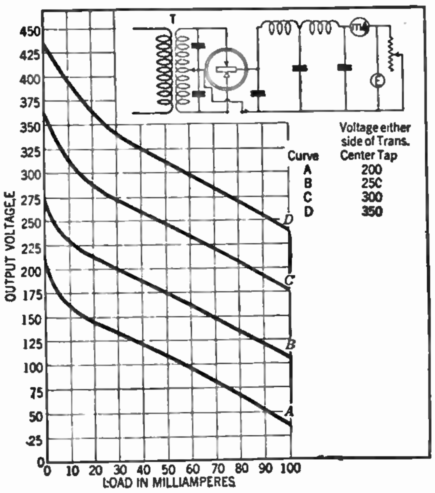
These curves indicate the following facts:

(A.) That the slope of all of the curves is the same. This is to be expected because the slope is determined entirely by the resistance of the circuit, which does not vary.

(B.) That an increase of 50 volts in the transformer voltage is effective in producing an average of 75 volts increase in the output voltage.

(C.) That the output voltages of the system at no load have approximately the same value as the transformer voltages.

(D.) That the total resistance of the rectifier-filter system is about 1340 ohms. (This value is determined by dividing the difference of any two voltages on the straight portion of any one curve by the difference of the corresponding load currents.) The resistance of the choke coils used was known to be 600 ohms so that the effective resistance of the rectifier is about 740 ohms.



No. 147 RADIO BROADCAST Laboratory Information Sheet

"Gain"

SIMPLE MATHEMATICAL CALCULATION

THE diagram on this Sheet shows an ordinary tuned circuit with a source of high-frequency voltage, e, in series with it. The voltage e can be considered to be the voltage induced in the tuned circuit from another coil, the primary of a radio-frequency transformer for example. This voltage will cause a current to flow in the tuned circuit and the ratio of the voltage E, developed across the entire circuit, to the voltage e, induced in the circuit, is known as the "gain" of the tuned circuit. The more efficient the tuned circuit is, the greater will be the "gain." We will now derive a mathematical expression for the "gain" of a tuned circuit.

The current, I, flowing in a tuned circuit at resonance is:

$$I = \frac{e}{R} \quad (1.)$$

where e = the voltage induced in the circuit and R = resistance of the circuit. The current flowing through the inductance coil, L, generates a potential across the coil, determined as follows:

$$E = \omega LI \quad (2.)$$

where ω = 6.28 times the frequency of the current, L = inductance of coil in henries, and I has the same meaning as in equation (1.) Substituting in equation (2.) the value for I given in equation (1,) we have:

$$E = \frac{\omega Le}{R} \quad (3.)$$

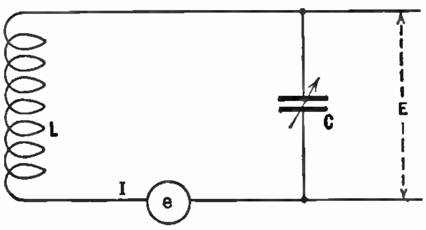
and dividing through by e we get:

$$\frac{E}{e} = \frac{\omega L}{R}$$

But, as stated previously, the ratio of E to e is the gain of the circuit. Therefore:

$$\text{Gain} = \frac{\omega L}{R} \quad (4.)$$

This final expression indicates that, to obtain greatest efficiency from a tuned circuit, it is essential that the ratio of the inductance reactance (ωL) to the resistance of the coil should be made as large as possible.



No. 148 RADIO BROADCAST Laboratory Information Sheet

An A. C. Audio-Frequency Amplifier

WHAT PARTS TO USE

THE introduction of the new a. c. tubes makes possible the construction of an a. c. audio amplifier with the necessary A, B, and C voltages supplied directly from the light socket. The list of parts necessary to construct such an amplifier is given on this Sheet. The circuit diagram is given on Laboratory Sheet No. 149.

An amplifier of this type is well suited for use with a small receiver consisting of one or more stages of radio-frequency amplification and a detector. The circuit has been so designed that B voltages for the r. f. and detector tubes can be obtained from the audio amplifier device.

The following parts are necessary to construct this amplier:

A—A. C. Tube, Type UX-226 (CX-326) or Equivalent.
B—UX-171 (CX-371) or Equivalent.
T_1, T_2—Two High-Quality Audio Transformers.
T_3—Filament-Lighting Transformer to Supply Tube A.
T_4—Power-Supply Transformer Designed for use in 171 Type B Power Units.
L_1, L_2—Filter Choke Coils.
L_3—Output Choke Coil.
C_1, C_2—1-Mfd. Bypass Condensers.
C_3, C_4—2 Mfd. Filter Condensers.
C_5—4-Mfd. Filter Condenser.
C_6, C_7, C_8—1-Mfd. Filter Condensers.
C_9—2-4-Mfd. Fixed Condenser.
R_1—30-Ohm Center-Tapped Resistance.
R_2—1500-Ohm Fixed Resistance Capable of Carrying 4 mA.
R_3—2000-Ohm Fixed Resistance Capable of Carrying 20 mA.
R_4—Tapped Resistance for Use in Output of B Power Units.

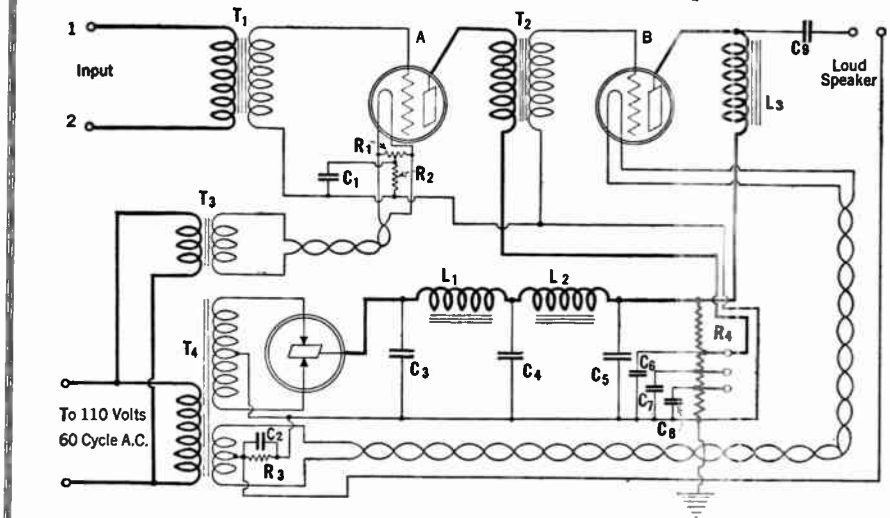
In wiring this amplifier, be sure to twist the filament leads to the two tubes, to prevent hum. C bias for the first tube, A, is obtained from resistance R_2, and resistance R_3 supplies the output tube with grid bias.

The input terminals of the amplifier should connect to the output of the detector tube, terminal No. 1 connecting to the plate and terminal No. 2 to the detector B plus.

To prevent hum it is essential that the negative B be carefully grounded.

No. 149 RADIO BROADCAST Laboratory Information Sheet

Circuit Diagram of an A. C. Audio Amplifier



Here is the circuit diagram of an all a. c. audio amplifier. The list of parts is given on Sheet No. 148.

No. 150 RADIO BROADCAST Laboratory Information Sheet

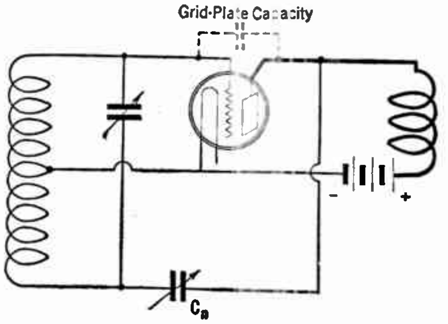
Oscillation Control

THE USE OF NEUTRALIZATION

IT HAS been pointed out many times that an ordinary three-element tube has an inherent tendency to oscillate due to the feed-back that occurs from the plate circuit to the grid circuit through the grid-plate capacity, indicated by dotted lines in the accompanying diagram. This diagram represents the circuit of a single-stage of tuned radio-frequency amplification, using the Rice system of neutralization, and the following explanation will make clear why the tube tends to oscillate and why the tendency to oscillate can be overcome by using some system of neutralization.

When a tube acts as an amplifier, the voltage developed in the plate circuit is greater than the voltage originally impressed on the grid circuit and, consequently, if the plate circuit is coupled to the grid circuit in any manner whatsoever, current will tend to flow from the point of high potential, that is the plate, to a point of lower potential, in this case the grid. If this current flowing to the grid circuit has the same phase as the original signal impressed on the grid, then the grid voltage will become somewhat greater and will be equal to the original signal in the grid circuit plus the voltage induced in the grid circuit from the plate. An increase in the grid voltage again produces an increase in plate voltage which in turn reacts back on the grid until the voltage is increased to a point where the losses in the circuit are overcome, and then the tube breaks into continuous oscillation.

It should be evident that if we can place in the circuit some device that will impress a potential on the grid kind of an equal and opposite to that caused by the coupling between the grid and plate, then the resultant effect will be zero and the tendency for the circuit to build up and break into continuous oscillation will be nullified. The Rice system of neutralization is one way of doing this, the circuit for which is shown in the accompanying diagram. The grid-plate capacity is shown in dotted lines and this is the capacity through which current flows from the plate to the grid circuit and which ordinarily causes the tube to oscillate. This capacity is neutralized in the Rice system by connecting condenser C_n as indicated.



No. 151 Radio Broadcast Laboratory Information Sheet

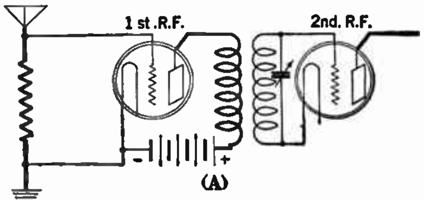
Single-Control

BOOSTING SENSITIVITY

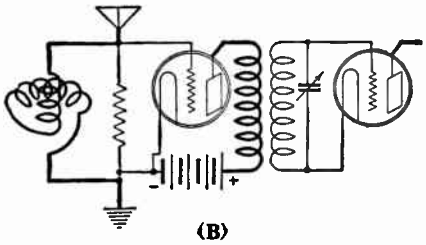
On Laboratory Sheet No. 33, October, 1926, some facts were given regarding the tandem tuning of several condensers, to decrease the number of controls. It was pointed out that, to obtain single control, it is necessary to overcome the effect of the antenna circuit in some manner, and that a common method of doing this is as indicated in sketch A on this Sheet. The owner of a receiver of this type may greatly increase its sensitivity by connecting a variometer between the antenna and ground posts as indicated in sketch B. This, of course, adds one more control to the set but in those cases where greater sensitivity is necessary, the additional control is justified.

The increase in sensitivity that results when the variometer is used in the antenna circuit is due to the fact that it brings the antenna into resonance with the signals being received and the resultant gain in amplification is practically equal to that which would be obtained from an additional stage of radio-frequency amplification.

In some cases when this variometer is used, it will be found that the receiver tends to oscillate, or actually does oscillate, when all of the circuits are brought into resonance. Fortunately, however, most single-control receivers have a volume control in the radio-frequency system and it will be found that, by cutting down the volume control, a point will be reached where the set will stop oscillating and usually the actual volume obtained with the antenna circuit tuned will be much greater than that obtained before with the volume control turned to the "maximum" position. The tendency of the circuit to oscillate can also be lessened by somewhat decreasing the r. f. plate voltage.



(A)


(B)

No. 152 Radio Broadcast Laboratory Information Sheet

Speech

SOURCES OF INFORMATION

The nature of speech has been the subject of many scientific inquiries and many of the investigations in connection with speech have been recorded in various scientific journals.

Back in 1873, Alexander Graham Bell, familiar to us as the inventor of the telephone, did considerable work in analyzing speech and in "devising methods of exhibiting the vibrations of sounds opticallly," and much of the recent research has been done by engineers and physicists associated with the laboratories of the telephone companies.

A bibliography is given below of some of the important articles and books on the subject with which we are familiar. This bibliography is by no means complete in itself but if the references given are studied it will be found that some of them contain many references to other papers on the subject. I. B. Crandall's article, in the October, 1925, *Bell System Technical Journal*, in particular, contains about twenty-six references to other sources of information on speech and related subjects.

REFERENCE SOURCES

Bell System Technical Journal

C. F. Sacia and C. J. Beck; "The Power of Fundamental Speech Sounds." July, 1926.

I. B. Crandall: "Sounds of Speech." October, 1925.

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Irving B. Crandall: "Dynamical Study of the Vowel Sounds." January, 1927.

C. R. Moore and A. S. Curtis: "An Analyzer for the Voice Frequency Range." April, 1927.

Journal of the American Institute of Electrical Engineers

Jones; "The Nature of Language." April, 1924.

Martin and Fletcher: "High-Quality Transmission and Reproduction of Speech and Music:" March, 1924.

Maxfield and Harrison: "Method of High-Quality Recording and Reproducing of Music and Speech Based on Telephone Research." March, 1926.

Books

Miller: *Science of Musical Sounds.* Second Edition. Macmillan.

Sabine: *Collected Papers on Acoustics.* Harvard University Press.

No. 153 Radio Broadcast Laboratory Information Sheet

Standard- and Constant-Frequency Stations

BROADCASTERS WITH ACCURATE FREQUENCIES

The *Radio Service Bulletin*, published monthly by the Radio Division of the Department of Commerce, Washington, District of Columbia, contains a list of standard and constant frequency broadcasting stations as determined by the Bureau of Standards. This bureau makes measurements on an average of about three times a month on the transmissions of a small number of stations and as a result of these tests data are published in the *Bulletin* on those stations which have been found to maintain a sufficiently constant frequency to be useful as standards. These are known as "Standard Frequency Stations." The list of "standard frequency stations" is supplemented with a list of "constant frequency stations." No regular tests are made on these latter stations but each station in the list employs a special device, such as a crystal, to maintain its frequency accurately so that they can be generally relied upon to maintain their correct frequency.

STANDARD FREQUENCY STATIONS

Call Letters	*Frequency Kc.*
WEAF	610.00
WRC	640.00
WJZ	660.00
WGY	790.00
WBZ	900.00
KDKA	950.00
WBAL	1050.00

CONSTANT FREQUENCY STATIONS

Call Letters	*Frequency Kc.*
WMAQ	670
WJAD	670
WCCO	740
WTAM] WEAR]	750
WBBM	770
KGO	780
KTHS	780
WCAD	820
WJJD	820
WLS	870
WSM	880
WKAQ	880
KOA	920
KFAB	970
WBAA	1100
WHK	1130
WMBI	1140
WABQ	1150
WEBJ	1170
KWUC	1230
KFVS	1340

No. 154 Radio Broadcast Laboratory Information Sheet

Resistors

DETERMINING WHAT SIZE TO USE

In choosing a resistance for any particular purpose it is necessary to determine the value required, the current it must carry and then from these two facts determine the wattage rating required. The chart published on this sheet will prove useful to determine:

(*a*) the wattage rating a resistor must have to carry a given current

(*b*) the current a resistor, of given wattage rating, will carry

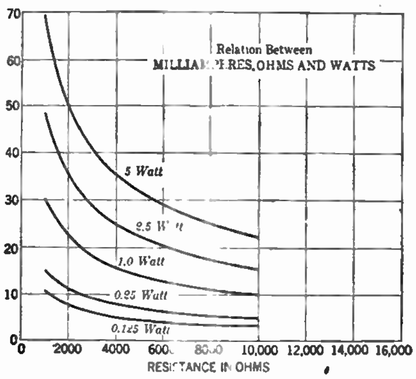
The curve is plotted to cover resistors up to 10,000 ohms and wattage ratings up to 5 watts.

Example: A resistor is to be used to supply C-bias to a 171-A type tube. The plate current of the tube (which must flow through the resistor) is 20 milliamperes. The required C-bias voltage is 40 volts. What value of resistance and what wattage rating should the resistor have?

To calculate the required value of resistance we use Ohm's law.

$$\text{Resistance} = \frac{\text{Voltage}}{\text{Current in amperes}} = \frac{40}{0.020} = 2000 \text{ ohms}$$

Referring to the chart below, we find that the vertical line corresponding to 2000 ohms crosses the horizontal line corresponding to 0.020 amperes (20 milliamperes) at the point indicated between the curves of 1.0 and 0.25 watt resistors. In such a case we must, of course, always use the larger size and therefore in this case we should use the 1.0-watt resistor.



No. 155 Radio Broadcast Laboratory Information Sheet

Tube Life

EFFECT OF EXCESSIVE LINE VOLTAGE

The life obtained from a vacuum tube depends very much upon the filament voltage at which it is operated, for voltages slightly above normal produce a marked decrease in life. This is true of all types of tubes, a. c. or d.c., storage-battery or dry-cell-operated. In a battery-operated receiver we are able to control the filament voltage applied to the tubes quite accurately and normal life is therefore generally obtained from the ordinary types of storage-battery or dry-cell tubes. In an a.c.-operated receiver, however, where the filament voltages are obtained directly from the power lines, the operator of the receiver has little or no control over the filament voltage applied to the a.c. tubes. Most filament transformers are designed for a line voltage of about 115 but in many communities, rural ones especially, voltages in excess of this are frequently encountered. This higher line voltage of course affects the output voltages of the filament transformer so that the tubes are subjected to a filament voltage above normal.

It is suggested that experimenters working on a.c.-operated receivers include in the circuit some device which will enable them to control the voltage applied to the filament transformer. In cases where the line voltage is found to vary considerably so that at times it is above normal and at other times normal or below normal, it will be preferable to include in the circuit a variable resistance in the primary side of the filament transformer having a value of about 25 ohms. In those cases where the line voltage is found to be above normal but constant at this value, a fixed resistance may be placed on the primary side of the filament transformer to absorb the excess voltage so that the transformer receives its rated voltage or slightly less, for it has been found that a.c. tubes will generally give satisfactory service on somewhat less than the operating voltage at which they are rated.

When remedies for excessive line voltage, such as we have suggested here, are made use of, each case must be treated more or less individually, and when, as is usually the case, the line voltage is not constant, a manually controlled resistance may be essential. These facts have been appreciated by many receiver and parts manufacturers. It is probable that devices will soon be available to home constructors which when placed in the primary side of a transformer will automatically control the voltage actually applied to the receiver, so that the tubes will always receive rated voltage despite fluctuations in the actual line voltage.

No. 156 Radio Broadcast Laboratory Information Sheet

Wavelength-Frequency Conversion

A TABLE FOR THE BROADCASTING BAND

On Laboratory Sheet No. 157 is given a wavelength-frequency conversion table covering the broadcasting band. Broadcasting is assigned to channels 10 kc. apart on frequencies that are divisible by 10. It is simple to use the table. If we knew that some station was transmitting on 1000 kc. we can determine from the table the corresponding wavelength, which in this case is approximately 300 meters. The wavelength corresponding to any given frequency can be determined by dividing the frequency in kc. into 300,000.

A 10-kc. separation between broadcasting stations is necessary to prevent bad interference between two stations on adjacent channels. When a broadcasting station is transmitting it actually uses a band of frequencies (side bands) 10,000 cycles wide —5000 cycles either side of the "carrier" frequency. The carrier frequency is the frequency assigned a station by the Federal Radio Commission, but as mentioned above, in the ordinary process of modulation a frequency band 10,000 cycles wide is used.

When a station is transmitting it also radiates a frequency exactly double its carrier frequency. The additional wave is called the second harmonic, being equal in frequency to the carrier frequency multiplied by two. Careful design and operation of the transmitter will keep these harmonics small in amplitude and this is essential if interference is to be prevented. If a station transmits on, say, 600 kc. and also radiates a strong second harmonic with a frequency of 1200 kc., it will interfere with another station transmitting on a carrier frequency of 1200 kc.

Any radio station might be considered to have two ranges; first the broadcasting range, being the distance area over which the program on the station may be received satisfactorily and, secondly, the interference range, being the area over which a station causes interference due to the production of a heterodyne whistle between its carrier and the carrier of another station. The first range is much smaller than the second and a station having a service area of 100 miles will have an interference range of probably about 1000 miles.

No. 157

RADIO BROADCAST Laboratory Information Sheet

Table for Wavelength-Frequency Conversion

Kc.	Meters	Kc.	Meters	Kc.	Meters	Kc.	Meters
550	545.1	800	374.8	1,050	285.5	1,300	230.6
560	535.4	810	370.2	1,060	282.8	1,310	228.9
570	526.0	820	365.6	1,070	280.2	1,320	227.1
580	516.9	830	361.2	1,080	277.6	1,330	225.4
590	508.2	840	356.9	1,090	275.1	1,340	223.7
600	499.7	850	352.7	1,100	272.6	1,350	222.1
610	491.5	860	348.6	1,110	270.1	1,360	220.4
620	483.6	870	344.6	1,120	267.7	1,370	218.8
630	475.9	880	340.7	1,130	265.3	1,380	217.3
640	468.5	890	336.9	1,140	263.0	1,390	215.7
650	461.3	900	333.1	1,150	260.7	1,400	214.2
660	454.3	910	329.5	1,160	258.5	1,410	212.6
670	447.5	920	325.9	1,170	256.3	1,420	211.1
680	440.9	930	322.4	1,180	254.1	1,430	209.7
690	434.5	940	319.0	1,190	252.0	1,440	208.2
700	428.3	950	315.6	1,200	249.9	1,450	206.8
710	422.3	960	312.3	1,210	247.8	1,460	205.4
720	416.4	970	309.1	1,220	245.8	1,470	204.0
730	410.7	980	303.9	1,230	243.8	1,480	202.6
740	405.2	990	302.8	1,240	241.8	1,490	201.2
750	399.8	1,000	299.8	1,250	239.9	1,500	199.9
760	394.5	1,010	296.9	1,260	238.0		
770	389.4	1,020	293.9	1,270	236.1		
780	384.4	1,030	291.1	1,280	234.2		
790	379.5	1,040	288.3	1,290	232.4		

No. 158

RADIO BROADCAST Laboratory Information Sheet

The Three-Tube Roberts Reflex

CIRCUIT CONSTANTS

THERE have been many requests from readers for further information on the Roberts 3-tube receiver illustrated in the August, 1927 issue of RADIO BROADCAST on page 209. This receiver is a reflex set consisting of a stage of r.f. amplification, a regenerative detector, one stage of reflexed transformer-coupled audio amplification, followed by another straight audio stage. The circuit, which was not given in the article mentioned above, and which many readers have requested, is published on Laboratory Sheet No. 159. The list of parts is given below.

L_1, L_2—R. F. transformer. L_2 may consist of 45 turns of No. 24 wire wound on a 3-inch tube. L_1 should contain 40 turns of No. 24 wire with a tap at each 10 turns. L_1 should be wound alongside the filament end of L_2.

L_3, L_4, L_5—Interstage r.f. transformer. L_3 and L_4 have the same specifications as L_1 and L_2 with the exception that L_3 should be wound with No. 26 or No. 28 wire and should only be tapped at the exact center instead of at every 10 turns. That end of L_3 nearest the grid end of L_4 should connect to the plate of the r.f. tube, the center tap connects to transformer T_2, and the other end of L_3 connects to the neutralizing condenser. L_5 is a movable tickler coil consisting of 20 turns of No. 26 on a 1½ inch tube.

T_1, T_2—Any good audio transformers.

T_3—Any good output transformer.

C_1, C_2—0.0005-mfd. variable condensers.

S_1—Antenna tap switch.

S_2—Filament switch.

J_1—Double-circuit interstage jack.

J_2—Single-circuit jack.

V—Volume control, 50,000-ohm variable resistance.

C_3—Neutralizing condenser, 0.000015 mfd.

C_9—Grid condenser, 0.00025 mfd.

R_9—4-megohm grid leak.

R_1—10-ohm rheostat.

R_2—0.5-ampere fixed filament control resistance.

C_4—0.001-mfd. fixed condenser.

C_5—0.0001-mfd. fixed condenser.

C_6—0.00025-mfd. fixed condenser.

Eleven binding posts

Three sockets

Hook-up wire

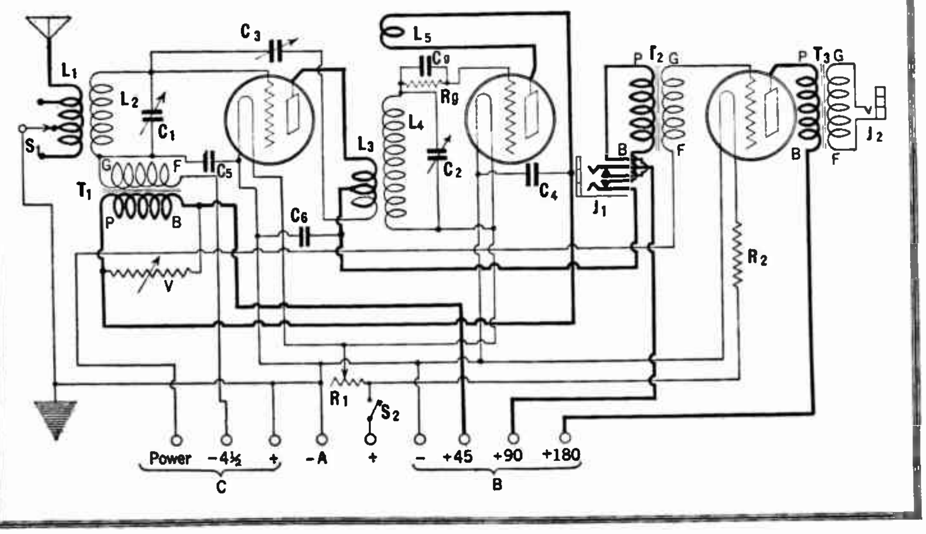
For best results a power tube should be used in the last socket. If a 171 type tube is used with 180 volts on the plate, the C bias required is 40.5 volts.

When the receiver has been completed it should be neutralized by tuning-in some station, adjusting the tickler until the detector oscillates and a whistle is heard and then varying the neutralizing condenser until the whistle changes in pitch the least amount (its loudness will change considerably) as C_1 is varied.

No. 159

RADIO BROADCAST Laboratory Information Sheet

The Three-Tube Roberts Reflex



No. 160 RADIO BROADCAST Laboratory Information Sheet

Line Voltage Variations

EFFECT ON TUBE LIFE

LETTERS from readers have been received by the Laboratory from time to time to the effect that the life of the 171 type tube used in their power unit was very short, sometimes lasting only about 100 hours. The normal life of a 171 type tube should be at least 1000 hours. The probable cause, in many cases, of such short life is excessive filament voltage.

The transformer in a power unit is designed generally to operate with a line voltage of 110 volts a.c. With this voltage across the primary the voltage across the filament terminals of the 171 type power amplifier should be 5 volts. If the voltage across the primary is less than 110 volts, then the voltage across the filament of the tube is less than 5 volts and conversely, with input voltages higher than 110 volts the voltage across the filament of the tube will be excessive, i.e., more than 5 volts.

If the filament voltage drops very much, the electronic emission from the filament will decrease and distortion of the signal will result. If, on the other hand, the filament voltage is excessive, the output of the system is not audibly affected and so with no audible indication of the excessive voltage, it is likely that it will go by unnoticed. It is excessive filament voltage which must be guarded against however, if a normal length of life is to be obtained from any tube.

The extent of the fluctuations in line voltage is, of course, different in different parts of the country—in large cities the voltage is generally quite constant, while in rural communities comparatively large variations in line voltage are probable.

These problems, brought about by inconstancy of line voltage, are becoming more serious as the use of a.c. operated receivers becomes more popular. In such receivers, all of the tubes are operated directly from the power line and decreased tube life due to excessive filament voltage is to be carefully guarded against.

The solution of these difficulties lies in the design of a device which will automatically control the voltage actually applied to a power unit. The type 886 tube is a device of the sort, designed to insure constant input to power operated radio receivers, despite fluctuations in line voltage. Several devices to accomplish regulation by other means are also being developed by other manufacturers and will probably be available shortly.

No. 161 RADIO BROADCAST Laboratory Information Sheet

Comparing the 112, 171, and 210 Type Tubes

THEIR RESPECTIVE OUTPUTS

ON LABORATORY SHEET No. 162 are shown three curves that indicate an interesting relation between the three most common types of power tubes, *i.e.*, the 112, 171, and 210 types. The curves indicate the relation between the power output of the tubes and the value of the signal voltage impressed on the grid. The plate impedance and amplification constants of the 112 and 210 type tubes are practically identical and, therefore, the curves for these two tubes coincide from zero up to that point corresponding to the maximum output power of the 112, which is approximately 195 milliwatts, or 0.195 watts.

If a vertical line is drawn at any point on the curve, for example, at A, the points at which this line crosses the various curves will indicate the power output obtained from the particular tube associated with the curve being examined. In this particular case, line A, drawn at the point corresponding to a signal voltage on the grid of 15 volts indicates that, with this value of signal voltage, the power output of a 210 tube with 425 volts on the plate is approximately 0.34 watts. The power output of a 171 at the same point is approximately 0.1 watts. The maximum grid voltage that can be impressed on a 112 without resultant output distortion is about 10.5 volts and, therefore, a 112 tube cannot be used if the signal input voltage is greater than this value. At B we have drawn another line corresponding to a signal on the grid of 8 volts. Here we find that the power output of a 112 is approximately 0.1 watts and the power output of a 171 about 0.01 watts. It is therefore evident that at low values of input voltage a 112 tube is capable of putting more power into the loud speaker than is a 171. If the signal voltage, however, is in excess of 10½ volts, the 112 cannot be used and the choice then lies between the 210 and the 171. The curves indicate that the 210 will give much more power output than a 171 but it should be realized that much greater plate voltages are necessary on the 210 than on the 171. With 180 volts on the plate the 171 can deliver approximately 740 milliwatts of power, but 250 volts on the plate of the 210 will only permit this tube to handle signal voltages up to 18 volts and the maximum output power will be only 460 milliwatts. From these data the following conclusions can be arrived at:

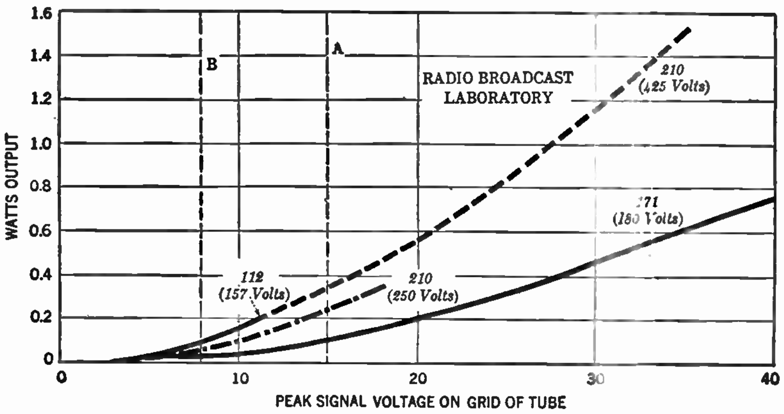
(1.) For input signals on the grid of the power tube of 10 volts or less the 112 tube will deliver the most power to the loud speaker.

(2.) When more power output is required and only moderate plate voltages are available (not in excess of 200 volts) a 171 is capable of giving greater output than can be obtained from a 210 under similar conditions of plate voltage.

(3.) Where high plate voltages around 400 volts are available the 210 should be used and under the same input signal it will give approximately 2¼ times as much power as can be obtained from a 171.

No. 162 RADIO BROADCAST Laboratory Information Sheet

112, 171, and 210 Tube Curves



These curves indicate how the power output of the 112, 171, and 210 type tubes varies with different values of signal voltage on the grid of the tube. The significance of these curves is explained in detail on Laboratory Sheet No. 161.

No. 163 RADIO BROADCAST Laboratory Information Sheet

Testing Receivers

USING THE MODULATED OSCILLATOR

THE accurate determination of the characteristics of a radio receiver requires a careful laboratory test, but it is possible to construct comparatively simple apparatus of much practical value for the testing and repairing of receivers. The instrument that will enable us to make such tests is the modulated-oscillator. From a modulated oscillator we can obtain an audio-frequency tone which can be fed into the input of the audio amplifier in a radio receiver and the functioning of the audio amplifier thus checked, or by turning on both r.f. and a.f. oscillators we can obtain a modulated wave which can be used to test both the r.f. and a.f. circuits.

The circuit diagram of a modulated-oscillator will be found on Laboratory Sheet No. 164. The following paragraphs will explain how to use the instrument for testing receivers.

(1.) Audio Amplifiers

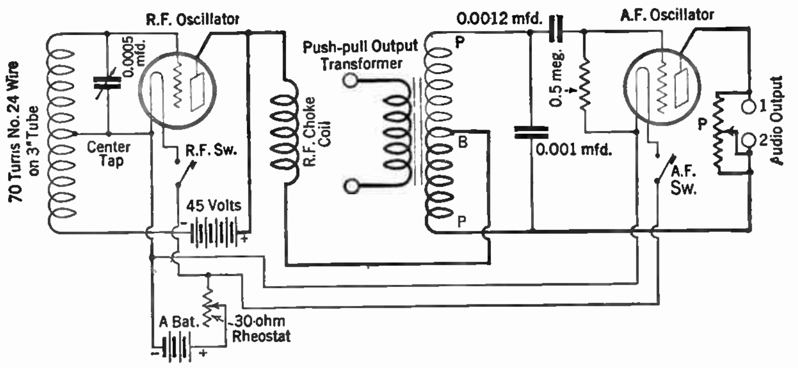
Place all the tubes in and connect all the batteries to the amplifier. Do not place the detector tube in its socket. Connect the plate terminal of the detector tube socket to audio output terminal No. 1 on the modulated oscillator. Connect both the B + detector lead on this receiver and terminal No. 2 on the modulated oscillator to B — on the receiver. Turn on the receiver and audio circuit of the modulated oscillator and adjust potentiometer P to give an output of medium intensity from a loud speaker connected to the output of the audio amplifier. A defect in the amplifier is indicated if the output is low or distorted or both.

(2.) Radio-Frequency Amplifiers.

A test of the r.f. amplifier of a receiver is accomplished by first placing all the tubes in the receiver and connecting all the batteries, and then winding about two turns of insulated wire around the coil on the oscillator, connecting the other end of this wire to the antenna post on the receiver. The oscillator should be located about ten feet away from the receiver. If the a.f. and r.f. tubes in the modulated oscillator are turned on and the receiver's tuning circuits adjusted to resonance, an audio-frequency tone should be audible in the output. Since the a.f. amplifier in the receiver was tested previously, any defect in the operation of the receiver must be located in the r.f. amplifier or detector circuit.

No. 164 RADIO BROADCAST Laboratory Information Sheet

A Modulated-Oscillator



All the constants of the apparatus used in the instrument are given on the diagram. Some information on the use of this instrument will be found on Laboratory Sheet No. 163. The frequency of the audio-frequency oscillations can be varied by using various values of capacity across the push-pull transformer.

No. 165 RADIO BROADCAST Laboratory Information Sheet

Audio Amplification

GENERAL CONSIDERATIONS

AN AUDIO system can be considered satisfactory if it amplifies the signals impressed on its input sufficiently to operate adequately a loud speaker and does so without distorting the signals to an extent sufficient to become apparent in the output of the loud speaker. Such performance can only be realized when the amplifier has been correctly designed and is operated properly.

The overall frequency characteristic of an amplifier is frequently quite dissimilar to the characteristic of a single stage. This is especially true of transformer- or impedance-coupled amplifiers and is probably due, in most cases, to coupling in the plate supply. Regenerative effects are thereby introduced into the circuit, which may produce considerable changes in the frequency characteristic of the audio system. Such effects are also present, at times, in resistance-coupled amplifiers and generally cause such an amplifier to "motor-boat."

The solution of such difficulties is either to design the amplifier so that with the regenerative effect present the system has a flat characteristic or to design two units to have a flat characteristic and then arrange the circuit so carefully that regenerative effects will not be present. This necessitates feeding all the grid and plate circuits through resistances or choke coils and bypassing all the circuits with condensers.

Some recent audio transformers are designed to have a fairly sharp cut-off at about 5000 cycles to reduce the effect of various extraneous sounds, such as tube noise, high-frequency heterodyne whistles, etc., which are composed mostly of frequencies above 5000 cycles. Frequencies above this value add little to the quality of the speech or music and can therefore be eliminated without introducing noticeable distortion. It is doubtful whether the majority of broadcasting stations themselves transmit notes of more than 5000 cycles in frequency.

Also many amplifiers have a tendency to oscillate at very high audio frequencies and sometimes at supersonic frequencies. If the amplifier is designed, however, to give little or no amplification to frequencies much above 5000 cycles, this tendency of the amplifier to oscillate will be nullified.

No. 166 RADIO BROADCAST Laboratory Information Sheet

Acoustics

DAMPING AND REVERBERATION

THE quality of reproduction from any loud speaker depends to a considerable extent upon the room in which it is used and upon the room's furnishings. The reason why the room and its furnishings influence the output of the sound generator, whether it be a piano, phonograph, or a loud speaker, is not difficult to understand, and will be explained briefly here.

In an average room the sounds from a piano, for example, are somewhat damped by the hangings, carpets, furniture, etc., so that they decrease to inaudibility quite rapidly. When the furniture, rugs, etc, are removed and the piano is permitted to stand on the bare boards, the sounds from it will be prolonged and the music will become jumbled, especially when playing forte. This effect is due to the absence of the furniture, which normally acts as a damping agent, and also due to the fact that the piano is resting directly on the floor so that the latter acts to increase the effective area of the sound board. The sounds produced by the piano when it is in direct contact with the floor will be somewhat louder than usual, indicating increased efficiency.

Under any given room conditions the rate at which a sound dies away is the same whether the sound at its beginning is loud or soft. However, the time taken for the sound to become inaudible depends upon the loudness of the original sound and, of course, the louder the sound, the longer it will take to decrease in volume to a point where it is inaudible. In a room containing furnishings that cause considerable damping, we may, therefore, play much louder than in an unfurnished room, without causing any excessive blurring.

A room can be too completely damped, when the playing will sound "dead." A certain amount of blurring or intermingling of succeeding chords is considered good, for it adds coloration to the music.

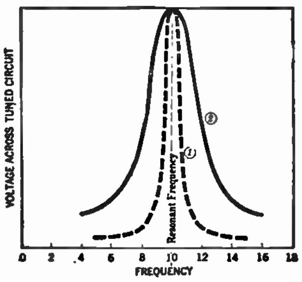
The importance of these matters in relation to the design of the studios in broadcasting stations is evident. The correct amount of damping must be obtained to prevent deadening the music (too much damping) or to obviate difficulties due to reverberation (too little damping.)

No. 167 RADIO BROADCAST Laboratory Information Sheet

Resonant Circuits

GAIN AND SELECTIVITY

THE current at resonance in a tuned circuit is equal to the voltage induced in the circuit divided by the total resistance of the circuit. The actual capacity of the condenser or the inductance of the coil used in the circuit do not enter into the calculation once the induced voltage and the resistance are known. The voltage across the coil in the circuit is equal to a constant times the current times the inductance of the coil and, the voltage is, therefore, larger the greater the inductance of the coil. Since a vacuum tube is a voltage rather than a current operated device, it might appear that best results, *i.e.*, greatest amplification, would be obtained by making the coil very large. When we increase the inductance of a coil by adding to the number of turns, however, we also increase the resistance and the increase in resistance nullifies to some extent the advantage gained through the use of a larger coil.



The selectivity of a tuned stage in a receiver depends upon the series resistance of the circuit; with low-resistance circuits the selectivity is good while with high-resistance circuits the selectivity is poor. The curves on this Sheet indicate the effect of resistance in the tuned circuit. Curve 1 shows the characteristic of a very low-resistance tuned circuit and curve 2 a comparatively high-resistance circuit. Since practically all of the resistance in a tuned circuit is in the coil, it follows that carefully constructed, fairly "low-loss" coils should be used in a radio-frequency circuit. A coil can be made so good as to cut "side-bands," however, and thereby distort the received signal head-band suppression results in the loss of the high audio frequencies in the modulated wave.

If the ratio of the inductive reactance of the coil (6.28 times the frequency times the inductance of the coil) to the radio-frequency resistance of the coil at the same frequency is made much more than 250, distortion of the "side-bands" results.

No. 168 RADIO BROADCAST Laboratory Information Sheet

The Ear

ITS CHARACTERISTICS

THE characteristics of the human ear have been determined and investigated by many different scientists, and some of these characteristics are given below:

(a.) There is a minimum sound intensity below which the ear cannot detect any sounds. A curve was published on Laboratory Sheet No. 109, indicating how this minimum audible intensity varied with frequency.

(b.) There is a maximum intensity of sound above which the auditory sensation is one of pain rather than sound. The intensity and its variation with frequency was also explained on Lab Sheet No. 109.

(c.) There is a lower limit of the pitch of a sound below which the ear will not respond. This lower limit is about 20 cycles.

(d.) There is an upper limit to the pitch of a sound above which the ear will not respond. The upper limit is about 20,000 cycles.

(e.) The ear can distinguish between about 300,000 separate sensations of sound.

(f.) The ear can respond to pressure changes between the pressure required to produce a minimum audible sound and a pressure 100 million times greater. These two pressures correspond to an energy ratio of 10,000 trillion.

(g.) The ear can distinguish between the loudness of various sounds. At low levels of sound intensity a change of about 25 per cent. is necessary to be distinguishable. At greater intensities a change of 10 per cent. in loudness is detectable by the ear.

(h.) The ear can distinguish between the pitch of various sounds. At medium frequencies a change in frequency of about 0.3 per cent. can be detected; at low frequencies a change of about 1 per cent. is necessary.

A knowledge of these characteristics is useful to the student interested in problems of sound reproduction.

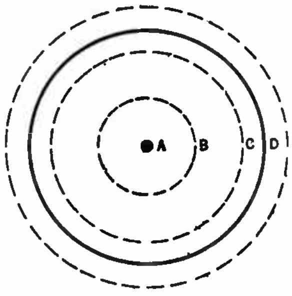
No. 169 RADIO BROADCAST Laboratory Information Sheet

The Type 222 Screened-Grid Tube

CONSTRUCTION

THE new type 222 screened-grid tube is designed especially for use as a radio-frequency amplifier and when used as such it is capable of giving greater amplification than can be obtained from other tubes. A receiver using these tubes does not have to be neutralized. This Laboratory Sheet gives details regarding its construction.

The arrangement of the elements as we look down on a type 222 tube is indicated in the drawing on this Sheet. At the center is the filament, A, consisting of a single straight wire. Surrounding the filament is the control or signal grid, B. The plate, D, is located between C and E, which are two comparatively coarse "screen grids." The filament terminals, the plate terminal, and the extra grid terminal (grids C and E are connected together inside the tube), are brought down to a standard four-prong base. The signal grid, B, is connected to a small brass cap on top of the tube.



The amplification constant of this new tube is of the order of 200 to 300, the mutual conductance is about 300 micromhos, and its plate impedance is around one megohm. These values will vary widely, depending upon the voltages. The amplification of the tube in an r. f. circuit may average about three times that possible with a 201-A type tube. Three times as much amplification in the r.f. stage is equivalent to 81 times as much power in the loud speaker.

When a 201-A type tube is used as an r.f. amplifier there is a strong tendency for it to oscillate, due to feed-back through the grid-plate capacity. The plate of the type 222 is shielded from the signal grid by the screen grid C-E, and the tendency toward oscillation due to feed-back through the tube is practically nullified.

The general characteristics of the tube, and the correct voltages to employ when it is used as an r. f. amplifier, are given below:

Filament Volts............3.3
Plate Voltage.......90 to 135
Screen-Grid Voltage......+45
Signal Grid Bias—1 to-1.5 volts

No. 170 RADIO BROADCAST Laboratory Information Sheet

Selectivity and Sensitivity

DESIRABLE CHARACTERISTICS

THE ideal receiver should be as selective as is possible; that is, it should receive a channel of frequencies 10,000 cycles wide (or only 5000 cycles wide in the case of single side-band transmission) equally well, but should not receive other frequencies at all. A receiver for reception of broadcast programs cannot be made any more selective than this without impairing the quality of reproduction. When a receiver is this selective, it will offer a barrier to all frequencies except those lying in the channel to which it is tuned.

The ideal receiver should not need to be any more sensitive than is necessary to amplify interfering noises to more than tolerable loudness under conditions of least interference. When the interference is greater, the sensitivity should be cut down to keep these noises from becoming objectionably loud. In summertime the interfering radio waves manufactured by nature are generally the strongest.

Assuming that an ideal radio receiver is available, there is only one way left (other than the invention of a static eliminator or reducer) to reduce interference to any further extent and thereby increase the distance over which satisfactory reception is possible. This second method of reducing interference is through the use of increased power at the transmitting station. If the signal strength at any given location is increased, the ratio between the signal and the static is thereby increased and reception in this way made freer of interfering noises. Just as in the case of land wire telephony, however, we will probably never be able to put enough power into the ether to give good transmission across the continent in spite of bad interference.

In so far as sensitivity and selectivity are concerned, the super-heterodyne type of receiver is probably the most desirable. These characteristics in a receiver of this type depend, however, in large measure on the design of the intermediate-frequency amplifier. This amplifier can be designed only to amplify a very narrow band of frequencies (a good design for reception of code signals), or, by the use of band-pass filters, the equal amplification of a band of frequencies can be accomplished (a satisfactory design for the reception of ordinary broadcast signals).

No. 171 RADIO BROADCAST Laboratory Information Sheet

The Type 112 and 171 Tubes

FURTHER COMPARISONS

THE two types of power tubes best adapted for medium B voltages are the type 112 and the type 171. The former tube, introduced first, came into immediate favor, and for a time was more popular than the type 171. This initial preference was due to several factors, the most important ones being, first, the fact that the voltages required by this type were identical with those required by type 201-A tubes, and therefore, the tube could be substituted without battery changes. Secondly the horn type loud speaker, generally more sensitive than the cone loud speaker, was still popular, and there was less necessity for the greater power output given by the 171. A third factor was the misapprehension about battery voltages, many not realizing that although the 171 could be used to best advantage at the maximum voltage of 180 volts, the quality of reproduction was equally good at 135 volts, and the volume ample for average home service.

During the current season the standing of the two tubes is rapidly being reversed, the type 171 assuming the leadership, partly because of the large number of new receivers for which the tube is specified, and partly because of better facilities for using the tube to its best advantages. As improvements in audio amplification and in loud speaker design are made, the advantage of using this type of tube becomes increasingly apparent. The higher frequencies are usually reproduced satisfactorily by any type of output tube, but to secure full undistorted reproduction of low frequencies, or the bass notes, a tube having low internal resistance, such as the 171 is required.

In installing the 171, the first precaution with which the user has to become familiar is the use of a high grid biasing, or C, battery voltage—from 16½ to 40½ volts, depending upon the B voltage used. With general purpose tubes, which the power tubes replaced, the use of a C battery was to a large extent optional with the user, although the fact that better quality was obtained with this battery was generally recognized.

Laboratory Sheets Nos. 161 and 162 gave some interesting data and curves on the type 112 and 171 tubes. The 210 type tube was also covered in these latter sheets.

No. 172 RADIO BROADCAST Laboratory Information Sheet

A Simple Wavemeter

CONSTRUCTION AND CALIBRATION

A WAVEMETER is a very useful asset to the laboratory of any radio experimenter. A coil of wire and a condenser, connected together properly, are all that is required to make this instrument.

The circuit diagram of a wavemeter is given on the curve published herewith. It is evident from the diagram that the coil is simply connected across the condenser. The coil should preferably be a solenoid wound on a piece of tubing so that it will be able to withstand some abuse without any alteration in its inductance, and should have sufficient number of turns to cover the frequency band it is to be used on.

The construction of the wavemeter presents no problems. The method of calibrating it and plotting a calibration curve may, however, require some explanation. The procedure is as follows:

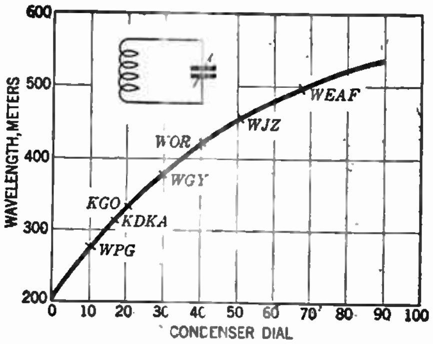
(1.) Set the wavemeter at a distance of about two feet from your radio receiver.

(2.) Take the lead from the antenna and wrap one turn around the coil of the wavemeter and then run the antenna lead over to the regular antenna post on your receiver.

(3.) Turn on the receiver and tune-in the signals of some station. Now slowly revolve the dial on the wavemeter and at some point on the dial the signal output of the receiver will decrease. Note the reading on the wavemeter condenser dial which cuts out the signal most completely. Make the same test on some other stations.

(4.) Now draw the curve, using the data obtained, in a manner similar to that indicated on this Laboratory Sheet. The wavelengths, or frequencies, on which the various stations are transmitting can, of course, be obtained from any list of broadcasting stations.

Such a wavemeter aids materially in the identification of stations heard on a receiver which is not calibrated.



No. 173 RADIO BROADCAST Laboratory Information Sheet

The Regulator Tube

WHY IT IS USED

THE voltage regulator tube, or glow tube, as it is sometimes called, has found rather wide use in the design of B power units, making them capable of delivering a voltage output that is practically constant over a wide range of load. The output of a power unit not using a glow tube will, of course, vary with the load, although the magnitude of this variation may be held to comparatively low values by good design. A power unit supplying an output voltage that does not depend upon the load may be used with practically any receiver with a knowledge that the voltage actually delivered to the receiver will be correct. Constant voltage output is, however, only one of the advantages accruing from the use of a regulator tube.

The action of the tube in holding the voltage of the output circuit constant serves also to eliminate the small ripples which may be present as a result of incomplete filtering, and this action makes possible a reduction in the capacity, and therefore the expense, of the final filter condenser. In fact, the tube, when in operation, has many properties in common with a large fixed condenser. One of these properties is extremely low a. c. impedance which, when combined with its instantaneous response as a voltage regulator, entirely eliminates the annoying "motor-boating" effect which generally results when an attempt is made to use one of the ordinary B power units with many forms of amplifiers.

The fact that the regulator tube keeps the output voltage constant also permits the safe use of condensers of a lower voltage rating than would be permissible if the tube were not used. The rating of the condensers used in an ordinary power circuit is fixed by the maximum values of voltage that they must handle. The voltage output of some units, at no load, rises to comparatively high values and the condensers must therefore have a rating sufficient to withstand these voltages. The output voltage of a power unit with a regulator tube is limited, even at no load, to values only slightly above rated voltage and, therefore, the condensers are not called upon to withstand voltages greater than the rated output of the unit.

No. 174 RADIO BROADCAST Laboratory Information Sheet

Grid Bias

WHY IT IS USED

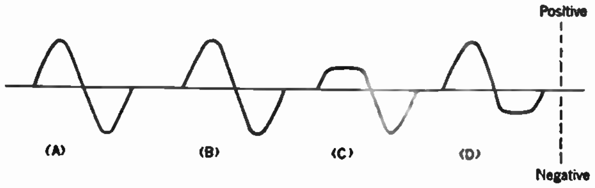
THERE are apparently many, as indicated by letters to the Laboratory, who still feel that the major reason for using C bias on a tube is to reduce the plate current. Although negative bias on the grid of a tube does decrease the plate current, this is not really the most important reason for its use.

C bias is used primarily to reduce distortion and make the tube operate more efficiently. In an ordinary receiver, C bias is most important in the audio-frequency amplifier and we will, therefore, discuss on this Laboratory Sheet the effect of using various values of C bias on the grid of a tube.

The curves A, B, C, and D indicate the distortion of signals which results when too little or too much bias is used. Curve A represents the voltage on the grid of the tube. Curve B shows how the plate current of the tube varies if the bias on the tube is correct. It should be noted that the form of this curve is the same as curve A, indicating that there is no distortion being created by the tube. If too little bias is used, the positive halves of the input voltage wave will cause the grid to become positive when the grid draws current, and the positive peaks are then cut off as indicated at C. If the bias is too great the tube operates on the lower bend of its characteristic and this causes the negative half of the signal to be flattened out, as shown in curve D. To prevent distortion, therefore, the proper C bias must be used.

It is especially important that the bias on the last tube be correct, for this tube must handle the greatest amount of signal current and will, therefore, overload and distort most easily. As a matter of information the correct bias for a 112 or 171 type tube is given below:

TUBE	PLATE VOLTS	C BIAS
112	90	6.0
	135	9.0
	157	10.5
171	90	16.5
	135	27.0
	180	40.5



No. 175 RADIO BROADCAST Laboratory Information Sheet

Filter Choke Coils

EFFECT OF AIR GAP

IF THE filter circuit of a B power unit is to eliminate satisfactorily all hum, it is essential that the filter choke coils have sufficient inductance under actual operating conditions. The value of the inductance of a choke coil as measured without any direct current flowing through it will differ from the value obtained with direct current, so all measurements on choke coils should, therefore, be made with d. c. flowing in the winding.

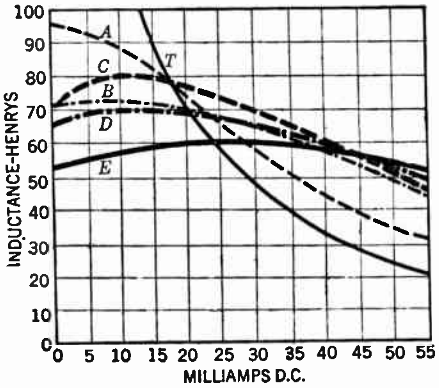
When direct current flows through a filter coil it produces a certain amount of magnetic flux, or "lines of force," in the core. This flux tends to saturate the core of the choke and, when this occurs, the unit will no longer function satisfactorily in eliminating the hum.

Manufacturers are always willing to supply data on the maximum amount of d. c. current their filter choke coil can handle and this value should not be exceeded in practice.

When the filter coil is constructed, the core may be clamped tightly together or a small air-gap may be left. As the current capacity rating of the coil is increased, the air-gap should be increased also, and this tends to prevent magnetic saturation. The group of curves on this Sheet show this effect. The conditions under which they were obtained are given below:

T—No air gap
A—Average air gap
B—Air gap at one end, 0.01 inches
C—Air gap at both ends, 0.005 inches each
D—Air gap at both ends, 0.0075 inches each
E—Air gap at both ends, 0.01 inches each

If the d. c. current is to be 10 milliamperes, construction type T is best, while type C is best at a current of 30 milliamperes, or if the current through the choke is to be 55 milliamperes, type E should be used.



No. 176 RADIO BROADCAST Laboratory Information Sheet

How the Plate Circuit Affects the Grid Circuit

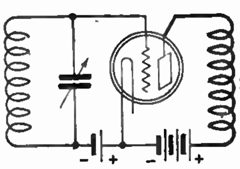
REVERSE ACTION

IN WORKING with tubes, we normally consider that the plate circuit is controlled by the grid and that there is no reverse action. This, however, is not strictly true, for the plate circuit does affect the grid circuit in two ways.

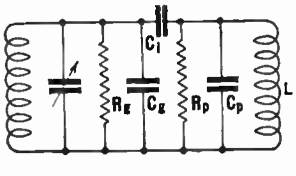
In the first place the plate acts as a grid with respect to the regular grid in the tube and large variations in plate voltage have the same effect with respect to the grid as has slightly varying the grid voltage. The reverse effect is generally not appreciable so long as the grid is held negative, as is the case in an amplifier. The reverse effect is important in oscillator circuits, however, where the grid is not always negative. In making an accurate analysis of the action of an oscillator, it would be necessary to consider this effect.

The second manner in which the grid is controlled by the plate is through the grid-plate capacity of the tube. At (A) in the diagram on this Sheet, we have indicated the circuit of an ordinary r. f. amplifier and at (B) is shown the equivalent circuit with the inter-electrode resistances and capacities indicated. R_g is the grid-filament resistance of the tube, C_g the grid-to-filament capacity, C_i the inter-electrode capacity between the grid and the plate, R_p the plate filament resistance, C_p the plate-filament capacity, and L the load impedance. Probably the most important of the capacities shown is the grid-plate capacity, C_i, for it is this capacity which permits the grid circuit to be affected by what goes on in the plate circuit. In radio-frequency amplifiers it is this capacity which causes the tube to oscillate.

The diagram at (B) should give some idea of the complexity of the network represented by a tube, and the action of this network of resistances, condensers, and inductances must be understood if the action of a tube in any particular circuit is to be accurately foretold. J. M. Millen, in *Scientific Paper of the Bureau of Standards No. 351*, carefully and completely determined the dependence of the input circuit of a tube upon the output circuit.



(A)



(B)

No. 177 RADIO BROADCAST Laboratory Information Sheet

Characteristics of Speech

ARTICULATION

CLEAR speech is only possible when the person speaking uses careful articulation. Articulation is especially important in radio for if we do not understand something, we cannot have it repeated. In analyzing speech sounds a clear understanding of how the various sounds are produced is essential.

The human voice consists of sustained and transient notes and noises. The sounds which are ordinarily difficult to recognize (and which therefore require careful articulation), are the transients such as are associated with the sounds "t" and "d" or "p" and "b." These sounds are hard to reproduce accurately for they contain many of the highest frequencies found in sounds of speech.

If we examine the manner in which the sounds "p" and "b," for example, are produced, they will be found to have much in common. They are both produced by first compressing the lips together and then rapidly opening them. To pronounce the word "pa," we first produce the "p" sound by suddenly opening the lips and permitting the air to rush through them and then the vocal chords are set in motion to produce the vowel sound "a." The syllable "ba," is produced with a very similar motion of the lips but the vocal chords are set into motion and the lips open at the same instant and also there is only a slight rush of air from between the lips. The "pa" sound is characterized by an initial sound of high intensity; the "ba" sound does not have this feature. If the radio loud speaker cannot reproduce accurately the strong portion of the former sound, "pa," it will sound very much like "ba."

Some of the sounds most difficult to reproduce accurately are noises such as the dropping of a book on a table, for these sounds contain frequency components extending throughout the entire range of audible sounds.

The study of how words are formed is very interesting and can best be done with the aid of an oscillograph, which is an instrument with which we can obtain photographic records of the wave form associated with any sound. An analysis of these records, which are sometimes termed "audiograms," is helpful in determining the range of frequencies which must be handled by a radio broadcasting system if the reproduction is to sound natural.

No. 178 RADIO BROADCAST Laboratory Information Sheet

The Exponential Horn

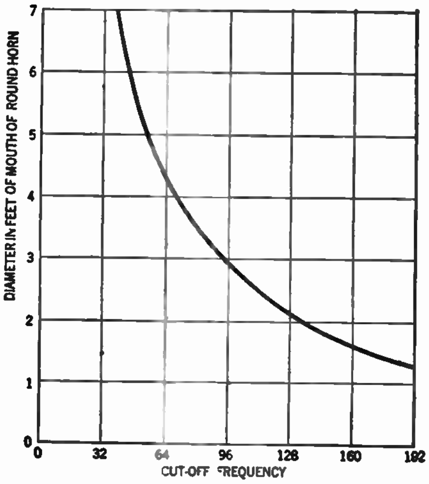
THE CUT-OFF FREQUENCY

THE LOWEST frequency transmitted by a horn of the exponential type is determined by the rate of expansion of the cross sectional area of the horn, and to eliminate reflection the diameter of the mouth of the horn (if it is round) must be made equal to one-quarter of the wavelength corresponding to the lowest frequency to be transmitted.

The velocity of sound in air is 1120 feet per second and, therefore, the wavelength (in feet) corresponding to any particular frequency may be found by dividing 1120 by the frequency. The diameter of the mouth of the horn in feet must then be equal to this wavelength divided by 4.

The accompanying curve shows graphically the relation between the diameter of the mouth of a round horn and the cut-off frequency. It should be realized that the diameter of the mouth is not the only factor determining the lowest frequency that the horn will satisfactorily transmit and that the size of the mouth is an indicator of this frequency only if the remainder of the horn has been correctly designed. As shown by the curve, to transmit frequencies down to 64 cycles, for example, it is necessary that the horn's mouth have a diameter of about 4.5 feet.

If the horn is square rather than round, it will be satisfactory to make the area of the mouth equal to that of the equivalent round horn.



No. 179 RADIO BROADCAST Laboratory Information Sheet

A Problem in Audio Amplification

THE EFFECT OF TRANSFORMER RATIO

PROBLEM:—The audio amplifier in a receiver comprises a 3:1 transformer in the detector circuit, followed by a 201-A type tube in the first audio stage, a 4:1 audio transformer for the second stage, and a power output tube. What will be the effect on the amount of signal voltage supplied to the grid of the power tube of substituting a 6:1 transformer for the 4:1 transformer?

ANSWER:—Let us first calculate the gain of the original amplifier. The total amplification to the grid of the power tube will be equal to the turns ratio of the first transformer multiplied by the effective amplification of the tube times the turns ratio of the second transformer. The effective amplification of a tube in a properly designed transformer-coupled audio amplifier can be taken as about 80 per cent. of the amplification constant of the tube; for a 201-A type tube, therefore, we take 80 per cent. of 8, which is 6.4. The total gain of the amplifier is, therefore:

$$3 \times 6.4 \times 4 = 76.8$$

Similarly the amplification with the 6:1 transformer substituted for the 4:1 will be:

$$3 \times 6.4 \times 6 = 115.2$$

The substitution of the 6:1 transformer, therefore, has increased the voltage gain by 50 per cent.; this represents a gain of 3.6 TU.

Now, the power into the loud speaker is proportional to the square of the signal voltage on the grid of the power tube feeding the loud speaker. When the voltage gain is increased 50 per cent., therefore, the power into the loud speaker is increased 125 per cent. This corresponds to a power gain of 3.5 TU which, while not very great, is appreciable. (The minimum gain audible to the ear is 1 TU.)

If the power tube is a 171 type with 40 volts on the grid, then using the original amplifier, approximately 0.5 volts (40 divided by 76.8) are required out of the detector tube in order to place 40 volts signal voltage on the grid of the 171. When the 6:1 transformer is used, only 0.3 volts (40 divided by 115.2) are required from the detector in order to "load up" the power tube.

No. 180 RADIO BROADCAST Laboratory Information Sheet

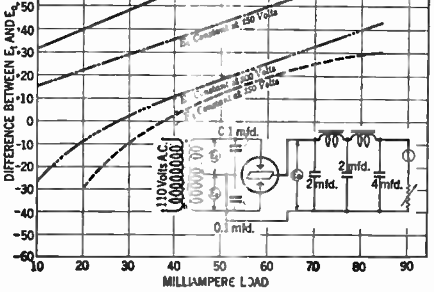
B Power Unit Characteristics

EFFECT OF TRANSFORMER VOLTAGE

THE CURVES published herewith were made by the Raytheon Manufacturing Company using one of their BH type tubes with an ordinary filter, as indicated in the accompanying circuit diagram. The curves show the relation between the voltage, E_t, across the secondary of the transformer and the input voltage, E_o. The output load in milliamperes as measured by the meter I is plotted along the horizontal axis and along the vertical axis has been plotted the difference between the effective value of the transformer voltage E_t and the average value of the voltage E_o into the filter system. The line marked +20, for example, indicates the voltage E_t to be 20 volts greater than E_o; the line marked +20 indicates the converse.

These curves show that (to take an example) with a transformer voltage of 200 volts per anode, the average value of the voltage into the filter is 27 volts higher than the transformer voltage when the load is 10 milliamperes. At a load of 28 milliamperes the voltages are equal and at a load of 60 milliamperes the input voltage to the filter has dropped to a value 25 volts below the transformer voltage. During these tests the transformer voltage, E_t, was held constant.

Other data showing the effect of various transformer voltages, obtained with the same circuit used here, were given on Laboratory Sheet No. 146, published in the December, 1927, RADIO BROADCAST.



No. 181 RADIO BROADCAST Laboratory Information Sheet

R. F. vs. A. F. Amplification

A COMPARISON

THE SIGNAL output from a radio receiver may be increased by augmenting either the audio-frequency or radio-frequency amplification or by boosting the detecting efficiency. On this Laboratory Sheet we give briefly the comparative merits of audio-frequency and radio-frequency amplification. In the accompanying table is shown the effect on the power into the loud speaker of increasing the a.f. or r.f. amplification. The first column gives the increase in amplification and the second column the increase in power into the loud speaker if this extra amplification is introduced in the audio amplifier. The third column shows the increase in power into the loud speaker if the extra amplification is placed in the r.f. amplifier.

This table is based on the fact, first, that the power into the loud speaker is proportional to the square of the voltage on the grid of the power tube and, secondly, that the output of the detector is proportional to the square of the voltage on its grid. When the audio-frequency amplification is multiplied by 10, for example, the power into the loud speaker is 100 times greater. When the radio-frequency amplification is multiplied by 10, however, the output of the detector is 100 times greater and the power into the loud speaker is 10,000 times greater. It is evident from these figures, therefore, that increases in r.f. gain are much more effective in producing greater signal than increases in audio-frequency gain.

Added Amplification	*Increase in Power into Loud Speaker* A. F.	R. F.
2	4	16
5	25	625
10	100	10,000
20	400	160,000
50	2500	6,250,000

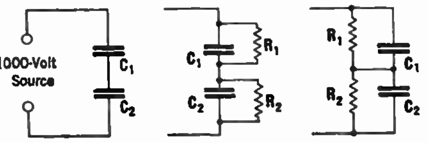
No. 182 RADIO BROADCAST Laboratory Information Sheet

Filter Condensers

HOW TO CONNECT THEM IN SERIES

IF WE desire to place a filter condenser across, for example, a 1000-volt source of direct current and we have available two large-capacity 500-volt condensers, it is ordinarily not possible to connect them in series across the 1000-volt leads with safety. Why this is so will be explained on this Laboratory Sheet.

At A in the diagram is shown the connection of two condensers, C_1 and C_2, in series across the 1000-volt source. Now, a condenser has a definite d.c. resistance, which is generally very high but nevertheless finite, and this resistance is represented as R_1 and R_2 in B as external resistances across each condenser. A small amount of current will flow through these resistances and the voltage drop across the two resistances will be in direct proportion to the resistances. The resistances of condensers vary widely and therefore it is extremely unlikely that we would have two condensers with the same d.c. resistance. For example, condenser C_1 might have a d.c. resistance of 100 megohms while the d.c. resistance of condenser C_2 might be 900 megohms. The d.c. voltage drops across the two condensers being proportional to the resistances there would then be 100 volts across C_1 and 900 volts across C_2. If the two condensers were both rated at 500 volts, the obvious result would be that condenser C_2 would have a very short life because of the overload being placed on it. The solution for this difficulty is to connect external resistances R_1 and R_2 across each condenser as indicated at C with a sufficiently low value in comparison with the internal resistance of the condenser (which is always very high) so that the voltage drops will be determined by the external resistances rather than by the internal resistances



A B C

of the condensers. If we have two 500-volt condensers connected to a 1000-volt source, we might equalize the voltage across them by connecting two 100,000-ohm resistances in series across the source, as indicated at C. There would be 500 volts drop across each resistance and, therefore, 500 volts across each condenser, and the latter would then be satisfactory in operation and have normal life.

No. 183 RADIO BROADCAST Laboratory Information Sheet

The Type 280 and 281 Tubes

THEIR CHARACTERISTICS

THE characteristics of the type 280 and 281 rectifier tubes are given below. These tubes are for use as rectifiers in B power units, the 280 in circuits designed for full-wave rectification and the 281 in half-wave circuits. Two 281 tubes may be used, if desired, to give full-wave rectification:

TYPE 280 FULL-WAVE RECTIFIER

Filament Voltage	*5 Volts*
Filament Current	*2 Amperes*
A.C. Plate Voltage (Max. Per Plate)	*300 Volts*
Max. D.C. Output Current	*125 Milliamperes*
Max. D.C. Output Voltage	*260 Volts*
Height of Tube	*5⅝ Inches*
Diameter of Tube	*2$\frac{3}{16}$ Inches*

TYPE 281 HALF-WAVE RECTIFIER

Filament Voltage	*7.5 Volts*
Filament Current	*1.25 Amperes*
A.C. Plate Voltage (Max.)	*750 Volts*
A.C. Plate Voltage (Recommended)	*650 Volts*
D.C. Output current (Recommended)	*65 Milliamperes*
D.C. Output Current (Max.)	*110 Milliamperes*
D.C. Output Voltage (Max.)	*620 Volts*
D.C. Output Voltage (Recommended)	*620 Volts*

The type 280 tube may be used in circuits designed especially for it or may be used in circuits designed for the type 213 tube. The characteristics of these two tubes are similar with the exception that the former tube is capable of somewhat greater output than the 213. If a 280 tube is used in place of a 213, the 280 will be operating at less than full load and will consequently have a very long life. These facts are also true with regard to the 281, which may be used satisfactorily in place of a 216-B type tube.

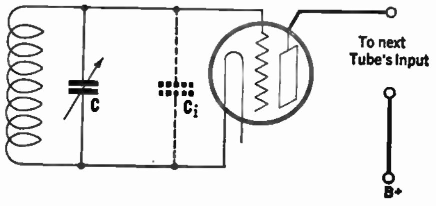
If more than about 65 milliamperes at 600 volts is necessary to operate a radio installation, it will be a good idea to use two type 281 tubes in a full-wave circuit with about 650 or 700 volts a.c. on the plate of each tube. With this arrangement an output in excess of 100 milliamperes at 600 volts will be available.

No. 184 RADIO BROADCAST Laboratory Information Sheet

Tuning

THE EFFECT OF DISTRIBUTED CAPACITY

A RADIO receiver to cover the broadcasting band must be able to tune-in signals from 550 kc. to 1500 kc., a ratio of 2.73 to 1 in frequency. It can be shown mathematically that, in order to obtain this range, the ratio of the maximum to minimum of the capacity across a tuning coil must be 8.6 to 1 approximately. If we use a tuning condenser with a maximum capacity of 0.0005 mfd. then the minimum capacity across the coil must theoretically be (if the desired tuning range is to be obtained) 0.0005 divided by 8.6, or 0.000058 mfd. An ordinary condenser might have a minimum capacity of about 0.000025 mfd. and, therefore, it



appears that we should be able to cover the broadcasting band very easily. In the circuit, however, there is another capacity across the coil which has an important effect. This additional capacity is the effective input (grid-to-filament) capacity of the tube, indicated as Ci in the diagram, and this capacity varies with the amount of amplification the tube is producing in the circuit. This capacity, Ci, is in parallel with C, the tuning condenser, and its effect must therefore be added to that of C. The result is that the actual minimum capacity of the circuit is greater than that of the minimum capacity of C, and this will tend to restrict the tuning range of the receiver unless the precaution is taken that a variable condenser with a low minimum capacity is used to tune the circuit, that the coil itself does not have much distributed capacity, and that long leads in the circuit do not introduce objectional capacity.

If a station transmitting on the lowest frequency (longest wavelength) used in the broadcasting band tunes-in on the set with the condenser plates all in (as they should be) but it is found impossible to tune-in a station operating on the highest frequency (shortest wavelength), it is possible that the cause may be due to a tuning condenser with a large minimum capacity or excessively long leads connecting the coil with the condenser.

No. 185 RADIO BROADCAST Laboratory Information Sheet

Tube Overloading

EFFECT OF INCORRECT VOLTAGES

DURING recent years many familiar types of radio tubes have played the rôle of "Jack of all trades," and as a result have frequently been placed in service under conditions never intended or contemplated by the manufacturer.

What constitutes "overload" on a tube, resulting in shortened life? It might be imagined that the last tube in a receiver tuned-in on a strong local station, and with the volume turned up beyond the point where the music sounds clear, would fall under this classification, but this is not the case. This is a form of overloading, but one which only results in distorted music, and in general the tube is not affected at all. A severe overload permanently affecting the tube occurs, however, when the manufacturer's specifications as regards filament, plate, and grid voltages are disregarded and higher voltages are used.

One of the popular tube types affords a good illustration of this condition. The voltages recommended for type 201-A tubes are a filament voltage of 5.0 volts, and plate voltages of 90 to 135 volts, with the grid bias specified as −4.5 and −9.0 volts respectively. If the grid bias of 4.5 volts recommended at 90 volts is omitted it is equivalent to adding about 35 volts to the plate voltage, or in other words, is equivalent to operation of the tube at 125 volts with −4.5 volts bias. The overload is, of course, correspondingly more severe if the plate voltage is raised. This is clearly shown in the table below:

PLATE VOLTS	GRID VOLTS	CURRENT M A.	EXTENT OF OVERLOAD
90	4.5	2.0	Below maximum
135	9.0	2.5	Normal
90	0	6.0	58%
120	0	9.8	240%
135	0	12.0	380%

The 201-A type tube is capable of withstanding some overload more successfully than other types of tubes, but as a general rule it is always advisable to follow the manufacturer's ratings regarding tube voltage.

No. 186 RADIO BROADCAST Laboratory Information Sheet

The Type 250 Tube

A NEW POWER AMPLIFIER

THE type 250 is the latest tube designed for use as a power amplifier to supply large amounts of undistorted power for the operation of loud speakers. The large output obtainable from this tube prevents any possibility of overloading of the last stage of an audio amplifier.

The filament rating is 7.5 volts, 1.25 amperes. The material used in the filament is the rugged coated ribbon form, similar to that used in the type 280 rectifier, the filament operating at a dull red. The filament current may be supplied from the 7.5-volt winding of a power transformer. The low operating temperature and the increased size of this type of filament results in minimum ripple voltage or "hum."

It should be noted that, although the filament and plate voltages are the same as those for the type 210 tube, the plate current is 55 milliamperes at a plate voltage of 400 volts whereas under similar conditions, the plate current of the type 210 is only 18 milliamperes. The grid voltages for these two tubes, at a plate voltage of 400 volts, are respectively —70 and —31.5 the larger voltage being necessary on the type 250 tube. Because of the higher plate current and grid bias required by this new tube it cannot always be used to replace the type 210 tube without changing the circuit.

	RECOMMENDED				MAXIMUM
Plate Voltage	250	300	350	400	450 Volts
Negative Grid Bias	45	54	63	70	84 Volt
Plate Current	28	35	45	55	55 Milliamp.
Plate Resistance (a.c.)	2100	2000	1900	1800	1800 Ohms
Mutual Conductance	1800	1900	2000	2100	2100 Micromhos
Voltage Amplification Factor	3.8	3.8	3.8	3.8	3.8
Max. Undistorted Power Output	900	1500	2350	3250	4650 Milliwatts

Filament 7.5 Volts 1.25 Amperes
Max. Overall Height $6\frac{1}{4}$" Diameter $2\frac{11}{16}$"
Base: Large Standard UX (CX)

No. 187 RADIO BROADCAST Laboratory Information Sheet

Grid Bias

HOW TO CALCULATE BIAS

THIS Laboratory Information Sheet gives some information regarding grid bias and how it depends upon the voltage of the grid battery and the manner in which the filament circuit of the tube is wired.

The bias voltage on the grid of a tube is always specified with respect to the negative end of the filament. In drawing A of the diagram on Sheet No. 188, the grid voltage is zero.

In drawing B, the filament resistance *R* has been placed in the negative leg of the filament, and since the drop across this resistance is 1.0 volt, the grid bias is also −1.0 volt.

In drawing C, a 4½-volt battery has been introduced in the circuit so that the grid bias is now equal to the voltage of this battery plus the voltage drop across the resistance *R*. The bias is therefore − 4½ plus − 1.0 or −5½ volts.

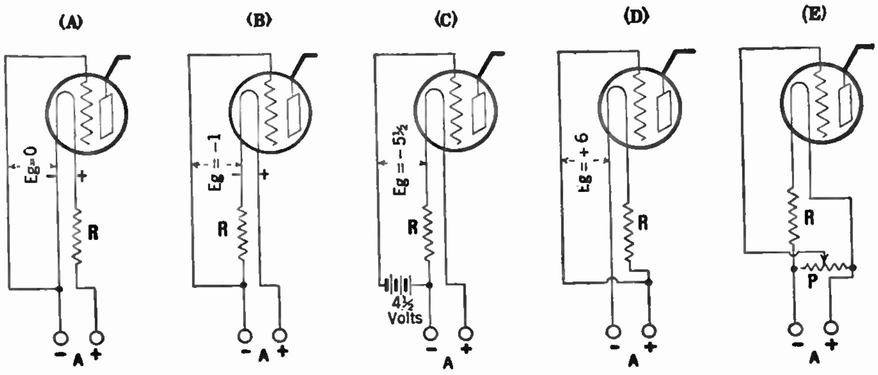
A positive grid bias of +6.0 volts is obtained if the resistance *R* is connected in the positive leg of the filament and the grid return is connected to the +A terminal of the battery. See sketch D. If the grid return was connected to the other leg of the resistance, the grid bias would be equal to the voltage drop in the filament or +5.0 volts.

A variable grid bias from −1.0 to +5.0 volts can be obtained by means of the potentiometer *P* in drawing E. With the potentiometer at the extreme left-hand position, the bias is —1.0 volt (due to the voltage drop in *R*) and with the arm moved over to the extreme right-hand position the bias is +5.0 volts.

From the information given in this Sheet it should be possible to determine the grid bias with any circuit arrangement.

No. 188 RADIO BROADCAST Laboratory Information Sheet

Grid Bias Calculations



Laboratory Sheet No. 187 explains these five circuit arrangements. Determination of the grid bias of any circuit arrangement is a simple matter once the information contained on these sheets is mastered

No. 189 RADIO BROADCAST Laboratory Information Sheet

The A. C. "Universal" Receiver

PARTS REQUIRED

LABORATORY Sheet No. 190 gives the circuit of the "Universal" receiver wired for a.c. operation. The d.c. receiver was described in the December, 1926, RADIO BROADCAST and the circuit of the d.c. receiver was also given on Laboratory Sheet No. 100, June, 1927. The a.c. circuit is published in response to many requests from readers.

L_1—*Antenna coil* consisting of 13 turns of No. 26 d.s.c. wire wound at one end of a 2¾-inch tube.

L_2—*Secondary coil* consisting of 50 turns of No. 26 d.s.c. wire wound on the same tube as L_1. The separation between L_1 and L_2 should be ¼ inch.

L_3—*Primary of interstage coil* constructed in same manner as L_1 and tapped at the exact center.

L_4—*Secondary winding* constructed in same manner as L_2 and tapped at point A, the 15th turn from that end as L_4 which is nearest to L_3.

C_1, C_2—Two 0.0005-mfd. *variable condensers*.

C_3—*Neutralizing condenser*, variable, 0.000015 mfd.

C_4—*Regeneration condenser*, 0.00005 mfd.

L_5—*R.F. choke coil*, made by winding 400 turns of No. 28 wire on ½" dowel.

T_1, T_2—Two *audio-frequency transformers*.

R_1—*Fixed resistance*, 1000 ohms.

R_2, R_3, R_4—*Center-tapped resistances* for a.c. tubes.

R_5—*Fixed resistance*, 2000 ohms.

R_6—*Grid leak*, 2 megohms.

C_5, C_6—*Bypass condensers*, 1-mfd.

C_7—*Grid condenser*, 0.00025-mfd.

C_8—*Output condenser*, 200 volts, 4-mfd.

L_6—*Output choke*, 60 henries.

VT_1, VT_3—226 type *a.c. tubes*.

VT_2—227 type *a.c. tube*.

VT_4—171 type *tube*.

Three standard *four-prong sockets*.

One *five-prong socket*.

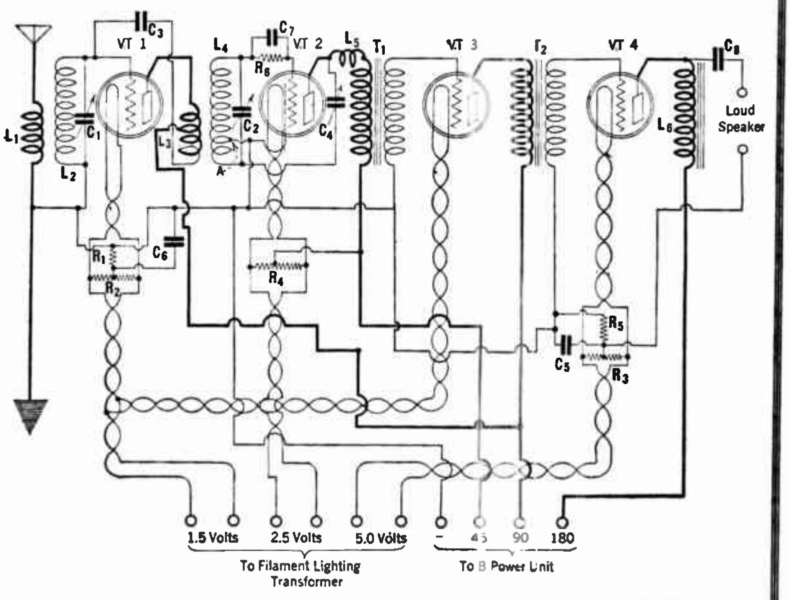
Binding posts.

C bias for the tubes is obtained from resistances R_1 and R_5.

The 227 type detector tube requires about 30 seconds to heat up and begin functioning and therefore about this length of time must lapse between the time the power is turned on and the set begins to operate. The receiver must, of course, be carefully neutralized.

No. 190 RADIO BROADCAST Laboratory Information Sheet

A revised arrangement of the well-known "Universal" circuit which provides for the use of a.c. tubes. It is fully described on Laboratory Sheet No. 189



Radio Broadcast's Home Study Sheets

Determining the Capacity and Inductance of a Radio Circuit

COILS and condensers are the foundation on which every radio circuit is erected. The coils possess an electrical quantity known as Inductance, and as every radio experimenter knows, the quantity that makes a condenser useful is its Capacity for storing electricity. When a current flows through the coil, lines of force surround it; the sum total of these lines is known as an electromagnetic field. The word *magnetic* is important here, for a compass—which normally points one end of its swinging needle toward the earth's north magnetic pole—will be deflected when brought near such a coil. When a current flows through a condenser, lines of force surround it. The total of these lines is known as the electrostatic field. It can be detected, not by a compass needle or any other device using the magnetic principle, but by a *charged* body such as a small bit of paper which had been rubbed on the sleeve.

The unit of capacity is the farad, named after Michael Faraday, a distinguished English experimenter. In radio circuits, however, the millionth of a farad, a microfarad, is ordinarily the quantity dealt with, or even the micro-microfarad, the million-millionth of a farad. The unit of inductance is the henry, named from Joseph Henry, a famous American experimenter. In radio circuits the unit dealt with is the milli- or microhenry, thousandths or millionths of henries. The table on this page shows how to convert farads and henries to microfarads or milli- or microhenries. For example, to change henries to millihenries, you multiply by one thousand. To convert mmfd. to mfd. you divide by one thousand; and so on.

It is the size of the coil and the condenser that controls the wavelength or frequency to which a circuit tunes. The designer of the world's best receiver must know within very close limits what the inductance of his coils must be; he knows how large a capacity he must have to cover a certain band of frequencies. It is always important to know the exact value of these two electrical quantities, capacity and inductance. The following experiment will enable anyone to find out the capacity of a condenser, and the inductance of a coil.

APPARATUS REQUIRED

1. A coil of wire. The dimensions of the coil used in the Laboratory are given in Fig. 1.
2. A variable condenser fitted with a dial. About 500 mmfd. is the best size of condenser.
3. A radio receiver, preferably with an oscillating detector; or a tube wavemeter.

PROCEDURE

1. Connect the coil and condenser across each other and bring the coil near the coil in the receiver or that of the tube wavemeter.
2. Tune the receiver to a known station near the center of the broadcast band, or if a wavemeter is used, set its wavelength to about 300 meters.
3. Change the setting of the variable condenser across the coil whose inductance is unknown, until resonance with the receiver is indicated by a decrease in signal strength, or by a click if the oscillating detector is used, or by a dip in the indicating needle of the tube wavemeter. A good meter is the modulated oscillator in the June, 1927, RADIO BROADCAST.
4. Tune the receiver, or wavemeter, to other wavelengths above and below the first medium wavelength setting until the whole of the condenser has been used, at each wavelength noting down the data as is shown in Table 1.
5. Compute the inductance of the coil from the following formula—which is one used by Professor Hazeltine.

$$\text{Inductance in Microhenries} = \frac{0.2 \times d^2 \times N^2}{3d + 9b}$$

where d is the diameter of the coil in inches
N is the number of turns of wire
b is the length of the winding in inches

As an example below is the manner in which the inductance of the coil illustrated in Fig. 1 is calculated.

$$\text{Inductance} = \frac{0.2 \times 3.06^2 \times 64^2}{3 \times 3.06 + 9 \times 1.875} = \frac{.2 \times 38400}{9.18 + 16.85} = \frac{7680}{26.03} = 292\,\mu h$$

6. Compute the capacity of the condenser at each of several of the long wavelength settings from the formula

$$\text{wavelength} = 1884 \sqrt{L \times C}$$

where L is the inductance in microhenries
C is the capacity in microfarads

For example, the 292-microhenry inductance tuned to 527 meters at 55° on the condenser dial. What is the capacity of the condenser at that point? To simplify the problem let us change the above formula to read

$$(\text{wavelength})^2 = 3.54 \times 10^6 \times L \times C$$

$$527^2 = 3.54 \times 10^6 \times 292 \times C$$

$$C = \frac{527^2}{3.54 \times 10^6 \times 292} = 270 \text{ mmfd.}$$

To provide additional examples, the capacity column in the data Table 1 has been left blank.

7. Plot this data as shown in Fig. 1
8. Make a tap at the center of the coil and repeat the above calculations and experiment.
9. Pick out some condenser setting on each set of calculations, say 60 degrees, and see how nearly the calculated capacities check.

DISCUSSION

IN THE experiment we have demonstrated the phenomenon known as resonance: that is, a circuit composed of inductance and capacity absorbing energy from another also composed of inductance and capacity, to which it is properly tuned. We have calculated the inductance of a coil by means of a formula which will give us a result accurate to within two or three per cent., provided, *a.* we measure the dimensions of the coil accurately; *b.* we make no mistake in our arithmetic, and *c.* provided the length and diameter of the coil are not too different in dimensions. The formula will be most accurate when the length of winding equals the diameter of the coil.

We have demonstrated that knowing the wavelength to which a coil-condenser combination tunes, and knowing the inductance, we may calculate the capacity. This is one means of calibrating a condenser, that is, determining the relation between dial degrees or divisions and microfarads of capacity. The accuracy with which we determine the capacity by this method is none too great, but for all practical purposes it is good enough provided, *a.* we make no error in our arithmetic; *b.* we know the wavelength accurately; *c.* we can set the condenser dial accurately to the wavelength of the receiver or wavemeter, and *d.* the capacities being measured are fairly large, say 250 mmfd. and more. This latter proviso is because the actual capacity across the coil is made up not only of the capacity of the condenser but of the leads connecting coil and condenser and the distributed capacity of the coil. This latter capacity is a bothersome factor in all experimenters' calculations and experiments. It is discussed in the Signal Corps book, *Principles Underlying Radio Communication*, page 244, in the *Bureau of Standards Bulletin* 74 on pages 137–8 and in Morecroft's *Principles of Radio Communication*, page 230–235.

The capacity of the condenser used in the Laboratory, a General Radio "tin can" Type 247E, was actually 300 mmfd. at 55° while our calculations showed it to be 270 mmfd.—an accuracy of 10 per cent. The coil as measured on a bridge had an inductance of 280 microhenries instead of 292 as calculated—an accuracy of 95.6 per cent.

TABLE 1

condenser setting in degrees	*condenser capacity in mmfd. (calculated)*	*wavelength in meters*	*frequency in kilocycles*	*(wavelength)²*
78.5	270	621	483	385,000
55.0		527	568	277,000
41.0		458	655	210,000
32.0		408	735	166,600
26.5		370	810	133,700
22.0		338	888	114,000

TABLE 2

Name of unit	*abbreviation*
farad	f.
microfarad	mfd.
micromicrofarad	mmfd.
henry	h.
millihenry	mh.
microhenry	µh.

TABLE 3

f.	= one million	mfd.	= 10^6 mfd.
f.	= one million million	mmfd.	= 10^{12} mmfd.
mfd.	= one million	mmfd.	= 10^6 mmfd.
mfd.	= one millionth	f.	= 10^{-6} f.
mmfd.	= one millionth	mfd.	= 10^{-6} mfd.
mmfd.	= one million millionth	f.	= 10^{-12} f.
h.	= one thousand	mh.	= 10^3 mh.
h.	= one million	µh.	= 10^6 µh.
mh.	= one thousand	µh.	= 10^3 µh.
mh.	= one thousandth	h.	= 10^{-3} h.
µh.	= one thousandth	mh.	= 10^{-3} mh.
µh.	= one millionth	h.	= 10^{-6} h.

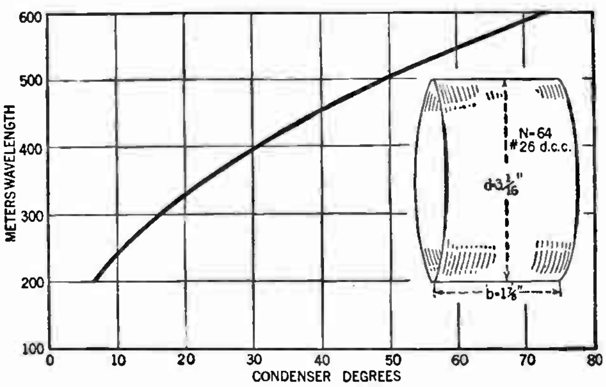


FIG. 1

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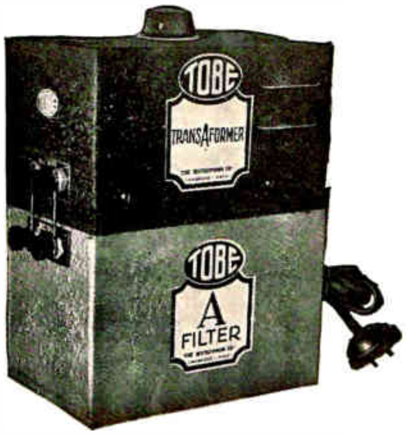

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