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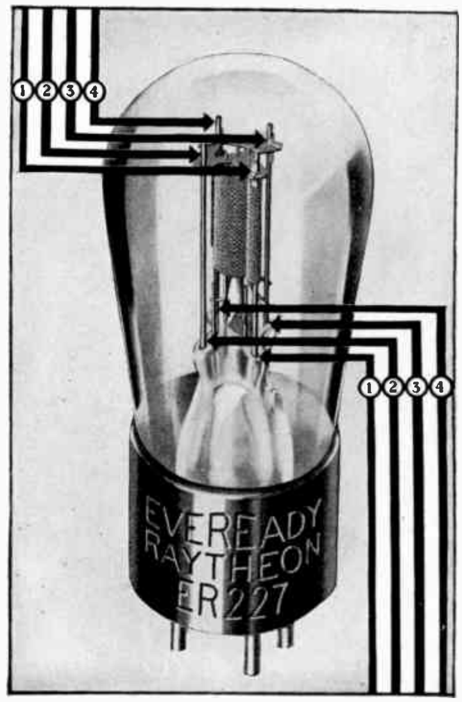

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The Radio Broadcast

LABORATORY INFORMATION & SET DATA SHEETS

by
HOWARD E. RHODES
Radio Broadcast Laboratory

SERIES TWO

Numbers 193-345

With Index On Page 64

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No. 193 RADIO BROADCAST Laboratory Information Sheet

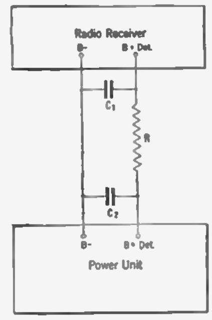
"Motorboating"

HOW IT CAN BE PREVENTED

MANY amplifiers at times show a tendency to "motorboat" due generally to interaction coupling between stages, due to common coupling in the plate-supply unit. This effect can generally be eliminated by using the circuit shown on this Laboratory Sheet. This circuit was suggested in a recent bulletin from the E. T. Cunningham Company.

The anti-motorboating circuit consists of a network of condensers and resistances connected between the power unit and the B-plus detector terminal on the radio receiver. The effect of this circuit apparently is to eliminate coupling effects at the low frequencies at which such effects are most troublesome. The circuit has been used with good results in the Laboratory, in connection with resistance-coupled amplifiers which generally show the strongest tendency to motorboat, but the circuit may be satisfactorily used with any type of amplifier.

It is not difficult to add this circuit to any existing receiver installation. To do this it is simply necessary to connect the resistance R in series with the lead connecting between the B-plus detector terminal on the receiver and the B-plus detector terminal on the power unit. One 2.0-mfd. condenser C_1 must then be connected between the B-plus terminal and the B-minus on the receiver and another condenser C_2 connected between the B-plus detector and minus B terminal on the power unit. It is preferable to locate the resistance at a point close to the receiver rather than near the power unit.



The value of the resistance depends to some extent upon the characteristics of the receiver and the power unit. With some amplifiers we have found a value of 10,000 ohms to be satisfactory, and with other amplifiers, a resistance of 50,000 to 100,000 ohms was required to prevent motorboating. A value of about 50,000 ohms seems to be satisfactory in most cases.

No. 194 RADIO BROADCAST Laboratory Information Sheet

Push-Pull Amplifiers

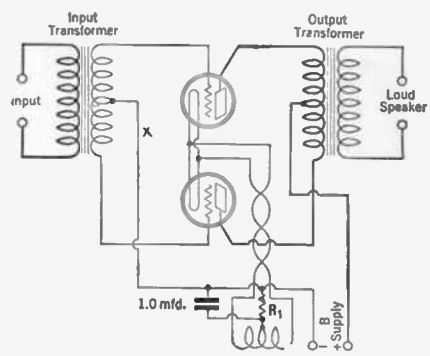
HOWLING

PUSH-PULL type amplifiers in many cases exhibit a tendency to howl at some audio frequency due to feedback through the interelectrode capacity of the tubes. When this occurs it is obviously impossible to obtain satisfactory operation from the amplifier. The howling in push-pull amplifiers can generally be readily prevented by connecting a choke coil or resistance at the point marked X in the circuit diagram. When constructing an amplifier of this type it is wise to include such a choke or resistance in the circuit; no by-pass condenser should be placed across the unit.

The inclusion of choke or resistance in this circuit will not affect the quality for this circuit does not have to carry any audio-frequency currents. In some instances it will be found necessary to prevent howling to include also a choke coil in the lead from the center tap of the output transformer and the B-plus terminal of the plate supply.

If a resistance is used in the grid circuit it should have a value of about 50,000 ohms. Since it does not have to carry any current, any ordinary grid leak type of resistance unit may be used. The chokes used may be any type with an inductance of about 10 henries or more. The primary of an old audio-frequency transformer might be used in the grid circuit but is not satisfactory for inclusion in the plate circuit between the center tap of the output transformer and the plate supply for when connected at this point, the choke must carry the plate current of the two tubes, which may be enough to burn out the windings of an ordinary audio transformer. Use at this point some device designed to carry 50 or 60 milliamperes. The circuit given on this sheet also shows the use of a resistance R_1 to supply C bias to the two tubes. Its value, depending upon the type of tubes used, is given below

Type of Tube	R_1
112-A	750 ohms
171-A	1000 ohms
210	1100 ohms



No. 195 RADIO BROADCAST Laboratory Information Sheet

A Resistance-Coupled Amplifier With Screen-Grid Tubes

CONSTRUCTIONAL DATA

THE February, 1927, RADIO BROADCAST reported some experiments made in the Laboratory on the use of the screen-grid tube in audio-frequency and radio-frequency amplifiers, and in the article there appeared a circuit diagram of a resistance-coupled, audio-frequency amplifier using two screen-grid tubes. Many letters have been received requesting constructional data on this amplifier and we have therefore reprinted the circuit diagram on Laboratory Sheet No. 196 and the list of parts necessary to construct the amplifier appears at the end of this Sheet.

The publication of this circuit diagram and list of parts should not be taken to indicate unqualified endorsement of the amplifier for its high voltage gain of 2200 (the voltage gain of an average two-stage transformer coupled amplifier is 250) in some cases will prove more of a disadvantage rather than an advantage. The disadvantage of a high gain audio-frequency amplifier will become evident when an attempt is made to operate it from a B-power unit. When an ordinary amplifier is used with a plate-supply unit which provides hum-free operation no difficulty may ensue; but when this same supply is connected to a high-gain, screen-grid amplifier, the hum is greatly magnified and may be of entirely too high a value. If the screen-grid tubes are operated from batteries, however, this amplifier will give very satisfactory results.

To construct this amplifier the following parts are necessary:

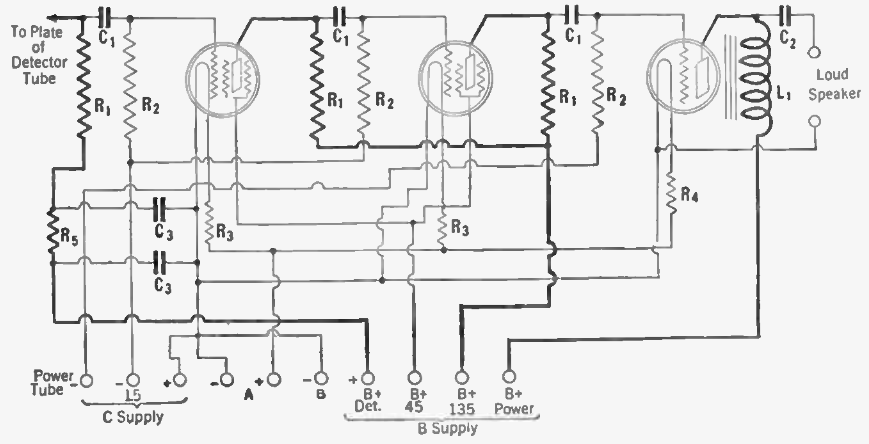
R_1, 0.25-Megohm Resistors
R_2, 2.0-Megohm Resistors
R_3, 20-Ohm Filament Resistors
R_4, 4-Ohm Resistor
R_5, 0.1-Megohm Resistor
C_1, 0.01-Mfd. Fixed Condensers
C_2, 4.0-Mfd. Fixed Condensers
C_3, 2.0-Mfd. Bypass Condensers
Three Sockets
Binding Posts

No special care is required in the construction of this amplifier although it is wise to arrange the layout so that the various grid and plate leads are short. The condensers C_3 and the resistor R_5 are incorporated in the circuit to prevent the amplifier from motorboating. This circuit will also help to keep the hum low if the device is operated from a B-power unit.

A frequency characteristic curve of this amplifier made in this Laboratory showed it to be flat from 100 to 10,000 cycles.

No. 196 RADIO BROADCAST Laboratory Information Sheet

Circuit of a Resistance-Coupled Screen-Grid Amplifier



No. 197 RADIO BROADCAST Laboratory Information Sheet

Amplification Constant

HOW IT MAY EASILY BE MEASURED

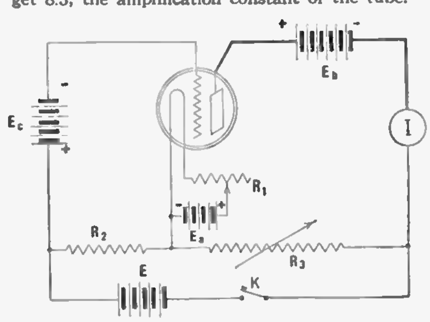
IT IS not difficult with simple apparatus to measure the amplification constant of any tube The important apparatus required to make such a test are two accurate resistances, one variable, the other fixed, and a milliammeter capable of carrying the normal plate current of the tube under test. The circuit diagram to be followed in making this test is given here. The following parts are used in the circuit:

E_c—C-battery with a value correct for the tube under test. E_b—B-battery with a value correct for the tube under test. E_a—Source of filament voltage. E—45 volt B-battery. R_1—Filament rheostat. R_2—Accurate 10-ohm resistor. R_3—Accurate variable resistor, having a maxmum value of 300 or 400 ohms. I—Milliammeter having a maximum range of about 20 milliamperes. K—Key to open and close the circuit.

The important resistor in this circuit is R_1 which must be calibrated. A good potentiometer may be used, provided it is supplied with a dial so that the amount of resistance included in the circuit can be calculated. For example, if the potentiometer has a resistance of 400 ohms and the dial reads from 0 to 100 then each degree would include 4 ohms.

The test is conducted as follows. With K open, adjust E_c and E_b so that the tube is being operated under the correct conditions of grid and plate voltage. Note the plate current reading. Now depress K and note the change in the reading of the milliammeter. Adjust R_1 so that as the key is opened and closed no change takes place in the reading of the milliammeter. When resistor, R_1, has been adjusted so that the plate current remains constant, calculate the amount of resistance at R_1, included in the circuit. Divide this resistance by 10, the value of R_2, and the quotient will be the amplification constant of the tube.

EXAMPLE: A 201-A type tube is being tested and a balance is obtained when there are 83 ohms included in the circuit at R_1. Dividing 83 by 10 we get 8.3, the amplification constant of the tube.



No. 198 RADIO BROADCAST Laboratory Information Sheet

The Screen-Grid Tube as an R. F. Amplifier

CALCULATING GAIN

PROBLEM:—Suppose that we have a radio-frequency amplifier connected as indicated in the figure and that a screen-grid tube is used. How can we calculate the amplification that can be obtained?

SOLUTION:—To solve the problem we must make use of the tube constant known as the mutual conductance, which, for the screen-grid tube, has a value of about 350 micromhos or 0.000350 mhos. The mutual conductance Gm by definition,

$$G_m = \frac{I_{ac}}{E_g} \quad (1)$$

where G_m is the mutual conductance in mhos; I_{ac} is the alternating current flowing in the plate circuit, E_g is the alternating voltage impressed in the grid; transposing this equation we get

$$I_{ac} = G_m \times E_g \quad (2)$$

The voltage E_t across the tuned circuit is equal to the impedance of the circuit Z times the current through it

$$E_t = I_{ac} \times Z \quad (3)$$

and therefore

$$E_t = G_m \times E_g \times Z \quad (4)$$

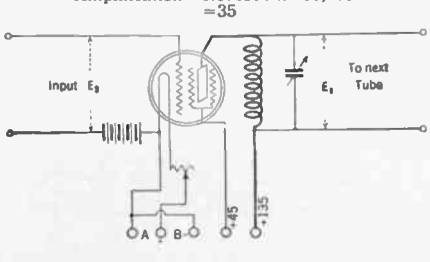
The amplification of the circuit is equal to the voltage across the output E_t divided by the voltage across the input E_g. Transposing equation (4) to get this ratio we obtain

$$\frac{E_t}{E_g} = G_m \times Z \quad (5)$$

This equation shows that the gain of this circuit using a screen-grid tube is simply equal to the mutual conductance of the tube in mhos, times the effective impedance of the tuned circuit.

Therefore, if we know the impedance into which the tube is working, we can, by multiplying the impedance by G_m, obtain the amplification. If the tuned circuit at resonance has an effective impedance of 100,000 ohms then the amplification would be

$$\text{Amplification} = 0.000350 \times 100{,}000 = 35$$



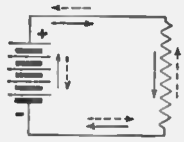
No. 199 RADIO BROADCAST Laboratory Information Sheet

Current

ITS DIRECTION OF FLOW

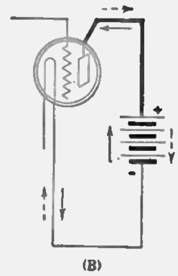
THE direction of flow of current around a simple circuit consisting of a battery and a resistance is generally considered to be as indicated by the solid arrows in sketch A on this sheet. As indicated, the current is thought of as flowing out of the positive terminal of the battery, through the resistance and into the negative terminal of the battery.

Now let us look at the circuit of a vacuum tube, as indicated in sketch B. In this circuit, we would assume that the current would flow as indicated by the solid arrow, *i. e.*, out of the positive terminal through the tube and into the negative terminal just as it did in circuit A. However, we know that the filament of the tube is the electron-emitting substance and that the electron flow is from the filament to the plate. Apparently we have two currents flowing in the circuit, and this has led some experimenters to believe that there were two distinct currents flowing in the circuit, on the battery current and the other the electron current. This is not so and there is only one current flowing in the circuit, the electron circuit.



(A)

The idea that the electric current flows from the positive to the negative originated before anything was known about electrons. This direction of flow has since been proved to be wrong. It is now realized that an electric current is actually a flow of electrons and that electrons, being negatively charged, flow toward the point of positive potential. Therefore the actual flow of current in the tube circuit B and the battery circuit A is as indicated by the dotted arrows.



(B)

Fortunately the incorrect assumption that was made years ago for the direction of the flow of current is not important in the solution of electrical problems so long as we remain consistent regarding the direction in which the current is assumed to flow.

Many meters used in electricity are marked with plus and negative signs and the winding of the meter is arranged so that the pointer on the meter will deflect in the right direction when the positive terminal of the meter is connected to the more positive part of the circuit.

No. 200 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

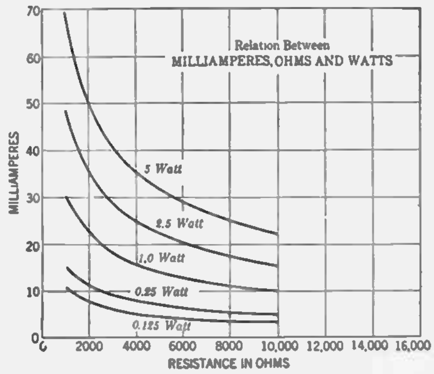
The curve is plotted to cover resistors up to 10,000 ohms and wattage ratings up to 5 watts.

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. 201 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. 202 Radio Broadcast Laboratory Information Sheet

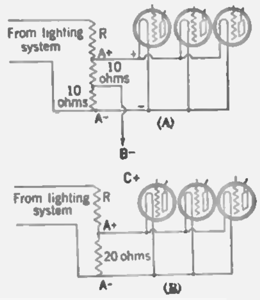
Farm Lighting Systems

AS A SOURCE OF FILAMENT CURRENT

THIS Laboratory Sheet is provided in response to requests from several readers for information on how to make use of power from a farm-lighting installation for the operation of the filaments of the tubes in a radio receiving set.

Farm-lighting systems are of two types, those using a generator powered by a gas engine in which the energy for the lights is obtained directly from the generator and those systems in which the generator is used to charge a bank of storage batteries which in turn supply energy for lighting. The voltages of these systems are generally either 32 or 110 volts.

To make use of this current in the radio receiver it is necessary to reduce the voltage by means of the resistance, R, the value of the resistance depending upon the number of tubes in the set and upon the voltage of the supply, as indicated below.



NO. OF TUBES IN RECEIVER	32 VOLT SYSTEM R IN OHMS	32 VOLT SYSTEM WATTS IN R	110 VOLT SYSTEM R IN OHMS	110 VOLT SYSTEM WATTS IN R
1	51	15	190	57
2	35	22	130	84
3	27	30	100	105
4	21	37	80	135
5	18	43	65	160
6	15	50*	58	90
7	13	57	50	210
8	12	66	45	240

Two circuits are given, circuit B being the easier to use, but sometimes with this arrangement there may be some hum audible in the loud speaker. In such a case it is necessary to use circuit A.

With circuit B it is simply necessary to connect the resistance R in series with a 20-ohm resistor and connect the plus and minus A terminals to the corresponding terminals in the radio receiver.

Using circuit B the same changes must be made but in addition the B minus and C plus leads are removed from where they connect on the receiver and are connected instead to the center point of the 20-ohm resistor. When this arrangement is used the C voltages should all be increased by minus 3 volts to compensate the positive bias produced with the C plus and B minus leads connected to the center tap.

No. 203 Radio Broadcast Laboratory Information Sheet

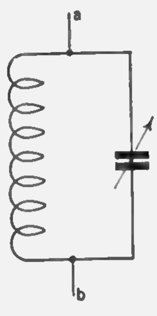
Tuned Circuits

CALCULATING EFFECTIVE RESISTANCE

LABORATORY Sheet No. 198, published in the June issue, explained how to calculate the gain of a radio-frequency amplifier using a screen-grid tube. In calculating the gain we had to make use of the factor R which denoted the effective resistance of a tuned circuit at resonance. In this Sheet we will explain how this effective resistance is calculated.

A simple tuned circuit is indicated in the sketch and it can be proved mathematically that, at resonance, the circuit between points a and b acts like a high resistance with a value equal to

$$R = \frac{\omega^2 L^2}{r}$$



where

R is the effective resistance of the circuit at resonance as measured between points a and b

ω is equal to 2π times the frequency

L is the inductance of the coil in henries

r is the series resistance of the circuit.

The value r is the series resistance of the tuned circuit when actually connected in a tube circuit.

EXAMPLE: What is the effective resistance of a tuned circuit whose resonant frequency is 1000 kc. (300 meters), the series resistance of the circuit being 20 ohms and the inductance of the coil 0.25 millihenries (0.00025 henries)

$$R = \frac{(2\pi \times 1{,}000{,}000)^2\ (.00025)^2}{20}$$

$$= 115{,}000 \text{ ohms, effective resistance}$$

If this circuit were to be used in conjunction with a screen-grid tube the gain, calculated using the formula given in Sheet No. 198 would be:

$$\text{Gain} = G_m \times R = 0.000350 \times 115{,}000 = 40$$

No. 204 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. 205 RADIO BROADCAST Laboratory Information Sheet

Electrical Measuring Instruments

THE GALVANOMETER

THIS is the first of a series of Laboratory Information Sheets to be devoted to the subject of electrical measuring instruments. In this Laboratory Sheet we discuss what is probably the oldest instrument for measuring current and voltage. This instrument is the galvanometer, and most of our modern ammeters and voltmeters are merely adaptations in one form or another of the galvanometer.

The galvanometer in its earliest form consisted of a compass needle suspended in the center of a coil of wire. When a current passed through the coil the compass needle was deflected from its normal position. It was termed a tangent galvanometer, for the current flowing in the coil is proportional to the tangent of the angle through which the needle is deflected. The tangent galvanometer is not very sensitive and, finding no practical use to-day, its major interest is historical.

Sir William Thomson (Lord Kelvin) did considerable work to improve the galvanometer and succeeded in developing an instrument of high sensitivity. Instruments made in accordance with his recommendations are known as Thomson galvanometers. Thomson made use of two coils in his galvanometer arranged to neutralize each other and found it possible to make the needle of the instrument move with only an exceedingly small current flowing in the coils. Galvanometers of this type have been made so sensitive that $\frac{1}{10}$-billion of an ampere would cause the pointer to deflect. A Thomson galvanometer, although very sensitive, has the disadvantage that in its simplest form it does not return to the zero point very quickly when the current flow through the coil is stopped and also the pointer oscillates back and forth for quite a long period of time before it finally comes to rest at any position. Thomson galvanometers can be made more satisfactory by attaching a vane to the suspension so that the air resistance created as the vane turns tends to bring the galvanometer to rest more quickly. This mechanical type of "damping" is the only type that can be applied to the Thomson galvanometer and for this reason another form of the instrument has come into more general use, known after its inventor as the D'Arsonval galvanometer.

In the Thomson galvanometer we had a stationary coil and a moving magnetic needle; in the D'Arsonval type we use a stationary magnet and a moving coil. The magnet is a very strong one and the coil moves in a small air gap in the magnetic circuit. The constructional features of such an instrument will be given in a Sheet to follow this.

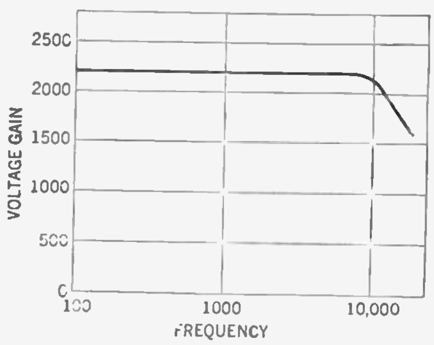
No. 206 RADIO BROADCAST Laboratory Information Sheet

A Screen-Grid Resistance-Coupled Amplifier

ITS FREQUENCY CHARACTERISTIC

THE frequency characteristic of a resistance-coupled amplifier using screen-grid tubes is included on this sheet and indicates clearly the excellent quality which such an amplifier is capable of delivering. The screen-grid amplifier used in making this curve was described in the June, 1928, Laboratory Information Sheets Nos. 195 and 196.

The frequency characteristic which is obtained from an amplifier of this type depends upon several factors. One of the most important is the voltages at which the screen-grid tubes are operated. The power unit supplying the amplifier should be capable of delivering 135 to 180 volts and the screen-grid voltage should generally be 22½ although 45 volts is satisfactory if the 180 volts is used. This curve was made using 0.25-megohm plate resistors, 2.0-megohm grid resistors and 0.01-mfd. coupling condensers.



The high-frequency response of the amplifier would be poorer with higher values of coupling resistance because under such conditions the input and output capacities of the tubes, forming a shunt around the resistors, would produce a decrease in high-frequency response. The high-frequency response in this screen-grid amplifier is much better than is ordinarily obtained from a resistance-coupled amplifier using type 240 tubes. There is this to say, however, that the high-frequency response of this amplifier as indicated by the curve on this sheet is really better than it need be, for frequencies above 6000 or 7000 cycles do not contribute very much to the naturalness of the reproduction.

The low frequency response of the amplifier is determined by the size of the coupling condenser; the smaller the capacity the poorer the low-frequency response. The value of 0.01 mfd. which was used is evidently satisfactory judging from the curve, and probably values considerably smaller than 0.01 mfd. would also be satisfactory.

The high gain of this amplifier has some disadvantages which were pointed out in Laboratory Sheet No. 195 to which we refer the reader for further information.

No. 207 RADIO BROADCAST Laboratory Information Sheet

Equalizing Wire Lines forBroadcasting

VALUES INVOLVED

IT IS obvious that the fidelity of reproduction obtained from a radio receiver cannot be any better than that transmitted by the broadcasting station and in discussing the subject it is therefore of value to know what frequencies are at present being transmitted by the better broadcasting stations. Some data on this subject was published in the article by C. E. Dean in the June, 1928, RADIO BROADCAST.

What frequencies are transmitted by broadcasting stations depends, among other things, upon the audio-frequency characteristics of the apparatus—microphones, amplifiers, modulators—used at the broadcasting station and upon the characteristics of the wire lines used to connect the broadcasting studio with the transmitter. Many of the better transmitting stations are now located outside of cities and therefore must use a wire connection between the transmitter and the studios located within the city. At the present time the characteristic of the wire lines is very important in determining what audio frequencies will finally be impressed upon the carrier wave.

The wire lines used with the broadcasting stations are at present equalized, that is made to transmit equally well, frequencies from 100 cycles to 5000. The characteristic of these lines below 100 cycles is probably quite good, but in no case can it be certain that a station is actually transmitting any frequencies, at their proper amplitude, below about 100 or above about 5000.

It is certain that as better loud speakers become available capable of reproducing frequencies below and above the limits given above that higher and lower frequencies will be included in the transmissions of broadcasting stations. In fact we may expect that the characteristics of the wire lines will be improved even before such loud speakers are generally available. The Telephone Company controlling the wire lines has always followed a policy of being prepared to furnish lines better than are actually essential at the time, considering the quality of the remainder of the apparatus included in the link between the microphone in the studio and the loud speaker at the listener's home.

A wire line ordinarily tends to transmit the lower frequencies much better than the higher frequencies and it is therefore the function of the equalizer to lower the high-frequency response so that a flat characteristic is obtained over the entire band.

No. 208

Radio Broadcast Laboratory Information Sheet

Power Values in Radio Receiving Antennas

RELATION OF DISTANCE AND MEASURED RECEIVER VOLTAGE

IT IS interesting to compare the amount of power ordinarily intercepted by a radio receiving antenna with the power which is required to operate an ordinary 60-watt incandescent lamp, for example. In Professor Morecroft's book, *The Principles of Radio Communication*, some figures are given for the amount of current in a receiving antenna which had a resistance of about 60 ohms. In the figures which he gives for received antenna current, we find that when the receiver was located about a mile from the particular transmitter which was used (the power rating of the transmitter is not given) that the current in the receiving antenna was approximately 70 microamperes. If we square this current and multiply it by the resistance of the receiving antenna which is 60 ohms, we obtain the power in the receiving antenna, which proves to be approximately 3×10^{-9} watts. For those who do not realize what this exponent signifies, the power specified in the orinary way is

0.000000003 watts

The power required to operate an ordinary electric light bulb is 60 watts. Therefore the power required by the electric light would be sufficient to supply antenna power to operate approximately twenty billion radio receivers each requiring 70 microamperes of current in the receiving antenna as specified above.

The figures given at the end of this Laboratory Sheet, which have been taken from Morecroft, also indicate that the amount of power in the receiving antenna varies approximately inversely with the distance between the transmitter and the receiver. At a distance of 100 feet the received current is twice as great as when the separation is 200 feet. The power is proportional to the square of the current and therefore a ratio of two in current means a ratio of four in power. Twice the distance therefore gave one fourth the power.

DISTANCE IN FEET BETWEEN ANTENNAS	CURRENT IN RECEIVING ANTENNAS (MICROAMPERES)
100	12320
200	6435
300	4548
400	3108
1200	715
2120	283.5
3700	105
4600	96.5
6220	69.5

No. 209

Radio Broadcast Laboratory Information Sheet

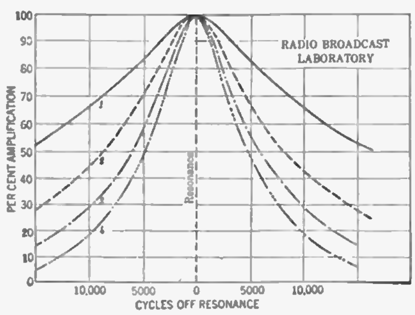
Selectivity

AS EFFECTED BY NUMBER OF R.F. STAGES

THE selectivity of a radio circuit depends upon many things, including the number of tuned stages, amount of coupling in the r.f. transformers, the characteristics of the tubes, the amount of regeneration in the circuit, the accuracy with which the individual circuits are tuned, etc. In this Sheet we will consider the effect on selectivity of increasing the number of tuned stages in a receiver. Future Laboratory Sheets will discuss the influence, on selectivity, of some of the other factors mentioned above.

Curve 1 represents the selectivity curve of a single r.f. stage. At a point 5,000 cycles off resonance the circuit gives 83 per cent. of the amplification at resonance; at 10,000 cycles off resonance the amplification has dropped to 65 per cent.

Now suppose we add more r.f. stages, with characteristics the same as that of the first stage. We then get the selective action indicated in Curve 2.



If, at a certain point off resonance, the first stage reduced the amplification to 83 per cent., then the second stage would reduce the amplification to 83 per cent. of what came through the first stage. Refering to the curves, at a point 5,000 cycles off resonance, the various stages introduce a selective action as indicated below.

First stage = 83 per cent.
Second stage = 83 x 83 = 69 per cent.
Third stage = 83 x 83 x 83 = 57 per cent.
Fourth stage = 83 x 83 x 83 x 83 = 47 per cent.

This means that if we had a four-stage r.f. amplifier with these characteristics, that a signal 5,000 cycles off the resonance frequency to which the stages were tuned, would be amplified only 47 per cent. as much as a signal at the resonant frequency. Since a radio wave includes modulation frequencies up to 5,000 cycles off resonance, it is evident that such an r.f. amplifier would cause considerable side hand suppression with consequent signal distortion.

No. 210

Radio Broadcast Laboratory Information Sheet

Protecting the Rectifier Tube

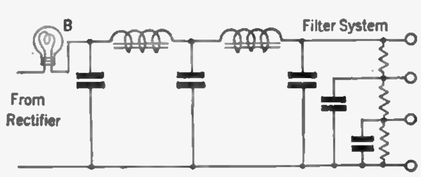
A PILOT LAMP TO INDICATE OVERLOAD

MOST of the rectifier tubes available at the present time will be severly injured if they are subjected to accidental short circuits or to excessive overload for any considerable period of time. In constructing power units it is therefore wise to place in the circuit some device which will serve to indicate any overload. Such an indicator is described in this Sheet and is applicable to power units of all types whether they use gaseous or filament type rectifiers.

The main precaution to be observed in operating rectifier tubes is that of avoiding an overload with respect to plate current. The shorting of the rectifier output, such as may occasionally occur due to the failure of some part of the apparatus (as by the breakdown of a filter condenser) will overload the filament and result in filament failure (in the case of filament type rectifiers) unless the current is turned off promptly.

To indicate an overload it is a good idea to connect a small lamp in series with the rectifier output as indicated at B in the circuit diagram on this Sheet. A small lamp such as is used as a dial light may be used for this purpose. Excessive brilliancy of this lamp will immediately indicate an overload, which can then be remedied before damage results.

In constructing power amplifiers and B supplies it is also a good idea to place a fuse in the primary side of the power transformer. This fuse will protect the transformer from damage in case its secondary is accidentally short circuited. The fuse should preferably be of the ordinary plug type with a rating of about three amperes. Only one fuse need be used, connected in series with one side of the line and the transformer.



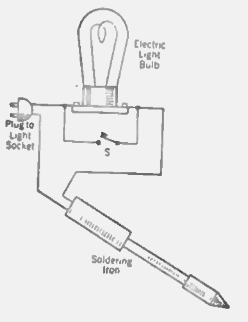
No. 211 Radio Broadcast Laboratory Information Sheet

Soldering Irons

HOW TO CARE FOR THEM

PRACTICALLY all commercial soldering irons are designed to heat rapidly so that they will be brought to an operating temperature within a short time after they are connected to the line. Unfortunately, however, if they are left connected to the line after they have reached an operating temperature they become too hot for satisfactory work, the tip blackens very quickly, becomes pitted, and in a comparatively short while the iron requires a new soldering tip. All this trouble can be easily overcome, and the manner in which it is done in the Laboratory may be of interest to readers.

The arrangement used in the Laboratory is indicated in the diagram. The soldering iron is connected in series with an ordinary electric light bulb across the power line. A short-circuiting switch, S, is provided across the bulb. The procedure when some soldering is to be done is to push the plug in to the light socket and close switch, S. With the switch. S, closed the iron is then connected directly across the line and reaches a satisfactory operating temperature quickly. When this temperature is reached the switch is reopened so that the electric light is in series with the iron. The size of electric light used is such that the iron is maintained at the correct temperature and does not overheat even though the power is left on for hours without using the iron. If an arrangement such as this is used the tip of the iron will remain tinned for a long time, and a better soldering job can be done.



The wattage of the electric light bulb that is used depends upon the soldering iron. The particular irons used in the Laboratory work best with a 75-watt lamp. The switch, S, may be almost any type although it is a good idea to use some kind of enclosed switch designed for use on 110-volt lighting circuits.

No. 212 Radio Broadcast Laboratory Information Sheet

Equalizers

WHY THEY ARE USED

IN TRANSMITTING outside events (programs that do not originate in the studio) broadcasting stations have to make use of wire lines to connect the control room of the station with the microphone and amplifier apparatus located at the point at which the program originates. These wire lines must transmit with equal efficiency a band of frequencies from about 100 cycles to about 5,000 cycles. In order to give a wire line such a characteristic it is necessary that it be "equalized" so that the transmission efficiency will be equal over the entire band of audio frequencies. The device used to give a line such a characteristic is termed an "equalizer" and its action will be explained in this sheet in conjunction with the diagram on Sheet No. 213.

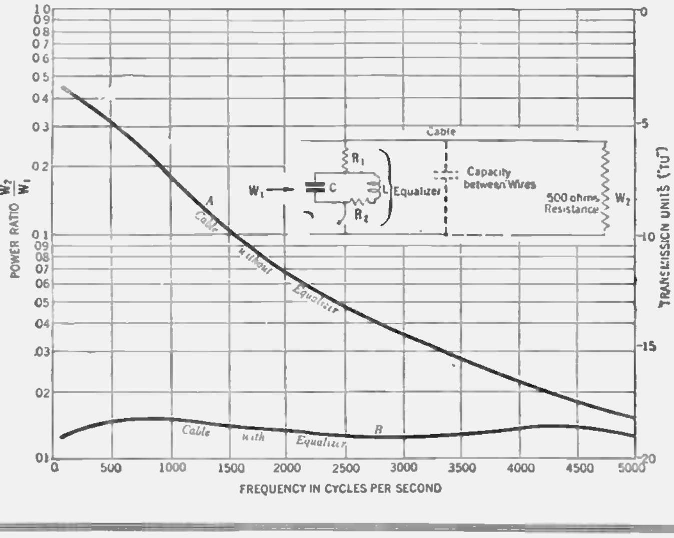
The frequency characteristic of a seven-mile length of cable is indicated in curve A on Sheet No. 213. This characteristic shows that the cable transmits the low frequencies much better than the high frequencies, due to the fact that there is considerable capacity between the two wires that form the pair of cables and this capacity tends to bypass the higher frequencies. Equalization is accomplished by introducing into the circuit a device that will lower the transmission efficiency at low frequencies to a value equal to the efficiency at high frequencies; this is the function of the equalizer.

The equalizer consists of a network of resistances, capacities, and inductances of values such that they introduce a considerable loss at low frequencies where the transmission efficiency of the cable is high and practically no loss in efficiency at the high frequencies where the transmission efficiency is low. The result is that the efficiency of the entire system is reduced to approximately the efficiency of the cable at the highest frequencies to be transmitted.

The curve B shows the characteristics of the cable with the equalizer in use; the frequency characteristic is sensibly flat from 100 cycles to 5,000 cycles. As was mentioned above this betterment in the frequency characteristic is obtained at a considerable reduction in overall efficiency. The low efficiency is then compensated by connecting repeaters (power amplifiers) in the circuit to raise the power level of the entire system. The broadcasting circuit connecting New York with Chicago contains about eight repeater points. Power amplifiers are located at these points and function to boost the power in the line to overcome the loss in the cable. As a result we frequently find cases where the final amount of power at the receiving end is considerably greater than the power originally introduced in the line at the transmitting end.

No. 213 Radio Broadcast Laboratory Information Sheet

Frequency Characteristic of a Seven-Mile Cable

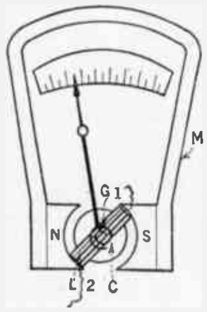


No. 214 Radio Broadcast Laboratory Information Sheet

Measuring Instruments

HOW THEY WORK

THE drawing on this sheet shows in simple form the arrangement of the parts in an electrical measuring instrument such as might be used to measure the currents and voltages in a radio receiver. The instrument consists essentially of a very strong permanent magnet, M, a cylindrical soft iron core, C, a moving coil, L, the ends of which connect to the leads 1 and 2 which would be connected to the binding posts on the instrument. The space between the poles of the magnet, marked N and S, and the iron core, C, is made quite small so that an intense magnetic field will exist in the air space between the core and the pole pieces. The coil, L, is free to move in this gap. To the coil is fastened a small spring, G, and a pointer which is generally made of aluminum so that it will be very light in weight. The coil is pivoted at its center on jeweled bearings and the spring is adjusted so that with no current flowing through the instrument the pointer rests at zero on the scale. When current passes through the coil, it moves on its pivots. This motion is opposed by the spring and for each value of current there is some position of the coil at which the turning force produced by the current is exactly balanced by the force due to the spring; the pointer therefore comes to rest at a position on the scale corresponding to the point at which these two forces balance. The scale can be marked off in values so as to indicate by its position on the scale the amount of current flowing through the instrument.



With strong magnets, delicate parts, and accurate workmanship, instruments can be built which take only a very small fraction of an ampere to move the pointer over its entire range; the scale may be calibrated in thousandths of an ampere, or milliamperes; the instrument is then known as a milliammeter.

No. 215 Radio Broadcast Laboratory Information Sheet

The Hi-Q Six

THE PARTS USED

THE circuit diagram of the Hi-Q Six, the 1928 model of the kit receiver produced by the Hammarlund-Roberts Corporation, is published on Laboratory Sheet No. 216. On this Sheet we give some details regarding the circuit and parts used so that readers who are keeping a file of these sheets may have on hand for ready reference the data on this kit. Other sheets to follow will give information on other popular kits.

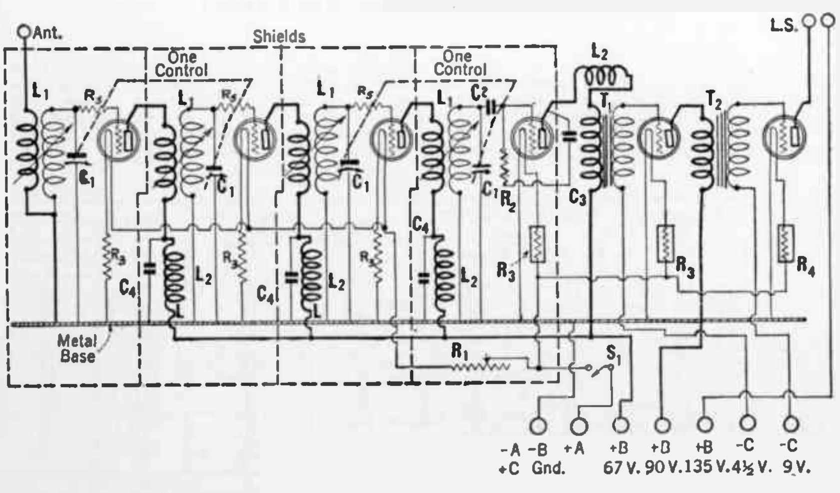
The circuit consists of three stages of r.f. amplification, followed by a non-regenerative detector and a two-stage transformer-coupled audio amplifier. The r.f. coils are arranged so that the coupling between the primary and secondary is varied automatically as the receiver is tuned. This feature helps to make the receiver perform equally well over the entire broadcast band. The first two tuning condensers are ganged to one tuning control and the other two condensers are ganged to the other control on the drum dial. Volume control is accomplished by means of a rheostat in the filament leads of the r.f. tubes. All of the r.f. stages are shielded.

The following parts were specified for the official kit; the notation in this list refers to the diagram on the following Laboratory Sheet.

T_1—Samson Symphonic Transformer. T_2—Samson Type HW-A3 Transformer (3–1 Ratio). C_1—4 Hammarlund 0.0005-Mfd. Midline Condensers. L_1—4 Hammarlund "Hi-Q" Six Auto-Couple Coils. L_2—4 Hammarlund Type RFC-85 Radio-Frequency Chokes. C_2—Sangamo 0.00025-Mfd. Mica Fixed Condenser. C_3—Sangamo 0.001-Mfd. Mica Fixed Condenser. R_1—Carter 1R-6 "Imp" Rheostat, 6 Ohms. S_1—Carter "Imp" Battery Switch. R_2—Durham Metallized Resistor, 2 Megohms. C_4—3 Parvolt 0.5-Mfd. Series A Condenser. R_3—4 Amperites No. 1-A. R_4—Amperite No. 112. R_5—3 500-ohm grid resistors. Hammarlund illuminated Drum Dial. 1 Pr. of Sangamo Grid Leak Clips. 6 Benjamin No. 9040 Sockets. 3 Eby Engraved Binding Posts. 1 Yaxley No. 660 Cable Connector and Cable. 1 Hammarlund Roberts "Hi-Q" Six Foundation Unit (containing drilled and engraved Westinghouse Bakelite Micarta panel, completely finished Van Doorn steel chassis, four complete heavy aluminum shields, extension shafts, screws, cams, rocker arms, wire, nuts, and all special hardware required to complete receiver).

No. 216 Radio Broadcast Laboratory Information Sheet

The Circuit of the Hi-Q Six



No. 217 RADIO BROADCAST Laboratory Information Sheet

Using a Milliammeter as a Voltmeter

WHAT RESISTANCES MUST BE USED

BY CONNECTING accurate fixed resistances in series with milliammeters it is possible to make very useful voltmeters that may be used to read filament voltages, plate voltages, C voltages, the output voltage of B-power units, etc. The accuracy of such a home-made voltmeter depends upon the accuracy of the milliammeter and the fixed resistance. Resistors accurate to within a few per cent. can be obtained by purchasing them directly from any reputable manufacturer.

The table on this sheet gives the values of resistances required with different milliammeters to read voltages from 1 volt up to 1000 volts. For example, if a 5-mA meter is to be used to read voltages up to 50 volts then a 10,000-ohm resistor is necessary. A 1.0-mA meter may be used to read voltages up to 1000 volts if a resistor with a value of 1,000,000 ohms (1 megohm) is placed in series with it. The values of resistance required to read voltages not given in the table, or for use with meters with higher ranges may be determined by dividing the voltage to be measured by the maximum current in amperes of the meter. Suppose that a 50-mA meter is to be used to read voltages up to 300 volts. Three hundred volts divided by 0.050 amperes (50 mA) gives 6000 ohms as the required value of the resistance.

Resistors with a wattage rating of 1.0 watt will be satisfactory for all those values given in the table, but it is advisable to use resistors with a rating of about 5.0 watts so that there will be little possibility of the value of the resistance changing due to heating. Also resistors with a rating of 5 watts, operating at considerably below their rated dissipation, will be likely to hold their calibration a much longer time than resistors of lower wattage.

VOLTAGE MULTIPLIER FOR MILLIAMMETERS

Milli-Amperes	1,000 Ohms	10,000 Ohms	100,000 Ohms	1,000,000 Ohms
1.	1. volt	10 volts	100 volts	1000 volts
1.5	1.5 "	15 "	150 "	
2.	2. "	20 "	200 "	
3.	3. "	30 "	300 "	
5.	5. "	50 "		
8.	8. "			
10.	10. "			

No. 218 RADIO BROADCAST Laboratory Information Sheet

Servicing Radio Receivers

HOW FAULTS SHOULD BE LOCATED

THE tracing of faults in a radio receiver is not always an easy matter. There is a tendency to delve at random into the vitals of the receiver rather than to follow a systematic procedure by which the fault may generally be more quickly and easily located. In locating and remedying faults the systematic testing of the circuit and the apparatus in the receiver is essential.

Measuring instruments are frequently helpful in making these tests but a great deal may be done with a simple and inexpensive device. In the testing of the component parts in a receiver a pair of telephones connected in series with a small battery is useful in determining where the fault exists. The windings of a transformer may be readily tested by means of this simple circuit. When the two terminals are connected across the transformer winding a click will be heard if the circuit is continuous. Fixed condensers may also be tested, and here a click should be heard when the leads are placed across the terminals of the condenser, but no click will be heard when the terminals are removed unless the condenser is defective. If the insulation in the condenser is poor, however, or the condenser is definitely short-circuited, a click will be heard both when the circuit is closed and when it is opened.

Ordinary radio-frequency transformers and super-heterodyne intermediate-frequency transformers, audio-frequency or radio-frequency choke coils, etc. may also be tested for continuity by connecting the test terminals across the terminal of the device under test. If the device being tested has a high resistance the click will be of less intensity than that obtained when testing a low resistance device. In any case, no click at all will indicate an open circuit.

When a radio receiver fails to operate, such tests as we have outlined here can be applied to the various components of the receiver to determine whether or not a piece of apparatus is at fault.

No. 219 RADIO BROADCAST Laboratory Information Sheet

Sizes of Tap and Clearance Drills

TABLE OF SIZES

THE table on this sheet will be found useful in constructing radio receivers and power units, when it is necessary to tap or drill holes to take a certain size machine screw. The first and second columns, headed "Screw Number" and "Threads per Inch" in each section of the table, identify the machine screw, and the third column headed "For Tap" gives the drill size if the hole is to be tapped so that the screw will thread into the hole. If the hole is to be drilled so that the machine screw passes through the hole, then the "Clearance" size drill should be used.

SCREW NUMBER	THREADS PER INCH	DRILL NUMBER		SCREW NUMBER	THREADS PER INCH	DRILL NUMBER	
		For Tap	*Clearance*			*For Tap*	*Clearance*
3	48	45	38	7	30	31	21
3	56	44	38	7	32	30	21
4	32	43	31	8	24, 30	30	17
4	36	42	31	8	32	29	17
4	40	41	31	9	24	29	13
5	30, 32	40	29	9	28	28	13
5	36	38	29	9	30	27	13
5	40	37	29	9	32	25	13
6	30, 32	35	26	10	24	25	8
6	36	33	26	10	30	22	8
6	40	32	26	10	32	21	8

No. 220 RADIO BROADCAST Laboratory Information Sheet

The Roberts Four-Tube A. C. Receiver

PARTS REQUIRED

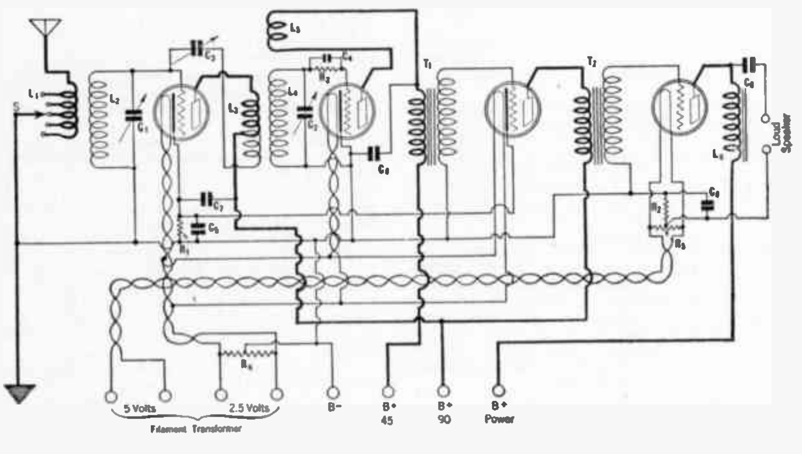
On Laboratory Sheet No. 221 is published a circuit diagram that has been requested by many readers in their letters to the Technical Information Service. It is the circuit diagram of a 4-tube Roberts receiver for a.c. operation using three 227 type a.c. tubes and one 171A type tube.

The following parts are required for the construction of the receiver:

C_1, C_2—2 Tuning condensers of a size such as to cover the broadcast band with the coils used. Homemade coils made according to the specifications given below require 0.0005-mfd. condensers
C_3—Neutralizing condenser, 0.00002 mfd. maximum capacity.
C_4—Grid condenser, 0.00025 mfd.
C_5, C_6, C_7—3 Bypass condensers, 1.0 mfd.
C_8—Output condenser, 2 to 4 mfd.
C_9—Bypass condenser 0.0002 mfd.
L_1, L_2—2 Thirteen point spider-web coils L_1 consists of 35 turns of No. 22 d.c.c. wire tapped at every five turns. L_2 consists of 44 turns of the same size wire.
L_3, L_4, L_5—3 Thirteen point spider-web coils. L_3 is a double wound primary consisting of two parallel windings of 18 turns of No. 26 d.c.c. L_4 is the same as L_2. L_5 consists of 12 turns of No. 22 d.c.c. mounted on a form so that its coupling to L_4 may be varied.
L_6—Output choke coil, 30 henries.
R_1—C bias resistor, 500 ohms.
R_2—C bias resistor, 2000 ohms.
R_3—Grid leak, 2 megohms.
R_4, R_5—2 filament resistors, 20 ohms, center-tapped.
S—Antenna tap switch.
T_1, T_2—2 audio transformers.
3 five-prong sockets.
1 four-prong socket.
Filament transformer supplying 2.5 and 5.0 volts.

No. 221 RADIO BROADCAST Laboratory Information Sheet

Circuit of the Roberts Four-Tube A. C. Receiver

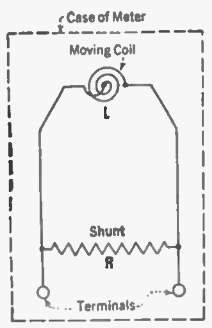


No. 222 RADIO BROADCAST Laboratory Information Sheet

Measuring Instruments

THE AMMETER

Laboratory Sheet No. 214 in the August issue explained the operation of a simple measuring instrument. An instrument of the type illustrated in that sheet can only be constructed to handle small currents, for to handle large currents the moving coil, L, and the leads to it would have to be made of very heavy wire. Since the coil, L, is part of the moving element, it must be kept light in weight; it is possible, therefore, to use only a fine wire on the coil. For larger currents the arrangement indicated in the sketch on this sheet is used. R is a resistor called a "shunt" consisting of one or more strips of a special alloy. The current in the circuit divides, most of it going through the shunt because its resistance is small in comparison with that of the moving coil of the meter. The current through the coil, however, is a certain definite fraction of the total current and therefore if we know the current flowing through the coil we can readily determine what the total current in the circuit is.



As an example, if the resistance of the shunt, R, is 0.01 ohms and that of the moving coil of the meter 0.99 ohms then the current divides in the same ratio. Out of every unit of current flowing through the circuit into which the meter is connected 99 parts flow through the shunt and one part flows through the meter. The current in the meter is therefore an accurate measure of the total current in the circuit and therefore for any one shunt the scale on the meter is calibrated to read directly the total current.

Meters with current ranges up to 50 or 75 amperes may be obtained with the shunt built inside of the case. For higher ratings the shunt forms an extra piece of apparatus and the meter is connected across it by means of a pair of wires.

No. 223 Radio Broadcast Laboratory Information Sheet

Radio Transmission

HOW DISTANCE AFFECTS THE SIGNAL

PROBLEM: A receiver is tuned to a broadcast station located a certain distance away and signals from it produce sufficient power in the loud speaker circuit to make reception satisfactory. By what percentage will the power in the loud speaker be reduced if the receiver is removed to a point twice as far away from the transmitter, assuming, of course, that the sensitivity of the receiver remains unchanged.

Solution: To solve this problem we must know how the output power of a receiver varies with the r.f. input at the antenna and we must know how the received energy varies with the distance between the receiver and the transmitter.

(a) The power in the plate circuit of the power tube (and therefore the power supplied to the loud-speaker) varies as the square of the signal voltage on the grid of the power tube.

(b) The voltage output of a detector tube varies as the square of the voltage on its grid.

(c) Therefore, the power into the loudspeaker varies as the fourth power of the voltage impressed on the grid of the detector tube.

(d) The voltage impressed on the detector tube is proportional to the voltage at the antenna. Therefore the power into the loud speaker varies as the fourth power of the voltage impressed in the antenna.

(e) The voltage at the antenna varies as the field strength.

(f) Therefore, the power into the loud speaker varies as the fourth power of the field strength.

Statement (f) tells us how the power into the loud speaker varies with field strength. But the field strength surrounding an antenna varies inversely as the square of the distance between the transmitter and the receiver. Therefore, the power into the loud speaker varies inversely as the eighth power of the distance between the transmitter and the receiver.

The problem states that the distance between the receiver and the transmitter has been doubled, i.e. the distance has been multiplied by 2. The eighth power of 2 is 256; therefore by doubling the distance between the receiver and the transmitter we have cut down the power in the loud speaker to 1/256 of what it had been.

No. 224 Radio Broadcast Laboratory Information Sheet

Text Books on Radio

THERE are certain books and radio magazines that the serious radio experimenter should not be without and in this sheet we give a list of some of what we consider the more important of the publications. The short descriptive sentence following each title will help to classify the book in our readers' mind.

Radio Instruments and Measurements. A 345-page book, presenting information regarding the more important instruments and measurements actually used in radio work. The contents is of interest to all radio engineers. The book is published by the Department of Commerce and is known as Circular No. 74. Obtainable from the Superintendent of Documents, Government Printing Office, Washington, D. C., for sixty cents.

Principles Underlying Radio Communication. Another government publication to be recommended. This book is quite an excellent elementary text book of radio and general electricity and may be easily understood by anyone with a fair knowledge of algebra. Everyone should have it. It is known as Radio Communication Pamphlet No. 40, and the Superintendent of Documents, Government Printing Office, sells it for $1.00.

Principles of Radio Communication, by J. H. Morecroft. This is probably the most complete book on radio engineering. The text deals with all phases of the art of radio communication and the treatment is very complete, the book containing about 1000 pages. Published by John Wiley and Sons, Inc., New York City. Price: $7.50.

Thermionic Vacuum Tube, by H. F. Van Der Bijl. An excellent book setting forth the principles of operation of vacuum tubes. It is a very useful book for any radio engineer. Published by the McGraw-Hill Book Co., Inc., New York City. Price: $3.00.

Radio Engineering Principles, by Lauer and Brown. A book less extensive than Morecroft's but excellent for those whose requirements are satisfied with a shorter and less expensive text. It is a very scholarly presentation. Published by McGraw-Hill Book Co., Inc., New York City. Price: $3.50.

Radio Frequency Measurements, by E. B. Moullin. A book dealing with the theory and practice of radio measurements. A handbook for the laboratory and a text book for advanced students. Many of the measurements are made with the aid of the vacuum tube voltmeter. Published in England but it can be obtained from the J. B. Lippincott Co., in Philadelphia.

Practical Radio Construction and Repairing, by Moyer and Wostrel. This book aims to be of service to the amateur constructor and radio service man. It is essentially practical in its treatment. Published by McGraw-Hill Book Co., Inc., New York City. Price: $1.75.

No. 225 Radio Broadcast Laboratory Information Sheet

Calculating Grid Bias for A.C. Tubes

CORRECT RESISTANCE VALUES

IN ALL a.c. receivers, grid bias for the various tubes is obtained by connecting resistances of the correct value at the correct point in the circuit. The calculation of the value of the resistance and its placement in the circuit have been the subject of quite a few letters written to the Technical Information Service and we have therefore devoted this Laboratory Sheet to the subject. The circuit diagrams of six combinations are given on Laboratory Sheet No. 226.

If these diagrams are examined one important point will be noted, which is that the resistance, R, which supplies C bias to the tube, is always connected between the center of the filament, or the cathode in the case of heater type tubes, and negative B. The resistance is placed in this position in relation to the circuit no matter what tube or combination of tubes is used. With the resistor in this position the plate current of the tube must go through it in order to reach the filament, or cathode, and therefore the voltage drop across the resistance is equal to the plate current times the resistance in ohms. To calculate the value of resistance, we must therefore know the value of grid bias that we desire to obtain and also the plate current flowing through the resistance. For example, in diagram A we have indicated a 226 type tube. By reference to any table of tube characteristics we can determine that the 226 type tube with 90 volts on the plate requires a grid bias of 6 volts and the plate current is 3.5 milliamperes. R is found by dividing the grid voltage required, 6, by the plate current in amperes, 0.0035, which gives a value of 1700 ohms as the required value of resistance.

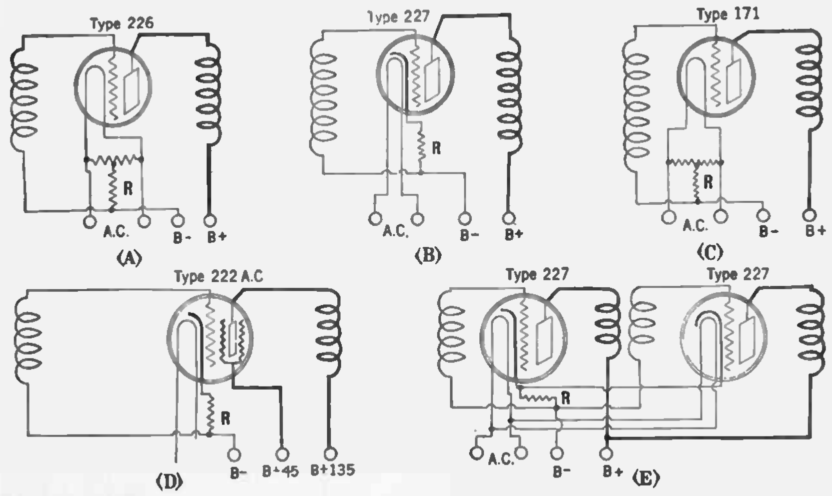
In diagram C, a 171 tube is used, forty volts of grid bias are required if the plate voltage is 180 volts. The plate current under such conditions is 20 milliamperes, and 40 divided by 0.02 amperes gives 2000 ohms as the value of resistance required for C bias.

If a circuit utilizes more than one tube of the same type for which we require the same value of grid bias, the circuit is arranged as indicated at E, in which case the plate current of both of the tubes flows through resistance R. If the plate voltage on the 227 type tube is 90, the plate current is 3.7 milliamperes and the required grid bias is 6 volts. The grid bias resistance is then equal to 6 divided by 7.4 (the total current of the two tubes) which gives 800 ohms as the correct value for R.

No. 226

RADIO BROADCAST Laboratory Information Sheet

Grid Bias Circuits for A.C. Tubes



No. 227

RADIO BROADCAST Laboratory Information Sheet

The Audio Transformer

THE EFFECT OF ITS INDUCTANCE

THE diagram on this sheet indicates at A a single stage of audio-frequency amplification; B is the equivalent circuit, in which E_g is the signal voltage in the plate circuit, L_s is the leakage reactance of the transformer, L is the inductance, and C is the distributed capacity of the secondary and the tube input capacity, transferred to the primary. R_p is the plate resistance of the tube. Let us study this circuit to see what happens at various frequencies. The treatment given below is not exact but is approximately correct.

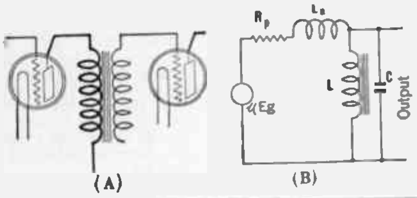
At low frequencies the reactance of C in comparison with L is very large and the reactance of L is very large in comparison with that of L_s. Therefore at low frequencies the voltage in the plate circuit divides between L and R_p. The voltages across these two parts of the circuit are 90 degrees out of phase and the percentage of the total voltage that appears across L depends upon the ratio of the reactance of L to the resistance of R_p, and varies as indicated in the second column in the table, column 1 being the ratio of the reactance of L to the resistance, R_p.

Now suppose that we desire to work the transformer out of a 201A-type tube with an R_p of about 11,000 ohms and that at 60 cycles we want to utilize at least 70 per cent. of the total voltage. Then, from the table we will have to make X_L, reactance of the coil L at 60 cycles, equal to the resistance of the tube. Therefore:

$$X_L = 11{,}000$$
$$2\pi fL = 11{,}000$$
$$6.28 \times 60 \times L = 11{,}000$$
$$L = 30 \text{ henries}$$

We might look at the problem in another way. Suppose we desire a transformer with a voltage drop at 60 cycles of not more than 1 TU. When a circuit is 1 TU down in voltage, the actual voltage loss is about 11 per cent., leaving 89 per cent. This corresponds to a ratio of X_L over R_p of 2. Therefore, from the table the reactance of L at 60 cycles must be twice the resistance of the tube or 22,000 ohms.

$$2\pi fL = 22{,}000$$
$$L = 59 \text{ henries}$$



TABLE

$\frac{X_L}{R}$	*Percentage of total voltage across L*
4.0	97
2.0	89
1.0	71
0.5	44.6
0.3	28.7

No. 228

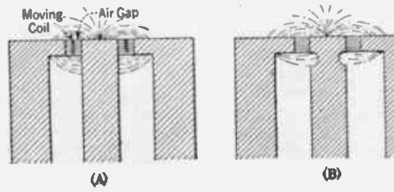
RADIO BROADCAST Laboratory Information Sheet

The Dynamic Loud Speakers

THE FIELD MAGNET

THE dynamic-type loud speaker depends for its operation on the production of a very strong magnetic field in the air-gap in which the moving coil is placed. This air-gap is indicated in the sketch on this sheet. The useful magnetic flux is that indicated by the light solid lines flowing directly across the gap, and the leakage flux—that part of the magnetic field which serves no useful purpose—is indicated by the dot-dash lines.

The flux which any given amount of magnetic material, such as iron or steel, can handle efficiently is definitely limited by saturation. When the iron is saturated its resistance—reluctance is the technical term—to the flow of magnetic lines through it increases and then the leakage flux increases. The flux will tend to take that path which has the lowest reluctance. To prevent leakage the pole pieces are frequently shaped in some peculiar manner, such as indicated at B, in order that the actual air-gap will be a very much lower reluctance path for the flux than any other path. The leakage flux in sketch A does not have to travel a path much longer than the actual air-gap, i.e., the two paths have about the same reluctance. In the pole shape indicated at B the flux path outside the air-gap is much longer than the path through the air-gap. The latter arrangement therefore tends to reduce the leakage flux.



Assuming that the iron does not saturate, the flux in the air-gap will increase very rapidly as the size of the gap is decreased, and in practice the gap is always made as small as possible, leaving just sufficient room for the coil to move without any danger of its striking the pole pieces.

No. 229

RADIO BROADCAST Laboratory Information Sheet

The Telephone Transmission Unit

No. of TU	Power Ratio		No. of TU	Power Ratio		No. of TU	Power Ratio		No. of TU	Power Ratio	
	Gain	*Loss*		*Gain*	*Loss*		*Gain*	*Loss*		*Gain*	*Loss*
0.1	1.023	.977	2.7	1.862	.537	5.3	3.39	.295	7.9	6.17	.162
0.2	1.047	.955	2.8	1.906	.525	5.4	3.47	.288	8.0	6.31	.158
0.3	1.072	.933	2.9	1.950	.513	5.5	3.55	.282	8.1	6.45	.155
0.4	1.096	.912	3.0	1.995	.501	5.6	3.63	.275	8.2	6.61	.151
0.5	1.122	.891	3.1	2.04	.490	5.7	3.72	.269	8.3	6.76	.148
0.6	1.148	.871	3.2	2.09	.479	5.8	3.80	.263	8.4	6.92	.144
0.7	1.175	.851	3.3	2.14	.468	5.9	3.89	.257	8.5	7.08	.141
0.8	1.202	.832	3.4	2.19	.457	6.0	3.98	.251	8.6	7.24	.138
0.9	1.230	.813	3.5	2.24	.447	6.1	4.07	.245	8.7	7.41	.135
1.0	1.259	.794	3.6	2.29	.437	6.2	4.17	.240	8.8	7.59	.132
1.1	1.288	.776	3.7	2.34	.427	6.3	4.27	.234	8.9	7.76	.129
1.2	1.318	.759	3.8	2.40	.417	6.4	4.37	.229	9.0	7.94	.126
1.3	1.349	.741	3.9	2.45	.407	6.5	4.47	.224	9.1	8.13	.123
1.4	1.380	.724	4.0	2.51	.398	6.6	4.57	.219	9.2	8.32	.120
1.5	1.413	.708	4.1	2.57	.389	6.7	4.68	.214	9.3	8.51	.118
1.6	1.445	.692	4.2	2.63	.380	6.8	4.79	.209	9.4	8.71	.115
1.7	1.479	.676	4.3	2.69	.372	6.9	4.90	.204	9.5	8.91	.112
1.8	1.514	.661	4.4	2.75	.363	7.0	5.01	.200	9.6	9.12	.110
1.9	1.549	.645	4.5	2.82	.355	7.1	5.13	.195	9.7	9.33	.107
2.0	1.585	.631	4.6	2.88	.347	7.2	5.25	.191	9.8	9.55	.105
2.1	1.622	.617	4.7	2.95	.339	7.3	5.37	.186	9.9	9.77	.102
2.2	1.660	.603	4.8	3.02	.331	7.4	5.50	.182	10.0	10.00	.100
2.3	1.698	.589	4.9	3.09	.324	7.5	5.62	.178	20.0	100	.01
2.4	1.738	.575	5.0	3.16	.316	7.6	5.75	.174	30.0	1,000	.001
2.5	1.778	.562	5.1	3.24	.309	7.7	5.89	.170	40.0	10,000	.0001
2.6	1.820	.550	5.2	3.31	.302	7.8	6.03	.166	50.0	100,000	.00001

No. 230

RADIO BROADCAST Laboratory Information Sheet

Filters

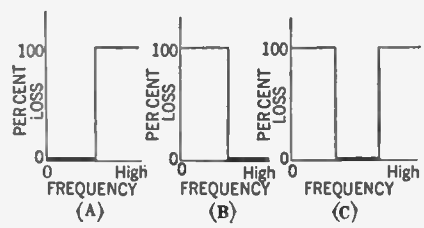
HOW THE VARIOUS TYPES DIFFER

IN TELEPHONE and radio circuits various types of filters are used and in this Laboratory Sheet we will indicate how the several types differ.

First let us define a filter. We might say that a filter is a circuit arrangement that will separate direct current from alternating current or vice versa or a circuit that will separate alternating currents of one or a group of frequencies from alternating currents of a different frequency or group of frequencies.

Filters can be divided into three general classes: (A) low pass filters; (B) high pass filters; (C) band pass filters.

Low pass filters. A low pass filter is designed to pass all the low frequencies below a certain cut-off frequency and to oppose the passage of frequencies above the cut-off frequency. The frequency characteristic curve of an ideal low pass filter is given in sketch A. The r.f. choke coil used in the plate circuit of a detector tube functions as a low pass filter, since it permits audio frequencies to pass into the audio amplifier but excludes from the amplifier the high carrier frequencies.



High pass filters. Sketch B gives a frequency characteristic of an ideal high pass filter and it will be noted that it has the opposite effect to a low pass filter in that it permits the passage of high frequencies and obstructs the flow of low frequencies. The r.f. chokes and condensers used in the plate circuits of an r.f. amplifier are an example of a high pass filter, functiong to pass the high frequencies directly to the filament, thereby keeping them out of the plate supply, but obstructing the passage to the filament of the d.c. plate current (which can be considered a current of o frequency).

Band pass filters. This type of filter permits the passage of a band of frequencies and excludes all those frequencies below or above this band. A very common type of band pass filter is used in radio receivers—the tuned circuit. When a coil-condenser combination is tuned to a given broadcasting station it permits the passage of that band of frequencies associated with that broadcasting station and excludes to a more or less greater degree frequencies either lower or greater than that of the station we are trying to receive. The ideal curve of a band pass filter is indicated in sketch C.

No. 231

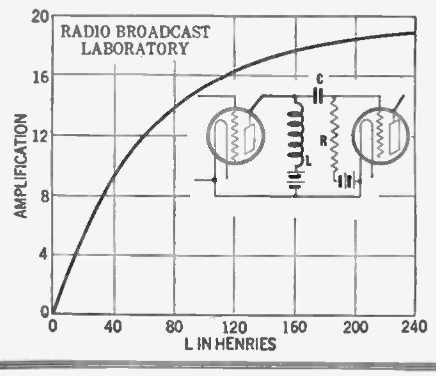
RADIO BROADCAST Laboratory Information Sheet

Impedance-Coupled Amplifiers

THE EFFECT OF THE SIZE OF THE INDUCTANCE

IN CONNECTION with impedance-coupled audio amplifiers, the statement is frequently made that the coupling inductances should have as large an inductance as possible, creating the impression thereby that the larger the inductance the better the results. Such is not the case. First, let us examine the effect of the inductance at low frequencies.

The curve on this sheet indicates how the amplification from a stage of impedance-coupled audio varies with the inductance in henries of the coupling coil, L. This curve is calculated for a frequency of 60 cycles, assuming that this is the lowest frequency which we desire to amplify uniformly. It is assumed that the tube has a plate impedance of 30,000 ohms and a mu of 20, and that the coupling condenser, C, and the grid resistance, R, are of such values as not to affect the amplification. If 100 per cent. amplification were obtained, the gain would be 20, and with an infinitely high inductance this gain might be realized at low frequencies. With practical values of inductance, however, the gain is less than this and varies with the inductance as indicated by this curve.



The value of the coupling inductance should be the smallest value that will give satisfactory gain at the lowest frequency to be amplified, which we have assumed in this case to be 60 cycles. At medium frequencies the amplification obtained from a circuit of this sort is approximately equal to the amplification constant of the tube and we might assume as a reasonable figure that the amplification at 60 cycles shall not be less than 75 per cent. of the amplification obtained at medium audio frequencies. 75 per cent. of 20 is 15, the value therefore of the gain at 60 cycles. This corresponds to an inductance of 100 henries.

If a value of inductance much greater than this is used to obtain more amplification at low frequencies, it will be found that the high frequencies begin to fall off due to the shunting effects of the tube and coupling coil capacities. Amplifier curves with various values of coupling impedance will be given and explained in a future Laboratory Sheet.

No. 232 RADIO BROADCAST Laboratory Information Sheet

The Voltmeter

HOW IT WORKS

IN PRECEDING Laboratory Sheets, Nos. 205, 214 and 222 we explained the construction of the galvanometer and the ammeter and indicated how they differed. The voltmeter is quite similar to these two instruments, differing in only one important respect to be explained below.

A voltmeter is used obviously to measure voltage. We desire to measure this voltage using as little power as possible, for if the instrument itself requires any great amount of power it is liable to affect the voltage reading of units such as batteries or B-power units which are designed to deliver only a small amount of power.

To measure the voltage of some source of potential we might take a very low reading ammeter, one having a maximum scale reading of perhaps 0.01 amperes, place it in series with a known high resistance and then connect it across the source of potential. The ammeter would read the current that flowed and then by Ohm's law, which states that the voltage is equal to the current times the resistance, we could calculate the value of the voltage.

In a voltmeter this high resistance is permanently connected inside of the instrument and the scale is calibrated to read volts instead of amperes. In other words we might say that the instrument solves Ohm's law for us and makes it unnecessary to calculate the IR drop every time we wish to measure a voltage.

Ammeters and voltmeters may in general be distinguished in one other way other than the fact that they are marked "volts" or "amperes" on the scale of the instrument. It will generally be found that ammeters have fairly large terminals and they are generally of metal. Voltmeters have small terminals and they are always of the insulated type. Ammeters are equipped with metal terminals because no damage results to the instrument or the circuit in which it is connected if the terminals are accidently short-circuited; ammeters are always connected in series with a circuit and have a very low resistance, so that shorting them affects the circuit very little. Voltmeters, on the other hand, are always connected *across* the source of potential, and if the voltmeter terminals are accidentally short-circuited then the source of potential is short-circuited. A short-circuit may not be a serious thing when measuring a B battery, but may cause damage if it occurs when measuring the voltage at a light socket or when measuring the output voltage of a large generator.

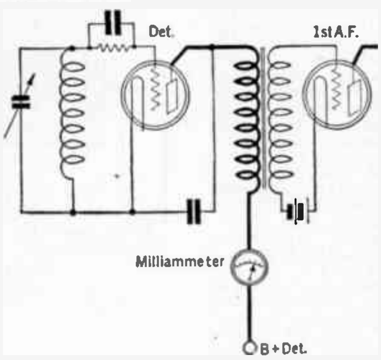
No. 233 RADIO BROADCAST Laboratory Information Sheet

Balancing Radio Receivers

AN EASY METHOD

THE change in the plate current of the detector tube, when a signal is being received, may be utilized to balance the various tuned circuits in a single-control receiver. If the several tuned circuits in a multi-stage r.f. amplifier are not properly ganged, the set will be insensitive and the selectivity will be poor. It is essential, therefore, that the various stages be accurately aligned. How this can be done is the subject of this Laboratory Sheet. The method used is simple and is based on the action of a detector when a signal is being received.

If a milliammeter with a range of about 2 milliamperes is connected in series with the B-plus lead to the detector, as indicated in the diagram, it will be found to read about 1 mA. if the detector is of the grid leak and condenser type and about 0.2 mA. if a C-battery type detector is used. If a station is tuned-in, the plate current of the detector tube will decrease if the former arrangement is used and increase with a C-battery detector circuit, the amount of the increase or decrease being proportional to the strength of the signal—the stronger the signal the greater the change in current. Therefore, when the set is accurately tuned and all of the condensers are perfectly aligned the deflection of the meter—and therefore the output of the set—will be greatest.



Balancing therefore becomes a matter of tuning in some station, preferably one operating on a short wavelength, and then adjusting the various condensers, by whatever means are provided by the manufacturer, so that the greatest change is indicated on the meter in the plate circuit of the detector. When circuits have been adjusted so that the greatest current change is obtained, the set is balanced. It is best to make this adjustment with the set tuned to a short wavelength, for it is in this part of a receiver range that the greatest lack of balance is liable to occur.

No. 234 RADIO BROADCAST Laboratory Information Sheet

The Audio Transformer

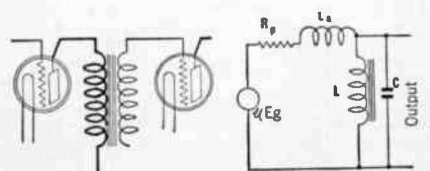
OPERATION AT HIGH AUDIO FREQUENCIES

IN LABORATORY Sheet No. 227, in the October number, we studied the characteristics of audio transformers and pointed out that the lowest frequency response depends upon the ratio of the reactance of the transformer to the plate resistance of the tube. Here we will consider the high frequencies. For convenience we have reprinted here the diagram from Sheet No. 227.

At high frequencies the reactance of L is very large in comparison with C, and it may therefore be neglected. Essentially, we then have a circuit consisting of R_p, L_a and C in series. As L_a and C come into resonance, the impedance of the circuit will decrease and more current will flow, thereby tending to increase the voltage across C, which is the voltage applied to the grid of the next tube. However, the voltage across C, for a given current, is inversely proportional to the frequency, and this will tend to lower the voltage across it at high frequencies. In some transformers, however, there is a marked peak at about 6000 cycles, corresponding to the resonant frequency of L_a and C in series, the output falling off rapidly beyond the point.

If this upper resonant peak is very pronounced the gain of the entire amplifier will increase greatly at this point, tending to make the amplifiers oscillate. Good design requires that the peak be kept as small as possible.

At frequencies higher than that at which La and C resonate, the reactance of L_a continues to increase, and the reactance of C to decrease; therefore, the voltage across C rapidly falls. If some transformer curves are examined, it will frequently be found that the curve drops rapidly beyond the upper resonant point.



(A) (B)

The problem of design is to adjust the leakage inductance, L_a, and the effective capacity, C, so as to give satisfactory high-frequency response.

No. 235 Radio Broadcast Laboratory Information Sheet

Television

FREQUENCY BAND REQUIRED

IN TELEVISION transmission a problem which must be given careful consideration is the width of the band of frequencies which must be transmitted to reproduce at the receiver end, with good quality, the scene being scanned by the television transmitter.

Theoretically, a television signal contains components of all frequencies from zero to infinity. In practice the frequency band is much more restricted and depends upon various factors.

The width of the band of frequencies which must be transmitted is a function of the number of elements scanned per second at the transmitter. For example, if the number of lines into which the picture is broken—which is equal to the number of holes in the scanning disc—is 50, then the number of elements into which the picture will be broken will be 50 times 50, or 2500. If we transmit 20 pictures per second, the total number of elements transmitted per second will be 50,000. The highest frequency which must be transmitted, to get good quality, can be taken as equal to half this figure, or 25,000 cycles. The table given herewith shows how the value of the highest frequency which should be transmitted varies with the number of scanning lines and the number of pictures per second. For example, a 50-line picture sent 15 times per second requires up to 19,000 cycles.

No. of lines	*No. of pictures per second*		
	10	15	20
25	3,100	4,700	6,000
50	12,000	19,000	25,000
75	28,000	42,000	56,000
100	50,000	75,000	100,000

A station transmitting within a broadcast band is limited to 5000-cycle modulation. Therefore, any broadcast station transmitting television programs and using a number of lines and number of pictures per second such that requires a frequency band greater than 5000 cycles must either modulate above the legal limit or suppress in the amplifiers the frequencies above 5000 cycles.

No. 236 Radio Broadcast Laboratory Information Sheet

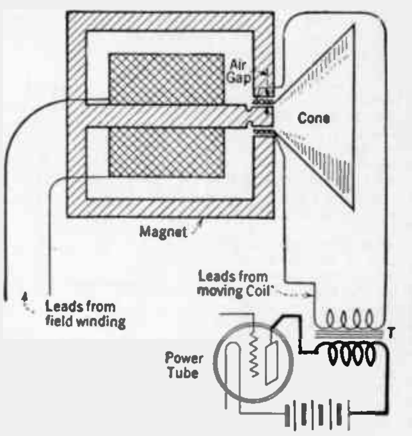
Moving-Coil Loud Speakers

THEIR OPERATION

THE important characteristic of the dynamic or, more properly named, moving-coil type loud speaker is the fact that it has a coil fastened directly to the cone, which is caused to move back and forth in an air gap in a magnetic circuit, the movements being in accordance with the frequencies flowing through the coil.

The moving coil is mounted at the apex of the cone, as indicated in the diagram, and connects to the secondary of the transformer, T, the primary of which connects to the plate of the power tube. The moving coil of a well-designed unit has a fairly constant impedance over the entire range of audio frequencies and the transformer, T, is designed to "match" the coil's impedance to the output impedance of the tube. So long as the power tube works into an impedance about equal to or somewhat greater than twice the tube's plate impedance, satisfactory power transfer from the tube to the moving coil will be obtained. The instructions covering the use of one of these loud speakers should indicate what tubes or combination of tubes are recommended for use with the unit.

The term "dynamic loud speaker" is not a very accurate description of a type of loud speaker whose distinguishing feature is that it has a moving coil. The word "dynamic" is defined as "mechanics treating of the motion of bodies and of the action of forces in producing or changing their motion." Since all loud speakers move they can all be called "dynamic." We have seen descriptions and advertisements of "dynamic" loud speakers which consisted mainly of an ordinary electromagnetic unit coupled to a cone. This term used to describe such loud speakers is probably misleading to some although technically it is not incorrect.



No. 237 Radio Broadcast Laboratory Information Sheet

Power Output

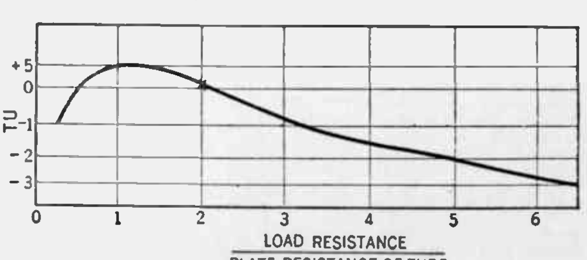
HOW IT DEPENDS UPON IMPEDANCE RATIOS

IT HAS been proved mathematically and experimentally that a tube delivers the maximum amount of *undistorted* power when it works into a load resistance equal to twice the plate resistance of the tube; maximum power output, however, is obtained when the load resistance equals the tube's plate resistance. The curve on this sheet indicates relatively in TU how the power in the load varies with the ratio of the load resistance to the tube's plate resistance (sometimes called plate impedance). The X on the curve indicates where a tube is normally operated, the load resistance at the point being twice the tube resistance.

We frequently see statements to the effect that the loud speaker we use must be matched to the tube to get the largest amount of undistorted power into the loud speaker. Such is the case, but the curve indicates that there can be considerable mismatching without serious loss of power. For example, even when the load resistance is about five times greater than the tube's resistance, there is only a 2 TU loss—a loss which would hardly be noticeable to the ear.

It is unwise, however, to work a tube into a load resistance less than its own resistance, because under such conditions the tube's characteristic is curved (see Laboratory Sheet No. 124) and this curved characteristic introduces distortion.

In cases where the element of the loud speaker has a low impedance, for example, it is necessary to use a transformer between the tube and the loud speaker to compensate the differences in impedance. A moving-coil type, i.e., dynamic loud speaker, might have an impedance of, say, 20 ohms at some frequencies, and if it is to be used with a 2000-ohm tube (171A) which requires a load impedance of 4000 ohms to get maximum undistorted power, then the coupling transformer would have an impedance ratio of 4000 divided by 20, or 200, corresponding to a turns ratio of the square root of 200, or 14.



LOAD RESISTANCE / PLATE RESISTANCE OF TUBE

No. 238 — Radio Broadcast Laboratory Information Sheet

A Hook-up for Short-Wave and Broadcast Receivers

A METHOD FOR SWITCHING OVER

IT IS general practice in constructing short-wave adapters to arrange them with extension leads so that they may be plugged into the broadcast set in the detector socket in place of the regular detector tube. This practice is all right when one is building an adapter that perhaps will not be used continually, but when both the broadcast and the short-wave tuners are going to be used frequently, it is better to arrange the circuit as indicated in the diagram on Sheet No. 239, which permits one to change from broadcast to short waves by a simpler means than taking out a tube and plugging in an adapter.

The diagram shows the detector of the broadcast receiver and the detector of the short-wave receiver. They are both wired to the same A and B voltages, and either set is thrown in or out of operation by simply turning the proper filament switch, S_1 or S_2; S_1 turns on and off the broadcast receiver and S_2 similarly controls the short-wave set.

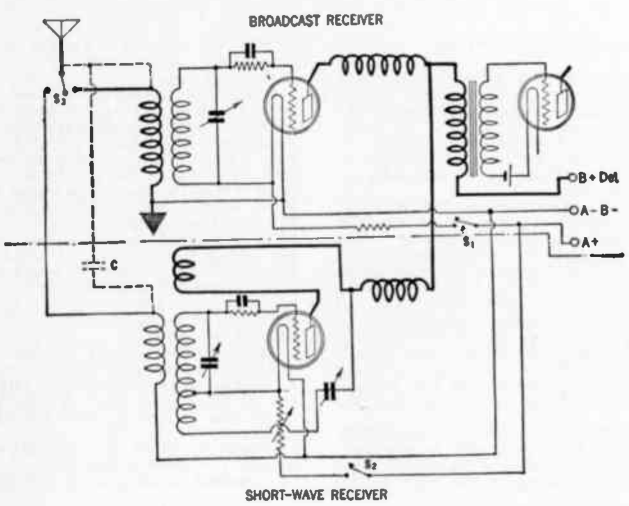
The two plates are permanently wired together, and for this reason the arrangement we have indicated should only be used when the two sets are located close to each other (which is usually the case) so that the plate lead running from one set to the other is not more than 1 or 2 feet long.

Most of us have available only one antenna to use with both sets. To use it with both receivers a single-pole double-throw switch, S_3, can be placed in the antenna circuit; thrown to one side it connects the antenna to the broadcast set, and thrown the other way it connects the short-wave receiver.

An easier arrangement, which works well in practically all cases (how well it works depends upon the characteristics of the two receivers) is indicated by dotted lines. The antenna is connected directly to the broadcast set and through a 50-mmfd. condenser, C, to the short-wave set. This small condenser will block the broadcast signals from the short-wave set but permit these latter currents to pass quite readily.

No. 239 — Radio Broadcast Laboratory Information Sheet

Circuit for Short-Wave and Broadcast Reception



No. 240 — Radio Broadcast Laboratory Information Sheet

Television

DATA ON THE BELL TELEPHONE LABORATORIES' METHOD

THE demonstrations of television given by the Bell Telephone Laboratories, associated with the American Telephone and Telegraph Company, rank higher, in our opinion, than any of the other demonstrations so far given, in quality of the results. In the following paragraphs are summarized some of the most important elements of the apparatus used by these Laboratories.

(a) The scanning discs contained 50 holes and revolved at a speed of 1062.5 revolutions per minute, giving 17.7 pictures per second.

(b) The output voltage of the photo-electric cells at the transmitter was about 10 microvolts.

(c) The range of frequencies decided upon as being essential for good quality extended from 10 to 20,000 cycles. Overall measurements on the final amplifier indicated a frequency characteristic constant within plus or minus 2 TU over this range.

(d) The signals from the transmitter were amplified and delivered to the transmission line at a level of 10 milliwatts. The amplification from the photo-electric cell to the line was 130 TU.

(e) Synchronization was accomplished by the use of synchronous motors containing 120 poles and having a synchronous speed of 1062.5 r.p.m. The angular phase displacement was above 0.07 degrees. This magnitude of phase displacement corresponds roughly to the angular twist in a steel shaft 6 feet long of 1 inch in diameter, operated at full load.

(f) With regard to the effect of extraneous currents due to noise, it was found that satisfactory results were obtained if the average picture currents were 10 times greater than the average noise currents.

This corresponds to 20 TU, or a power ratio of 100. In ordinary sound broadcasting the noise in the telephone lines is kept at a level 60 TU below 10 milliwatts, giving a power ratio of 1,000,000. It is evident that it is permissible to have the noise level much higher in television reception than in sound reception.

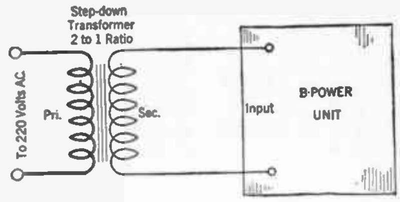
No. 241 RADIO BROADCAST Laboratory Information Sheet

Supplying Power Devices from 220 volts A.C.

USE OF STEP-DOWN TRANSFORMERS

LETTERS are received frequently from readers in which the following question is asked. "I live in a district in which the only a.c. supply is 220 volts. How can I adapt a 110-volt B-power unit for operation on a 220-volt line?"

There are two methods by which this may be accomplished. First, a resistance of such a value as to produce a drop of 110 volts and leave remaining 110 volts for the power unit may be connected in series with the 220-volt line. This method is not very satisfactory, however, for the value of resistance which must be used varies considerably with different power units and with the load on the output of the power unit. Also, unless one has available instruments for measuring the a.c. voltages there is no simple means of determining what value of resistance must be used in order to reduce the line potential to 110 volts. If one has available an a.c voltmeter this method can, of course, be used quite readily. The variable resistance is connected in series with one side of the line, the voltmeter is connected directly across the input terminals to the power unit, and the resistance then adjusted until the voltmeter reads 110 volts.



The second method of adapting 110-volt B-power units for operation on a 220-volt line is somewhat more expensive, however, it is much simpler and does not require that any voltage measurements be made. This system of reducing a line potential to 110 volts calls for placing a separate power transformer between the power unit and the line. The transformer should have a step-down ratio f 2 to 1 so that with 220 volts across its primary 110 volts will be developed in the secondary winding.

The secondary is connected directly across the terminals of the B-power unit as indicated in the diagram. The same transformer may be used with any B-power unit so long as the input power to the B-power unit does not exceed the power rating of the step-down transformer. Such transformers are now made by several manufacturers.

No. 242 RADIO BROADCAST Laboratory Information Sheet

Resistance-Coupled Amplifiers

PREVENTING DISTORTION

AT VARIOUS times letters asking how to reduce distortion have been received from readers, who have constructed resistance-coupled amplifiers. The correspondent usually explains that the amplifier produces considerable distortion unless the volume is kept down very low. In this sheet we have endeavored to indicate what we consider the causes of the distortion.

As proof that a resistance-coupled amplifier, when properly constructed and operated, is capable of giving excellent results, we might refer to the use of such an amplifier in the demonstration of television by the Bell Telephone Laboratories. In this work an amplifier of this type was used to amplify the output of the photo-electric cell and it was essential that the audio response curve be practically flat over a very wide frequency band. Distortion in an amplifier of television signals would be much more serious than similar distortion in the amplification of music, the eye being a much more critical judge of quality than the ear.

What, then, is the probable cause of the distortion which many notice when using such an amplifier? The answer is, first overloading of the amplifier, and secondly, common coupling in the plate-voltage supply, be it batteries or a power unit, although, of course, such coupling generally will be more serious in the latter case.

If any of the tubes in a resistance-coupled amplifier are overloaded so that the grid of one or more tubes goes positive, some grid current will flow and produce so-called "blocking." If the overloading is very slight, the blocking may not be noticeable as such, but the amplifier will distort. The important point is that the blocking does not affect only the signal which *caused* the blocking but will also affect the following signals until the blocking current leaks off through the high-resistance grid leak. If the signals were fed into a transformer-coupled amplifier some overloading might occur but the tubes would not block because the transformer windings are of low resistance in comparison with the resistance of the grid leaks used in a resistance-coupled amplifier.

The resistance-coupled amplifier is, therefore, much more critical with regard to overloading, than a transformer-coupled amplifier, and in the operation of the former type of amplifier the signal input *must* be kept down to a level at which no overloading occurs.

Laboratory Sheet No. 243 discusses a second cause of distortion in resistance-coupled amplifiers, i.e., common coupling in the plate-supply circuits.

No. 243 RADIO BROADCAST Laboratory Information Sheet

Resistance-Coupled Amplifiers

EFFECT OF COMMON COUPLING

LABORATORY Information Sheet No. 242 gave some data on distortion in resistance-coupled amplifiers due to overloading. A second cause of distortion (which applies to this type of amplifier as well as to any other type of amplifier) is that due to common coupling between the plate circuits of the various tubes. This form of coupling is generally due to the resistance or reactance of the plate-supply device.

In a resistance-coupled amplifier the phase relation of the input voltage and the output voltage is practically 180 degrees, and, therefore, if any signal voltage from the plate circuit is returned to the grid circuit in any way, this feed-back voltage will be in exact opposition to the original input voltage and will tend to decrease the amplification. In a multi-stage amplifier the various feed backs from the different circuits combine; in some instances they may neutralize each other but more frequently they produce regeneration or anti-regeneration, either of which distorts the frequency characteristic of the amplifier so that good quality is not obtained.

To prevent common coupling in the plate-supply unit it is essential that the grid and plate circuits of each of the amplifier tubes be filtered so that none of the signal currents have to pass through the plate supply unit. In this way common coupling and its effects are prevented.

Laboratory Information Sheet No. 193 illustrated a circuit for preventing resistance-coupled amplifiers from motorboating. The circuit presented afforded a means of thoroughly filtering the plate circuit to the detector tube and it was found by experiments in the Laboratory that such a circuit will almost invariably prevent an amplifier from motorboating. This circuit can also be used advantageously with transformer-coupled amplifiers, it frequently being found that oscillations in amplifiers of this type can be prevented easily by this means.

In a later Laboratory Information Sheet we will illustrate a resistance-coupled amplifier with filter circuits in each of the various plate and grid leads. This sheet will explain what determines the values of resistance and capacity generally used in such filters.

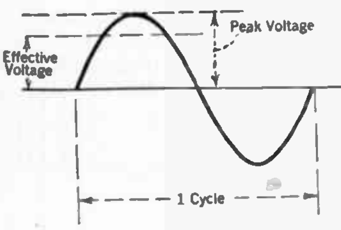
No. 244 RADIO BROADCAST Laboratory Information Sheet

Alternating-Current Ratings

EFFECTIVE VS. PEAK VOLTAGES

AT THE present time there are several devices used in radio receiving sets, such as power transformers, filament transformers, filter condensers, etc., which are rated in terms of a.c. voltages. References are made frequently to the peak value of an alternating-current voltage, to the effective value of such a voltage, and to the r.m.s. value of the voltage. The significance of these various terms is explained in this sheet.

The first and most important point is that alternating-current apparatus almost invariably is rated in terms of effective voltage, and effective voltage has *exactly* the same meaning as the r.m.s. voltage so that these two terms may be used interchangeably. If the secondary of a power transformer is rated at 350 volts it means that the effective value of the voltage is 350. Power lines in homes generally have an effective value of voltage of about 110 volts. The filaments or heaters of alternating-current tubes are rated in terms of effective voltage.



The letters r.m.s. are an abbreviation for root-mean-square, this value of an alternating voltage being such that it gives exactly the same heating effect as a direct current of the same potential. It is for this reason that the r.m.s. value of an alternating voltage is termed the effective value.

The peak value of an alternating voltage is the maximum value to which the voltage rises during any part of the cycle. The shape of a.c. voltages with which one ordinarily deals are such that the potential is proportional to a sine of an angle and it is for this reason that we frequently hear the term "sine wave." If the voltage wave has such a form then the peak value is equal to 1.4. times the effective or r.m.s. value.

No. 245 RADIO BROADCAST Laboratory Information Sheet

Power Output

HOW MUCH IS REQUIRED

IN THE last audio stage of one's receiver there are more than half a dozen arrangements that can be used. We might use a single 171A or two of these tubes in push-pull, but perhaps some prefer a single 210, a single 250 or either of these tubes in push-pull. From these and other combinations one can obtain equally good quality provided the tubes are not overloaded. The question one naturally asks is what tube or combinations of tubes he should use? How much power output does one need for ordinary home reproduction? These are questions about which we all want definite information, but which unfortunately cannot be answered very simply.

How much power is available from any one tube or combination of tubes can be determined by referring to the table published on Laboratory Sheet No. 246. Although opinions differ as to how much power is required for ordinary home reproduction, George Crom, Engineer of the American Transformer Company, in a recent paper read before the Radio Club of America, states that for a sound level slightly above normal, using a good loud speaker, from 1 to 1.5 watts input power is required. By referring to the table on Laboratory Sheet No. 246 it would appear, therefore, that to obtain a power output of about 1.5 watts we must use either a single 210-type tube, a 250-type tube operated at low voltage or lower power tubes, such as the 171A operated in push-pull or parallel.

The phrase "normal output" referred to in the preceding paragraph is obviously a rather ambiguous one, and, since the ear is not especially sensitive to variation in power, it is probable that an increase or decrease of 3 TU would not affect seriously the loudness as heard by the ear. 3 TU corresponds to a power ratio of approximately 2. In other words, variations from 1 to 2 watts in the power available in the output circuit would not produce very great changes in volume.

The table given on Laboratory Sheet No. 246 will also be helpful in determining the power output of any power amplifier that one may have or may contemplate purchasing. For example, if the power amplifier uses two 171A-type tubes in push-pull, then the power output will be about three times that of a single tube or 2100 milliwatts. Large power amplifiers are used frequently to supply several loud speakers in an auditorium, hotel, etc. An approximate determination of the number of loud speakers which such an amplifier can supply may be obtained by remembering that each loud speaker requires approximately 1.0 watt, and then the number of loud speakers which can be supplied may be determined easily.

No. 246 RADIO BROADCAST Laboratory Information Sheet

Power Output Characteristics of Vacuum Tubes

A USEFUL TABLE

THE table below gives the power output of the various types of power tubes used in radio receiving sets. The table has been arranged in order of power output, starting with the 120-type tube with a power output of 110 milliwatts and ending with the 250-type tube with a power output of 4650 milliwatts. If two tubes are used in a push-pull amplifier, then the power output of the combination will be equal approximately to three times the power output of a single tube. Two more or tubes used in parallel will have a power output equal to the power output of a single tube multiplied by the number of tubes used.

Tube	Plate Voltage	Negative Grid Voltage	Milliwatts* Power Output
120	135	22.5	110
112A	135	9	120
171A	90	16.5	130
112A	157	10.5	195
171A	135	27	330
210	210	18	340
210	300	22.5	600
171A	180	40.5	700

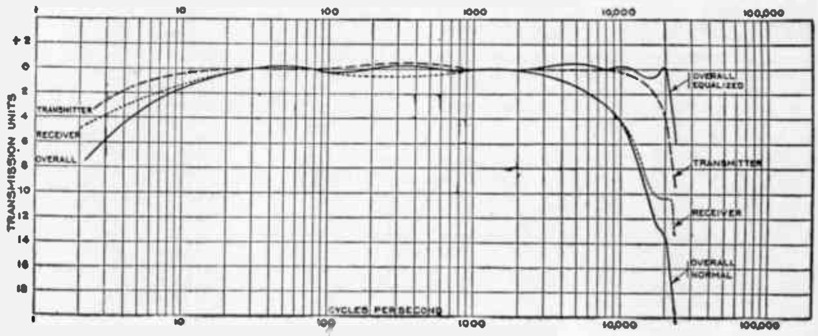
Tube	Plate Voltage	Negative Grid Voltage	Milliwatts* Power Output
250	250	45	900
210	350	27	925
210	400	31.5	1325
250	300	54	1500
210	425	35	1540
250	350	63	2350
250	400	70	3250
250	450	84	4650

*1000 milliwatts is equal to 1 watt of energy.

No. 247

RADIO BROADCAST Laboratory Information Sheet

Frequency Characteristics of Television Amplifier Developed by the Bell Telephone Laboratories



No. 248

RADIO BROADCAST Laboratory Information Sheet

Television

AMPLIFIER CHARACTERISTICS

On LABORATORY Sheet No. 247 are published a group of curves taken from the October, 1927 *Bell System Technical Journal* where the apparatus used in connection with the demonstration of television made by the Bell Telephone Laboratories was described. In this demonstration a complete radio system was used. The television transmitter was located at the transmitting station and the output of the television transmitter, after being amplified, was sent over the air, the frequency of the radio transmitter being 1450 kilocycles. A superheterodyne receiver was used at the receiving end, and the television signals, after being detected, were sent through the necessary amplifiers and finally made to modulate the neon tube used in the television receiver. In order to insure that the reproduction of the picture might not suffer distortion careful frequency measurements were made on all of the apparatus and the results of these tests were plotted and are reprinted on Laboratory Sheet No. 247. The dash curve gives the characteristic of the radio transmitter and it is evident from the curve that the frequency characteristic of this system is excellent. There was practically no loss down to 10 cycles and only a 4 TU loss at 20,000 cycles.

The receiver characteristic is indicated by the dotted curve. At 10 cycles there was a loss of about 1.5 TU. At 10,000 cycles there was a loss of about 4 TU and at 20,000 cycles a loss of 10 TU. The "overall normal" curve indicated as a solid line shows about 1.5 TU loss at 10 cycles and a loss of about 13.5 TU at 20,000 cycles. This characteristic was unsatisfactory since the engineers had determined previously that it was desirable that the frequency characteristic be constant within about 2 TU. up to 20,000 cycles.

The necessary improvement in the characteristic was obtained by the use of equalizers and the final curve of the equalized system is indicated by "overall equalized." This overall curve is down about 1.5 TU at 10 cycles and there is 0 TU loss at 20,000 cyles. Between these two limits there are slight variations in the curve although none of these variations are as large as 1 TU.

No. 249

RADIO BROADCAST Laboratory Information Sheet

A Resistance-Coupled Amplifier

PARTS REQUIRED

On LABORATORY Sheet No. 250 is published the circuit diagram of a resistance-coupled amplifier illustrating the use of filter circuits in the plate and grid leads. As explained in Sheet No. 243, lack of proper filter circuits will cause distortion due to common coupling in the plate supply. It will frequently be worth while to incorporate such filter circuits in existing resistance-coupled amplifiers, especially if the amplifier exhibits a tendency to "motorboat" or distort.

In operating a resistance-coupled amplifier it is especially important that overloading be prevented by keeping the volume down to the point where none of the tubes draw grid current, and it is up to the user of the amplifier to operate it so that grid current does not flow.

In constructing the amplifier illustrated on the next sheet the following parts will be required:

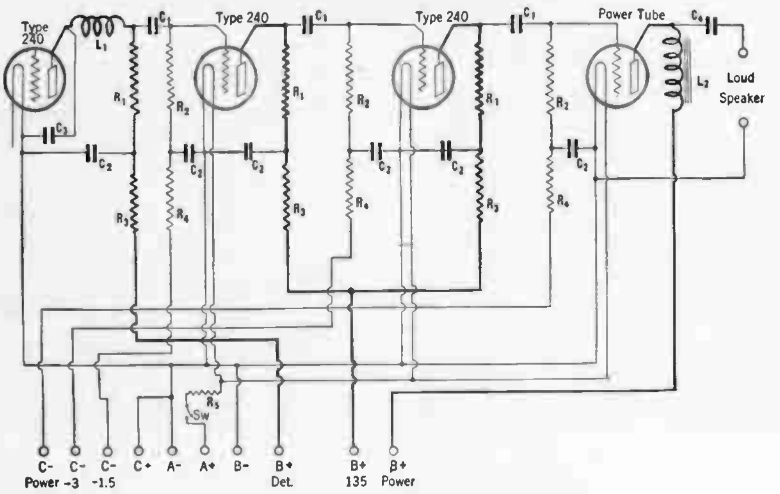
R_1—Three plate-coupling resistors, 250,000-ohm;
R_2—Three grid resistors, 2-megohm;
R_3—Three plate-circuit filtering resistors, 25,000-ohm;
R_4—Three grid-circuit filtering resistors, 50,000-ohm;
R_5—Filament rheostat, 6-ohm;
C_1—Three coupling condensers, 0.01-mfd.;
C_2—Six by-pass condensers, 1-mfd.;
C_3—One by-pass condenser, 0.0002-mfd.;
C_4—Output condenser, 4-mfd.;
L_1—R.F. choke coil;
L_2—Output choke coil, 30-henries;
Sw—Filament switch.

The detector and the first two of the audio amplifiers may be 240-type tubes and the power tube may be any type, depending upon the personal preference of the builder. The voltages applied to the B-plus power terminal and the C-minus power-terminal will, of course, depend upon the type of power amplifier; it is recommended that a 171A-type power tube be used.

The simplest and most satisfactory construction to follow in building a resistance-coupled amplifier is to mount the tube sockets and the resistor mounts for the grid- and plate-coupling resistors all in a line. With this arrangement the grid and plate leads between the tubes and the coupling resistors are very short.

No. 250 RADIO BROADCAST Laboratory Information Sheet

A Resistance-Coupled Amplifier



No. 251 RADIO BROADCAST Laboratory Information Sheet

Moving-Coil Loud Speakers

DESIGN OF THE COUPLING TRANSFORMERS

WHEN an engineer designs a moving-coil loud speaker, he also has to design the input transformer which is used to couple the loud speaker and receiver. The impedance ratio of this transformer will depend upon the impedance of the moving-coil system and upon the plate resistance of the power tube in the receiver. Since the engineer doesn't know what type of power tube the buyer of the loud speaker is going to use, upon what facts does he base his decision regarding the impedance ratio of the transformer which is finally incorporated in the loud speaker?

The fact has been mentioned many times in these data sheets that the maximum undistorted output is obtained from a tube when the load into which it works is equal to twice the plate resistance of the tube. A curve was also given on Laboratory Sheet No. 237 showing how the power output changed with variations in load impedance and this curve indicated quite clearly that a large percentage of the maximum amount of undistorted power was still available in the load, even though the load resistance was 5 or 6 times greater than the plate resistance of the tube. Suppose the engineer designed the coupling transformer so that looking into the primary the impedance is 4000 ohms. The plate resistance of a 171A-type tube is 2000 ohms and if this tube were used the maximum undistorted power output would be obtained (since 4000 ohms is twice the plate resistance of a 171A). If, however, this loud speaker were to be used with a 112A- or 210-type tube, both of which have a plate resistance of about 5000 ohms, then only 40 per cent. of the maximum available power would appear across the loud-speaker circuit. Also, when a high plate resistance tube is used with a low-impedance load the tube characteristic is curved (see Laboratory Sheet No. 124) and this produces distortion. Evidently then, if such a design were decided upon, the power loss would be somewhat greater than half when using a 112A- or 210-type tube and also distortion would be produced due to curvature of the tube's characteristic.

If the transformer were designed so that from the primary the impedance was 10,000 ohms then the maximum amount of undistorted power would be obtained from a 112A- or 210-type tube, since they are both 5000-ohm tubes. On the other hand, if a 171A-type tube with a 2000-ohm plate resistance were used with this transformer we still would obtain 70 per cent. of the maximum power, and, since the plate load, 10,000 ohms, is much greater than the tube resistance, 2000 ohms, distortion would not be introduced due to curvature of the characteristic. This design of the transformer is obviously the correct one.

No. 252 RADIO BROADCAST Laboratory Information Sheet

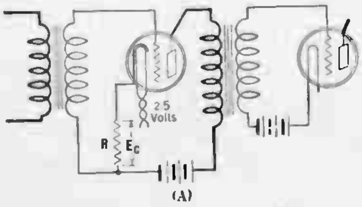
Audio Amplifiers

IMPORTANCE OF BY-PASS CONDENSERS

IN SKETCH A on this sheet we illustrate the circuit of a single-stage audio amplifier. Resistor R, being connected in series with the cathode of the tube, functions to supply C bias to the grid of the tube. Should the resistance, R, be bypassed with a condenser?

If this circuit were casually analyzed one would be inclined to answer this question negatively, since this resistance is in series with the primary of the audio transformer, T, and the impedance of this circuit is very high. Consequently the a.c. currents around through the plate circuit and through the resistance ought to be very small. If, however, we draw out the equivalent circuit, as we have done in sketch B, a different condition is seen to exist. This equivalent circuit represents what the tube and transformer look like at high audio frequencies, L_s being the leakage inductance in the transformer and C the distributed capacity reflected into the primary. R is the grid resistor and R_p the plate resistance of the tube. At high frequencies this is a series resonant circuit and the currents are, therefore, quite large. For this reason a comparatively large voltage may be developed across the resistor R which supplies the C-bias voltage, E_c, to the grid of the tube. This voltage, E_c, should obviously be only a d.c. voltage, but, since the circuit is a series resonant one, considerable a.c. voltage will be developed across the resistance and be impressed back on the grid of the tube. This voltage impressed back on the grid will be out of phase with the original voltage and it will, therefore, reduce the amplification at high frequencies.

These facts were checked on an amplifier in the Laboratory a short while ago and proved to be true. The low-frequency response of the amplifier was unaffected by the condenser across the C-bias resistor. At high frequencies, however, there was a very considerable loss in gain unless a by-pass condenser of 1 or 2 mfd. was placed across the resistance. It is therefore recommended that home constructors always make certain that all the C-bias resistors are properly bypassed.



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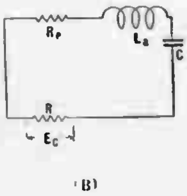


(B)

No. 253 RADIO BROADCAST Laboratory Information Sheet

Shielding

SUGGESTIONS REGARDING ITS USE

SHIELDING is used in radio receivers for two purposes. First, it prevents direct pick-up, by the coils in a receiver, of signals from powerful local stations, for, when such pick-up exists, the receiver is likely to be non-selective. Second, the use of shielding prevents electrostatic and electromagnetic coupling between the various parts of the circuit, particularly the various inductance coils. Electrostatic coupling is readily prevented, thin sheets of shielding material between the apparatus to be shielded generally being sufficient. Electromagnetic coupling is more difficult to prevent. The prevention of such coupling necessitates the use of very complete shielding, the joints must be tight and a material with a low electrical resistance must be used.

The shielding in a receiver should be used for only one purpose—shielding. It should not be used to conduct currents, for example, between a coil and a condenser. If this is done the usefulness of the shielding frequently will be destroyed due to the fact that these currents flowing through the shielding material constitute circuits which can readily produce coupling to adjacent conductors.

All the shielding in a receiver should be grounded and connected also to negative-B, negative-A, and plus-C wires. Except for the fact that the shield may be used for the A-minus conductor, the wiring of the set should be done as though the shielding were not present. In other words, the fact that some condenser, for example, one of the tuning condensers, is connected to the shield should not cause us to connect one end of a tuning coil to the shield and thereby complete the circuit through the shielding material. Instead a lead should be run from the tuning coil to the tuning condenser so that the currents in this circuit will pass through this lead and not through the shielding.

The coils in a receiver should preferably be located about central within the shielding compartment, since in this position the increase in resistance of the coil due to the shielding will be a minimum. If these simple rules are followed in constructing a shielded receiver, many difficulties will be prevented.

No. 254 RADIO BROADCAST Laboratory Information Sheet

A. C. Tubes

EFFECT OF FILAMENT VOLTAGE

IT IS becoming increasingly common to find manufacturers designing the filament windings on power transformers to supply voltages somewhat less than those rated for use with 226- and 227-type a.c. tubes. One parts manufacturer is marketing a filament transformer designed to supply 2.25 volts to the filament of a 227-type tube, although the rated voltage of this tube is 2.5 volts. A study of the circuit diagrams of manufactured receivers published in RADIO BROADCAST will bring to light other cases where a.c. tubes are supplied with somewhat lower than rated voltage.

The life of a vacuum tube depends very much upon the filament voltage with which it is supplied, and frequently a very small increase in voltage above the rated value will cause a considerable shortening in the life of the tube. With a.c. tubes this problem has assumed especial importance, for these tubes are subjected to variations in filament voltage in accordance with any fluctuations of the line voltage. If the line voltage becomes somewhat higher than that value at which the set is designed to operate, the various tubes receive excessive filament voltage and their life is shortened to a marked extent. It is for this reason that manufacturers have designed the power transformer to deliver somewhat lower than rated voltage to the tubes so that even if the line voltage rises above normal the tube filaments will not be overloaded.

A.C. tubes, types 226 and 227, will give entirely satisfactory operation at less than the rated voltage. The table on this sheet, obtained from figures in the *Cunningham Tube Data Book*, gives the characteristics of the 226-type tube with a filament voltage of 1.3 volts and 1.5 volts, the latter value being that at which the tube is rated. The slight increase in plate resistance and decrease in mutual conductance which results when the tube is operated at 1.3 volts is not sufficient to affect its operating characteristics. The 227-type tube saturates at about 1.9 volts on the filament and, therefore, it also may be operated at somewhat less than its rated voltage with satisfactory results.

TUBE	FILAMENT VOLTAGE	PLATE IMPEDANCE	MUTUAL CONDUCTANCE	AMPLIFICATION FACTOR
226	1.3	10,000	750	8.3
226	1.5	9,000	830	8.3

No. 255 RADIO BROADCAST Laboratory Information Sheet

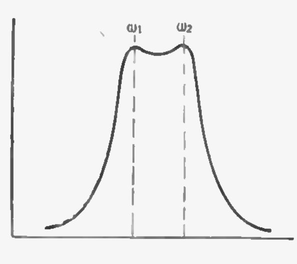
Band-Pass Circuits

WIDTH OF BAND

BAND-PASS filters, as used in radio receivers, consist of an arrangement of coils and condensers which produce a resonance curve of a form approximating that illustrated in the drawing on this sheet. It is possible to design a circuit to have a band-pass characteristic by the use of two separate tuned circuits, each tuned to exactly the same frequency and coupled. The coupling may be produced by condensers, by a separate coil, or by simply placing the coils of the tuned circuits in such relation that there is some coupling between them. One of the most important characteristics of a band-pass circuit is the distance between the two peaks in the curve, marked ω_1 and ω_2.

J. H. Morecroft in *Principles of Radio Communication* gives some formulas for coupled circuits. If two circuits are coupled inductively, then the width in kilocycles of the band between ω_1 and ω_2 is equal to the resonant frequency of either circuit alone multiplied by the percentage coefficient of coupling, k, between them. For example, we might take two coils and two condensers, arrange them in the form of two tuned circuits adjusted, say, to 1000 kilocycles. When there is 1 per cent. coupling between them then the width of the band will be equal to

band with $= \omega_1 \times k$
$= 1000 \times 0.01$
$= 10$ kc.



The width of the band is, therefore, 10 kilocycles. It should be noted that the band width is directly a function of ω_1 (or ω_2 since they are both tuned to the same frequency). Therefore, if the percentage coupling remains constant then the width of the band at 500 kc. is 5 kilocycles and at 1500 kc. is 15 kilocycles. The fact that the width of the band varies over the broadcast band in a ratio of 3 to 1 (5 kc. to 15 kc.) is a disadvantage, it being desirable, of course, that the width of the band should be constant over the entire broadcast range. If the circuits were capacitatively coupled the characteristic would be opposite to that when inductive coupling is used, i.e., at 1500 kc. the band width would be 5 kc., at 1000 kc. the width would be 10 kc., and at 500 kc. the band width would be 15 kc.

No. 256 Radio Broadcast Laboratory Information Sheet

Power Output

HOW MUCH IS REQUIRED?

HOW much available power in the output tube of a radio receiver does one need for ordinary home reception when using a standard loud speaker? This is a question about which one can find many diverse opinions. In Laboratory Sheet No. 245 we quoted George Crom to the effect that the usual loud speaker requires an input of 1 to 1.5 watts for a volume of reception slightly above normal. In the *Cunningham Tube Data Book* (which costs $2.50 and which we recommend that you purchase, if possible) we read, "For home reception, with a speaker of average sensitivity, a tube capable of supplying at least 100 milliwatts (0.1 watt) maximum undistorted power output is recommended. The use of a tube giving lower output is almost certain to result in distortion appreciable to the listener. It is very desirable to have additional reserve power available, up to approximately 500 milliwatts, if the "B" power required can be conveniently supplied. Under such conditions the quality will not suffer if the volume is turned a little above normal, as may be required in a large room or for dancing, or if the loud speaker is somewhat low in sensitivity."

The average of George Crom's figure is 1.25 watts and Cunningham recommends 0.500 watt. The mean of these two is 875 milliwatts, 0.875 watt. If the table of Laboratory Sheet No. 246 is referred to it will be found that the smallest power tube giving approximately this output is the 171A which is capable of supplying a maximum of 700 milliwatts to the loud speaker.

It, therefore, seems fair to state that any installation using a power tube or combination of tubes in the output such that the available power is about 0.7 watt, that this amount of power will be sufficient to permit loud-speaker reproduction at fair volume without overloading.

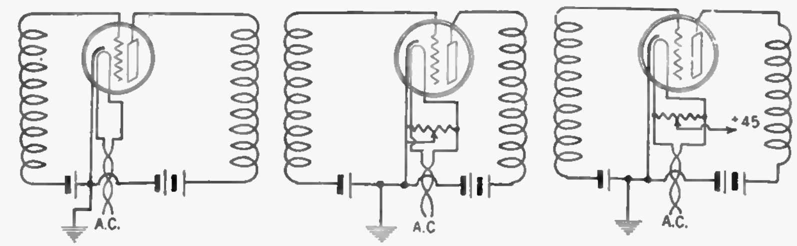
No. 257 Radio Broadcast Laboratory Information Sheet

Heater Connections for A. C. Tubes

AN EXAMINATION of the circuits of various a.c. receivers using one or more 227-type tubes shows several different ways the heaters of these tubes may be connected into the circuit.

In sketch A we show the heater of the tube quite independent of the remainder of the circuit. In sketch B the center tap of a resistor connected across the heater is grounded and in sketch C the center tap of the resistor connected across the heater is connected to the plus 45-volt terminal. Of these three arrangements the one most commonly used is B in which the heater is grounded, since such an arrangement gives satisfactory operation in most cases. It is generally unwise to arrange the circuit as indicated at A, since the heater under such conditions is more or less floating and is liable to introduce hum into some part of the circuit.

The reason for the use of the arrangement shown at C is somewhat complicated. When the heater of the tube becomes hot it, of course, emits some electrons and it is possible for some of these electrons to enter the plate circuit. Since the heater is operated on a.c. the emission from it is not uniform and, therefore, a hum will be produced if any appreciable number of electrons are drawn from the heater.



(A) (B) (C)

No. 258 Radio Broadcast Laboratory Information Sheet

An Analysis of Filter Circuits

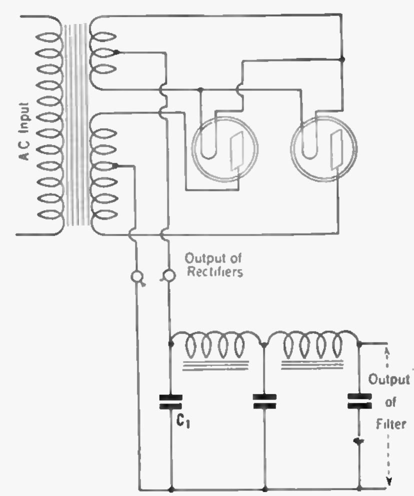
ON LABORATORY Sheet No. 259 are given a circuit diagram and set of curves showing the output voltage from a typical full-wave rectifier using two 281-type tubes. These curves will prove helpful in determining what voltage is necessary across the power transformer to deliver a given voltage to the filter system. The curves show the output of the rectifier with transformer voltages ranging from 550 volts per plate up to 700 volts per plate.

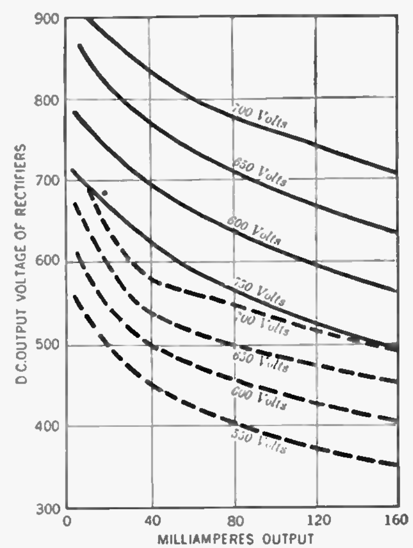
Two sets of curves are given, one set being obtained with the standard filter system indicated in the circuit diagram and the other with a special circuit recommended by the E. T. Cunningham, Inc. The solid curves show the voltages with a standard filter system and the dotted curves show the voltage with a special filter system. In determining the latter curves the first filter condenser, C_1, was omitted.

When using the standard type of filter system the load on the tube is quite heavy and the peak value of current, which the rectifiers are called upon to supply under full-load conditions, reaches values as high as 310 milliamperes, although the average current drawn from the filter system is only 125 milliamperes; the filament must be capable of supplying the maximum value of current, i.e. 310 milliamperes. With the first condenser, C_1, removed from the filter system the voltage output for a given transformer voltage decreases considerably, as indicated by the curve, but with this condenser removed the tube operates under much more satisfactory conditions. The peak value of current used in such a circuit is only 140 milliamperes when the load current is 125 milliamperes. In other words the peak current has been reduced from 310 milliamperes to only 140. This reduction increases the life of the filament, and a tube having a total emission of 150 milliamperes will still give satisfactory operation in the special filter circuit although it would not function satisfactorily in an ordinary filter circuit where the plate current reaches values up to 310 milliamperes. It is recommended that this special filter system be used wherever possible.

No. 259 Radio Broadcast Laboratory Information Sheet

Filter Circuit Characteristics





No. 260 RADIO BROADCAST Laboratory Information Sheet

Voltage Gain in Resistance-Coupled Amplifiers

LABORATORY Information Sheets Nos. 242, 243, 249, and 250, discussed resistance-coupled amplifiers; the latter two sheets gave the circuit diagram and a list of parts for the construction of a good amplifier of this type. In this sheet further data is given regarding resistance-coupled amplifiers in comparison with other types.

The overall voltage gain in a resistance-coupled amplifier is generally much greater than that of a transformer-coupled amplifier. For example, a standard two-stage transformer-coupled affair has a voltage gain of about 100 from the input to the grid of the power tube. The usual three-stage resistance-coupled amplifier using high-mu tubes has a gain of about 400 from the input to the power tube's grid. This additional gain is not always an advantage. If such an amplifier is used in a receiver operated entirely from batteries this high gain will simply have the effect of increasing the loudness of the signals, but if such an amplifier is used in a receiver operated from a B-power unit it is probable that the hum output will be much greater than it would be if a two-stage transformer-coupled amplifier were substituted for it. This is due to the fact that, as pointed out in Laboratory Sheet No. 261, the hum voltage developed across the loud speaker is a direct function of the overall gain of the amplifier and the amount of hum introduced into the detector circuit. Since the amplifiers have a ratio of about 4:1 in gain, the hum voltage developed when using the resistance-coupled amplifier will be about four times as great, assuming that all other conditions remain the same.

For these reasons it frequently is advisable to construct the resistance-coupled amplifier with somewhat lower gain. For example, if instead of using two 240 tubes we use one 201A and one 240 then the overall gain will be about 150 which is a very satisfactory value.

For some reason the resistance-coupled amplifier has not found wide use in manufactured or home-constructed receivers although when properly designed it is certainly capable of giving results as good as any other type of amplifier.

No. 261 RADIO BROADCAST Laboratory Information Sheet

Where A. C. Hum Originates

THE amount of a.c. hum audible in a loud speaker connected to a radio receiver depends upon various factors. With a given installation, however, the hum depends to the greatest degree upon the amount of a.c. ripple introduced into the plate circuit of the detector tube. This hum voltage may come from the B-power unit or from a.c. tubes, and in a.c. sets some hum is, of course, obtained from both of these sources.

It is important to realize the importance of any hum in the detector circuit. Consider an ordinary transformer-coupled amplifier using, say, a 3 to 1 ratio transformer between the detector and first a.f. tube, and assume that the first a.f. amplifier tube has a mu of 8. Between the plate circuit of the detector tube and primary winding of second a.f. transformer the gain is, therefore, 24. It follows from this calculation that, if a given amount of hum is obtained from a loud speaker when there is a certain hum voltage in the plate circuit of the first a.f. tube, that the same amount of hum will be obtained with only one twenty-fourth as much hum voltage in the plate circuit of the detector tube. For these reasons it generally is found that amplifiers which are noisy under normal operation are generally quiet if the output of the detector tube is short circuited—a definite indication that the major part of the hum arises in the detector circuit.

Let us consider a concrete example. Suppose that we have a two-stage a.f. amplifier with 3 to 1 transformers, the first audio tube having a mu of 8 and the power amplifier having a mu of 3 and that the load resistance in the output is equivalent to 4000 ohms. Assume that a hum potential of 0.1 volts is existant in the plate circuits of the detector tube and also the first audio amplifier. The hum voltage from the plate circuit of the first a.f. amplifier circuit will produce a hum potential of a 0.6 volts across the 4000-ohm load resistance. The hum voltage in the detector circuit will produce 14.4 volts in the load circuit. Even assuming that these two voltages are 180 degrees out of phase so that they oppose each other the voltage in the load circuit would be 13.8 volts. It follows from these figures that practically all the hum in the output will come from the detector circuit. The importance of proper design in the detector circuit to eliminate any small hum voltages cannot be overemphasized.

No. 262 RADIO BROADCAST Laboratory Information Sheet

Advantages of Dual Push Pull

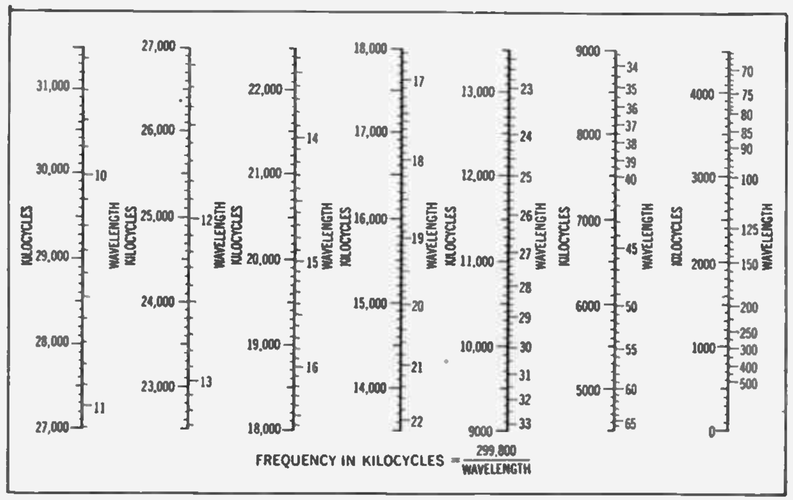
HIGH-GAIN a.c.-operated power amplifiers, designed particularly for use in public-address systems, frequently make use of two 250-type tubes in push pull in the output. If these tubes are operated at their rated voltage in order to obtain the maximum amount of undistorted power a total value of peak signal voltage across the secondary of the push-pull transformer feeding these tubes must be about 160 volts. Assuming that this transformer has a ratio of 3 to 1, the voltage across its primary must be 160 divided by 3, or approximately 53 volts. If the tube feeding this transformer has a mu of 8 then the voltage on its grid must be about 7 volts, and, in order to prevent the possibility of overloading, the grid bias should, therefore, be twice this value plus about 10 per cent. or 8 volts. We might consider using a 226-type tube to feed the push-pull stage, but using the rated voltage of this tube 90 volts with a corresponding grid bias of 6.0 volts is, from the figures given above, not sufficient.

It is for this reason that we find many of the power amplifiers designed for public-address work consisting of two push-pull stages, the power output stage being fed by a preceding push-pull stage using 227- or 226-type tubes. Through the use of the push-pull arrangement we are able to handle voltages somewhat greater than twice that which can be handled by a single tube. These tubes in push-pull can then handle without difficulty the voltages required to load up two 250-type tubes in push-pull. It follows obviously, from these figures, that any power amplifier using 250-type tubes in push-pull must be preceded by a push-pull stage if maximum output is desired, since a single 226- or 227-type tube will be overloaded when called upon to supply the necessary voltages. The above discussion, of course, does not consider the possibility of using a small power tube in the circuit preceding the push-pull stage.

If we assume that we can obtain from the detector circuit about 0.3 volt and that 160 volts are required on the grids of the power tubes, it follows that the gain in the amplifier must be about 530 (160 divided by 0.3). The gain of an ordinary amplifier, is about 100 and, consequently, when using 250's in push-pull it is essential that a three-stage audio amplifier be used under such conditions.

No. 263 RADIO BROADCAST Laboratory Information Sheet

Wavelength-Kilocycle Chart



No. 264 RADIO BROADCAST Laboratory Information Sheet

Three Types of Graphs

IF WE have before us a job of plotting a curve of an a.f. amplifier to show how the voltage gain varies with frequency, we must decide just how the curve is to be plotted. Curves may be plotted on several types of cross-section paper which will be illustrated in a future Laboratory Sheet. The problem is this, should we plot the curve on ordinary cross-section paper or on log or log-log paper, and should we plot frequency against DB or against voltage output.

The essential purpose of a curve is to enable one to obtain a visual idea of the characteristics of the amplifier. Since the purpose of an a.f. amplifier is to amplify currents which will finally be converted into sound, it is preferable to plot the curve to such a scale that its final shape indicates as nearly as possible the variations in response as they would be audible to the ear.

Now it has been determined that the ear hears variations in intensity in accordance with a logarithmic function. For this reason, if we are to plot frequency against output voltage, it is advisable to plot the curve on log-log paper so that the variations will be indicated on the curve in their relative importance as heard by the ear.

If we desire to plot frequency against DB then the curve should be plotted on log paper. In such a case we would find that the shape of the resultant curve was the same as that of the preceding curve plotted on log-log paper, for in converting from voltage to DB we take into consideration the logarithmic function.

In all cases the frequency scale should be plotted on a log scale so that each octave in the scale takes up an equal amount of space. Take a piece of cross-section paper with a log scale on it and measure the distance in inches between 10 cycles and 100 cycles, a change in frequency of 10 to 1. Then measure the distance between 100 and 1000 and between 1000 and 10,000. The distances are all equal and equal sections of the curve therefore receive an equal amount of space.

No. 265 RADIO BROADCAST Laboratory Information Sheet

Electrifying Battery-Operated Sets

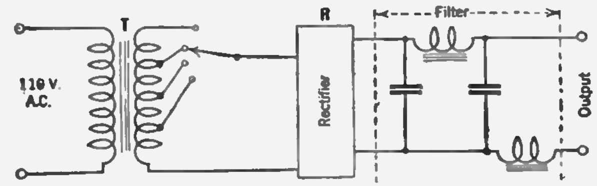
IT IS much easier and generally more satisfactory to change a battery-operated receiver over to complete a.c. operation by the use of an A-power unit than by rewiring the set for a.c. tubes; in both cases a source of B and C voltages is, of course, necessary. The use of an A-power unit to permit light-socket operation may be accomplished without rewiring the set, and, if the unit is a good one, one can be sure that the operation of the set from the A-power unit will be essentially the same as when it was run from the storage battery.

An A-power unit is somewhat similar to a B-power unit, both of them consisting of a transformer, rectifier, and filter system. The A unit differs from the B unit simply in the rectifier and filter system which must be capable of supplying two or three amperes instead of a few milliamperes.

The circuit of a typical A-power unit is given on this sheet. The transformer, T, supplies a.c. voltage to the rectifier, R, which feeds pulsating d.c. to the filter system where the ripple is removed so that the current leaving the output terminals of the filter system is practically pure d.c.

The arrangement of the chokes and condensers in the filter system varies in different units. In some cases both the chokes are placed in the same side of the line and three condensers are frequently used instead of two.

The transformer, T, is generally provided with taps on the secondary, as we have indicated, so that the output of the system may be corrected for different current drains. The greater the output current required from the unit, the higher must be the voltage impressed across the rectifier.



No. 266 RADIO BROADCAST Laboratory Information Sheet

Effect of Room Acoustics

MR. IRVING WOLFF, of the Technical and Test Department of R. C. A., remarks in an article on loud-speaker measurements (*Proc. I. R. E.*, December, 1928) that,

"We are sometimes annoyed after having conducted listening tests on a loud speaker, and having reached the conclusion that it is pretty good, to find it unsatisfactory when moved to a different room or even a different position in the same room. It is, therefore, very important when taking loud-speaker curves to consider the question of room acoustics and loud-speaker position.

"Some of the factors which may be expected to have a pretty big effect are:

Room absorption characteristics
Room resonances
Position of loud speaker in room
Position of listener with respect to loud speaker.

High frequencies are radiated in a beam. If high response is wanted the speaker should, therefore, be pointed and placed so as to cover as large a portion of the audience as possible. Placing the loud speaker in a corner or in any kind of a cavity will usually have a big effect on the response. The space between the back of the loud speaker and wall or other obstruction will act as a resonant chamber whose vibrations will be excited by the vibrations of the rear side of the loud speaker diaphragm. It is impossible to say whether this effect will be pleasing or otherwise. It will depend on the unadulterated response characteristic and whether the resonance is of such frequency as to supply a region which is lacking.

"Under present broadcasting conditions where the range of frequencies transmitted is cut off pretty sharply at 5000 cycles or below, tube overloading on a loud speaker which reproduces real high frequencies show up as a roughness, rasp, and very often as a sound which resembles a paper rattle. This is caused by the generation of harmonics and combination tones. These added notes show up particularly badly when they are produced at the higher frequencies, as there is no true transmitted sound of the same frequency to act as a mask."

No. 267 RADIO BROADCAST Laboratory Information Sheet

Power in Broadcast Harmonics

A BROADCASTING station is assigned to a definite frequency by the Federal Radio Commission. In the operation of the station it is essential that the major part of the radiation take place within 500 cycles of this assigned frequency. Since, however, for reasons of economy, the oscillators at the transmitter are generally overloaded rather than underloaded, it is always found that they generate, beside the fundamental frequency, a considerable amount of energy at harmonic frequencies. A transmitter operating on a frequency of 500 kilocycles will generate energy at 1000 kilocycles so that the program could be heard on both of the channels—and, of course, it is probable that the 1000-kilocycle wave would produce interference with a station assigned to that frequency. Some method must, therefore, be used to suppress the harmonics since, if they are permitted to get into the antenna, they will cause interference in other broadcasting channels. The greatest interference is caused in the channel corresponding to a frequency twice that on which the station is authorized to operate. In the August, 1928 *Bell Laboratories Record* the following interesting remarks were published relative to the suppression of harmonics from one of the experimental stations operated by the Bell Telephone Laboratories:

"In this respect, as in many others, 3XN, the latest broadcasting development of our Laboratories, marks a new level of attainment. The transmitter has a power input into the antenna system of 50 kilowatts for the carrier wave alone, and the instantaneous peak power during the broadcasting of a program may reach 200 kilowatts. And yet with all that power in the carrier wave, the amount of the second harmonic allowed to escape would not light the tiniest incandescent lamp made. To be exact, it is less than 0.005 watt and represents about one-ten-millionth of the power of the carrier wave.

"Ordinarily, a purity (lack of harmonics) of 80 to 95 per cent. can be readily and cheaply attained. To carry this to 99 per cent. costs considerably more and to carry it to 99.9 per cent. many times as much. The extent to which the purification is carried out is now left largely to the designers of the radio transmitter, and they look upon it as an economic balance between the job that they would like to do and the cost of the equipment that can be justified. The more powerful the broadcasting transmitter, the more important becomes the problem of attenuating its harmonics, and the greater the care which must be bestowed upon its harmonic filters."

No. 268 RADIO BROADCAST Laboratory Information Sheet

Mathematics of the Tuned Circuit

THE tuned circuit and its characteristics are important. Therefore, in this sheet are presented a few of the mathematical expressions concerning such circuits.

The current (I) flowing around a circuit consisting of a coil and a condenser connected in series may be determined by the following formula:

$$I = \frac{E_i}{\sqrt{R^2 + \left(\omega L - \frac{1}{\omega c}\right)^2}} \qquad (1)$$

where

- I = current in amperes
- E_i = voltage induced in the circuit
- R = resistance of circuit
- L = inductance of coil in henries
- c = capacity of condenser in farads
- ω = 2 π times the frequency in cycles

At resonance ωL equals $\frac{1}{\omega c}$ and equation (1) is therefore reduced to

$$I = \frac{E}{R} \qquad (2)$$

At resonance the energy stored in the condenser is

$$\frac{cE_g^2}{2} \qquad (3)$$

where Eg is the voltage across the condenser. The energy in the coil is

$$\frac{LI^2}{2} \qquad 4)$$

and if the resistance is small in comparison with ωL then the energy is equal in both cases and

$$I = E_g\sqrt{\frac{c}{L}} \qquad (5)$$

whence

$$E_g = I\sqrt{\frac{L}{c}} \qquad (6)$$

The last equation indicates that the voltage, Eg, across either the coil or the condenser is proportional to the ratio of L to c.

The gain of a tuned circuit may be defined as the voltage, Eg, generated across the circuit divided by the voltage, Ei, induced in the circuit.

$$E_g = I\omega L \qquad (7)$$

and combining equation (2) with (7) and solving for the gain, we have

$$\text{Gain} = \frac{E_g}{E_i} = \frac{\omega L}{R} \qquad (8)$$

No. 269 RADIO BROADCAST Laboratory Information Sheet

Importance of Bass Notes

SUPPOSE that a certain note on the piano is sounded in the studio of a broadcasting station and the characteristic of the radio circuit is such that the fundamental frequency of the tone is not transmitted but all the harmonics are. Even though the frequency of the fundamental never even reaches the loud speaker, if all the harmonics are reproduced we will be able to tell what note was sounded. It is a peculiar characteristic of the human ear that to a considerable extent it can, in some manner, supply to our consciousness many of the fundamental frequencies which are not reproduced by an ordinary radio system.

The fact that the ear is capable of supplying missing fundamental frequencies under some conditions does not mean that it is not worth while to design the radio system so that it is capable of reproducing them. The results would be much better if the fundamental were transmitted—this may be proved easily by playing the same note on the piano. The difference would be quite noticeable as the true note would sound much richer and be somewhat lower in pitch. The qualities which the note lacked when the fundamental was eliminated would be quite evident and the advantages, of designing a radio system to transmit the fundamentals of all the audio frequencies, of obvious value.

Since there is a large group of instruments in an orchestra—the trombone, 'cello, double bass, bassoon, drums, etc.—which sound many notes that are low in frequency, say below 150 cycles, it would seem that just as these instruments are essential in an orchestra to give correct balance, so the reproduction of the fundamental frequencies of their notes is essential for good quality. Imagine a symphony orchestra with all of these instruments lacking! However, it is usually unnecessary to reproduce notes below 60 cycles.

No. 270 RADIO BROADCAST Laboratory Information Sheet

Formulas for Power Output

THE undistorted power output of a tube is defined as the maximum power which can be supplied to a load without introducing more than five per cent. distortion due to the curvation of the tube's characteristic. It has been determined that the maximum amount of undistorted power is obtained from any given tube when the load resistance equals twice the plate resistance of the tube. The power output can be computed from the formulas

$$P = \frac{2\,(uE_{gr})^2}{9\,R_p}\,10^3 \qquad (1)$$

when

- P = power in milliwatts
- u = amplification constant
- E_{gr} = r.m.s. value of signal voltage on the grid
- R_p = plate resistance

If peak values of a.c. voltage on the grid are used instead of r.m.s. then the formula is:

$$P = \frac{(uE_{gp})^2}{9\,R_p}\,10^3 \qquad (2)$$

when E_{gp} = peak value of signal voltage on the grid.

Both of these formulas are calculated for the condition that the load is twice the plate resistance—the condition for maximum undistorted output.

These general formulas can be simplified if applied specifically to the various power tubes in use, and the table on this sheet gives these simplified formulas. For example, the power output of a 112A is equal to 2.86 times the square of the r.m.s. value of the a.c. voltage on the grid of the tube.

The column R_p indicates the plate resistance used in calculating the simplified formulas.

Type of Tube	R_p	Power in Milliwatts	
		R. M. S.	Peak
171A	2000	E_g^2	0.5 E_g^2
112A	5000	2.86 E_g^2	1.43 E_g^2
210	5000	2.86 E_g^2	1.43 E_g^2
250	1800	1.78 E_g^2	0.89 E_g^2

No. 271 RADIO BROADCAST Laboratory Information Sheet

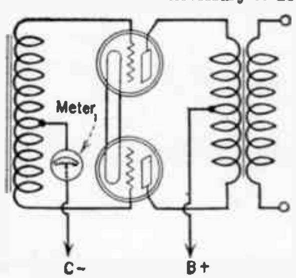
Test for a Faulty Push-Pull Amplifier

SEVERAL letters have been received recently by the Laboratory relative to the operation of push-pull amplifiers. Evidently some servicemen, quite capable of servicing any ordinary type of amplifier, are frequently unable to repair the push-pull amplifier that does not give good quality but which is wired correctly, uses good apparatus, and employs tubes that take normal plate current. The trouble is generally due to oscillations in the push-pull amplifier but to detect these oscillations it is necessary to apply to the push-pull amplifier a somewhat unusual test.

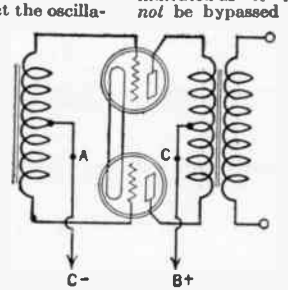
The test which is necessary to detect the oscillations consists of placing a meter in the C minus lead to the push-pull stages to determine if there is any grid current. The location of the meter is shown in sketch A. Under normal conditions there will be zero current in the grid circuit but if the circuit is oscillating several milliamperes may flow in the grid circuit. If such a test indicates that an amplifier is oscillating, then one or both of the following remedies must be applied.

The first thing to do is to connect a 50,000-ohm resistor in the common C-minus lead at the point indicated as "A" in sketch B; this resistance should *not* be bypassed with a condenser. The fidelity will not be affected in any manner by the inclusion of this resistor in the circuit but it is practically always effective in suppressing the oscillations.

In some cases a second change may have to be made to suppress completely the oscillations. If the resistance is not entirely effective, a choke coil, such as might be used in a B-power unit, may be connected at point "C" in sketch B. A choke coil must be used here instead of a resistance because of the loss in plate voltage which would be produced by a resistance.



(A)



(B)

No. 272

RADIO BROADCAST Laboratory Information Sheet

Importance of Correct Filament Voltages

THIS Laboratory Sheet supplies additional information on the subject covered in Sheet No. 254 published in the January issue. The latter sheet suggested the use of somewhat lower than rated voltage on the filaments of 226- and 227-type a.c. tubes. The information which follows from R. M. Wise, Chief Engineer of E. T. Cunningham, Inc., points out that the use of lower than rated voltages is not to be recommended generally.

"In using new tubes, and particularly with certain tube types, very satisfactory operation will be obtained at considerably reduced voltages. However, we find that reduction of the voltage below a certain point has little beneficial effect on tube life, and in some cases may shorten it due to the fact that the coated filament at times loses its activity when operated at very low temperatures.

"As an example, we find that average new c-327 tubes will give excellent performance below 2.0 volts, yet the emission life of the cathode at this temperature is not as satisfactory as is the case when it is operated at, or near, rated voltage.

"The c-327 heater voltage rating has been chosen with all of these factors in view, and, while for detector service we find it advisable for a time to recommend 2.25 volts, this recommendation has never been extended to the operation of the tube as an amplifier. As an amplifier we consider the preferred operating range to be from 2.4 to 2.6 volts, while as a matter of fact it will show satisfactory operation over a wider range of voltages. This recommendation has also been extended to include tubes used for detector service.

"It is particularly important to operate power and rectifier tubes within a range of + or — 5 per cent. from the rated value. Several instances of unsatisfactory operation of type cx-350 have been traced to operation at 6 volts. In each case satisfactory operation was obtained as soon as the filament potential was raised to 7.5 volts.

"It is true that there is not much change in characteristics when the tubes are operated somewhat below rated voltage. This holds for new tubes, but the question of maintaining uniform emission throughout the life of the tube is an important factor, and, as previously mentioned, this is best realized by operating the tube close to rated voltages. There is added advantage that when so operated a moderate change in emission will not affect operation, due to operation on or below the knee of the saturation curve, while if operated at reduced voltages a similar change in emission will result in impaired performance."

No. 273

RADIO BROADCAST Laboratory Information Sheet

Neutralizing and Compensating R. F. Circuits

PROBABLY two of the most common tasks which servicemen are called upon to perform are the adjustment of the neutralizing and compensating condensers in tuned r.f. receivers. These tasks are exceedingly important although not especially difficult.

If a set is not neutralized properly it will oscillate on some wavelengths, especially down around 200 or 300 meters. Therefore, if a set does oscillate it is necessary to reneutralize the various stages. This should be done in an orderly fashion, starting with the stage nearest the antenna and following with the other stages in order. Also, all servicemen should be equipped to perform these adjustments quickly on all receivers, and in this connection specially prepared tubes of the types used in r.f. amplifiers, the 201A, 226, and 227, are a great aid. These tubes are prepared by cutting off as close to the base as possible one of the filament prongs, in the case of a 201A- or 226-type tube, and one of the heater prongs in the case of the 227-type tube.

In adjusting a receiver tune-in a strong local station broadcasting on some wavelength between 200 and 300 meters, carefully tuning the dials to exact resonance. Then, with the prepared tube placed in the first r.f. socket in place of the good tube, carefully adjust the first neutralizing condenser to that position which gives the minimum signal from the loud speaker. Then remove the prepared tube, and replace the good tube. Now put the prepared tube in the second r.f. stage and repeat the operation, etc.

The compensating condensers in a receiver are placed across the main tuning condensers and function to compensate the slight differences in capacity between the various stages so that all the tuned circuits will be in exact resonance. Compensation should also be done with the set tuned to some station around 250 meters. When compensating a set it is best to tune-in some weak station, since slight changes in volume will then be noticeable more readily. The exact procedure is as follows. First tune-in a weak signal to maximum volume and then adjust all the compensating condensers to give the maximum signal strength. Retune the main dial to the point of maximum volume and then readjust the compensating condensers again.

No. 274

RADIO BROADCAST Laboratory Information Sheet

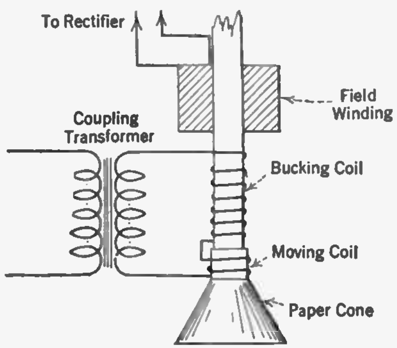
Bucking Coils in Dynamic Loud Speakers

MANY a.c. dynamic loud speakers use "bucking coils" to reduce the hum due to the use of rectified but poorly filtered a.c. to supply the field current. This bucking coil functions as follows.

Referring to the diagram, the bucking coil is connected in series with the moving coil and the secondary of the coupling transformer. The moving coil is, of course, fastened to the diaphragm. The bucking coil is wound around the pole piece of the electro magnet.

Now, since the rectifier supplies to the field a pulsating current, it follows that the magnetic flux produced by this current will also fluctuate. Since the moving coil is in the field of this flux, there will be a reaction between it and the varying magnetic flux and the coil will tend to move—and its movements would have the same frequency as that of the field current. If the diaphragm moves, sound is produced and as a result we would get an audible hum. The effect of the pulsating field current is, however, nullified (more or less) by the bucking coil. The coil is also in the magnetic field and it, therefore, has induced in it a voltage corresponding in frequency to that of the pulsating field current. This voltage induced in the bucking coil sends a current around the circuit consisting of the transformer, the moving coil, and the bucking coil. The magnitude of this current is such that its effect on the moving coil is equal and opposite to that produced directly on the moving coil by the flux. Since the two effects are equal and opposite they nullify each other and the hum is prevented.

It is evident that the important thing is to get into the moving-coil system a voltage that will nullify the forces tending to make the coil move and thereby produce hum.



No. 275

RADIO BROADCAST Laboratory Information Sheet

Obtaining Grid Bias from B-Power Units

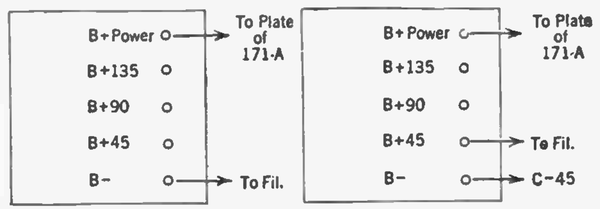
BOTH B and C potentials for a 171A tube may be obtained readily from a simple B-power unit without adding any resistors or condensers to the circuit; it is simply necessary to change a few connections.

Sketch A on the sheet shows an ordinary B-power unit and the connections which would be made to it if it were to supply only plate potential to the 171A power tube. Sketch B shows the connections if it is to supply C potential as well.

In these diagrams it should be noted that the connection of negative filament from the regular B-minus terminal on the power unit has been changed to the + 45-volt terminal. With this arrangement the + 45-volt terminal then becomes B minus, the plus 90 volt terminal becomes plus 45 and so on, each terminal supplying 45 volts less than it is marked. The regular B-minus terminal is now 45 volts lower in potential than the new B-minus terminal, and, therefore, from the regular B-minus terminal we are able to secure a negative potential of 45 volts which we can apply to the grid of the 171A-type tube. In this way we have, by a simple circuit change, made it possible to obtain C bias for the power tube.

Forty-five volts is slightly higher than normal, but not sufficiently so to affect seriously the output from the tube. This slightly higher than normal bias will help to lengthen the life of the tube.

The arrangement described above can be applied only to those B-power units capable of supplying under load a maximum of about 225 volts. This much voltage is necessary because 180 volts are required on the plate and 45 volts are used to supply C bias. With this arrangement 45 volts are obtained from the tap that normally supplied 90 volts and 90 volts are obtained from the tap that ordinarily supplied 135 volts.



(A) (B)

No. 276 RADIO BROADCAST Laboratory Information Sheet

Simple Two-Way Telephone Set

IN THE country friends who live some miles apart often wish to establish a telephone communication channel without the expense of installing a regular pole line. Lieutenant W. H. Wenstrom, U. S. A., suggests the following simple method of building such a communication system.

As can be seen from the diagram given in Laboratory Sheet No. 277 the set is simplicity itself. It is essentially a radio receiving tube (a 199-type tube is satisfactory) provided with input and output transformers. The best ratios are somewhere around 1:6 for the input and 3:1 for the output. The microphone may be an old, discarded telephone "mike."

Two sets are, of course, required for one communication channel. Due to the economy of apparatus, radiophone practice must be used in operation. A definite time for communication is arranged in advance. At this time "A" calls and "B" listens. When "A" finishes calling, both operators throw their switches, and "B" then answers "A." The procedure might be compared to two unusual people carrying on a conversation where each one politely waits until the other has finished before he himself begins.

Because two stages of audio-frequency amplification are used in the talking circuit, one at the sending end and one at the receiving end, the connecting wire line may be very much poorer than a standard telephone line. Continuous fence wire, or any medium-resistance metal circuit fairly well insulated from the ground may serve as one conductor, with the ground as the other conductor.

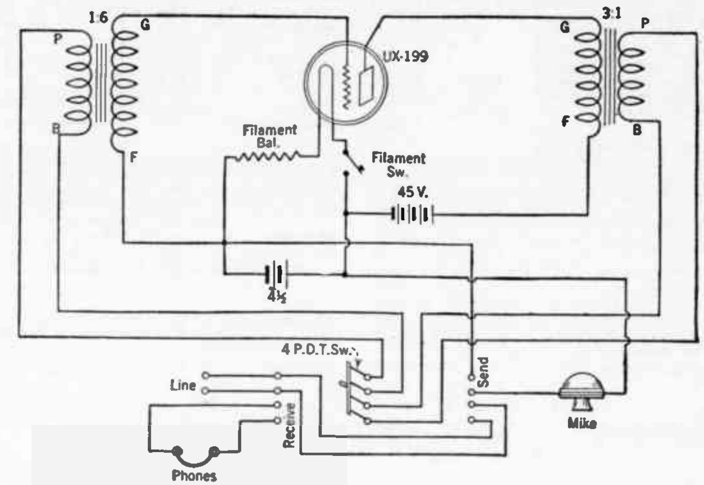
Parts Required

1 Audio transformer, 6:1-ratio
1 Audio transformer, 3:1-ratio. (connected reversed)
1 Four-pole double-throw switch
1 Microphone, telephone-type
1 Pair of headphones
1 199-type tube and socket
A battery, fil. ballast and fil. switch
B battery, 45 volts

The four-pole double-throw switch changes the set from "send" to "receive." It saves expense by permitting the use of the same tube and transformers for both operations.

No. 277 RADIO BROADCAST Laboratory Information Sheet

Simple Two-Way Telephone Set



No. 278 RADIO BROADCAST Laboratory Information Sheet

Inductance-Capacity Products

THE formula for determining the frequency to which a circuit will tune is

$$f = \frac{159,000}{\sqrt{LC}}$$

where f equals the frequency in cycles per second
L equals the inductance of the coil in microhenries
C equals the capacity of the circuit in microfarads

It is evident from this formula that the frequency to which a circuit tunes is not determined by the inductance or the capacity alone but by their product. Tables of LC products are to be found in many textbooks, and in "Laboratory Sheet" No. 279 is given a table of LC products covering the broadcast band. The usefulness of this table will become evident from the following examples.

Example 1: Suppose we have a radio receiver which uses 0.0005-mfd. tuning condensers and which tunes-in a station broadcasting on 525 meters at 100° on the dial, i.e., with the condenser plates all in. What is the inductance of the tuning coils used in the set?

Answer: From the table the LC product for 525 meters is 0.0776. Therefore, L times C equals 0.0776. We know that C is 0.0005. Therefore, 0.0776 divided by 0.0005 gives 155 microhenries as the inductance of the coil.

Example 2: Suppose we wanted to rebuild this set to use 0.00025-mfd. condensers? What would the inductance of the coil have to be? The LC product must remain the same, 0.0776. Therefore, 0.0776 divided by 0.00025 gives 331 microhenries for the coil inductance.

Example 3: The receiver described in example No. 1 will tune down to only 230 meters. Therefore, what is the minimum capacity of the circuit and what must it be reduced to to permit the set to tune down to 200 meters?

Answer: The LC product for 230 meters is 0.01489. From example No. 1 the inductance of the coil is 155 microhenries. Therefore, 0.01489 divided by 155 gives 0.000096 mfd. as the minimum capacity of the circuit. To tune down to 200 meters the capacity must be reduced to 0.01126 (the LC product for 200 meters) divided by 155 microhenries. The quotient is 0.000073 which is the minimum capacity (in mfd.) the circuit must have if the set is to tune down to 200 meters.

No. 279 RADIO BROADCAST Laboratory Information Sheet

Inductance-Capacity Products

THIS table gives the inductance-capacity products to tune to various frequencies throughout the broadcast-frequency band. L is in microhenries and C is in microfarads. The use of the table is explained in "Laboratory Sheet" No. 278.

Meters	f	L × C	Meters	f	L × C
200	1,500,000	0.01126	410	732,000	0.0473
210	1,429,000	0.01241	420	715,000	0.0496
220	1,364,000	0.01362	430	698,000	0.0520
230	1,304,000	0.01489	440	682,000	0.0545
240	1,250,000	0.01621	450	667,000	0.0570
250	1,200,000	0.01759	460	652,000	0.0596
260	1,154,000	0.01903	470	639,000	0.0622
270	1,111,000	0.0205	480	625,000	0.0649
280	1,071,000	0.0221	490	612,000	0.0676
290	1,034,000	0.0237	500	600,000	0.0704
300	1,000,000	0.0253	505	594,000	0.0718
310	968,000	0.0270	510	588,000	0.0732
320	938,000	0.0288	515	583,000	0.0747
330	909,000	0.0306	520	577,000	0.0761
340	883,000	0.0325	525	572,000	0.0776
350	857,000	0.0345	530	566,000	0.0791
360	834,000	0.0365	535	561,000	0.0806
370	811,000	0.0385	540	556,000	0.0821
380	790,000	0.0406	545	551,000	0.0836
390	769,000	0.0428	550	546,000	0.0852
400	750,000	0.0450			

No. 280 — Radio Broadcast Laboratory Information Sheet

Characteristics of the Ear

THE ear is undoubtedly the most commonly used of acoustical devices and the curves on "Laboratory Sheet" No. 281 illustrate a very important and interesting characteristic of the ear. These curves are known as curves of "equal loudness," for each curve shows the pressure required at different frequencies, to produce sounds of equal loudness.

The lowest curve marked "threshold curve" is sometimes called the curve of minimum audibility and it indicates the pressures which will produce sounds *just audible* to the average ear. This curve shows that at minimum audibility the ear varies greatly in sensitivity, at different frequencies. The upper curve, which indicates how the sensitivity of the ear varies with loud sounds, shows the ear to be almost equally sensitive throughout the entire range of frequencies.

These curves have a definite relation to the reproduction of radio programs and indicate why we seem to lose the bass when the volume is cut down very low and why a loud speaker seems to boom (too much bass) when the volume is increased greatly. Sounds must be reproduced at a normal volume level, i.e., that level at which we are accustomed to hear music, if the reproduction is to sound natural. Even though the intensity of all the tones in the music are amplified equally well the curves indicate that a relatively increased effect on the ear will come from the bass portion if the sounds are too loud and a relatively increased effect from the treble if the sounds are too low in intensity.

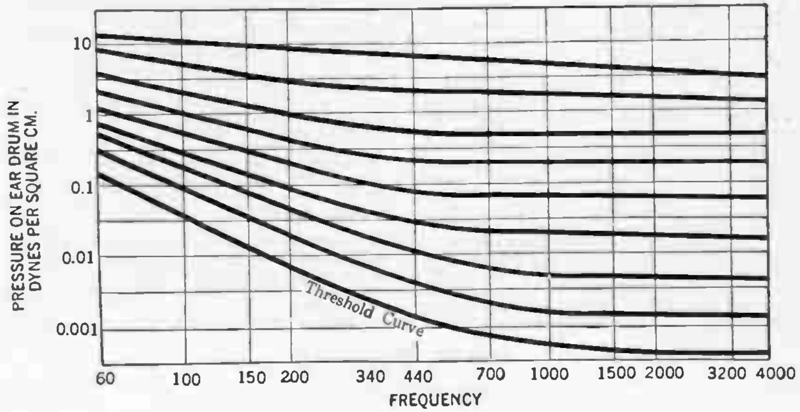
The data from which these curves were plotted was obtained from experiments made in the Bell Telephone Laboratories. The subjects listened to pure tones from a telephone receiver driven by current from an audio oscillator. The listeners compared different tones, two at a time, as to loudness and adjusted the intensity of the two tones so that they were equally loud. All of the apparatus was calibrated carefully and the engineers were able to determine from the setting of the adjustment the sound pressure in dynes per square centimeter.

Some additional data on this same subject will be found in "Laboratory Sheet" No. 109 in the July 1927, issue.

No. 281 — Radio Broadcast Laboratory Information Sheet

Characteristics of the Ear

THESE curves show the sound pressures which, acting on the ear, give sensations of equal loudness. They were prepared from data obtained from experiments made in the Bell Telephone Laboratories.



No. 282 — Radio Broadcast Laboratory Information Sheet

Amplifier Input Circuits

POWER amplifiers such as are coming into prominent use in auditoriums, theatres, dance halls, etc. may be employed to produce entertainment by connecting the input of the amplifier to a regular receiver, by making connections to a phonograph pick-up so that phonograph records may be played, or, in other cases, by connecting a microphone to the input. The amplifier may be used in any of these ways with practically no change in the circuit—the only change necessary is at the input to adapt the circuit to the source from which the signals are to be obtained.

These amplifiers are arranged normally so that they may be used with either a radio receiver or a phonograph pick-up. Appropriate terminals for these two devices form an integral part of the amplifier. In case the amplifier is designed for use only with a radio receiver, a phonograph amplifier may be used readily by connecting the two terminals of the pick-up across the primary of the first a.f. transformer of the amplifier. However, when it is desired to use a microphone at the input of such an amplifier a change is necessary since the microphone requires direct current for its operation and also the microphone is a low-impedance affair whereas the phonograph pick-up and radio receiver have high output impedances. With a microphone it is necessary that a special microphone transformer be used to adapt the impedance of the microphone to the input impedance of a tube. The primary of the microphone transformer should be connected across the microphone and in series with a few dry-cell batteries or a storage battery, the latter being preferable because of its greater capacity. The secondary of the microphone transformer is connected to the grid of the first a.f. amplifier tube. Microphone transformers are made by most of the well-known transformer manufacturers and complete instructions regarding their use can be obtained easily.

It should be realized that the above notes do not apply to all power amplifiers since some of them are equipped with three sets of input terminals so that either pick-up, radio, or microphone may be used. Obviously, the thing to do when purchasing such an amplifier is to decide what is to be used to supply the input signals and to then make certain that the amplifier under consideration is arranged with the proper input connections.

This sheet is the result of several letters received at the Laboratory from readers who have been under the impression that it is possible to obtain good results by simply connecting microphones across the input of an amplifier originally designed for use with a phonograph pick-up unit or radio receiver.

No. 283 — Radio Broadcast Laboratory Information Sheet

Hum-Voltage Characteristics

(226-AND 227-TYPE TUBES)

IT IS becoming increasingly common to find that most recent models of various well-known receivers use 227-type tubes in all the sockets rather than only in the detector socket with 226-type tubes in the r.f. stages and in the first a.f. stage. To explain this trend in receiver design the statement is generally made that 227-type tubes produce less hum than 226-type tubes. This is true—but it isn't an explanation. Why the 227 is a better tube is indicated by the curves on "Laboratory Sheet" No. 284 taken from the *Cunningham Tube Data Book*.

Curve A is for a 226-type tube and shows the relation between the hum voltage in the plate circuit of one of these tubes as a function of the plate current. The minimum hum voltage indicated by this curve is about that obtained from a 226-type tube under normal conditions. If, however, the plate voltage increases or decreases somewhat there is a rapid increase in the amount of hum. If the plate potential were 90 volts and the bias about 6 volts minimum hum would be obtained, but a 10- or 15-volt decrease in plate voltage would double the hum output.

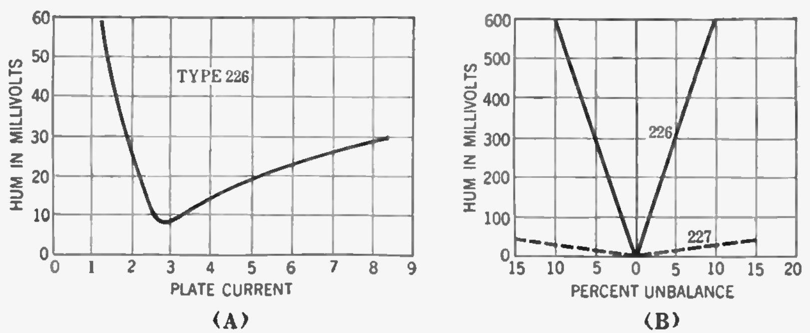
Curve B shows a comparison between the 227- and 226-type tubes with reference to hum. This curve shows hum output as a function of the accuracy of the center-tapped resistor connected across the tube's filament. It should be noted that the 227-type tube is affected only slightly by an unbalance of the center-tapped resistor whereas the 266-type tube necessitates the use of a very accurate center-tapped resistor. Specifically, the curve shows that if the resistor is unbalanced ten per cent. the hum voltage from a 227-type tube is increased very slightly. On the other hand, a ten per cent. unbalance in the resistor across the 226-type tube causes the hum voltage to increase from a minimum of 10 millivolts to about 600 millivolts!

The rather recent improvements in radio receivers—in loud speakers particularly—has made it especially important that everything possible be done to keep the hum output at the lowest possible level. The hum is not only annoying, as of itself, but it also has an apparent effect on the fidelity. When stimulated by a tone such as a hum, it is difficult for the ear to hear other tones of the same or nearly the same frequency and so we get an apparent reduction in low-frequency response. This technically is known as the "masking effect" of one tone on another.

No. 284 Radio Broadcast Laboratory Information Sheet

Hum-Voltage Characteristics

(226-and 227-type tubes)



(A) (B)

No. 285 Radio Broadcast Laboratory Information Sheet

Frequency Vs. Capacity and Inductance

In "Laboratory Information Sheet" No. 286 are given a group of curves indicating what capacity is necessary to tune a circuit to a given frequency when using a coil of known inductance. The curves are applicable to broadcast frequencies and the capacities cover the range of sizes ordinarily used in such receivers.

The curves were calculated by substituting in the formula.

$$f = \frac{159,200}{\sqrt{LC}}$$

where f = frequency in cycles per second
C = capacity in microfarads
L = inductance in microhenries

The curves were calculated for various frequencies between 500 and 1500 kc. A few examples will indicate quite clearly how the curves are used.

Example. What size condenser is necessary to tune to 600-kilocycles with a 200-microhenry coil? To determine this we locate the vertical line corresponding to 200 microhenries and follow it to the 600-kilocycle line and it is found that this point corresponds to 0.00035 mfd. which is the capacity necessary to tune the coils to 500 meters.

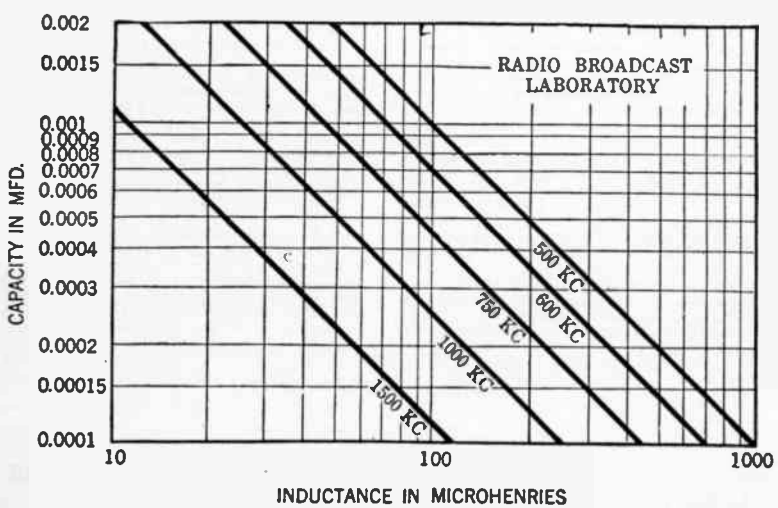
Example. To what frequency will a circuit tune if it consists of a 250-microhenry coil and a 0.0004-mfd. condenser? The unknown frequency in this case is determined by finding the intersection of the vertical line corresponding to 250 microhenries and the horizontal line corresponding to 0.0004 mfd. They intersect at the line corresponding to 500 kilocycles which is the frequency to which they would tune.

Example. How much inductance is required in parallel with a 0.0003-mfd. condenser to tune to 1500 kilocycles? Determine the intersection of the horizontal line corresponding to 0.0003 mfd. with the transverse line corresponding to 1500 kilocycles. The intersection is found to fall on the vertical line corresponding to 38 microhenries which is the required value of the coil's inductance.

If it is desired to make calculations of inductance, capacity, or frequency for values above or below the broadcast bands, the formula given at the beginning of the sheet may be used. It is simply necessary to substitute the known quantities and solve for the unknown.

No. 286 Radio Broadcast Laboratory Information Sheet

Frequency Vs. Capacity and Inductance



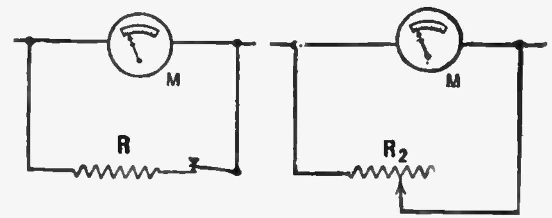
No. 287 Radio Broadcast Laboratory Information Sheet

Protecting Meters

Several Readers have written us and requested suggestions on how to protect a milliammeter in a set-tester or tube-tester from damage in case there is a defect in the circuit of the device being tested which would permit sufficient current to flow through the meter to damage it.

The simplest way of protecting the meter is by the use of the arrangement indicated in sketch A on this sheet. M is the meter to be protected and it is protected by the shunt circuit consisting of R and the switch S. The switch, S, is the type which is usually used as a voltmeter switch; it normally remains in a closed position and must be held in the open position by hand. The resistance, R, should have a value such that, with the switch closed and maximum rated current of the meter flowing through the circuit, the meter gives a very small deflection. For example, suppose that the meter had a range of 10 milliamperes. The procedure would be to pass 10 mA. through the meter so that the meter read a maximum and then to place across the meter a resistance such that the meter deflection decreased to, say, 0.5 mA. Now when we use the instrument in which the meter is located we first note the reading of the meter with the switch closed (its normal position) and if the meter reads more than 0.5 mA. we will know that excessive current is flowing through the circuit and the meter will be overloaded if the switch, S, is opened. If the meter reads less than 0.5 mA. it will be safe to open the switch.

Another good method of protecting a meter is by the circuit arrangement in B. In this sketch R_2 is a rheostat with a resistance of about 10 ohms. The procedure here is to start with the arm at the right and then to move gradually the arm to the left end. If as this end is approached the meter needle goes off scale it is an indication that current in excess of what the meter can read is flowing through the circuit.



(A) (B)

No. 290 RADIO BROADCAST Laboratory Information Sheet

FILTER CIRCUIT DATA

IN "LABORATORY SHEETS" Nos. 258 and 259 some data were given on filter circuits showing the effect on the regulation, output voltage, and tube load when using and when not using a choke at the input to the filter system. Similar data will be found in Roger Wise's article "Characteristics of Power Rectifiers" in the April, 1929, RADIO BROADCAST. Several readers have written us to the effect that they have not been able to duplicate these curves when using a choke in the input. Some have obtained greater and others less output voltage than was indicated by the curves in "Laboratory Sheet" No. 259.

This discrepancy between the values we gave and that readers have obtained is undoubtedly due to the use of a different size choke coil in the input than was used to obtain the curves on Sheet No. 259. For these curves a standard filter choke of some 30 henries was used. The output voltage, of course, is greatest when there is no choke coil connected in the input and will decrease when a choke is placed at the input. The greater the inductance of the choke, the greater the decrease in output voltage. Those experimenters who obtained greater voltages than the curves indicated probably used an input choke of low inductance and those that obtained smaller voltages used a choke of high inductance.

It could appear from these considerations that a small choke should be used but it should be remembered that the primary reason for the use of choke input circuits is to reduce the instantaneous load on the rectifier tubes so that their life will be a maximum. With chokes of low inductance this desirable effect of reduced load on the tube is not obtained to any considerable degree. In designing such systems a compromise must, therefore, be reached between the use of a large choke giving a good tube load characteristic and a small choke giving a less desirable load characteristic but greater output voltage (assuming that the transformer input voltage is not changed.)

No. 291 RADIO BROADCAST Laboratory Information Sheet

VOLTAGE-DOUBLING CIRCUITS

IN CASES WHERE there is need of a plate-supply device delivering greater voltages than can ordinarily be obtained from the usual type of rectifier tube, such as the type 281, it is possible to use these tubes in "voltage-doubling" circuits. Two circuits together with their regulation characteristics are given on Laboratory Sheet No. 292. Although the 281-type rectifier in ordinary circuits can supply only about 600 volts to the filter system it should be noted that when using these special circuits it is possible to obtain an input to the filter of approximately 1600 volts.

The circuit shown at A is probably the more familiar type of voltage-doubling connection. As indicated by the curves the voltage regulation is rather poor but, when only small amounts of current are to be drawn from the system, this circuit can be used and has the advantage that it requires but little apparatus.

Improved results can be obtained from the circuit shown at B. With this arrangement four rectifier tubes are used in a full-wave system supplied from a center-tapped transformer having a secondary potential of from 500 to 700 volts a.c. either side of the center tap. Two separate transformers, each supplying from 500 to 700 volts might, of course, be used. The curves for this rectifier system show it to have much better regulation than that obtained from the circuit in Sketch A. With circuit B a maximum current of up to 170 milliamperes can be drawn from the filter system.

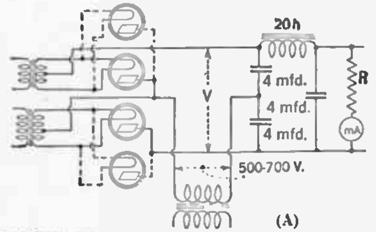
The disadvantage of circuit B over circuit A is that the former requires three separate filament windings each of which must provide the full output voltage.

The first filter condensers in these circuits must be capable of withstanding a potential of one half the load voltage. The second condensers must, of course, be able to withstand the full load voltage. The filaments of the tubes should be turned on before the high-voltage winding is closed. If this is not done, the initial charging current may overheat the tubes or cause them to arc over. Across the output of the filter systems resistors should be connected as indicated at R. In general a 100,000-ohm resistor may be used and it should be capable of carrying some 20 milliamperes. This resistor is especially necessary when using circuit A since, with this arrangement, the voltage tends to increase quite rapidly when the load is less than 20 milliamperes.

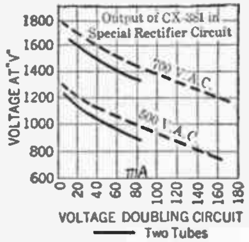
The data for this "Laboratory Sheet" were supplied by E. T. Cunningham, Inc.

No. 292 RADIO BROADCAST Laboratory Information Sheet

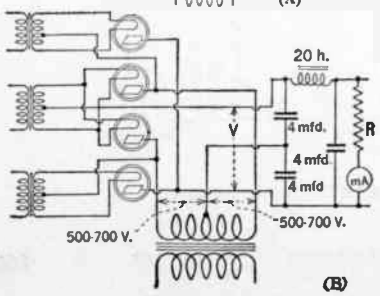
VOLTAGE-DOUBLING CIRCUITS



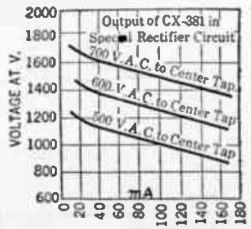
(A)



VOLTAGE DOUBLING CIRCUIT
— Two Tubes
– – – Four Tubes



(B)



FULL WAVE VOLTAGE DOUBLING CIRCUIT

No. 293 RADIO BROADCAST Laboratory Information Sheet

REGENERATIVE R. F. AMPLIFIERS

RADIO-FREQUENCY amplification may be obtained by the use of carefully designed r.f. circuits or by the use of carelessly designed circuits with regeneration. Many of the sets made a few seasons ago had considerable inherent regeneration in them, not because circuits to prevent regeneration were not known, but because the sets were not properly designed. The tendency to-day is to design the set so that without any regeneration the gain and selectivity are satisfactory. If an engineer relies on regeneration in a receiver to give it gain, it is generally found that in the mass production of the set in the factory it is not possible to control the set's characteristics closely enough to give just the right amount of regenerative amplification. As a result in production some of the sets will be found to oscillate while others will not have sufficient regeneration and will be practically dead. This is perhaps one of the major reasons why regeneration is being used less and less in manufactured sets.

There is one time, however, when the use of regeneration to increase the gain and the selectivity might be considered the best thing to do. This case arises in the servicing of an old receiver that has poor gain and poor selectivity. Such a set would be improved greatly by the use of some regeneration, and, since the serviceman who changes the circuit to give it some regeneration can introduce *just* enough in this *particular* set to provide satisfactory performance, there is little difficulty involved in its use.

Regeneration can be added most readily to an existing receiver by the use of one of the circuits indicated on Laboratory Sheet No. 294.

In Sketch A regeneration has been added by winding a coil (No. 32 or smaller wire) around the filament end of the secondary, L_1. The number of turns should be the maximum that can be used without causing the set to oscillate.

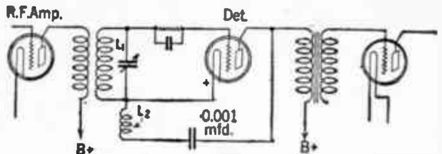
In Sketch B a small variable condenser, C_1—for example, a neutralizing condenser—is connected between the plate of the detector and the plate of the preceding r.f. amplifier tube. The capacity should be adjusted to the maximum possible without making the detector oscillate.

In Sketch C regeneration is secured by tapping the secondary, L_4, as indicated and connecting a small variable condenser (maximum capacity about 0.0001 mfd.) between the lower end of the secondary and the plate of the detector.

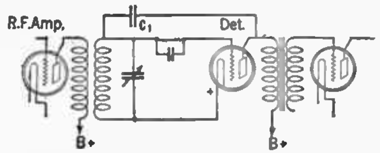
Arrangement B is generally the most convenient although in some cases it may be simpler to use the circuits of A or C.

No. 294 RADIO BROADCAST Laboratory Information Sheet

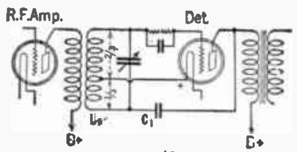
REGENERATIVE R. F. CIRCUITS



(A)



(B)



(C)

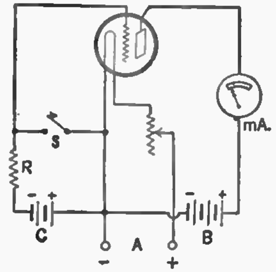
No. 295 RADIO BROADCAST Laboratory Information Sheet

TUBE-TESTING CIRCUITS

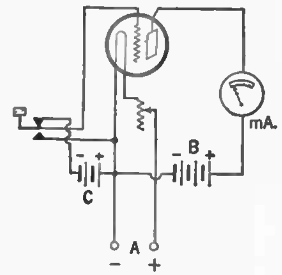
MANY COMMERCIAL tube-testing devices are equipped with a button which is used to determine whether or not the particular tube being tested is up to standard. Generally the procedure is to place the tube in the socket, read the plate current, then press the button, and again read the plate current. Then it is possible to determine from these two readings whether or not the tube is any good.

Just how this circuit functions should be of interest. The arrangement described below may not be the one actually used in some of the testers but the principles are certainly the same. When a tube is placed in the socket (see the sketch A on this sheet) the plate current as read on the plate milliammeter depends upon the plate voltage and upon the C-bias voltage. With the switch, S, which represents the button, in the open position, the bias is equal to the voltage of the C battery. When, however, the button is pressed the bias is reduced to zero. This change in bias, of course, produces a change in plate current and the amount of change determines how good the tube is. What we are actually doing is determining the mutual conductance of the tube by noting the change in plate current obtained from a given change in C bias.

This circuit, it should be pointed out, indicates only one of the many possible arrangements. Another arrangement, for example, would be to make S a single-pole double-circuit switch (sketch B) so that in one position the bias is zero and in the other position it has a value equal to that of the C-battery voltage.



(A)



(B)

No. 296 RADIO BROADCAST Laboratory Information Sheet

Output Transformer Ratios

SOME INTERESTING curves which were published in a recent bulletin issued by the Ferranti Company are given on "Laboratory Sheet" No. 297. These curves show the transformer turns ratio necessary for use with power tubes of different plate impedances when used with dynamic loud speakers of various impedances. The chart covers tube impedances up to 15000 ohms and loud speaker impedances up to 55 ohms.

The charts are calculated on a basis that the tube is to work into an impedance equal to twice its own impedance. That is, for example, a tube with an impedance of 4000 ohms should work into an 8000-ohm load. Transformer ratios for output circuits are always calculated under this condition and the chart ought to prove quite useful.

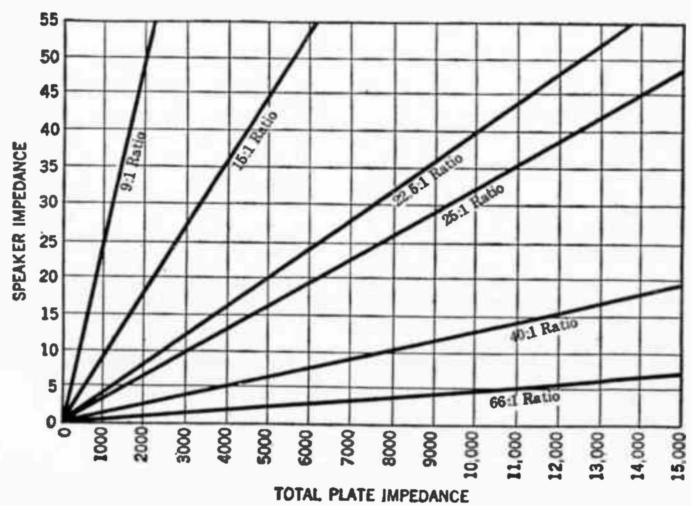
The required ratio of a coupling transformer is determined by taking the square root of twice the tube impedance divided by the loud speaker impedance. Expressed as a formula, the turns ratio of the transformer is equal to

$$T = \sqrt{\frac{2\,R_P}{R_L}}$$

where Rp is the plate resistance of the tube
RL is the impedance of the loud speaker
T is the required turns ratio of the transformer

As an example, suppose we have a loud speaker with an impedance of 40 ohms and that we were going to supply it from a push-pull stage using two tubes each with a plate impedance of 5000 ohms. Substituting in the above formula we obtain approximately 22.5 as the required turns ratio. Checking this on the curves we find that the line corresponding to 40 ohms and the line corresponding to 10,000 ohms (two 5000 ohm tubes in push-pull give a total impedance of 10,000 ohms) intersect at a point corresponding to the line giving a ratio of 22.5:1 which checks our calculation.

No. 297 RADIO BROADCAST Laboratory Information Sheet



No. 298 RADIO BROADCAST Laboratory Information Sheet

Circuits for the 245-type Tube

MOST OF the new radio receivers are using audio power amplifiers which employ either one or two 245-type tubes, the tubes being arranged in push pull when two are used. Because of the wide use of this tube we give on this sheet and sheet No. 299 some data on the various circuit arrangements generally used with the 245.

CIRCUIT A

Two 245-type tubes are indicated in circuit A on "Laboratory Sheet" No. 299. The plate voltage required is 300 volts, 250 of which is impressed on the plate of the tube and the remaining 50 supplying the necessary C bias. The filament is shunted by the 10-ohm resistance. The C-bias resistance is calculated by dividing the required C bias, 50 volts, by the plate current, 32 milliamperes, and dividing by two since there are two tubes. This calculation shows that the C-bias resistance should have a value of 750 ohms as indicated.

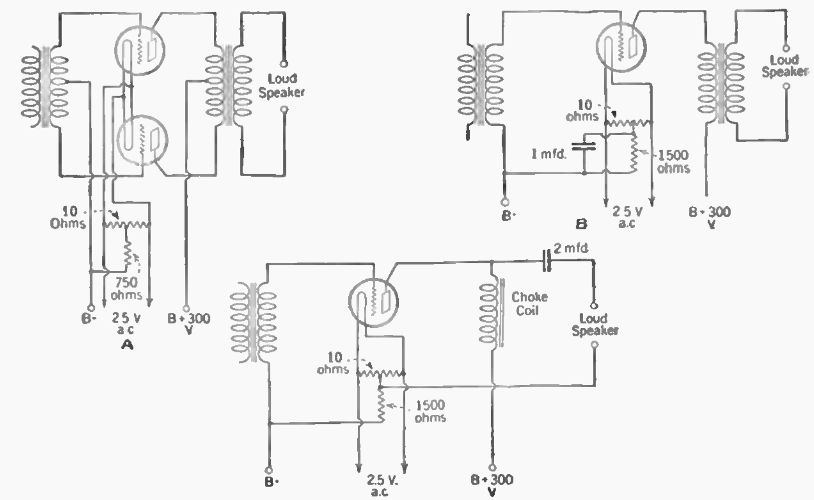
CIRCUIT B

This circuit shows a single 245-type tube with transformer output. The required plate voltage is 300 volts and the C-bias resistance is 1500 ohms. Since the a.c. current in the plate circuit must flow through the C-bias resistor to get to the filament, it is essential that the resistor be bypassed with a condenser of 1 or 2 mfd. The output transformer may be an ordinary one with a ratio of about 1:1, or it may be the transformer which couples the tube to the moving-coil system of a dynamic loud speaker, in which case, of course, it should have a step-down ratio.

CIRCUIT C

This arrangement is similar to that indicated at B except that a choke condenser output is used. With this arrangement d.c. current is kept out of the primary of the loud speaker or coupling transformer if one is required. Since one of the loud speaker terminals returns directly to the center-tapped resistor connected across the filament, it is not essential that any condenser be connected across this resistance.

No. 299 RADIO BROADCAST Laboratory Information Sheet



No. 300 RADIO BROADCAST Laboratory Information Sheet

Center-Tapped Filament Resistors

SEVERAL READERS have written us requesting information on what determines the value of the center-tapped resistance connected across the filament of an a.c. tube. In some cases it is apparently felt that this resistance must have a definite value in order to produce a definite load on the transformer secondary supplying the filament. This is seldon, if ever, the case, however.

No hard and fast rules can be given for the value of the resistance used across the filament. In fact a wide range of resistances can be used with equally good results. The important point to consider is the resistance of the filament across which the center-tapped resistor is to be connected and to make sure that the latter's resistance is fairly high in comparison with that of the tube. For example, if a tube filament has a resistance of 1 ohm then the total resistance of the center-tapped resistor should be at least 10 ohms and might well be higher. Never use a center-tapped resistor of an ohmage comparable to that of the tube across which it is to be connected.

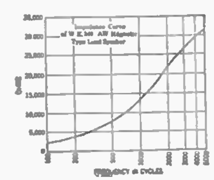
One other factor is of some importance, especially in connection with the resistors placed across the filaments of power tubes. C bias for these tubes in a.c. sets is obtained by means of an additional resistor whose value is equal to the C-bias voltage required divided by the plate current of the tube. Actually, however, the center-tapped resistor also supplies some of the bias for the current in returning to the filament must flow through both halves of this resistance. In effect, therefore, the plate current flows through a resistor equal to one half the total value of the center-tapped resistance, since both halves of it are in parallel from the standpoint of the plate current. In calculating required values of C-bias resistance, it is wise, therefore, to substract from the calculated results one half the value of the center-tapped resistance. For example, two 171A tubes in push pull draw 40 milliamperes and require a bias of 40 volts. The value of the C-bias resistor should, therefore, be 1000 ohms. If, however, a 200-ohm center-tapped resistor (values as high as this are frequently used) is placed across the filament of the tube, one half of this value (100 ohms) should be subtracted from the required 1000 ohms leaving 900 ohms. This value should then be used for the C-bias resistor.

No. 301 RADIO BROADCAST Laboratory Information Sheet

Output Transformer Ratios

OUTPUT transformer ratios required for use with cone or horn type loud speaker are shown on the chart on Sheet No. 302. This chart, reproduced from a recent bulletin of Ferranti, Inc., covers the range of loud speaker impedances from 0 to 6500 ohms and tube impedances from 0 to 15,000 ohms. On Sheet No. 297 in the Sept., 1929, issue, a chart was given of output transformer ratios for use with moving-coil type loud speakers.

In the case of horn and cone type loud speakers the bulletin suggests that the impedance used in determining the transformer ratio should be the impedance of the loud speaker at about 200 cycles. The impedance at this frequency may with fair accuracy be taken as 2.5 times the d.c. resistance of the winding. That is, a loud speaker with a d.c. resistance of 2000 ohms has an impedance at 200 cycles or approximately 2000 times 2.5 or 5000 ohms.



Owing to the fact that the impedance of cone type loud speakers frequency varies from 1000 to 30,000 ohms between 200 and 5000 cycles, ideal results are not possible but transformer ratios determined as indicated above will give best results. As an example of the manner in which the impedance of a magnetic loud speaker varies we show on this sheet an impedance curve the Western Electric 540 AW.

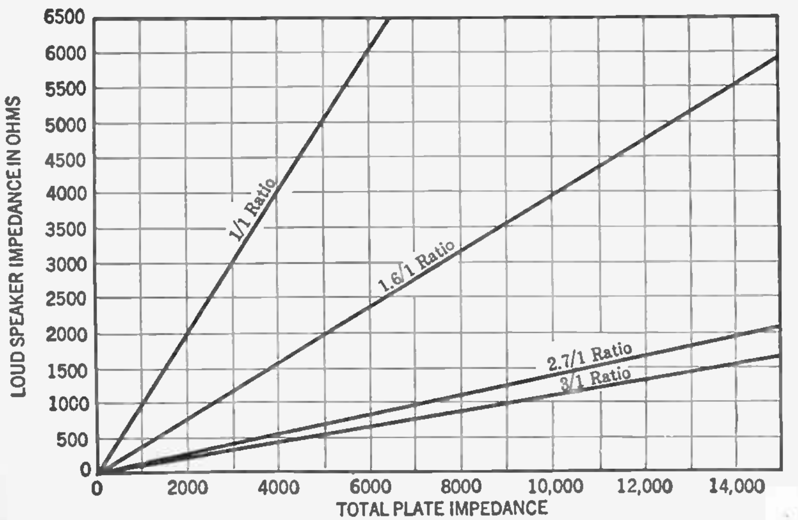
An example will help to make perfectly clear the use of the chart on sheet No. 302.

Example 1. A loud speaker has an impedance of 4000 ohms at 200 cycles. It is to be used in a push-pull circuit using two tubes each with a plate impedance of 5000 ohms. What transformer ratio is required?

Two 5000-ohm tubes in push-pull give a total impedance of 10,000 ohms. Referring to the chart we find the horizontal line corresponding to a loud speaker of 4000 ohms impedance intersects the vertical line corresponding to a tube impedance of 10,000 ohms at a point corresponding to a transformer ratio of 1.6 to 1.

No. 302 RADIO BROADCAST Laboratory Information Sheet

Output Transformer Ratios



No. 303 RADIO BROADCAST Laboratory Information Sheet

"Power" and "Linear" Detection Explained

POWER detection" and "linear detection" are two terms frequently used to describe certain characteristics of new receivers. On this sheet we explain briefly what these two terms mean.

A power detector (according to the popular definition) is one operated at fairly high values of input voltage. Power detectors are frequently followed by a single stage of audio frequency amplification because sufficient a.f. voltage can be obtained from them to load up a power tube. It should be realized, however, that power detectors are not always followed by single audio stages but may be followed by a two-stage audio amplifier. The important factor is the signal level at which they operate. Accurately defined, however, the power detector is one from which sufficient power may be obtained to operate a loud speaker directly.

Ordinary detectors operate on what is called a "square law," that is the a.f. output voltage is proportional to the square of the r f. input voltage. Such detectors produce some distortion especially if the r.f. input is modulated at fairly high percentages. The distortion reaches a maximum of 25 per cent. when the input signal is modulated 100 per cent. The present tendency in broadcasting is to increase the modulation to 100 per cent. so as to utilize as completely as possible the output of the transmitter. Linear detectors will produce very little distortion on 100 per cent. modulated signals and it is for this reason that this type of detector is increasing in use.

A detector is "linear" when its a.f. output is directly proportional to the r.f. input. Such detectors produce a distortion of about 10 per cent., with 100 per cent. modulated signals in comparison with the 25 per cent. distortion produced by square-law detectors. The decreased distortion (from 25 to 10 per cent.) due to the linear detector is readily noticeable to the ear.

It should be pointed out that the fact that the detector operates at high signal levels does not necessarily mean that it is linear. C-bias detectors are linear over only a small portion of their operating characteristic.

No. 304 RADIO BROADCAST Laboratory Information Sheet

Distributed Capacity Measurements

THE method commonly used in laboratories to determine the distributed capacity of a coil is to tune it to various wavelengths by means of a condenser and then plot a curve of wavelength squared against the capacity of the tuning condenser. The curve will be a straight line but will not pass through zero because of the distributed capacity of the coil. If the curve is extended so that it intercepts the line corresponding to zero wavelength, the intercept will give the distributed capacity of the coil. The method is simple and quite accurate provided the individual measurements are carefully made. If, however, there are slight discrepancies in the various measurements it is necessary to estimate as accurately as possible the correct position for the curve.

There is another method of graphically determining the distributed capacity which is not generally used but which is sometimes more accurate than the one described. This second method is illustrated on "Laboratory Sheet," No. 305.

The general method of procedure is similar. The coil to be measured is connected across known capacities and the resonant wavelength is determined. Some sample data is given below:

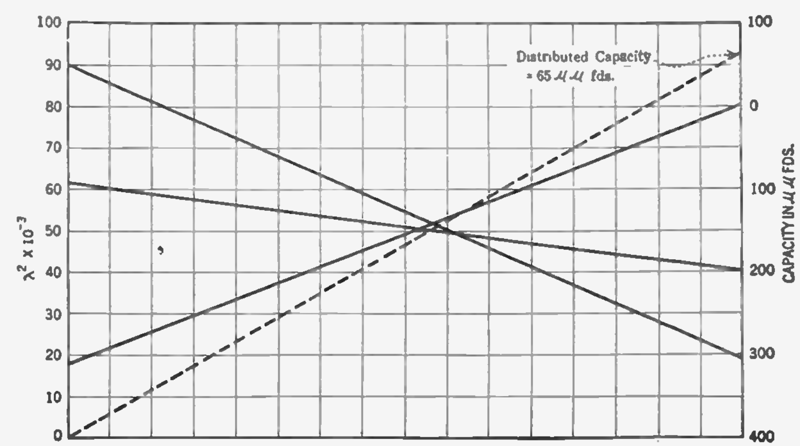
WAVELENGTH	CAPACITY TO TUNE TO RESONANCE-MMFD.
300	315
247	200
134	0

The next step is to lay out a curve sheet as shown on "Laboratory Sheet" No. 305. The left-hand axis is wavelength squared and the right-hand axis is the tuning capacity in micromicrofarads. Straight lines are now drawn being the various values of tuning capacity and the corresponding values of wavelength squared.

If all the measurements were perfect, these various straight lines would all intersect at a common point but because of slight inaccuracies they do not. As a result there is formed at the center a small polygon. The center of this polygon must now be estimated and between the center and the point corresponding to zero wavelength a straight line is drawn. This line will intersect the capacity axis at the point corresponding to the distributed capacity of the coil. This latter line is shown dotted on the curve.

No. 305 RADIO BROADCAST Laboratory Information Sheet

Distributed Capacity Measurements



No. 306 Radio Broadcast Laboratory Information Sheet

Advantages of Automatic Volume Control

THE use of automatic volume controls in receivers has certain definite advantages. The most obvious advantage is, of course, that such a control definitely determines the output of the receiver and maintains this output constant over wide variations in field intensity. Ordinarily as we tune from one local station to another the volume varies considerably, depending upon the field strength obtained from the station, but in a set equipped with an automatic volume control, all stations will give approximately the same volume.

The second advantage of an automatic volume control is that it helps to some extent to reduce the effects of fading, since, as the signal begins to fade, the sensitivity of the set automatically begins to increase and in this way partially compensates the fading.

A third advantage of this control system, is that by its use it is possible to apply an input to the detector tube of a definite value of r.f. voltage. The set may be so designed that with this value of voltage applied to the detector, the distortion produced in the detector circuit will be a minimum. The distortion ordinarily produced in detector circuits is a function of input voltage. It is high for small values of input voltage and also for very large values of input voltage. At some medium values determined by the operating voltages of the detector tube, the distortion will be a minimum and it is of course advisable to operate the detector tube always under the conditions for minimum distortion.

These three advantages are responsible for the greatly increased use of automatic volume control systems and it is probable that in the future their use will become quite general.

The automatic volume control tube generally works on the output of the r.f. amplifier and it automatically functions to control the output of the r.f. amplifier by varying its sensitivity. When the field strength is very high, the volume control tube causes a large reduction in the sensitivity of the amplifier and when the field strength is very low the tube functions to maintain the radio frequency amplifier at maximum sensitivity.

No. 307 Radio Broadcast Laboratory Information Sheet

Frequency-Band Requirements

ON SHEET No. 308 is reproduced a chart taken from an article by B. S. Cohen in the March, 1928, *Proceedings of the Institute of Electrical Engineers*, London. The chart shows eleven octaves of sounds. According to this chart we find that the

(a) Ideal frequency range for perfect speech and music and most noises is 30 to 10,000 cycles

(b) Reproduction of high-quality speech and music requires a frequency band from 100 to 5000 cycles

(c) Reproduction of good quality articulate speech requires a frequency band from 200 to 3000 cycles

Considering the reproduction of music, on reference to the chart it will be noted that the highest note of the organ, C[8], has a frequency of 8000 cycles so that if the ideal band extends to 10,000 cycles little or no deviation from a sinusoidal wave form would be included. However, the extreme upper notes of the organ or piano are used very infrequently and the correct reproduction of their timbre is probably not important. It is doubtful whether many persons could differentiate between say a piano, flute, and clarinet when listening only to the signal note C[8].

Although in the case of speech, the ear will reconstruct the fundamental frequency of a tone when the latter has been removed from the reproduction it is doubtful that the same thing applies in the case of music. In any case the practically pure sinusoidal frequencies produced for example by the organ would not be produced at all if below the lower transmission limit.

For the correct reproduction of noises such as tapping, hissing, etc. a very wide frequency range is required and it is in this connection that the ideal range of 30 to 10,000 cycles would probably be found most essential.

Attention should be drawn to one other point in the chart. The mean speech frequency from an articulation standpoint is 1500 cycles. By this it is meant that the removal of all frequencies above 1500 cycles produces the same decrease in articulation as does the removal of all frequencies below 1500 cycles.

The term "Gamut" in the chart on sheet No. 308 is simply the expression used in music for the standard notes of the musical scale.

No. 308 Radio Broadcast Laboratory Information Sheet

NOTE	CYCLES PER SECOND	ORGAN PIPE	REMARKS
C^8	32,768		Beyond limit of audibility for average person.
C^7	16,384		Telephone silent with 40 volts on receiver terminals.
	10,000		Considered ideal upper limit for perfect transmission of speech and music.
C^6	8 192	$\frac{3}{4}$ in	Highest note on fifteenth stop.
	5 000		Considered as satisfactory upper limit for high quality transmission of speech and music.
C^5	4 096		Highest note of pianoforte.
E^4	2 560		Approximate resonant point of ear cavity.
G^4	3 072		
	3 000		Considered as satisfactory upper limit for good quality transmission of speech.
C^4	2 048		
	2 000		Maximum sensitivity of ear.
	1 500		Mean speech frequency from articulation standpoint.
A^2	850		
Ab^2	800		Representative frequency telephone currents.
E^2	600		
A^1	$426\frac{2}{3}$		Orchestral tuning. See note below.
C^1	256		
	200		Considered as satisfactory lower limit for good quality transmission of speech.
C^0	128		
	100		Considered as satisfactory lower limit of high quality transmission of speech and music.
E_0	80		Lower note of man's average voice.
C_0	64	8 ft.	Lowest note of 'cello.
B_1	60		
C_1	32	16 ft.	Lowest note of average church organ.
	30		Considered ideal lower limit for perfect transmission of speech and music.
A_2	27		Lowest note of pianoforte.
G_2	25		
C_2	16	32 ft.	Lowest audible sound. Longest pipe in largest organ.

Notes of the "Gamut"	C	D	E	F	G	A	B	C
Vibration frequencies proportional to	1	$\frac{9}{8}$	$\frac{5}{4}$	$\frac{4}{3}$	$\frac{3}{2}$	$\frac{5}{3}$	$\frac{15}{8}$	2
Intervals between successive notes		$\frac{9}{8}$	$\frac{10}{9}$	$\frac{16}{15}$	$\frac{9}{8}$	$\frac{10}{9}$	$\frac{9}{8}$	$\frac{16}{15}$

NOTE:– Nearest note is indicated. Scale based on Middle C^1 (Physical Pitch) = 256 ~

No. 309 Radio Broadcast Laboratory Information Sheet

Volume *vs.* Fidelity

PARTICULARLY when reproducing music, the volume of the reception has quite a little to do with the naturalness of the reproduction. The loudness of the sounds influences the fidelity in two ways as explained in the following paragraphs.

In the first place, we should realize that we are accustomed to listen to different types of music—symphonies, jazz, string trios, etc.—at definite levels of volume. If we adjust our set so that the music is not reproduced at a volume of approximately the same level to which we are accustomed, then the reproduction will sound unnatural—in fact, it is unnatural. If we increase the volume so a soloist sounds like an entire orchestra, or decrease the volume so that the boom of the base drum sounds like someone tapping the table with a pencil, we have certainly distorted the original. For most natural reproduction the volume level must appear to the ear to be about the same as the original. The fact that we never increase the volume to such a level because we couldn't tolerate so much sound in a single room, and because we don't want to annoy our neighbors, does not invalidate the argument.

The second manner in which the reproduction of music at other than normal volume affects the naturalness of the sound is due to the characteristics of the ear. At low volume levels the ear is quite insensitive to high and low audio frequencies but as the volume level is raised the sensitivity of the ear becomes more uniform over the entire range of audio frequencies. The effect of this variation in the characteristic of the ear is such as to cause an apparent loss of low frequencies when the volume is turned down. This probably explains why a loud speaker seems to lose the lows when the volume is turned down—a point about which many experimenters have written us. Probably in almost all cases the loss of lows at low volume is not due to the characteristics of the loud speaker but is simply due, as indicated above, to the characteristics of the ear of the listener.

No. 310 RADIO BROADCAST Laboratory Information Sheet

Factors Considered in Receiver Design

IN THE DESIGN of a radio receiver certain factors must be considered in order to determine the circuits to be used. Some of these important factors are:

1. The limiting values (maximum and minimum) of the field strength from the transmitting station.
2. The output obtained from the antenna at a given field strength.
3. The power output required from the receiver.
4. The r.f. frequency band to be received.
5. The a.f. frequency band to be amplified.
6. The nature and strength of the interference from other radio transmitters and from noise.
7. The selectivity required to permit the satisfactory reception of the desired signal and the elimination of all undesired signals.
8. The stability of the frequency transmission characteristic and the gain of the receiver.

With these facts decided, it is possible to proceed with the design and to determine how much r.f. and a.f. amplification is required, how selective the r.f. circuits must be, and what type of audio-frequency output circuit must be used to supply power to the loud speaker.

In the design of broadcast receivers the tendency has been toward the building of stable, high-gain r.f. amplifiers that are able to deliver sufficient voltage to the detector for satisfactory output at field strengths in the order of 1 to 10 microvolts per meter. This represents a very high order of sensitivity and it is probable that the average noise level in many locations is of the same order or greater than the above field strengths, thereby making it of no advantage to endeavor to increase further the gain of the r.f. amplifier since this would simply result in an excessive ratio of noise to signal.

No. 311 RADIO BROADCAST Laboratory Information Sheet

Effect of Reflection and Echos

IN CONTEMPLATING the subject of fidelity in its relation to the problem of loud speaker reproduction there are many factors to be considered. In this connection one of the most important considerations is the condition under which the loud speaker is to be operated, whether it is to be operated in the open, in a large room with heavy drapes, in a room practically bare of furnishings, etc., for it should be realized that the naturalness of the reproduction will depend to a large extent upon these conditions.

When a loud speaker is operated in a room there is a certain amount of reflection of sound from the walls and standing waves are also generated. Both of these factors cause a change in response depending upon the position of the listener in the room. At one point we might hear a very intense sound at some particular frequency but, upon moving but a step or two away, the intensity of the sound will markedly decrease. If the loud speaker is supplied with a single-frequency tone this effect will be quite noticeable but it is not as effective in producing a definite audible change in intensity when listening to music. In music or speech the frequency changes so rapidly that the effects of standing waves are not especially noticeable, if at all.

From the above remarks it should not be thought that the effects of reflection and echoes are always detrimental. In many cases a certain amount of echo effect improves the reproduction, adding an effective vastness and a richness to the tones which would otherwise be lacking.

It is frequently the case that the naturalness of the reproduction is greater if one listens in some room adjacent to the one in which the loud speaker is located, and if possible it is frequently advisable to locate the loud speaker in some room other than that in which one ordinarily sits when listening to a program. In such a case the increased naturalness is probably due to the effect of the reflection and echoes which occur.

No. 312 RADIO BROADCAST Laboratory Information Sheet

Measurements of Sensitivity

IT IS BECOMING quite common to read statements to the effect that a certain receiver has a sensitivity of so many microvolts per meter. As this method of rating the sensitivity of receivers is becoming so popular, in this "Laboratory Sheet" we indicate exactly what this term means.

When a receiver is to be measured for sensitivity it is generally done in the following manner. A receiver is set up and a resistor is connected across the a.f. output circuit of the set. This resistor has a value such as to give maximum power output per volt on the grid of the power tube. In most cases the resistor will have a value equal to twice the plate resistance of the output tube.

The next step is to apply to an artificial antenna a known r.f. voltage modulated 30 per cent. at 400 cycles and to increase the r.f. input voltage until 50 milliwatts of audio-frequency power is developed across the output resistance. We then determine the magnitude of the input r.f. voltage required to produce this output by dividing by the effective height of the artificial antenna which is usually four meters. This gives us the microvolts per meter input required to produce the standard output of 50 milliwatts.

Assuming that such a method is used in determining the sensitivity of the set, it is simply necessary to give the microvolts per meter input for standard output in order to define completely the sensitivity of the receiver. We can, therefore, say, for example, that a certain set has a sensitivity of 10 microvolts per meter. This means that if a thirty per cent. modulated r.f. signal is impressed across the input, then 50 milliwatts of power will be developed in the output at 400 cycles.

During the past few years there have been remarkable improvements in r.f. amplifier circuits and as a result receiving sets to-day are much more sensitive than past models. Whereas a sensitivity of 50 or 100 microvolts per meter was not uncommon during past seasons, more recent receivers have a much higher sensitivity, in many cases being of the order of 3 or 5 microvolts per meter.

In many sets the sensitivity varies widely over the broadcast band, generally being low at low frequencies and high at high frequencies. This is a disadvantage which is gradually being overcome and sets are being produced which have a more uniform high sensitivity throughout the entire broadcast wave band.

No. 313 RADIO BROADCAST Laboratory Information Sheet

Fidelity in Radio Receivers

RADIO ENGINEERS, in rating the performance of radio receivers, now make use of three terms, sensitivity, selectivity, and fidelity. These three factors completely define the essential characteristics of a set and make it possible to compare readily one set against another.

Sensitivity is determined, as explained in "Sheet" No. 312, by impressing an r.f. voltage on the input of the set, of a value such that normal output—50 milliwatts—is obtained. In this sheet we explain the meaning of the term fidelity and explain briefly how it is measured. "Laboratory Sheet" No. 314 gives similar data on selectivity.

Fidelity is the term used to indicate the accuracy of reproduction, at the output of a radio receiver, of the modulation impressed on the r.f. signal applied to the input of the receiver under test. A receiver having perfect fidelity would be one in which the form of the output current was exactly similar to the form of the current used to modulate the r.f. signal. Fidelity is determined by setting up the receiver to be tested and impressing on its input an r.f. signal modulated at 30 per cent., the input signal having a value such that normal output is obtained. The frequency of the modulating signal is then varied (the modulation being held constant) over the entire audio-frequency band and the output power at each frequency is noted. From these data a curve can be plotted showing how the audio-frequency output power from the set varies with frequency.

Such curves are run at various radio frequencies—say 600, 1000, and 1500 kc.—in the broadcast band so that the variation in fidelity can be determined. In this way we can tell something regarding the characteristics of the r.f. amplifier system, for if the system tunes too sharply at some point in the broadcast band the sidebands will be suppressed partially and this will show up on the curve which we plot as a falling off in response at the higher audio frequencies.

In making such tests it is essential, of course, that the source of audio-frequency voltage used to modulate the r.f. input signal be quite pure, i.e., free from harmonics. Generally the total harmonic output from the a.f. oscillator should not be allowed to exceed five per cent.

No. 314 Radio Broadcast Laboratory Information Sheet

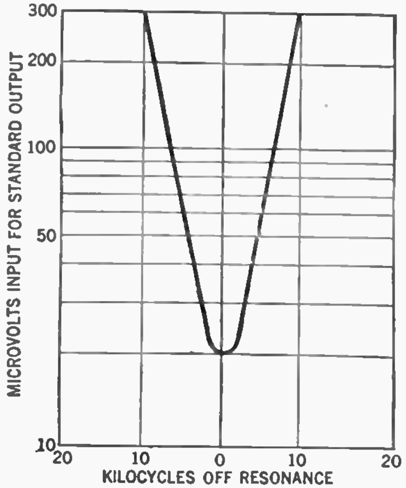
Selectivity of Radio Receivers

Practically speaking, the selectivity of a receiver is that characteristic which enables us to determine how well the set will tune-out one signal and tune-in another. Technically, it is defined in somewhat similar fashion, as the degree with which a radio receiver is capable of differentiating between signals of different carrier frequencies.

Selectivity is determined with the aid of an r.f. oscillator by means of which we are able to impress known r.f. voltages on the input of a radio receiver. There are various methods of carrying out the test but the one generally used is to impress a small known voltage on the input of the set, note the output of the set, and then to vary gradually the frequency of the r.f. oscillator, at the same time adjusting the voltage supplied to the receiver so as to maintain the same output. In this way we obtain a set of figures showing how the output of the receiver falls off either side of the frequency to which it is tuned. Generally the more rapidly it falls off the better is the selectivity.

Unfortunately a receiver's selectivity is, as has been pointed out many times, closely tied up with its fidelity, for if we make the selectivity too great the sidebands are suppressed and the high frequencies are partially suppressed. At least this is true of ordinary circuits.

Selectivity curves are, of course, made at various points throughout the broadcast band so that the variation in the receiver's selectivity at different points in the broadcast band can be determined. The results are finally plotted in the form of curves, an example is given below.



No. 315 Radio Broadcast Laboratory Information Sheet

C-Bias Resistor Values

The table on this sheet gives the values of C-bias resistor in ohms which must be used in conjunction with various types of tubes used in a.c. receivers to supply correct bias. It will be noted that the value of the resistor for use when the filament is operated on a.c. is slightly different from the value when the filament is on d.c. This is due to the fact that in the case of d.c. operation the returns are connected to the negative side of the filament and in a.c. operation they are connected to the mid point of the filament side. If the two tubes are connected in parallel, and obtain their C bias from a common resistor, then the value of the C-bias resistor should, of course, be half that indicated in the table.

Type of Tube	Plate Voltage	C-Bias Resistor in Ohms Fil. on D. C.	Fil. on A. C.
226	90		1700
	135		1500
	180		1800
227	90		2000
	135		1800
	180		2250
112A	90	850	1300
	135	1300	1650
	180	1350	1600
171A	90	1650	1900
	135	1700	1850
	180	2000	2150
210	250	1500	1800
	350	1700	1950
	425	1750	1950
250	250		1600
	300		1550
	350		1400
	400		1300
	450		1550
245	180		1250
	250		1550
224	180		350

No. 316 Radio Broadcast Laboratory Information Sheet

Range of Frequencies Required

Past and present improvements in quality of reproduction from radio receivers has been due in no small extent to the important research carried on by the laboratories of the Bell Telephone Company to determine the characteristics of the ear so that some rules might be laid down regarding the range of frequencies required for good reproduction and the range of pressure common in speech and music. A group of curves illustrating some of these important characteristics is given in "Laboratory Sheet" No. 317. These curves show how the sound pressure varies for sounds of constant volume over the entire band of audible frequencies. On the curve are also indicated some contour lines of equal volume which have been divided into three parts, the bass, the tenor or alto, and the soprano, corresponding to the range of notes produced by various instruments.

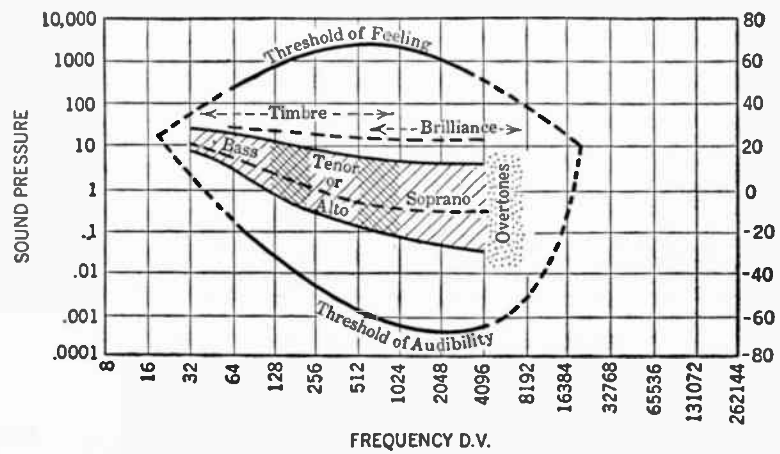
The vertical distance between the two limiting lines indicates the range in pressure and shows that although the pressure is greater at the low frequencies, the range of pressure is not as great as at the higher frequencies.

The musical instruments producing the greatest pressures are the percussion type such as the traps and drums. Although the fundamental tones produced by these instruments are quite low they are very rich in harmonics extending sometimes up to 10,000 cycles.

Generally speaking, the fundamental and first three overtones are essential in order to distinguish the notes of various instruments and better reproduction is obtained if the fourth overtone is reproduced. The frequencies used most in music are contained in the octaves between 128 to 512 cycles. As the fourth overtone of 512 cycles is 8192, tones of this frequency and below frequently occur in music. The average individual, however, would probably find it difficult to detect the elimination of all frequencies above 6000. The letters "DV" on the curve mean "double vibrations."

No. 317 Radio Broadcast Laboratory Information Sheet

Range of Frequencies Required



No. 318 Radio Broadcast Laboratory Information Sheet

60- and 120-Cycle Hum Measurements

In this "Laboratory Information Sheet" are given some data on hum measurements made in the Laboratory some time ago. The measurements were made using an a.c.-operated Wright DeCoster electrodynamic loud speaker. These measurements were made to determine how much a.c. voltage at 60 and 120 cycles was necessary across the primary of the coupling transformer in the loud speaker to produce an audible hum output.

Two series of measurements were made. The first to determine what voltage would produce a just audible sound and the second to indicate what voltage was required to produce the maximum hum that might be tolerated. The figures are useful in indicating how much hum voltage in the output circuit of a radio receiver is permissible. It is interesting to note from the figures given below that the ratio of the voltage at 60 cycles to the voltage at 120 cycles is approximately 10, which ratio agrees quite well with the variation in sensitivity of the ear between 120 and 60 cycles.

JUST AUDIBLE HUM	
60 cycles	1.3 volts
120 cycles	0.15 volt

MAXIMUM TOLERABLE HUM	
60 cycles	5.2 volts
120 cycles	0.54 volt

If we assume that most of the hum arises in the detector circuit, it is a simple matter to calculate the maximum permissible value of this hum. We simply have to divide the voltage indicated above by the gain of the amplifier. For example, if an amplifier had a gain of 200, then the amount of 60-cycle voltage in the plate circuit of the detector tube to produce a just audible hum from the loud speaker would have to be 1.3 divided by 200 which gives 0.0065 volt or 6.5 millivolts. The maximum permissible 120-cycle voltage is 0.15 divided by 200 which gives 0.00075 volt or 0.75 millivolts.

No. 319 Radio Broadcast Laboratory Information Sheet

Apparent Demodulation of Weak Signals

In November, 1929, *Experimental Wireless and the Wireless Engineer* S. Butterworth published a short article entitled "Notes on the Apparent Demodulation of a Weak Station by a Stronger One." In this article the author treated mathematically the effects which occur when two modulated carriers are applied to a linear detector of perfect characteristics, i.e., the detector that completely suppresses one half of the applied signal.

With such a detector it is found that the intensity of the two audio-frequency signals produced by demodulation do not bear the same ratio as do the carriers of the applied signals. Instead it is found that the ratio of the audio-frequency outputs is greater than the ratio of the carriers, the differences in these two ratios becoming greater with increases in the ratio of the two carriers. The only point at which the carrier ratio and the audio-frequency ratio are equal is where the two carriers have the same valve. When the two carriers have a ratio of 10 to 1 the audio-frequency signals produced by the demodulation of the carriers have a ratio of 200 to 1. In other words, if two modulated carriers have a ratio of 10 to 1 and the stronger carrier produces an audio-frequency output of 1 volt then the output due to the weak carrier is only 0.005 volt. The net result of this apparent demodulation of a weak signal by a strong signal is that the apparent selectivity, as judged by the ratio of the two audio-frequency outputs, is greatly increased.

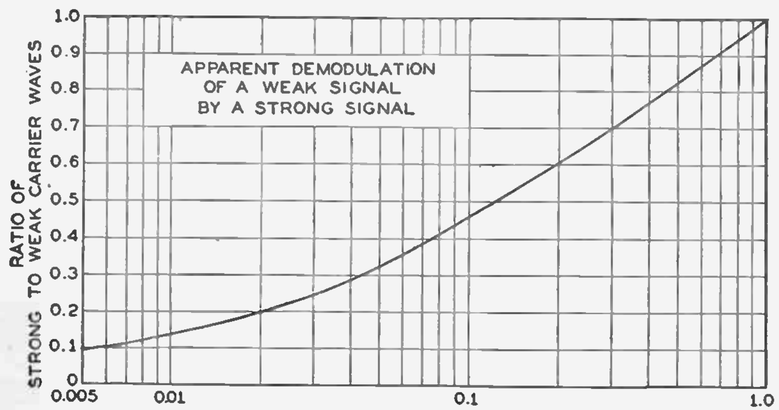
The figures given in Mr. Butterworth's article have been plotted in the form of a curve which appears on Laboratory Sheet No. 320. From this curve it is possible to determine quickly the audio-frequency ratio for carrier ratios of from unity to 10.

The audio-frequency ratios indicated on the curve are, of course, only obtained when the detector is perfect, and, as the detector departs from this characteristic, the apparent demodulating effect decreases.

This same effect treated mathematically by Mr. Butterworth was illustrated graphically and experimentally by F. E. Terman in his article entitled "Linear Power Detection" published on page 49 of November, 1929, Radio Broadcast.

No. 320 Radio Broadcast Laboratory Information Sheet

Apparent Demodulation of a Weak Signal



ACOUSTIC RATIO $= \frac{\text{a.f. DUE TO WEAK SIGNAL}}{\text{a.f. DUE TO STRONG SIGNAL}}$

No. 321 Radio Broadcast Laboratory Information Sheet

Service Procedure

In the servicing of radio receivers a sensible, systematic method of testing is most essential. Testing this, that, and the other thing—testing haphazardly, in other words—will finally lead one to the fault, but it can hardly be called the proper method of procedure. In servicing, as in most everything, there is a proper place to start and a proper procedure that will locate most quickly the thing we are looking for.

Voltages delivered to the tubes should first be checked. This should usually be done.

If there is some definite indication of the trouble it is usually a simple matter to fix it, but if there are no indications of what part of the circuit is at fault, it is generally best to proceed somewhat as follows:

First check the a.f. amplifier. Lightly tap the detector tube and listen for a response from the loud speaker. If the set has a phonograph connection (and most receivers have) connect a pair of head phones to the circuit, tap the diaphragm of the phones and listen for an answering tap from the loud speaker. If there is no response from the loud speaker, the fault must be in the a.f. amplifier, the power tubes, the loud speaker, or the voltage supply to these tubes.

The next part of the circuit to test is the detector. It is usually possible to disconnect the antenna from its usual location and connect it instead directly to the stator plates of the variable condenser tuning the detector circuit. By tuning the set it should then be possible to pick up powerful local stations providing the detector circuit is functioning properly. If the a.f. amplifier works satisfactorily but no signals can be picked up with the antenna connected as indicated above, there is probably some fault in the detector circuit.

After checking over the a.f. amplifier and detector circuits, it is then possible to check the r.f. amplifier, the simplest method being to touch the antenna to the plate terminal of the r.f. amplifier tube preceding the detector, then to the plate circuit of the preceding r.f. amplifier, etc., until the normal antenna connection is reached.

By systematically testing in this manner it is generally possible to locate quickly the point in the circuit where the fault lies and then to take whatever measures are necessary to correct it. The need of a good set tester in such work is, of course, obvious, for without one it is hardly possible to determine accurately the condition of the tubes and whether or not they are receiving proper voltages.

No. 322 Radio Broadcast Laboratory Information Sheet

Inductance of Coils

"Laboratory Sheet" No. 323 contains a set of curves by means of which the inductance of a coil in microhenries may be determined if the size of the tube, size of the wire, and number of turns are known; or conversely, a coil of any given inductance may be constructed using the number of turns indicated by the chart for the particular size of tube and size of wire to be used. The chart covers tube sizes of three and four inches and wire sizes of No. 16, 18, 20, 22, and 24. In all cases the wire is double cotton covered.

The curves are based on the simplified formula for the inductance of a coil—

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

where L = inductance in microhenries
a = tube radius in inches
v = length of winding in inches
n = number of turns of wire
K = a constant

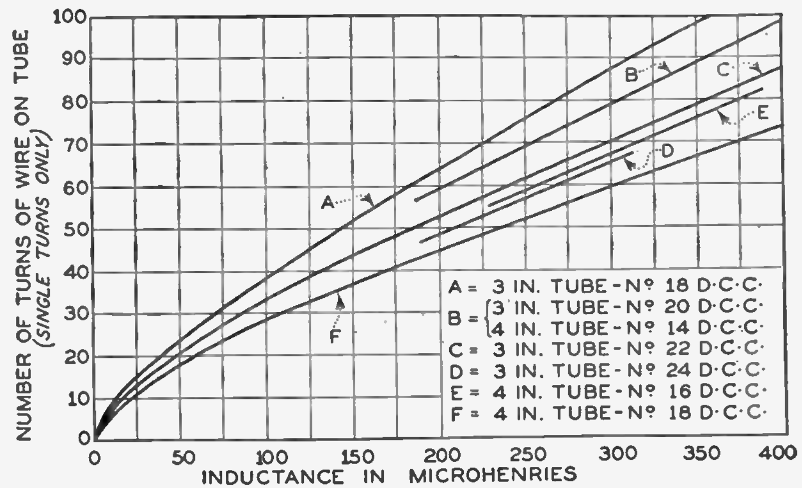
Using the chart on "Laboratory Sheet" No. 323 in conjunction with the chart given on "Laborntory Sheet" No. 286, it is possible to determine quickly how many turns of a particular size of wire are necessary on a given tube to cover the broadcast band with a certain size variable condenser.

For example, suppose a coil were made for use with a 0.0005-mfd. variable condenser. The chart on Sheet No. 286 indicates that 170 microhenries of inductance are required, to tune up to about 550 kc. Suppose we wanted to use a 3-inch tube wound with No. 22 wire. By referring to the chart on the following sheet we find that in order to obtain an inductance of 170 microhenries the coil must have 47 turns of wire.

With these two charts it is also possible to work back and find the size condenser necessary to tune a given coil over the broadcast band. Suppose we had a coil wound with 65 turns of No. 24 wire, the tube size being 3 inches. What size variable condenser will tune it over the band? By referring to the chart below we find that such a coil will have an inductance of 295 microhenries. Then, referring to the chart on Sheet No. 286, we can determine that a 0.0003-mfd condenser will be required.

No. 323 Radio Broadcast Laboratory Information Sheet

Inductance of Coils



No. 324 Radio Broadcast Laboratory Information Sheet

Hum *vs* Volume Control

There is a characteristic difference in the operation of receivers with and without automatic volume control circuits which has a fundamental effect on the amount of a.c. hum from the loud speaker.

In a receiver in which the volume control is located in the r.f. amplifier the detector must function at a level depending upon the setting of the volume control. At high volume levels the detector must work at r.f. input voltages large in comparison with those applied to the detector when the desired volume level is low. Now, in a set using an automatic volume control, the manual volume control is usually located in the a.f. amplifier and the automatic circuits function to apply a constant r.f. voltage to the detector. As a result the a.f. output from the detector is constant and volume is adjusted by impressing more or less of this constant detector output on the following a.f. amplifier tube. The fundamental difference between these two arrangements is, therefore, that in one case the detector input varies and in the other case it is constant.

The hum from the detector circuit is responsible for a large part of the hum finally impressed across the loud speaker. The hum voltage from the detector is constant—it does not depend on the setting of the volume control. Therefore, if the desired signal is much louder than the hum at all volume levels it is necessary to operate the detector at signal levels such that the desired a.f. output is always much greater than the hum output. With the volume control in the r.f. amplifier this is not always possible, for, when the volume is turned down very low, the desired signal output may become comparable with the hum output of the detector. If, however, the volume control is in the a.f. amplifier the detector is operated at high signal levels at all times regardless of the setting of the volume control. As a result, in receivers with automatic volume the ratio of desired signal to hum in the plate circuit of the detector tube is always high, and, other factors being equal, the hum from receivers using automatic volume control will be less than that from receivers not using automatic volume control, provided the manual volume control is in the a.f. amplifier.

It is, of course, at low volume levels that the difference in hum will be most noticeable, for it is at such levels that the hum voltage from the detector will be largest in comparison with the desired signals. At high volume levels there is no reason why the hum from sets without automatic volume control should not be equal to that from sets with automatic volume control.

No. 325 Radio Broadcast Laboratory Information Sheet

Beat-Frequency Oscillator

An article entitled "The Frequency Characteristics of Telephone Systems and Audio Frequency Apparatus, and Their Measurement," written by B. S. Cohen, A. L. Aldridge, and W. West, and published in the September, 1926, *Proceedings of the Wireless Section of The Institution of Electrical Engineers*, England, gives the circuit and constants of a beat-frequency oscillator for use in making measurements on telephone apparatus. This circuit is reproduced on "Laboratory Sheet" No. 326.

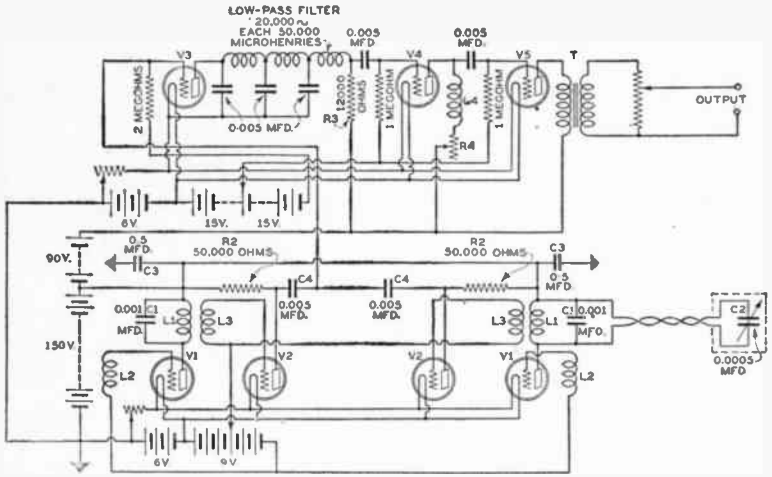
Each high-frequency oscillator circuit comprises a grid coil, L_2, of 50,000 microhenries coupled to a plate coil, L_1, of 20,000 microhenries and tuned by a fixed condenser, C_1, of about 0.001 mfd. A variable condenser, C_2, with a maximum value of 0.0005 mfd. is connected in parallel with condensers C_1 to cover a frequency range of about 5000 cycles. The output coils, L_3, each of 10,000 microhenries, introduce the high frequencies from each oscillator into the high-frequency amplifiers, V_2—the use of these high-frequency amplifiers serves to prevent interaction between the two oscillators. The coupling between the output of the high-frequency amplifiers and the detector is obtained through a coupling condenser, C_4, and the two-megohm leak in the grid circuit of the detector tube. The detector, V_3, is of the plate-rectification type. In the plate circuit of the detector is a low-pass filter having a cut off at about 20,000 cycles. The filter functions to reduce to negligible values the high frequencies in the output of the oscillator. Two stages of resistance-coupled amplification are used between the detector and the output of the oscillator.

With a special output transformer it was still found that there was a tendency for the output to fall off at high frequencies. This was corrected by reducing the output at low frequencies to the value obtained at high frequencies. This was accomplished by means of an 0.2-henry air-core inductance, L_4, in the plate circuit of the amplifier V_4. In series with the inductance is the variable non-inductive resistor, R_4, which in combination with the choke coil produced the desired rising frequency characteristic so that a uniform output could be obtained.

The harmonic output determined by means of an oscillograph was found to be less than 5 per cent. and could be further reduced by connecting a condenser in shunt across the input to the detector tube. This provided in the plate circuit of the high frequency amplifier tubes a lower impedance for the harmonics than for the fundamental and tended to improve the wave form of the high frequencies impressed on the detector tube.

No. 326 RADIO BROADCAST Laboratory Information Sheet

Beat-Frequency Oscillator



No. 327 RADIO BROADCAST Laboratory Information Sheet

Fidelity in Modern Receivers

THE ONLY way the user of modern radio apparatus can make his receiver distort is by (a) not tuning it accurately to the station to be received and (b) increasing the volume to the point where overloading occurs in one or more of the tubes. Distortion due to (b) rather than (a) is most generally found in practice, but trends in receiver design are gradually leading to receivers in which the tubes cannot be overloaded. Such receivers cannot be made to produce distortion other than that inherent in the characteristics of the circuit or that produced by improper tuning.

Tube overloading generally takes place in the detector and power tube long before it becomes serious in any of the other tubes. The task, therefore, is to design sets in which the amplified audio-frequency output of the detector is sufficient to apply the maximum permissible voltage to the grid of the power tubes (the maximum permissible voltage being limited by distortion in the power tube) and to include some method making it impossible to apply signal voltages in excess of the maximum permissible value to the power tube.

To design such a set we must first determine the maximum a.c. voltage which may be impressed across the power tube before distortion occurs. We then work back through the a.f. amplifier and determine how much a.f. voltage is required from the detector tube. Then, knowing the rectification characteristics of the detector tube, we can determine the maximum r.f. voltage which must be impressed on the detector. In order to impress on the detector a value of r.f. voltage which, when rectified and amplified, will impress the maximum permissible voltage across the power tube, automatic volume control circuits must be used. In such sets it is a function of the automatic control circuits to limit the detector input to this predetermined value regardless of the value of the field strength. Therefore, such a receiver cannot be overloaded.

The manual volume control in such a receiver is located in the a.f. amplifier so that the desired portion of the a.f. voltage from the detector may be impressed on the power tube. However, the design should be such that it is impossible to apply sufficient a.f. voltage to overload the power tube. The automatic volume control circuit which limits the maximum value of the a.f. output from the detector makes such a design possible.

No. 328 RADIO BROADCAST Laboratory Information Sheet

Loud Speaker Bibliography

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No. 329 RADIO BROADCAST Laboratory Information Sheet

Loud Speaker Bibliography

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No. 330 RADIO BROADCAST Laboratory Information Sheet

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No. 331 RADIO BROADCAST Laboratory Information Sheet

Modulated Oscillators and Output Meter

ONE OF the most important tasks in the servicing of radio receivers is the accurate alignment of the tuning condensers and the accurate adjustment of the neutralizing condensers. Although these operations may be carried out by tuning the set to some local station and making the necessary adjustments while listening to the a.f. output, this method is not very accurate. It is much better to set up a local oscillator and an output meter so that the input to the set and the a.f. output are reasonably constant and so that slight changes in the adjustments can be detected readily.

On "Laboratory Sheet" No. 332 are given the circuits of two simple modulated oscillators and two output meters that may be used in checking a receiver. Oscillator No. 1 is designed for operation on a.c. and oscillator No. 2 for operation from batteries. The a.c.-operated oscillator uses a 226-type tube supplied from a filament transformer and plate potential is obtained by connecting the plate lead to the primary of the power transformer. The oscillator will then have 110 volts a.c. on its plate and will be modulated by the a.c. The battery-operated oscillator uses a 199-type tube and the grid leak and condenser values are such that they will function to modulate the output. It is, essential, of course, that the oscillator be modulated so that a note will be audible in the output of the loud speaker connected to the set under test.

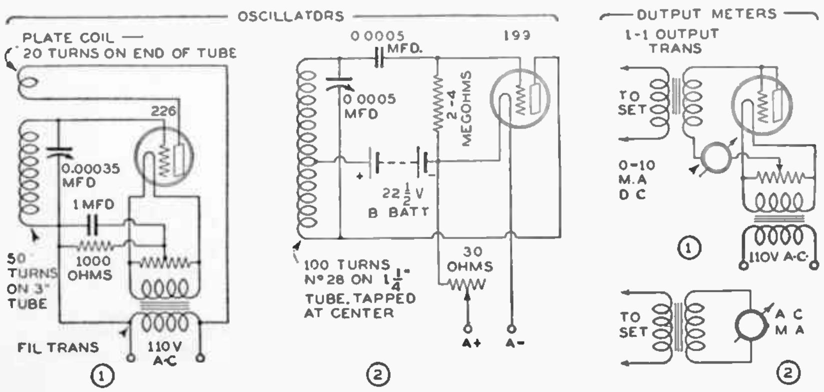
The output meter No. 1 uses a 226-type tube as a rectifier in series with an 0-10 milliammeter and a 1-to-1 output transformer. The output meter of oscillator No. 2 simply uses a 1-to-1 transformer to whose secondary an a.c. milliammeter is connected. If an a.c. milliammeter is available this is, of course, the simplest circuit but if a d.c. milliammeter must be used it is necessary to rectify the output by some circuit such as is indicated by circuit 1.

In use the output meter terminals marked "to set" are connected either directly across the moving coil of the electrodynamic loud speaker or, if necessary to get sufficient reading, across the primary of the transformer supplying the loud speaker. The oscillator is set up near the set and located at such a point that a satisfactory deflection is obtained on the output meter when the set is tuned to the frequency being generated by the oscillator. The various condensers can then be accurately aligned until maximum deflection is obtained on the meter.

No. 332 RADIO BROADCAST Laboratory Information Sheet

Modulated Oscillator and Output Meter

THE CIRCUITS on this sheet show arrangements that can be used to supply a constant modulated signal to a receiver for testing purposes and also output meter circuits that can be used to indicate qualitatively the output of the set. All specifications are given on the circuits and some notes on their use will be found in "Laboratory Sheet" No. 331.



No. 333 RADIO BROADCAST Laboratory Information Sheet

Calculating Power Output

ONE OF the simplest and most effective ways of calculating the power output of an ordinary three-element power tube is by the use of "load lines" plotted across a group of characteristics showing the relation between the plate current and plate voltage for various grid biases. A group of plate current-plate voltage curves for the 171A-type tube are given on "Laboratory Sheet" No. 334 and the following notes indicate how the load lines are determined.

It should be noted that these curves show the plate current obtained for various plate voltages at grid biases corresponding to from 0 to —80 volts. The first thing to do is to pick out the normal operating point of the tube, which in this case is —40, volts and 20 milliamperes. The tube has a plate resistance of 2000 ohms and for maximum undistorted output the load resistance would therefore be 4000 ohms. We now have to lay off the line to indicate the manner in which the plate current will change with grid voltage. This is not difficult. With no signal on the grid the plate current will be 20 milliamperes. Now assume that the plate current changes from 20 milliamperes to 40 milliamperes. This means that there will be a change of 20 milliamperes in the current flowing through the 4000-ohm resistor. By Ohm's Law the resistance, 4000 ohms, multiplied by this current, 20 milliamperes, gives the change in voltage across the 4000-ohm resistance, or in this case 80 volts. We, therefore, mark on the diagram point B at a plate current of 40 milliamperes and a plate voltage of 100 (80 volts less than the normal operating potential of 180 volts). A line is then drawn from the operating point at 20 milliamperes and 180 volts so as to pass through the point B. This is the load line corresponding to a load resistance of 4000 ohms.

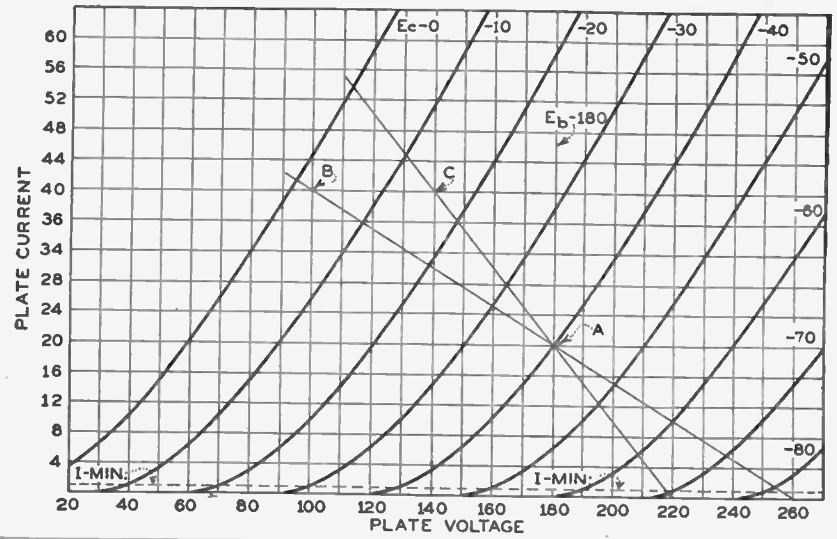
Load lines for values other than 4000 ohms can be calculated in this same manner. For example, if the load resistance is 2000 ohms then a 20-mA. increase in plate current will produce a 40-volt change across the load resistance. This gives us point C at a current of 140 milliamperes and a plate voltage of 40 volts. Drawing a line between C and the operating point A gives the load characteristic corresponding to 2000 ohms.

In future Sheets we will show how these load lines may be used to determine the power output of the tube and also the percentage of second-harmonic distortion.

No. 334

RADIO BROADCAST Laboratory Information Sheet

Calculating Power Output



No. 335

RADIO BROADCAST Laboratory Information Sheet

Undistorted Output *vs* Dynamic Range

THE DYNAMIC range in volume which a radio receiver can handle depends largely on the maximum undistorted power output from the power tubes, upon the minimum acoustic power output, and upon the efficiency of the loud speaker. In this sheet and the following some figures are given which serve to give some idea of the maximum undistorted power output required with loud speakers of various efficiencies for dynamic ranges of 20 to 60 DB, all the figures being based on the assumption that the acoustic sound output from the loud speaker at minimum volume is 5 microwatts. Some relative idea of this power may be appreciated from the fact that the average power in speech is about 10 microwatts.

An example will clearly indicate the basis on which these figures were determined. Assume that the sound output power at minimum volume is to be 5 microwatts, that the loud speaker has an efficiency of 3 per cent., and that the ratio between maximum and minimum volume is 40 DB, corresponding to 10,000 to 1 in power. If the minimum sound output is 5 microwatts then the power input to the loud speaker for minimum volume is equal to the sound output divided by the efficiency which gives 0.167 milliwatts input to the loud speaker. If the ratio of maximum to minimum power is 10,000, then the maximum power input to the loud speaker must be 10,000 times 0.167 or 1670 milliwatts which is equal to 1.67 watts. The figures used in this example correspond to those given in the second line of the data on "Laboratory Sheet" No. 336.

As will be noted the table on the following sheet is worked out for loud speaker efficiencies of from 2 to 10 per cent. and for dynamic ranges of from 20 to 60 DB. Each 10 DB increase in dynamic range, of course, requires a ten-fold increase in the maximum power output from the receiver. The maximum power output required for any given dynamic range is an inverse function of the efficiency of the loud speaker so that doubling the efficiency halves the power output required. The maximum output requirements also depend naturally upon what sound output at minimum volume is decided upon. In the table 5 microwatts is assumed but, of course, if this level is cut in half the power output for maximum volume is also halved. The power outputs indicated under the columns 20, 30, 40, and 50 DB are expressed in milliwatts. The power outputs under 60 DB are expressed in watts.

No. 336

RADIO BROADCAST Laboratory Information Sheet

Undistorted Output *vs* Dynamic Range

THE TABLE below serves to indicate what dynamic range in volume can be handled with a certain loud speaker efficiency and some definite value of acoustic power output at minimum volume.

The basis for the figures and a brief explanation of their meaning will be found on "Laboratory" Sheet No. 335. Note: The figures under columns 20, 30, 40, and 50 represent power output in milliwatts.

Efficiency of Loud Speaker	*Power Output for Minimum Volume*	*Maximum power output in milliwatts required for a DB difference between minimum and maximum volume of* 20	30	40	50	60
2 %	0.250	25	250	2500	25000	250 watts
3 %	0.167	16.7	167	1670	16700	167 "
4 %	0.125	12.5	125	1250	12500	125 "
5 %	0.100	10.0	100	1000	10000	100 "
8 %	0.062	6.2	62	620	6200	62 "
10 %	0.050	5.0	50	500	5000	50 "

No. 337

RADIO BROADCAST Laboratory Information Sheet

Measuring Resistance

ONE OF THE simplest methods of measuring resistances is by the use of a d.c. voltmeter connected in series with the resistor to be measured and across a known d.c. voltage. The circuit is shown on this sheet.

The procedure is to measure the d.c. voltage first with the voltmeter. The resistor to be measured is then connected in series with the meter and the reading of the meter noted. With these data the value of the resistor may be obtained from the formula—

$$R_o = \frac{E_o - E_r}{E_r} \times R_m$$

where R_o is the resistance in ohms;
E_r is the voltage read on the voltmeter with the resistance connected in series with the voltmeter;
E_o is the voltage of the source, i.e., that voltage indicated by the meter when it is connected directly across A-B;
R_m is the resistance of the meter.

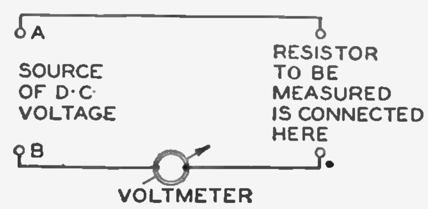
Therefore, the only data needed to measure resistances by this method is the resistance of the voltmeter. This information may be marked on the meter or, if not, it can be obtained from the manufacturer. In the following paragraphs are a few examples worked out by this method.

Example: A 250-volt meter with a resistance of 1000 ohms per volt is to be used to measure the value of an unknown resistor. The voltmeter is connected directly across three B batteries and the potential is found to be 140 volts. The unknown resistor is then connected in series with the meter and the meter reads 25 volts. What is the value in ohms of the resistance?

Since the voltmeter has a resistance of 1000 ohms per volt, the total resistance, Rm, is 1000 times 250 or 250,000 ohms. Eo as measured is 140 volts. Er is 25 volts. Therefore—

$$R_o = \frac{140 - 25}{25} \times 250{,}000$$

R_o = 1,150,000 ohms as the value of the unknown resistor.



No. 338 Radio Broadcast Laboratory Information Sheet

Three Types of Distortion

Several different types of distortion can be produced in the power tube. Distortion may result from (a) volume distortion, (b) frequency distortion, and (c) harmonic distortion.

Volume distortion: The ratio between the output obtained from a tube and the a.c. input voltage to its grid should be constant up to the point where the tube begins to overload. If the ratio between output voltage and input voltage increases as the input voltage increases the strong signals are amplified more than weak signals; if, conversely, the ratio decreases as the input voltage is increased, strong signals are amplified less than weak signals. In power tubes this type of distortion is slight, the power output per volt input squared being constant up to the point at which the tube overloads.

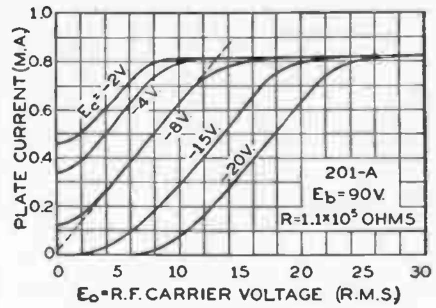
Frequency distortion: A tube and its associated circuits should give uniform amplification to all frequencies over the audio-frequency band it is desired to transmit. If the amplification varies with different input frequencies certain notes are amplified more or less than others. Over the audio-frequency band little distortion of this type is produced by the tube itself, although frequency distortion may be introduced by the apparatus associated with the power tube, such as the input or output transformer and loud speaker.

Harmonic distortion: If a pure sine wave at some frequency is applied to the grid of a tube and in the output of the tube the same and other frequencies appear, then harmonic distortion is occurring. All power amplifiers produce a certain amount of this type of distortion, its extent depending upon the characteristics of the tube itself and the circuits out of and into which it works. The amount of second-harmonic distortion is used as a basis for rating the maximum undistorted output from a tube. If an ordinary three-element tube is working into a load resistance equal to twice its own plate resistance, the second-harmonic current is about 5 per cent. at a point just before the tube begins to overload. This amount of distortion is considered small enough to be negligible. A tube may, of course, generate other frequencies besides the second harmonic and, in fact, when a tube is somewhat overloaded it produces large amounts of second-, third-, and fifth-harmonic distortion.

No. 339 Radio Broadcast Laboratory Information Sheet

Detection Characteristics

Detection characteristics showing the relation between the d.c. plate current and r.f. input to a detector are very useful in determining the best point at which to operate a tube as a detector. Such a group of curves are shown on this sheet, being taken from an article "Detection at High Signal Voltages" by Stuart Ballantine published in the *Proceedings* of the Institute of Radio Engineers.



The curves on this sheet are for a 201A-type tube operated with a resistance load in the plate circuit from a battery potential of 90 volts. Five curves are shown for grid biases from —2 to —20 volts. These curves were made by measuring the plate current as the r.f. input voltage was gradually increased from 0 up to 30 volts. The plate currents obtained with the various input voltages were then plotted and the series of curves shown on this sheet was obtained.

Minimum distortion will be obtained when the r.m.s. value of the carrier input is such as to bring the operating point of the tube at about the center of the straight portions of these curves. When this is done a linear characteristic is obtained and minimum distortion results. For example, the best operating point on the curve corresponding to the bias of minus 8 volts is with a carrier input of about 7 or 8 volts r.m.s. If the carrier input is greater or less than this figure some distortion will result especially at high values of modulation. Since many sets have the volume control in the r.f. amplifier so that the r.f. input to the detector varies depending upon the volume control setting an effect such as described above would take place. This can be prevented, however, by obtaining the bias of the tube from the plate current so that as the r.f. input changes the detector will tend always to operate on the proper characteristic.

No. 340 Radio Broadcast Laboratory Information Sheet

Calculating Detector Output

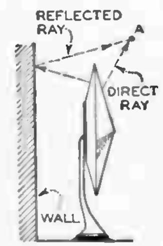
In "Laboratory Sheet" No. 339 is given the "transrectification" diagram of a 201A-type tube operated at a battery potential of 90 volts with a 110,000-ohm load in its plate circuit. This diagram shows the relation between d.c. plate current and r.f. input voltage with various values of C bias. The method of obtaining the curve and a brief explanation of what it means will be found on the same Sheet. In the following notes we explain how it is possible from this simple diagram to determine the audio-frequency output voltage from a detector with a given r.f. input signal.

To explain how this is done let us take for example the center curve corresponding to a grid bias of minus 8 volts. This particular curve then shows the plate current obtained with various r.f. voltages applied to the input. With zero r.f. input the plate current is approximately 0.12 milliamperes, and, as the r.f. input is increased, the plate current gradually rises and then flattens out. It reaches a maximum of 0.8 milliamperes. Let us assume that an r.f. input of 7 volts modulated at say 43 per cent. is applied to the grid. What will be the a.f. voltage appearing across the load resistance? The steady plate current obtained with an r.f. signal of 7 volts will be 0.46 milliamperes. If the r.f. is modulated 43 per cent. it means that the r.f. voltage varies about its mean value, 7 volts, by 43 per cent. Therefore, it reaches maximum values of $7 + (7 \times 0.43)$ or 10 volts and minimum values of $7 - (7 \times 0.43)$ or 4 volts. The plate current corresponding to 10 volts input is 0.63 milliamperes and the plate current corresponding to 4 volts is 0.27. The a.c. plate current will therefore be one having an absolute peak of 0.63 milliamperes and a minimum of 0.27, the difference between these two being equal to twice the peak value of the a.c. current. This difference is 0.36 and dividing by 2 we get 0.18 as the peak value of the audio-frequency current in the plate circuit. Dividing this peak value of 0.18 by the square root of 2 to get r.m.s. values we have 0.128 as the effective a.c. plate current. This current in amperes multiplied by the load resistance gives the a.c. voltage. In this case it is $0.000128 \times 110{,}000$ ohms which gives 14.1 as the audio-frequency voltage. This value of audio-frequency output obtained by calculation agrees very closely with the measured value. This method of calculating detector output is therefore very effective and comparatively simple.

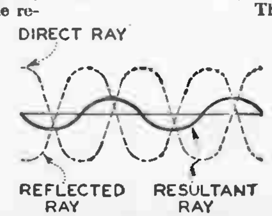
No. 341 Radio Broadcast Laboratory Information Sheet

Reflection of Sound

The intensity of the sound we hear at any point in a room when listening to the output of a loud speaker is a function of the intensity of the direct sound ray, the reflected ray, standing waves, and the amount of reverberation. The diagram on this sheet together with the following notes gives a simple idea of the effect of the direct and reflected rays.



The diagram shows a cone loud speaker placed a short distance in front of a wall. During operation of the loud speaker sound waves will be radiated in all directions and if the listener is located at point A the sound he hears will be due to the direct ray and the reflected ray—the reflected ray being the one which leaves the loud speaker, strikes the wall and is then reflected into the room. The amount of energy reflected from the wall of course depends on the material composing the wall—ordinary hard walls are good reflectors and a major portion of the sound is reflected. If the walls are draped or are made of some acoustic material the amount of sound reflected is much less.



The phase relation between the two waves at the point where the listener is located determines the intensity of the sound (neglecting reverberation), and if the two waves are exactly opposite in phase very little sound will be heard. On the other hand, some sound will always be audible because reflections are also taking place from all other parts of the room. The effects of this type of reflections are prevented somewhat by the use of a baffle (although this is not the most important reason for the use of a baffle). Reflection is most noticeable at low frequencies.

The curves on this sheet indicate graphically the effects which occur due to the direct and reflected rays. If the two waves are essentially 180 degrees out of phase the resultant, shown by the heavy line, is very small which means that the intensity of the sound is very low. However, reflection is not always a thing to be avoided. For example, it occurs in an auditorium and often adds atmosphere to the music being played.

No. 342 RADIO BROADCAST Laboratory Information Sheet

Grid Current in Tubes

IN MAKING measurements, especially on power tubes, it is frequently found that a small amount of current flows in the grid circuit even though the grid has a negative bias. Offhand this seems very serious for we usually operate a tube at negative potential to prevent the flow of grid current. Actually, however, the current flowing in the grid circuit when the grid is negatively biased may not affect the operation of the tube seriously for the following reason.

In the first place, it should be understood that we operate the grid of a tube at negative voltages so as to make the input impedance of the tube very high; in fact, the input circuit of an ordinary amplifier may have an impedance of a million ohms at audio frequencies. Since the impedance is very high practically no power need be expended in the grid circuit to develop comparatively large voltages. If, on the other hand, the input impedance is low the power required to develop the same voltage will be larger, and, as a result, the tube is a less efficient amplifier.

Now if the a.c. voltage across the grid circuit is E then the impedance of the input of the tube will be equal to the voltage E divided by I, the a.c. current in the circuit. That is—

$$\text{Input impedance} = \frac{E_{ac}}{I_{ac}}$$

So if I is zero then the impedance is infinitely large while if I is large then the input impedance is low. But it must be remembered that I is an *alternating current*. The d.c. current flowing in the grid circuit may be any value at all without affecting the a.c. input impedance of the tube. And now we reach the important point: it is not the value of the grid current as read on a d.c. meter that is important but rather it is to what extent this current *varies* with the applied a.c. input signal. In most cases the grid current which flows with negative voltage on the grid is a "gas" current, and about the same amount of current flows at all negative values of grid voltage. Therefore, even when an a.c. signal is applied to the grid so as to make the grid voltage vary about the operating point, the current in the grid circuit is constant (at least practically so) and the a.c. current produced is very small. This makes the denominator of the equation very small and therefore the input impedance very high. In summary, it may be said that grid current at negative grid voltages does not affect the input impedance of a tube unless this current varies considerably with grid voltage.

No. 343 RADIO BROADCAST Laboratory Information Sheet

Speech Power and Its Measurement

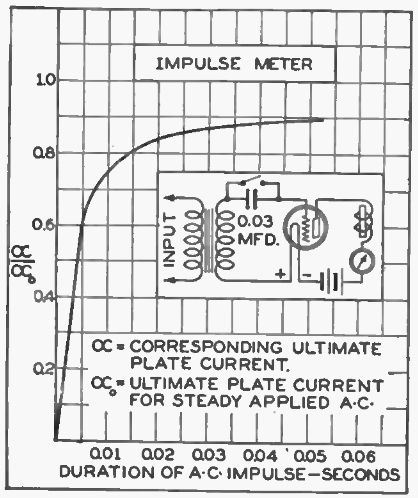
IN CONNECTION with a paper entitled "Speech Power and Its Measurement" by L. J. Sivian, published in October, 1929, *Bell System Technical Journal*, curves and data are given on two devices useful in many ways. Curves and circuits of the two units—a volume indicator and an impulse meter—appear on "Laboratory Information Sheet" No. 344 and the following are some notes regarding their use.

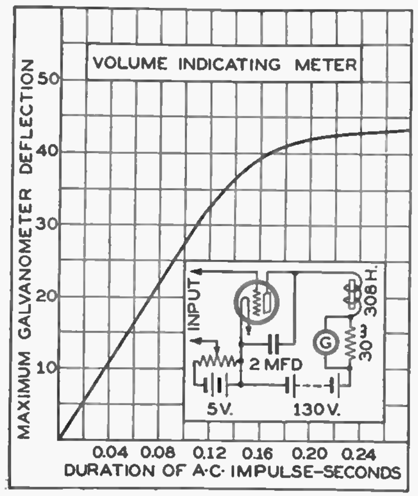
The volume indicator meter has been widely used for controlling amplification in radio broadcasting, in phonograph and film recording of speech and music, and for rapid measurement and control of speech levels. Essentially the volume indicator is a three-element vacuum-tube voltmeter with a rapid-action d.c. galvanometer in the plate circuit. The tube is operated on a part of its characteristic such that the rectified plate current is proportional to the square of the voltage input. The meter combined with the electrical circuit has a dynamic characteristic as shown by the curve on "Sheet" No. 344, which gives the maximum deflection as a function of the duration of the a.c. input voltage. For inputs lasting more than about 0.18 seconds the maximum deflection remains the same, and, since the average syllable duration in speech is of the order of 0.2 seconds, it follows that the maximum deflection is approximately proportional to the mean power.

The impulse meter is essentially a peak-reading voltmeter and the circuit is designed so as to cause the plate current to reach its ultimate value with an input of as short a duration as possible. The time required for the galvanometer to reach its maximum deflection is determined by the dynamic characteristic of the meter and its associated plate circuit as well as by the time constant of the condenser-charging circuit connected to the grid of the tube. The curve, therefore, shows the rate at which the potential on the blocking condenser builds up and by reference to the curve it will be noted that the plate current reaches 80 per cent. of its ultimate value with an a.c. input of only approximately 0.015 seconds.

No. 344 RADIO BROADCAST Laboratory Information Sheet

Speech Power and Its Measurement





No. 345 RADIO BROADCAST Laboratory Information Sheet

Regarding Grounds for A. C. Sets

IN THE INSTALLATION and use of a.c. radio receivers it is frequently found that more volume is obtained without any wire connected to the ground terminal than is obtained with a ground connection to the binding post. This effect has evidently given quite a few servicemen the impression that there was something wrong with the receiver. The fact is, however, that this quite common effect does not necessarily indicate that the receiver is defective.

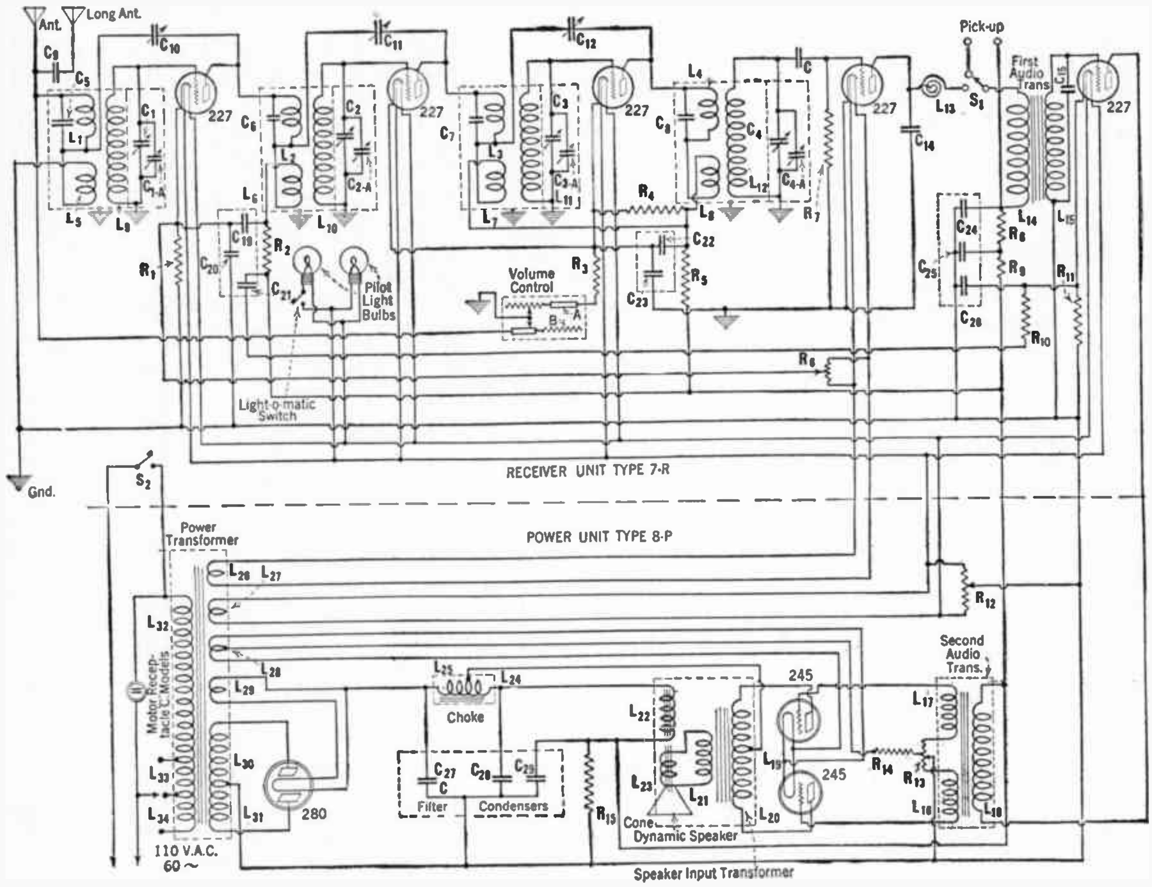
The volume obtained from a receiver depends upon the ability of the antenna system to pick up signals and upon the gain of the radio receiver. Modern high-gain receivers have to be very carefully designed from the standpoint of shielding, filtering, and grounding to make them absolutely stable and if any one of these points is neglected the set will have some regeneration. On the other hand, if the set depends for some of its amplification on regeneration its performance will depend somewhat upon the conditions under which it is operated. Proper grounding is an important point in the prevention of regeneration and the lack of a ground or a comparatively poor ground may cause an otherwise perfectly stable receiver to regenerate slightly.

This is the effect which is responsible for the peculiar operation of a.c. receivers with and without proper ground connections. With a proper ground the set has a gain approximating that which its makers intended it should have. If, however, no ground is used some regeneration will exist which will generally tend to increase the gain and, as a result, more volume is obtained. The disadvantage of not using a ground, however, is that this increased gain may only be obtained over a small part of the dial and at other points the set may tend to oscillate or the first tuned circuit may be thrown out of alignment so that the selectivity is impaired. For these reasons it is always advisable to operate a receiver with a ground if it is intended that it should have one. If for some reason the receiver must be operated without a ground it is worth while to try reversing the plug in the light socket in order to determine the position which gives the most satisfactory operation.

Radio Broadcast's Set Data Sheets

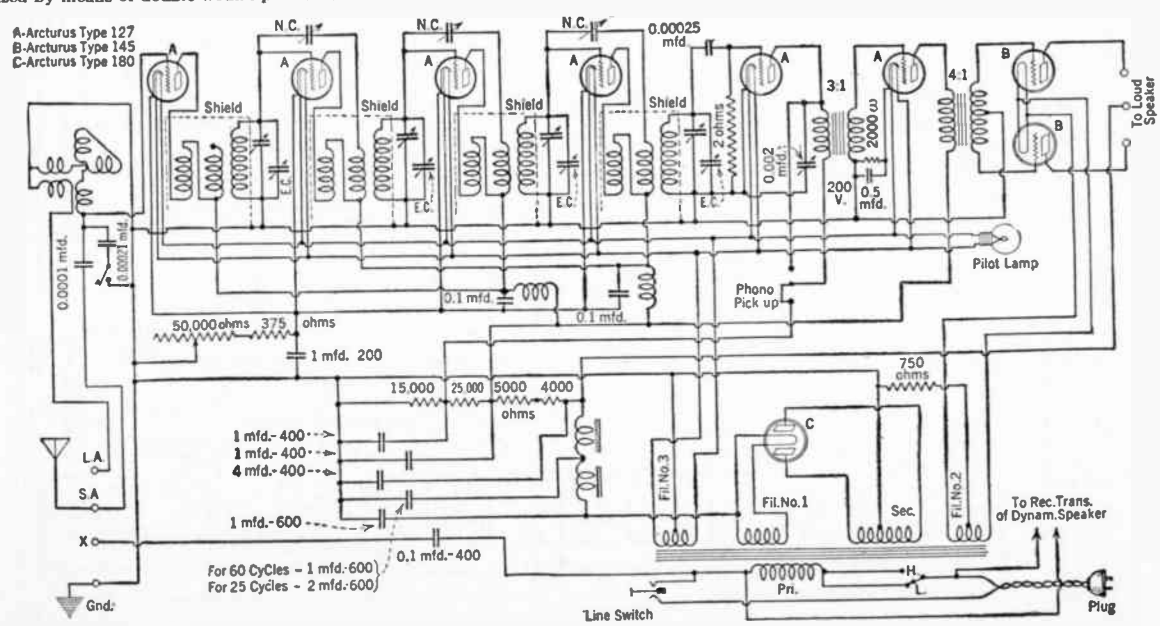
THE EDISON MODELS R-4, R-5 AND C-4 RECEIVER

These receivers incorporate several unusual features among which are an interesting hum adjustor (R-13) connected to the mid point of the push-pull transformer feeding the two power tubes, the double primary windings on each of the r.f. transformers, and the "light-o-matic" switch which automatically indicates when the set is tuned to a favorite station. Type 227 tubes are used throughout except in the output circuit where there are two 245's. The volume control functions to reduce the input from the antenna and also to increase the r.f. bias.



THE FREED-EISEMANN NR-95 A.C. RECEIVER

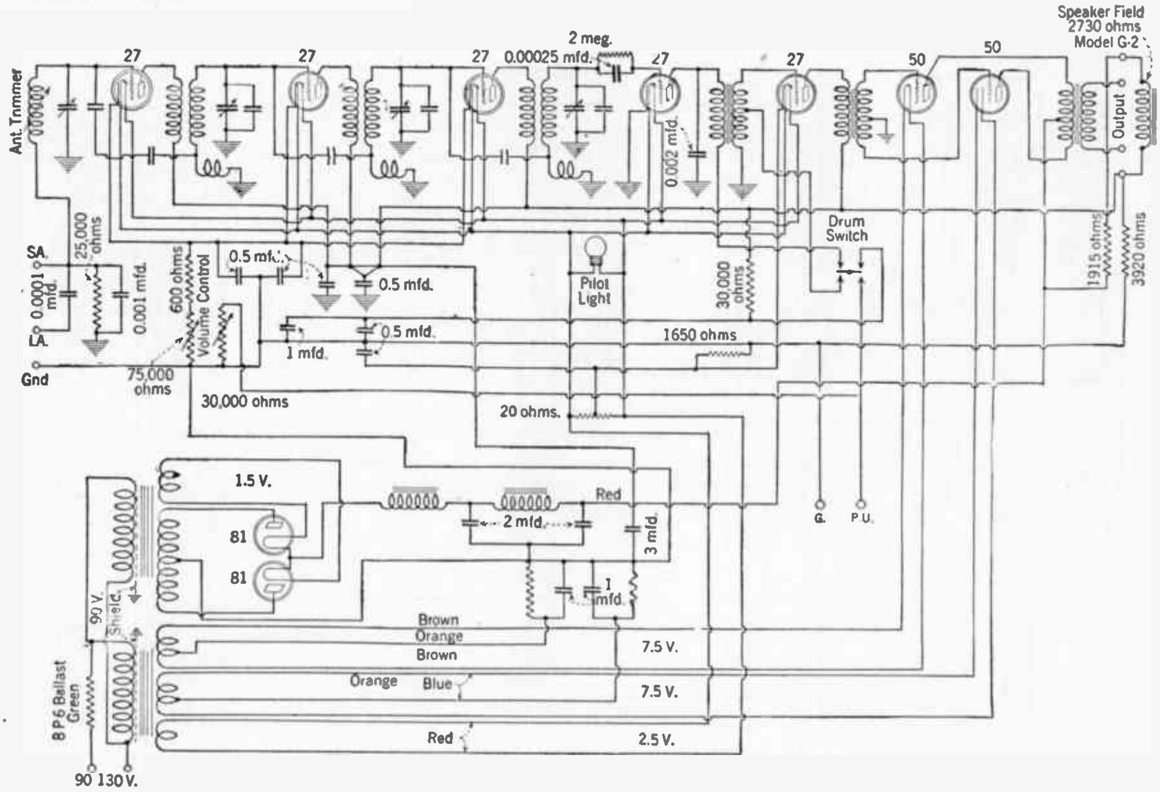
Four stages of r.f. amplification, a detector and two stages of audio-frequency amplification are used in this receiver. The antenna circuit is tuned by means of a variometer. Each r.f. amplifier stage is neutralized by means of double-wound primaries on the r.f. transformers. In all the stages except the last heater-type tubes are used. The use of heater tubes conforms with a general tendency among set manufacturers to utilize this type of tube rather than the 226 type. A light-socket antenna is provided in this receiver.



Radio Broadcast's Set Data Sheets

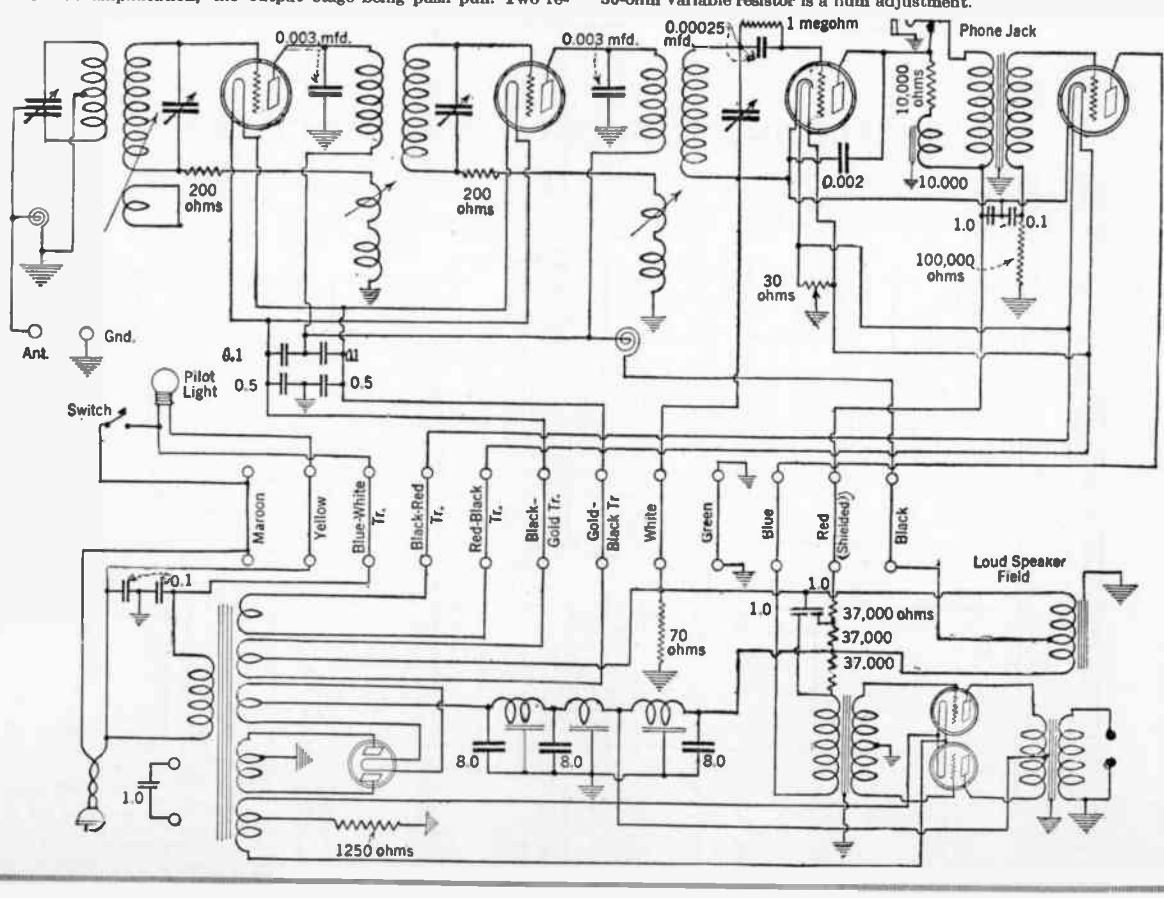
THE MAJESTIC MODEL 180 RECEIVER

Three stages of r.f. amplification are used in this Majestic receiver. The inductance associated with the antenna circuit is arranged so that it can be varied somewhat in order that this circuit may be brought into exact resonance with the other tuned circuits. It should be noted that heater-type tubes are used throughout the set except in the power stage. It is also interesting to note that the phonograph pick-up unit is connected across the small tapped section of the first audio-frequency transformer.



THE COLONIAL MODEL 31 A.C. RECEIVER

This receiver utilizes six a.c. tubes and a 280-type rectifier. It consists of two stages of r.f. amplification, a detector, and two stages of a.f. amplification, the output stage being push pull. Two resistors, not indicated in the diagram but connected in series with the lead to the light socket, function as automatic voltage controls. The 30-ohm variable resistor is a hum adjustment.



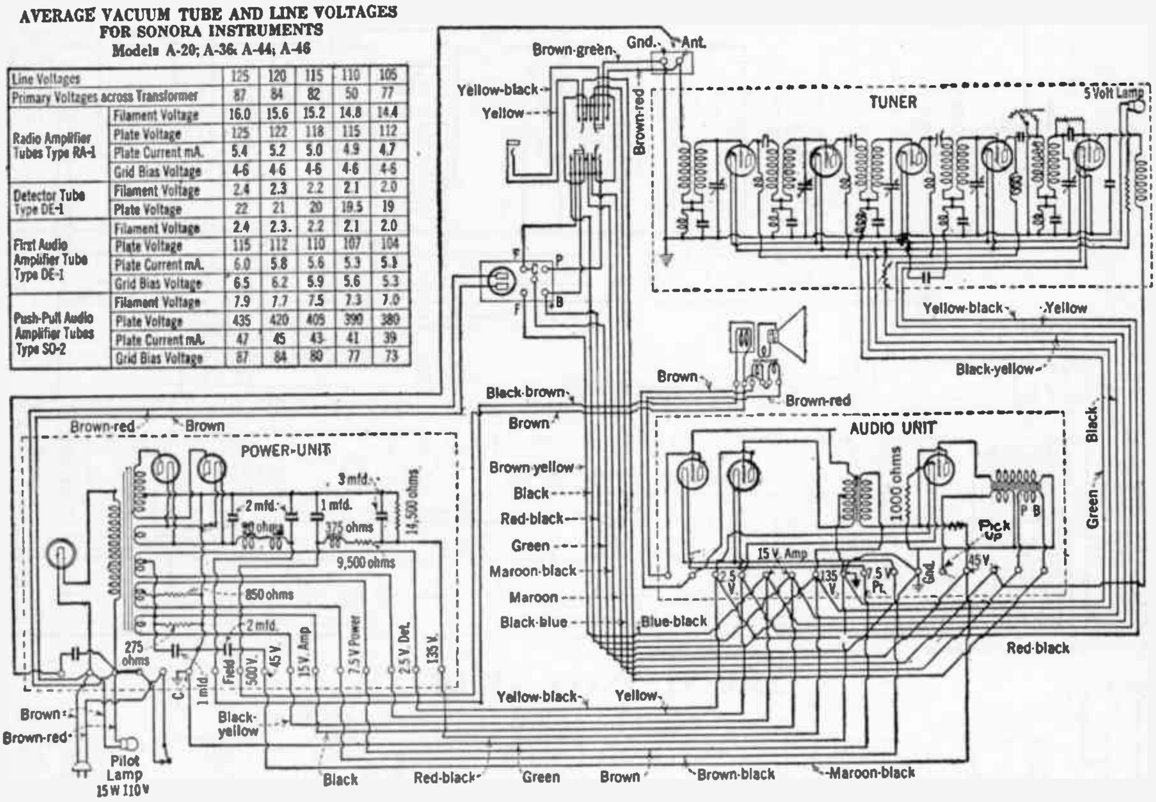
Radio Broadcast's Set Data Sheets

THE SONORA MODEL A-36 RECEIVER

This receiver consists of four stages of tuned r.f. amplification, a grid leak and condenser detector, and a two-stage transformer-coupled audio-frequency amplifier. The set contains the following interesting features: combined electromagnetic and electrostatic coupling in the r.f. amplifier, a special first-stage a.f. transformer phonograph pick-up, a push-pull output stage, an electrodynamic loud speaker, and an automatic control to compensate variations in line voltage.

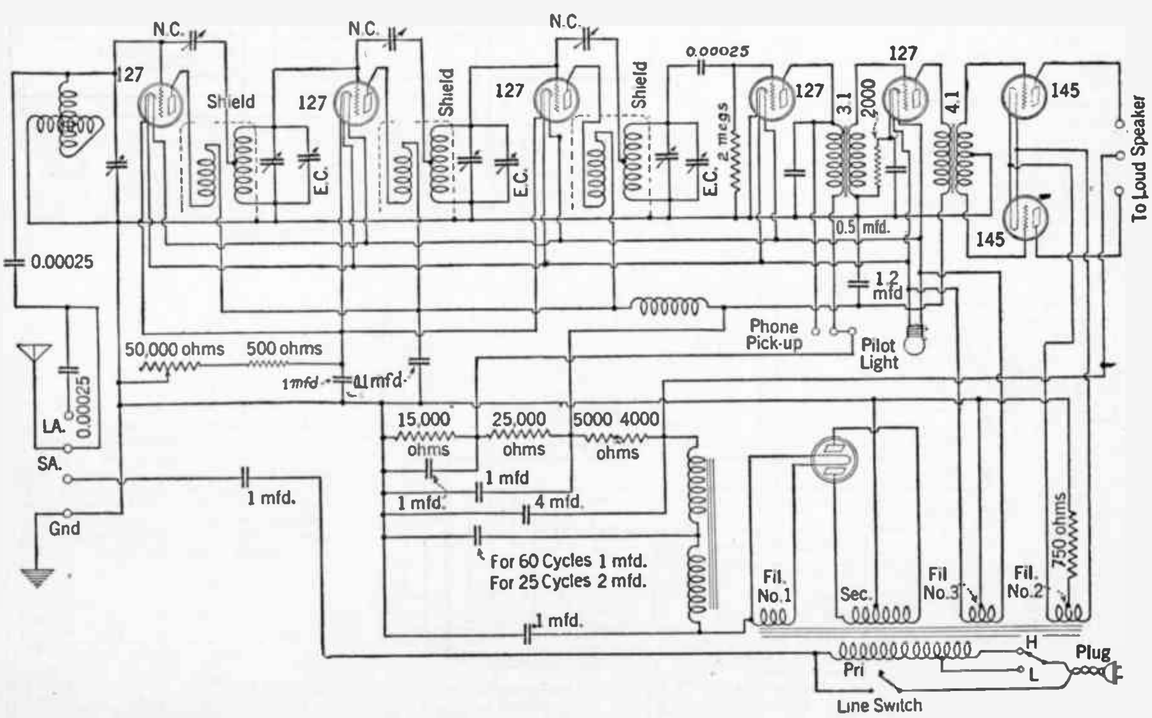
AVERAGE VACUUM TUBE AND LINE VOLTAGES FOR SONORA INSTRUMENTS
Models A-20; A-36; A-44; A-46

Line Voltages		125	120	115	110	105
Primary Voltages across Transformer		87	84	82	50	77
Radio Amplifier Tubes Type RA-1	Filament Voltage	16.0	15.6	15.2	14.8	14.4
	Plate Voltage	125	122	118	115	112
	Plate Current mA.	5.4	5.2	5.0	4.9	4.7
	Grid Bias Voltage	4-6	4-6	4-6	4-6	4-6
Detector Tube Type DE-1	Filament Voltage	2.4	2.3	2.2	2.1	2.0
	Plate Voltage	22	21	20	19.5	19
First Audio Amplifier Tube Type DE-1	Filament Voltage	2.4	2.3.	2.2	2.1	2.0
	Plate Voltage	115	112	110	107	104
	Plate Current mA.	6.0	5.8	5.6	5.3	5.1
	Grid Bias Voltage	6.5	6.2	5.9	5.6	5.3
Push-Pull Audio Amplifier Tubes Type SO-2	Filament Voltage	7.9	7.7	7.5	7.3	7.0
	Plate Voltage	435	420	405	390	380
	Plate Current mA.	47	45	43	41	39
	Grid Bias Voltage	87	84	80	77	73



FREED-EISEMAN RECEIVER MODEL NR-78 A.C.

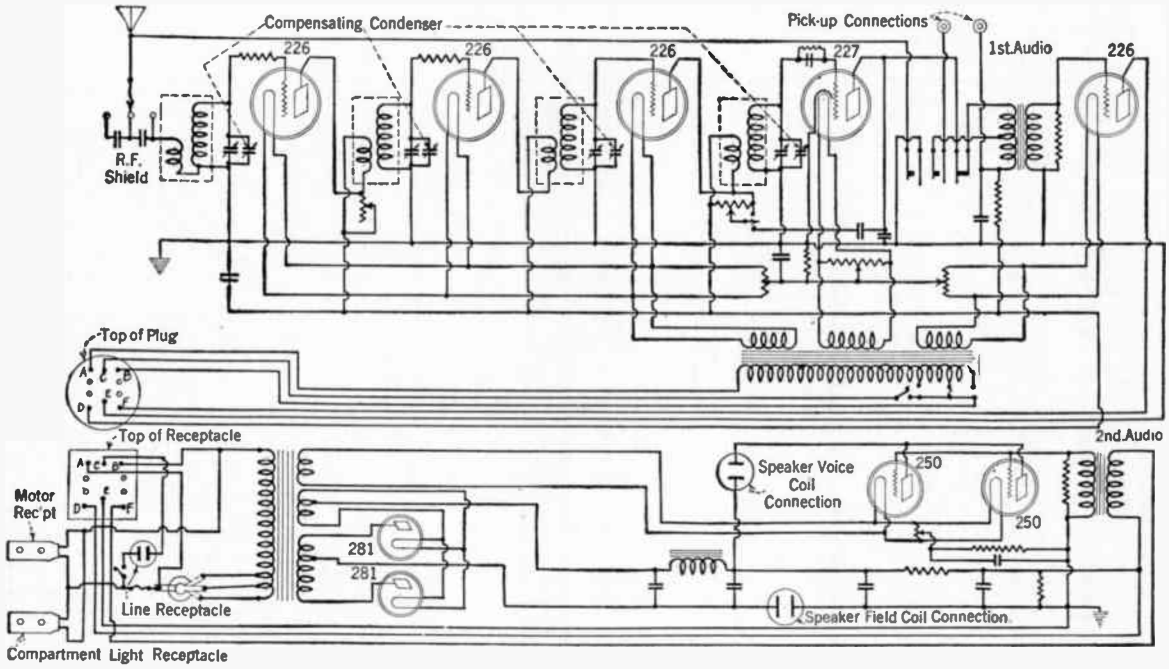
The NR-78 is a completely a.c.-operated receiver using five heater tubes, two power tubes arranged in push-pull, and a full-wave rectifier. Unlike many other sets, the antenna stage in this receiver is tuned by means of a variometer in conjunction with a variable condenser. Either a long or short antenna may be used. The set also contains a 1-mfd. condenser connected to one side of the power circuit so that the light socket may be used for the antenna by simply connecting together two binding posts.



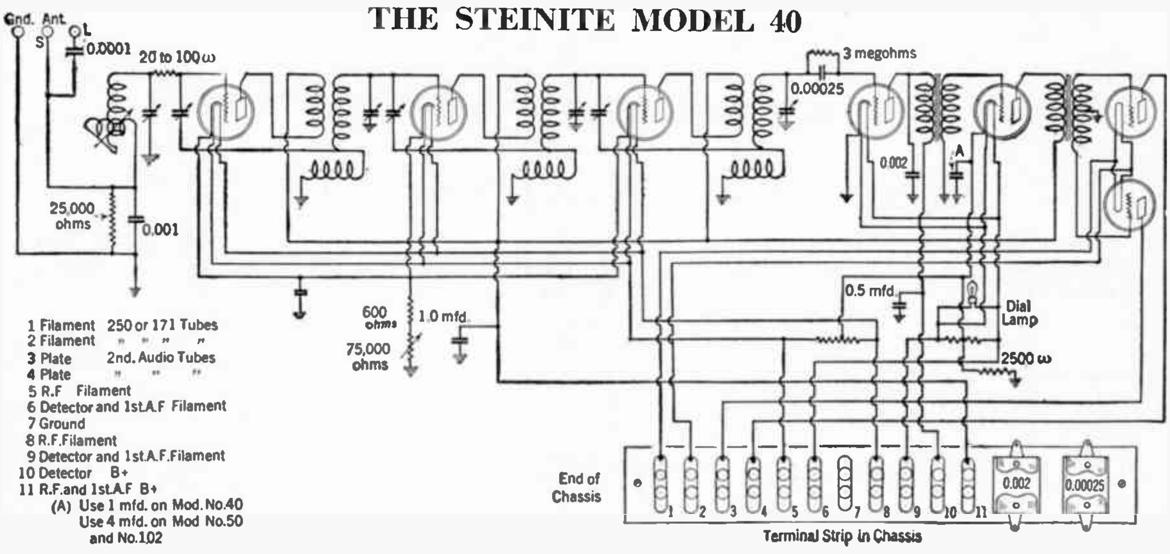
Radio Broadcast's Set Data Sheets

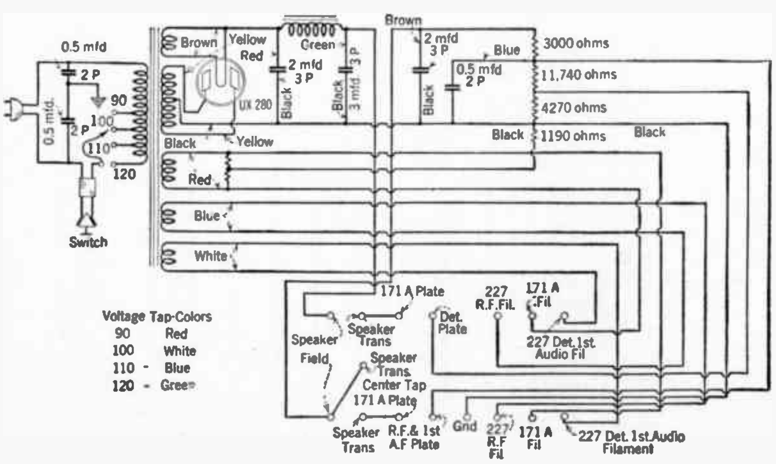
THE EDISON MODEL C-1

Two 250-type tubes in push pull are used in the output circuit of this receiver. Field supply for the dynamic loud speaker is obtained from the filter system. The circuit shows the switch controlling the connections to a phonograph pick-up unit. One detail which is not shown in this diagram is a grid suppressor connected in the grid circuit of the third 226-type tube.



THE STEINITE MODEL 40



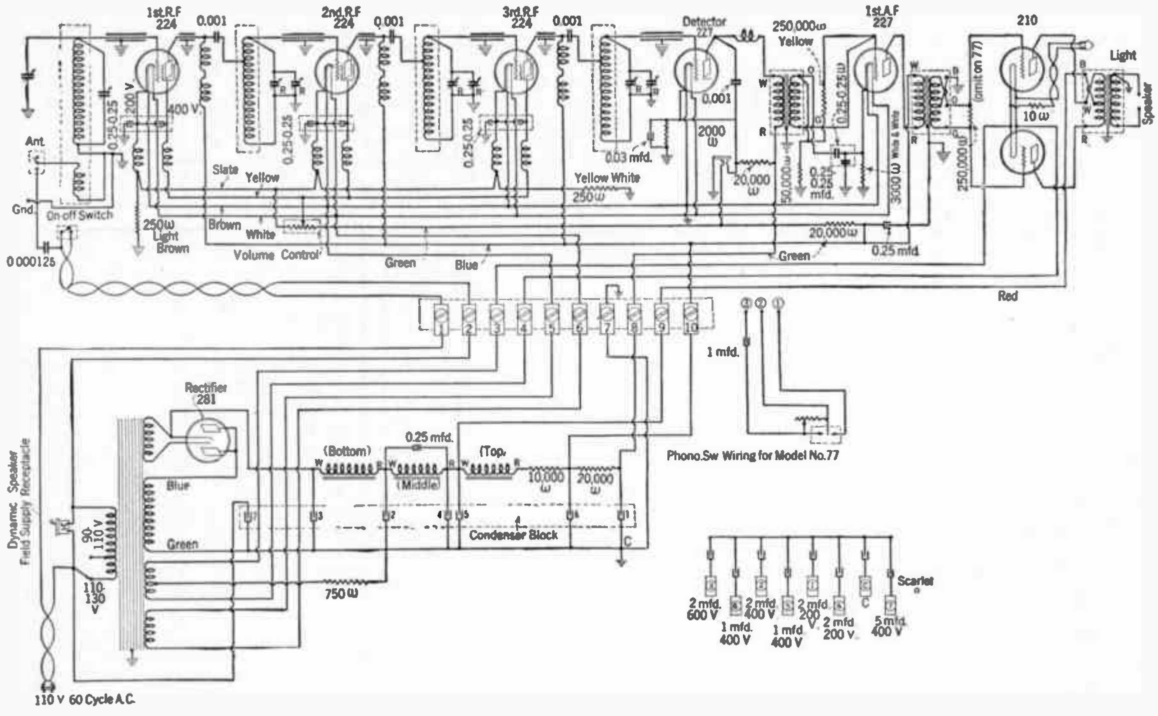


A six-tube receiver using a rather interesting arrangement for maintaining resonance between the first and other tuned circuits. The power unit is of conventional design using a 280-type full-wave rectifier. The power transformer primary is tapped at four points to permit satisfactory line voltage control from 90 to 120.

Radio Broadcast's Set Data Sheets

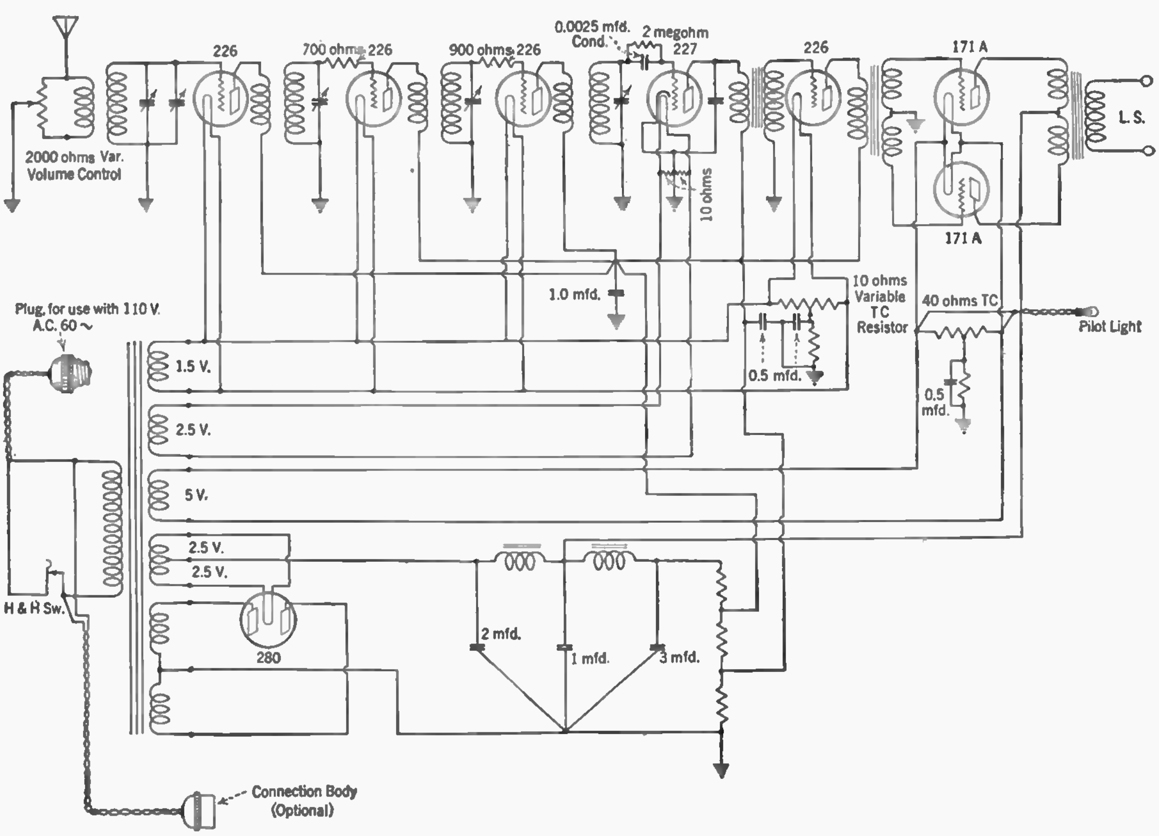
THE FADA MODELS 55 AND 77

This receiver uses three screen-grid tubes in the r.f. stages followed by a plate-circuit detector and a two-stage transformer-coupled audio amplifier. Note the shielding around the grid and plate leads of the r.f. amplifier tubes and the use of r.f. choke coils in the cathode and screen-grid leads. The output tubes are two 210's in push pull.



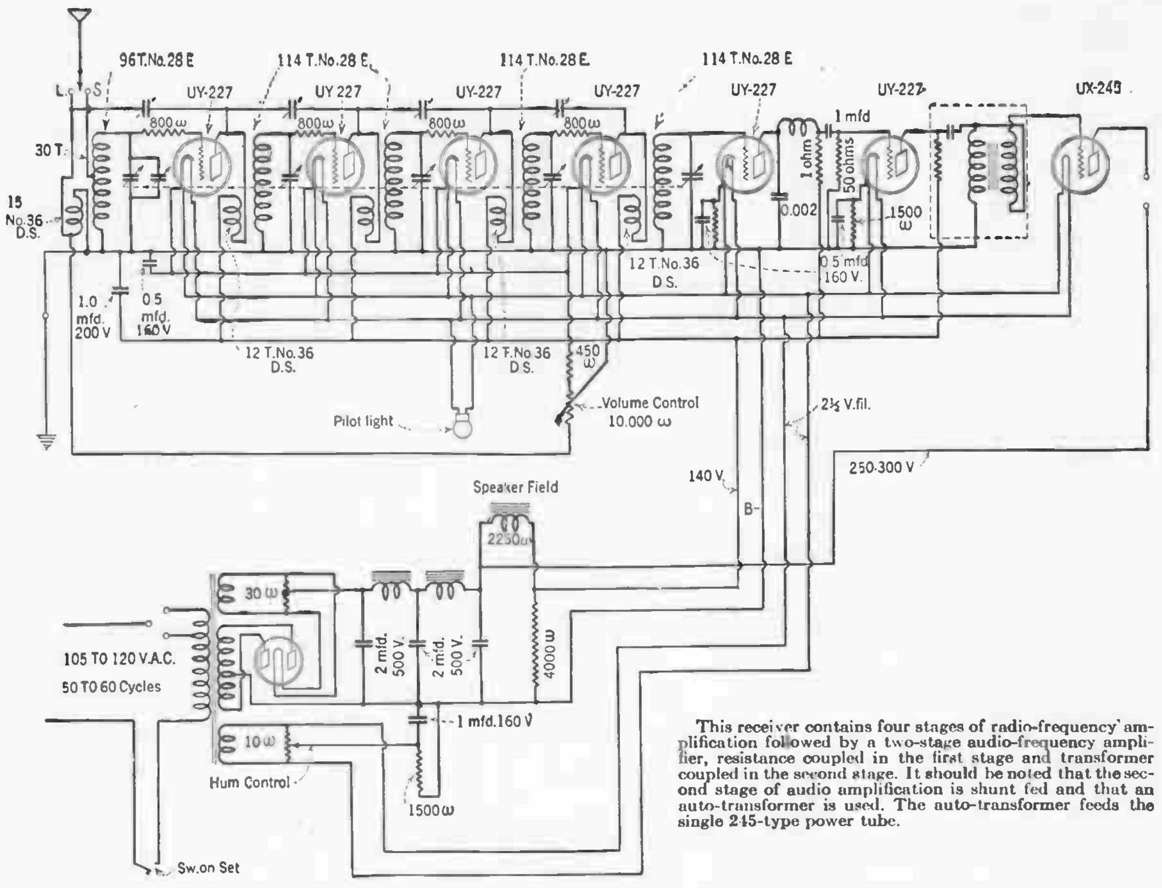
THE BUCKINGHAM MODEL 80

A conventional six-tube receiver using three stages of r.f., a grid leak and condenser detector, and a two-stage transformer-coupled audio amplifier. Grid suppressors are used to prevent oscillations. The volume control varies the input from the antenna circuit.



Radio Broadcast's Set Data Sheets

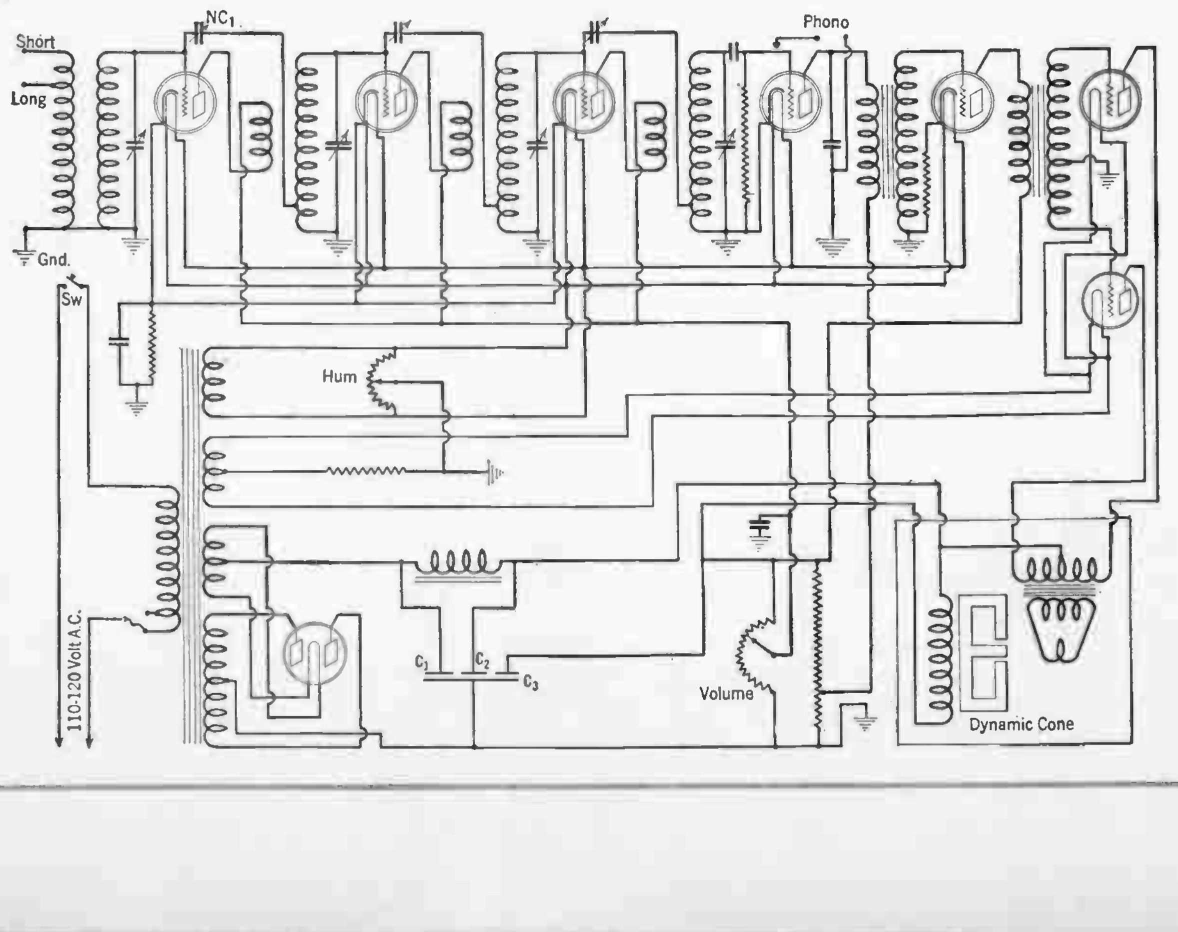
GILFILLAN MODEL 100 RADIO RECEIVER



This receiver contains four stages of radio-frequency amplification followed by a two-stage audio-frequency amplifier, resistance coupled in the first stage and transformer coupled in the second stage. It should be noted that the second stage of audio amplification is shunt fed and that an auto-transformer is used. The auto-transformer feeds the single 245-type power tube.

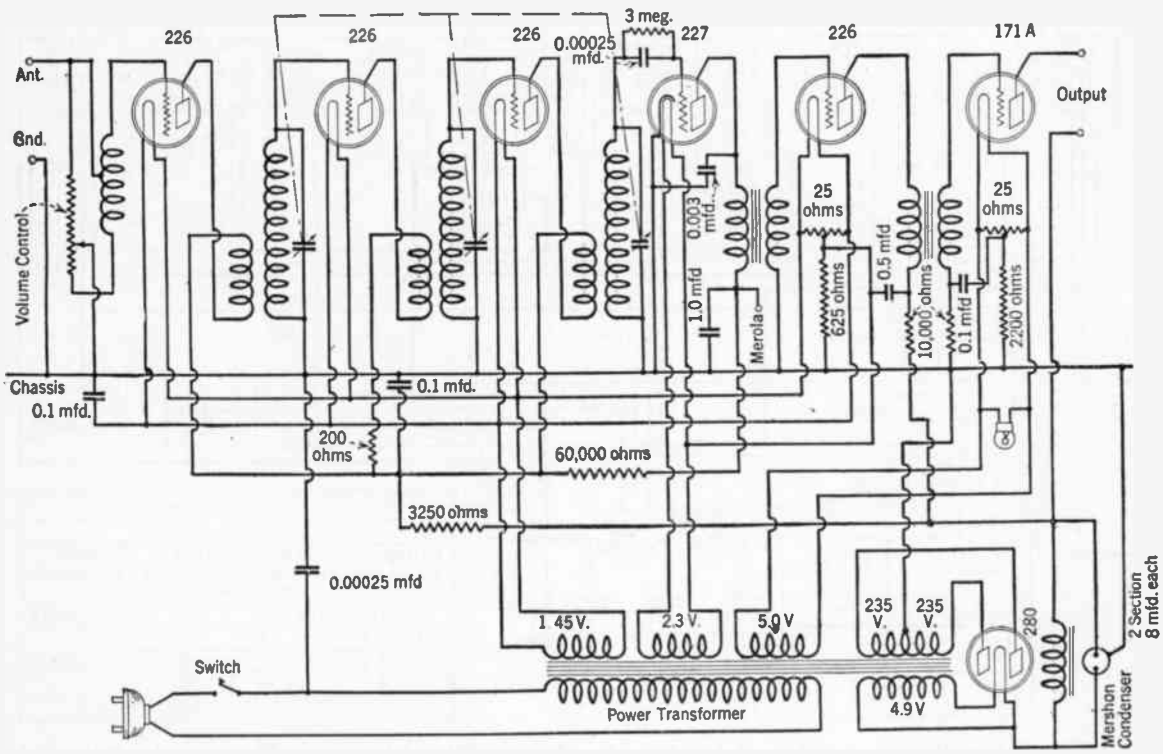
THE KENNEDY RECEIVER CHASSIS NO. 10

This seven-tube receiver employs a three-stage radio-frequency amplifier of high sensitivity and uniform gain. All tuning condensers are ganged to a single control. The detector is followed by the conventional two-stage transformer-coupled audio-frequency amplifier with two 245-type tubes in the output. The radio-phonograph switch connects the phonograph pick-up unit directly to the grid of the detector tube.



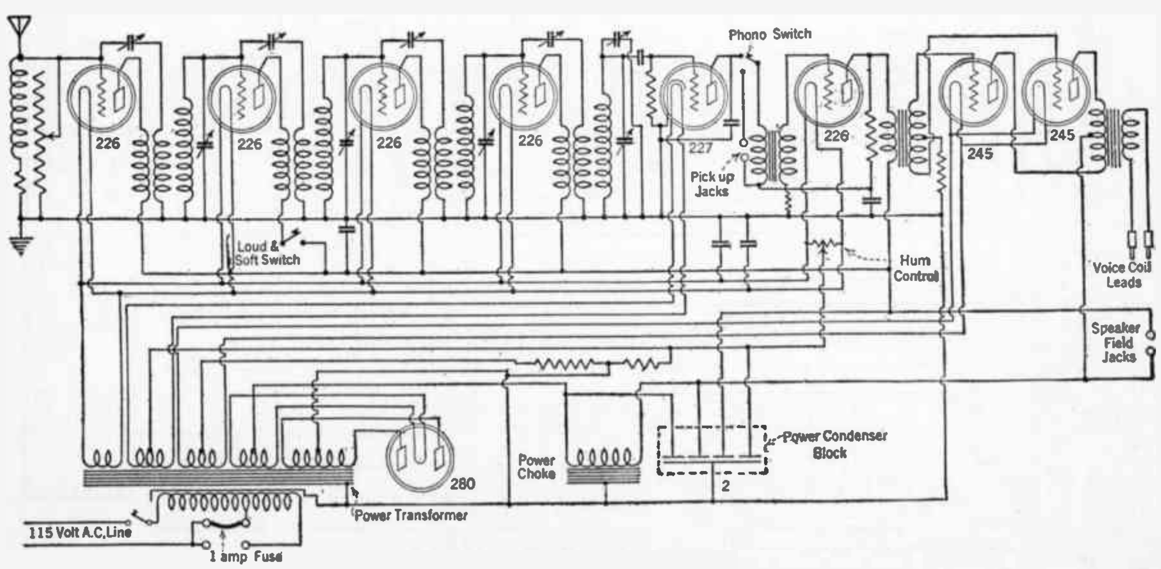
Radio Broadcast's Set Data Sheets

CROSLEY GEMCHEST MODELS 609 AND 610



This is a conventional tuned radio-frequency receiver using a grid-leak-condenser detector and two stages of audio-frequency amplification. The output tube is a single type 171A. Plate voltage is obtained from a 280-type full-wave rectifier the output of which is filtered by a choke in combination with a Mershon condenser. The volume control is a variable resistor across the antenna circuit.

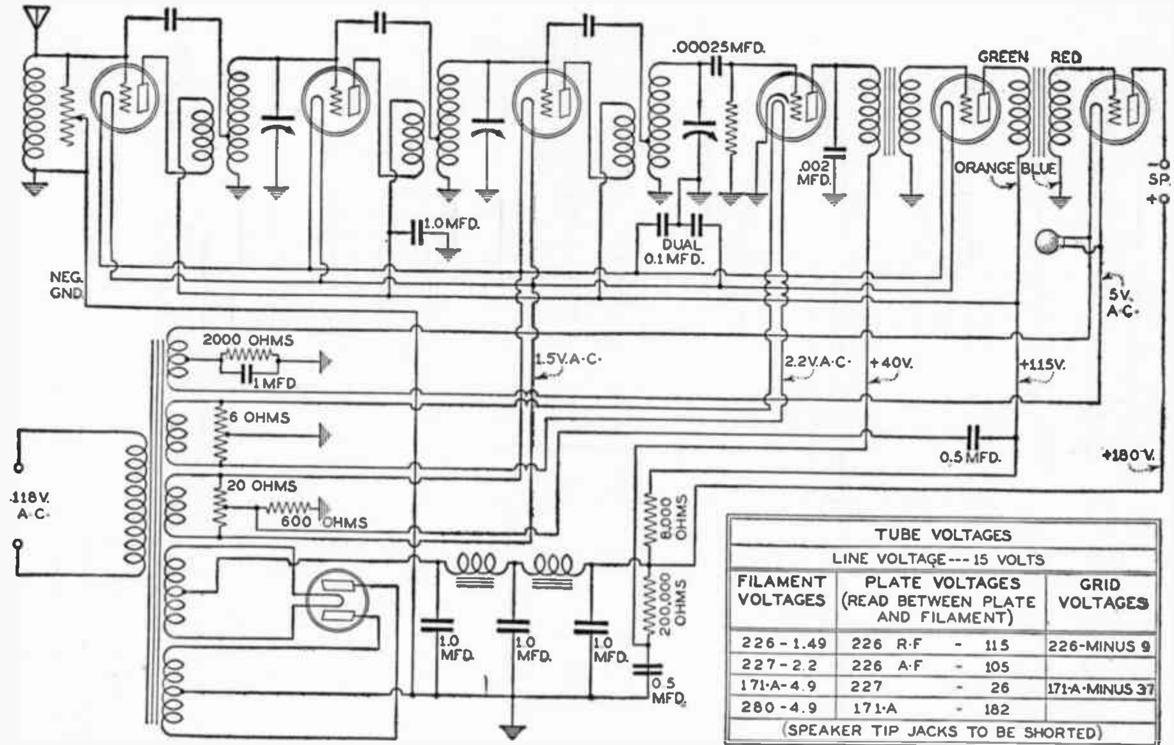
DAY-FAN MODEL 5091 RADIO RECEIVER



This Day-Fan receiver incorporates four balanced tuned stages of radio-frequency amplification, a semi-tuned input system, detector, one stage of straight audio-frequency amplification, and one stage of push-pull audio-frequency amplification. In the output are two 245-type tubes. Power for the electrodynamic loud speaker field is obtained from the filter system.

Radio Broadcast's Set Data Sheets

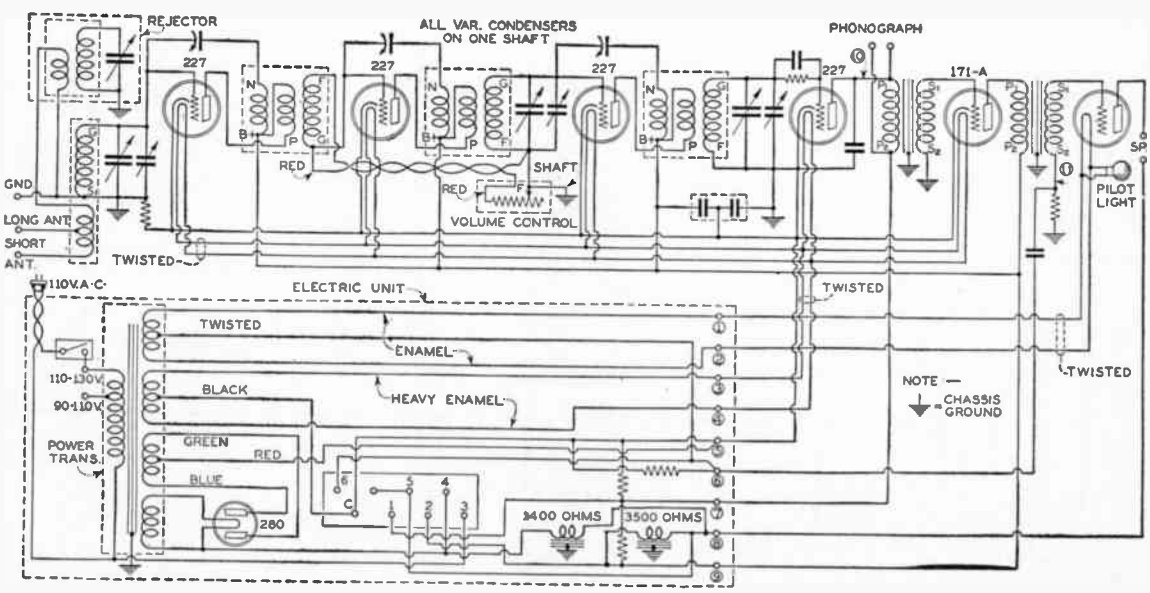
APEX MODEL 36



TUBE VOLTAGES		
LINE VOLTAGE --- 15 VOLTS		
FILAMENT VOLTAGES	PLATE VOLTAGES (READ BETWEEN PLATE AND FILAMENT)	GRID VOLTAGES
226 - 1.49	226 R.F - 115	226-MINUS 9
227 - 2.2	226 A.F - 105	
171-A - 4.9	227 - 26	171-A-MINUS 37
280 - 4.9	171-A - 182	
(SPEAKER TIP JACKS TO BE SHORTED)		

This is a six-tube a.c.-operated receiver consisting of three stages of tuned-radio-frequency amplification, a grid leak-condenser detector, and a two-stage transformer-coupled a.f. amplifier. In the r.f. and first a.f. stages 226-type tubes are used. The detector is a 227-type tube. The power tube is a type 171A. Plate voltages are obtained from a 280-type tube in a full-wave rectifier circuit.

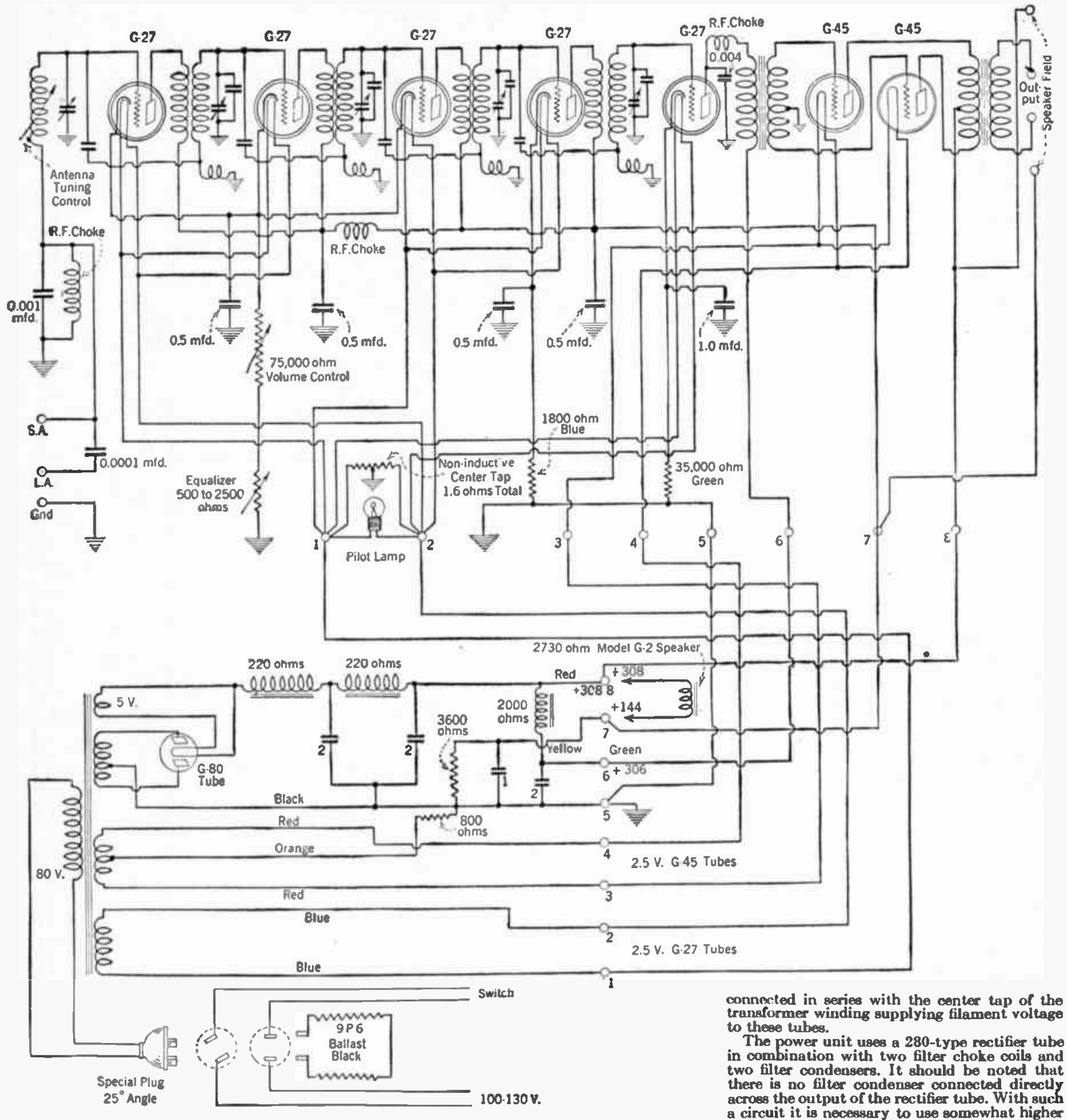
FADA MODELS 10, 11, 30, AND 31 RECEIVERS



One of the unusual features about this Fada receiver is the use of a "rejector" circuit in the antenna stage. The primary of this rejector circuit is placed in series with the primary of the usual antenna transformer. The rejector circuit is not, however, tuned to the frequency of the desired signals but is tuned so as to eliminate undesired signals. Another unusual feature is the use of an untuned r.f. transformer between the first and second r.f. amplifier tubes, the transformer being of such characteristics as to equalize the r.f. gain.

Radio Broadcast's Set Data Sheets

THE MAJESTIC MODEL 90



The Majestic Model 90 receiver uses the same fundamental type of radio-frequency amplifier circuits as did the previous Majestic receivers, Models 70, 70B, and 180. This set uses four stages of tuned-radio-frequency amplification followed by a C-bias detector and a single stage of audio-frequency amplification. There are five tuned circuits in the receiver, all of them controlled by the same tuning dial. Across the second, third, fourth, and fifth tuned circuits small compensating condensers are connected so that all the stages may be accurately tuned to resonance. The inductance of the antenna tuning circuit can be varied slightly so as to compensate the effect of the antenna circuit.

The volume output of the receiver is controlled by varying the grid bias applied to the first, second, and third r.f. amplifier tubes. For this control a variable resistor of 75,000 ohms is connected in series with the cathodes of the r.f. amplifier tubes. Increasing the value of this resistor increases the bias on the tubes and thereby decreases the gain, causing a reduction in volume.

To make the receiver uniformly sensitive over the entire broadcast band, an equalizer circuit is used. This equalizer consists of a variable 500–2500-ohm resistor connected in series with a 75,000-ohm volume control. The shaft of this equalizer is mounted on the rotor shaft of the gang condenser so that as the rotor is turned in tuning the movable arm on the resistor unit moves correspondingly. The result is that an automatic variation in grid bias is obtained which is sufficient to compensate the normal variation in r.f. gain of the receiver.

Grid bias for the fourth r.f. amplifier tube is obtained by the use of a fixed resistor of 1800 ohms connected in series with the cathode of this tube. Bias for the detector tube is obtained by the use of a 35,000-ohm fixed resistor in the cathode circuit of the detector. The two 45-type tubes obtain their bias from an 800-ohm resistor connected in series with the center tap of the transformer winding supplying filament voltage to these tubes.

The power unit uses a 280-type rectifier tube in combination with two filter choke coils and two filter condensers. It should be noted that there is no filter condenser connected directly across the output of the rectifier tube. With such a circuit it is necessary to use somewhat higher voltages across the secondary of the power transformer to obtain sufficient output voltage, but the advantage of such a system is that the load on the rectifier tube is much lighter than it would otherwise be and as a result the rectifier tube will have a long life. The full output of the filter circuit is used to supply grid and plate voltages to the two power tubes. This voltage is decreased for application to the other tubes in the receiver by connecting the field of the electrodynamic loud speaker in series with the high voltage tap so that the plate current of all the tubes except the power tubes must flow through the field winding. The resistance of the field winding is 2730 ohms.

The primary of the power transformer is wound for an input potential of 80 volts so that an automatic line voltage ballast may be used. This automatic ballast functions to supply approximately 80 volts to the primary of the power transformer even though the line voltage fluctuates between 100–130 volts.

Readings With the Weston Set-Tester Model 547

Type Tube	*Tube Position*	*"A" Volts*	*"B" Volts*	*"C" Volts*	*Cath. Volts*	*Nor'l mA.*	*Test mA.*
27	1 R.F.	2.3	150	14	19	3.4	6
27	2 R.F.	2.3	150	13	17	3.5	6
27	3 R.F.	2.3	150	13	18	3.6	6
27	4 R.F.	2.3	158	12	12	6.6	8
27	Det.	2.3	290	29	28	.8	1
45	P.P.	2.4	285	50		35	40
45	P.P.	2.4	285	50		35	40
80	Rect.	4.8				60	

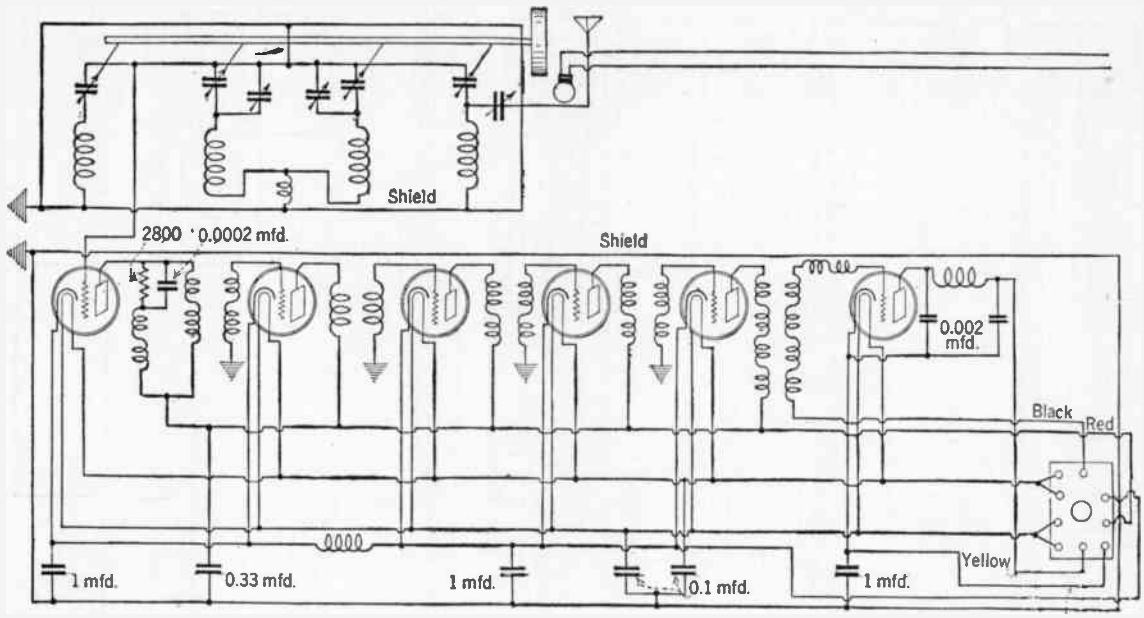
Voltage Readings With Supreme Diagnometer

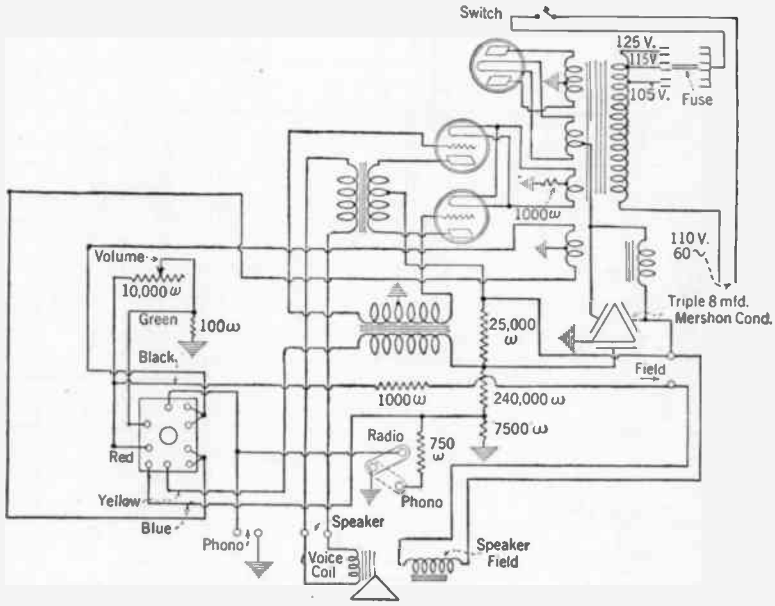
Tube Type	*Use*	*Fil. V.*	*Plate V.*	*Grid V.*	*K.*	*P. Cur.*
27	1 RF	2.35	130	8	8	5.5
27	2 RF	2.35	130	8	8	5.5
27	3 RF	2.35	130	8	8	5.5
27	4 RF	2.35	130	9	9	5
27	Detector	2.35	270	30	30	1
45	Power	2.45	250	50		32
46	Power	2.45	250	50		32

All readings under full load. Line voltage 115 volts.

Radio Broadcast's Set Data Sheets

THE A. C. DAYTON NAVIGATOR





The A-C Dayton Navigator receiver, the circuit of which appears on this sheet, is an example of a set using a system of "pre-selection" in which the signals to be received are selected by several tuned circuits before they reach the first r.f. amplifier tube. Reference to the circuit diagram shows that the tuning dial controls the setting of four variable condensers, each of which functions to tune a circuit to resonance. There are, therefore, four tuned circuits between the antenna and the grid of the first r.f. amplifier tube. Induced in the antenna circuit are signals from all broadcasting stations, but in the process of passing through the various tuned circuits all of these except the desired one are eliminated. Although there are many different signals across the input, in the output of the selector there is only one signal—the desired signal to which the various circuits have been tuned.

THE R. F. AMPLIFIER

After this signal goes through the tuned stages it reaches the first tube of the r.f. amplifier. In the r.f. amplifier there are five tubes and each of these functions to amplify the desired signal. The r.f. amplifier is untuned, that is, it is designed to amplify a signal of any frequency in the broadcast band that is impressed on its input. Since the selector circuits weed out all but the desired signal, the amplifier functions to amplify this signal whether it be from a station transmitting on 500 kc., 1000 kc., or any other frequency in the broadcast band.

The difference between the system described above and that used in many other receivers should be noted. In most sets a tuned circuit is placed between each tube so that the processes of selection and amplification occur in the same circuit. In this receiver the functions of selection and amplification are separate, the signal is first selected and then amplified.

THE DETECTOR CIRCUIT

The output of the r.f. amplifier supplies voltage to a C-bias detector operated at sufficiently high grid and plate voltages (see table) so that it can supply enough a.f. output to operate the two 245-type push-pull tubes at their maximum power. It should be noted that in the plate circuit of the detector tube there is an r.f. filter circuit consisting of r.f. chokes and two 0.002-mfd. condensers. This filter circuit bypasses to the heater of the detector all the r.f. currents in the plate circuit so that only audio-frequency currents will be applied to the primary of the a.f. transformer.

Plate voltage for all the tubes is obtained from the 280-type-rectifier tube which feeds into a filter circuit consisting of two chokes (one of which is the field of the electrodynamic loud speaker) and a three-section Mershon condenser with a capacity of 8 microfards per section. The primary of the power transformer is tapped for various line voltages from 105 to 125.

EASE OF SERVICING

In serving the receiver the fact that the set is made up of three separate sections—the selector, the r.f. amplifier, and the power amplifier and B supply—makes it possible to readily remove any one section and replace it with a new unit while the defective unit is being repaired. The chart of voltage and current readings given on this sheet will prove helpful in determining whether or not the various circuits are receiving the correct voltages and whether the plate current at these voltages is normal.

The fact that the r.f. amplifier is of the untuned type makes it possible to determine readily whether or not the selector unit is in proper working order. For example, if the set does not seem to have very much gain it might be due to some defect in the selector and this could be checked readily by removing the antenna from its usual location at the input of the selector and connecting it instead to the contact between the selector unit and the r.f. amplifier. If the signals from any local station then come in with tremendous volume it is a definite indication that the loss in gain is due to some defect in the selector which can then be removed and replaced with a new unit.

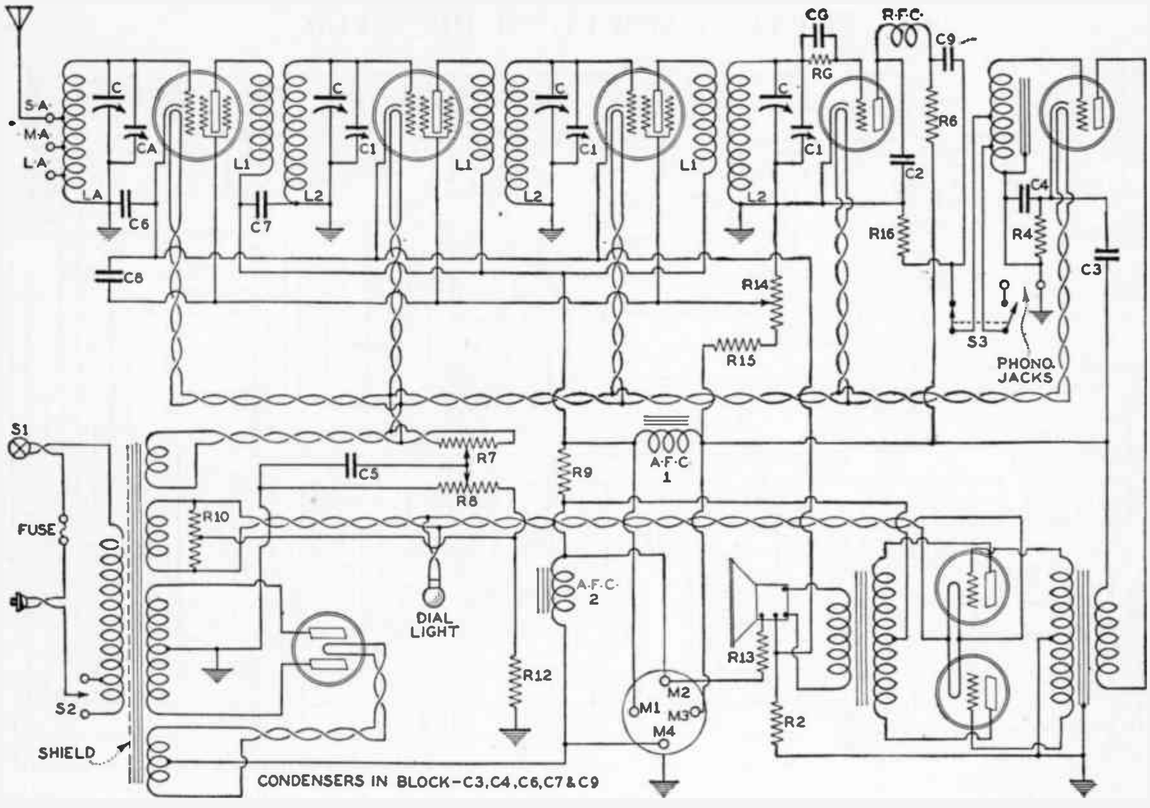
Average Voltage Readings of the A.C. Dayton Navigator Receiver

Tube Number	*Tube Type*	*Function of Tube*	*Heater Volts*	*"B"—Plate Voltage Min. Vol*	*Max. Vol.*	*"C" Bias Volts Min. Vol.*	*Max. Vol.*	*Normal Plate mA.*
1	27	1st. r.f.	2.4	20	110	4.5	3.5	4.5 to 5.0
2	27	2nd. r.f.	2.4	20	110	4.5	3.5	4.5 to 5.0
3	27	3rd. r.f.	2.4	20	110	4.5	3.5	4.5 to 5.0
4	27	4th. r.f.	2.4	20	110	4.5	3.5	4.5 to 5.0
5	27	5th. r.f.	2.4	20	110	4.5	3.5	4.5 to 5.0
6	27	Detector	2.4	180	185	15	15	1.0
7	45	Audio	2.4	230	230	50	50	20 to 24
8	45	Audio	2.4	230	230	50	50	20 to 24
9	80	Rectifier	4.75	330	330			

Note: The above readings for "Detector" are given with the "Phono-Radio" switch in the "Radio" position. With this switch in the "Phono" position, the detector should have the following readings: Plate Volts = 120; "C" Bias = 4.0 volts; Plate current = 5.0 mA.

Radio Broadcast's Set Data Sheets

THE AMRAD MODEL 81 RECEIVER



In these notes on the Amrad Model 81 receiver we have two purposes, first to give a general description of the receiver and secondly to bring to the attention of readers the excellent service manual which has been prepared by the Amrad Company on this set. The manual contains some ninety pages which give valuable data on the importance of service and an excellent description of the engineering basis for the design of the Model 81. It is supplied in a leather binder and can be obtained for $1.50 by writing directly to the Amrad Corporation. The following notes on the Model 81 have been obtained from the manual.

Three Screen-Grid Stages

The Model 81 receiver is designed to use three screen-grid tubes as radio-frequency amplifiers in special circuits of such characteristic as to match the operating characteristics of the screen-grid tube. In this way a design is obtained which gives the receiver a uniform sensitivity over the entire broadcast band, the gain actually varying less than ten per cent. The r.f. transformers are wound with a large number of turns on the primary, the winding being placed at the top end of the secondary. This type of primary does two things; first it gives higher amplification at 500 meters than at 200 meters, and secondly it changes the relation of the feed-back due to capacity between leads so that oscillations are prevented by such couplings rather than assisted as is the case with ordinary radio-frequency transformers. The amplification per stage varies from 30 at 500 meters to 16 at 200 meters. This change in amplification is just the reverse of that obtained in the antenna stage, the result being uniform sensitivity. The overall gain up to the detector measures 23,000 at 500 meters, 28,000 at 300 meters, and 20,000 at 200 meters.

The Detector Circuit

A grid leak-condenser detector is used because a large number of tests by the engineering department of the Corporation indicated that its advantages more than offset its disadvantages. Some of the advantages which are obtained through the use of a grid leak-condenser detector are:

A. Greater sensitivity
B. Does not cause detector tube overloading provided sufficient a.f. amplification is used in order to make the output power tubes overload first.
C. Has no appreciable effect on the fidelity as the selectivity of the r.f. tuning circuit starts to cut off high audio frequencies before the grid leak-condenser detector starts to cut them off.
D. The greater sensitivity of the circuit permits supplying the power tubes with maximum a.f. voltage without the possibility of overloading last r.f. amplifier tube.

The A. F. Circuits

Two stages of audio-frequency amplification are employed. Between the detector and first a.f. stage a special coupling system is used, the detector being shunt fed through a 100,000-ohm resistor, a tapped impedance being used in the grid circuit of the first a.f. amplifier tube and an 0.5-mfd. condenser functioning to couple the detector to the first a.f. tube. An r.f. choke and by-pass condenser are connected in the plate circuit of the detector to keep all audio-frequency currents out of the r.f. amplifier. The various audio-frequency components used in the set are designed to give uniform amplification. This receiver has sixty-two per cent. as much output at 60 cycles, and twenty-five per cent. as much output at 4000 cycles, as at 400 cycles. The lower output at 4000 cycles is largely compensated by a rising frequency characteristic in the loud speaker used.

Volume Control

Volume control is obtained by varying the positive voltage supplied to the screen grids of the r.f. amplifier tubes. Reducing the voltage, of course, reduces the gain and thereby lowers the volume. The resistance unit used is of the graphite type which does not corrode and cause noisy operation.

In the receiver circuit two hum adjusting potentiometers are provided. The first potentiometer permits the adjustment of the amount of positive bias applied to the heater and the other provides a mid-point connection to the heaters.

Reading with a Supreme Radio Diagnometer

Type Tube	*Tube Position*	*"A" Volts*	*"B" Volts*	*"C" Volts*	*Nor'l mA.*	*Screen-Grid Volts*
224	1 R.F.	2.25	180	1.5	4.0	80
224	2 R.F.	2.25	180	1.5	4.0	80
224	3 R.F.	2.25	180	1.5	4.0	80
227	Det.	2.25	30	0	1.5	
227	1 A.F.	2.25	160	10.5	4.1	
245	2 A.F.	2.25	250	50.0	28.0	
245	P. P.	2.25	250	50.0	28.0	
280	Rect.	4.65			110.0	

Line voltage = 120. Set on 120-volt tap. Volume control in full-on position.
Note: Hum-control potentiometer turned to ground side.

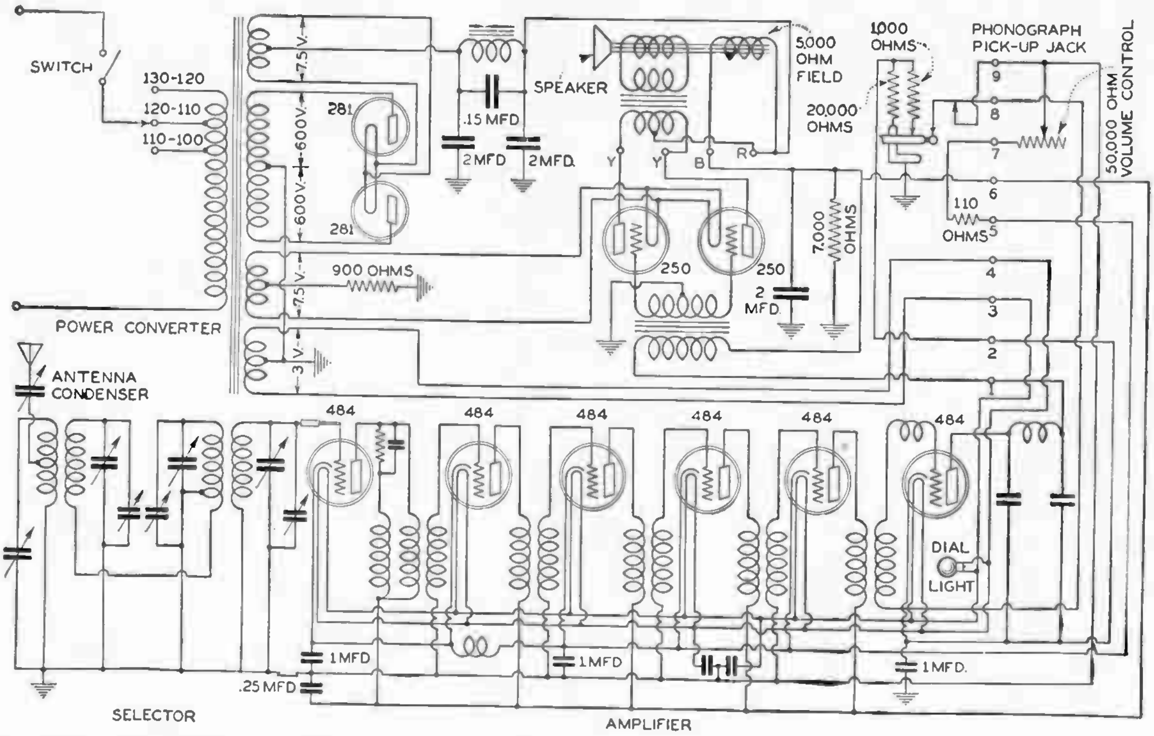
Readings with Jewell Set Analyzer Model 198

				Readings with Plug in Socket of Set and Tube in Tester							
Type of Tube	*Position of Tube*	*Tube Out A Volts*	*Tube Out B Volts*	*A Volts*	*B Volts*	*C Volts*	*Cathode-Heater Volts*	*Normal Plate mA.*	*Plate mA. Grid Test*	*Plate Change mA.*	*Screen Grid Volts*
224	1 R.F.	2.32	190	2.25	180	1.5		4.0	7.5	3.5	80
224	2 R.F.	2.32	190	2.25	180	1.5		4.0	7.5	3.5	80
224	3 R.F.	2.32	190	2.25	180	1.5		4.0	7.5	3.5	80
227	Det.	2.32	140	2.25	30	0		1.5	1.6	0.1	
227	1 A.F.	2.32	190	2.25	160	10.5		4.1	5.2	1.1	
245	2 A.F.	2.32	300	2.25	250	50.0		28.0	32.0	0.4	
245	2 A.F.	2.32	300	2.25	250	50.0		28.0	32.0	0.4	
280	Rect.			4.65				110.0			

Line Voltage = 120. Se. on 120 Volt Tap. Volume control in full-on position.
Note: To get the 10.5 V reading (4–8) the hum-control potentiometer must be turned to ground side.

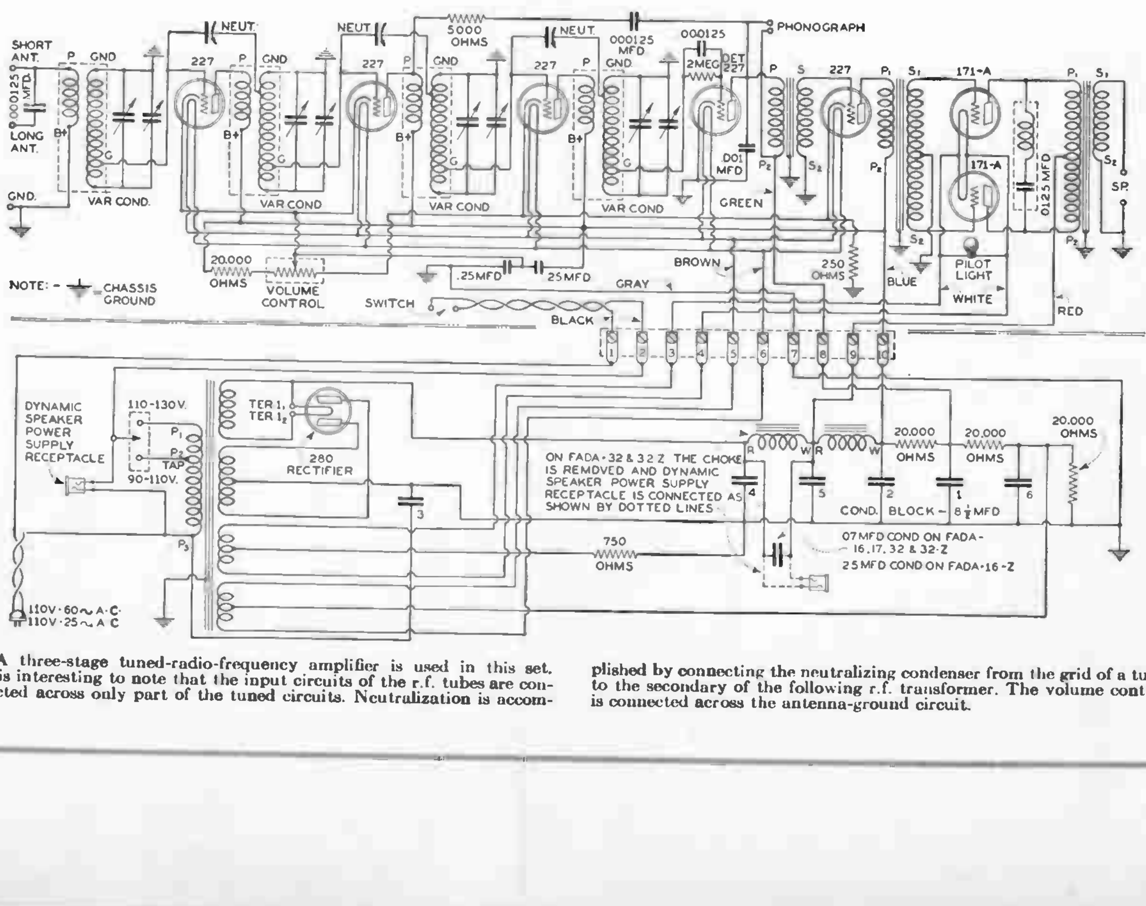
Radio Broadcast's Set Data Sheets

SPARTON MODEL 301 RECEIVER



This receiver uses two 250-type amplifier tubes feeding into an electrodynamic loud speaker. In the filter circuit of the rectifier a tuned circuit consisting of a filter choke coil shunted by an 0.015-mfd. condenser is used. This circuit is tuned to the fundamental frequency of the output of the 280-type rectifier and eliminates practically all of the ripple voltage. The field winding of the electrodynamic loud speaker constitutes the second filter choke coil. The schematic drawing shows how the untuned radio-frequency transformers are connected in the receiver circuit but it does not accurately indicate their unusual construction.

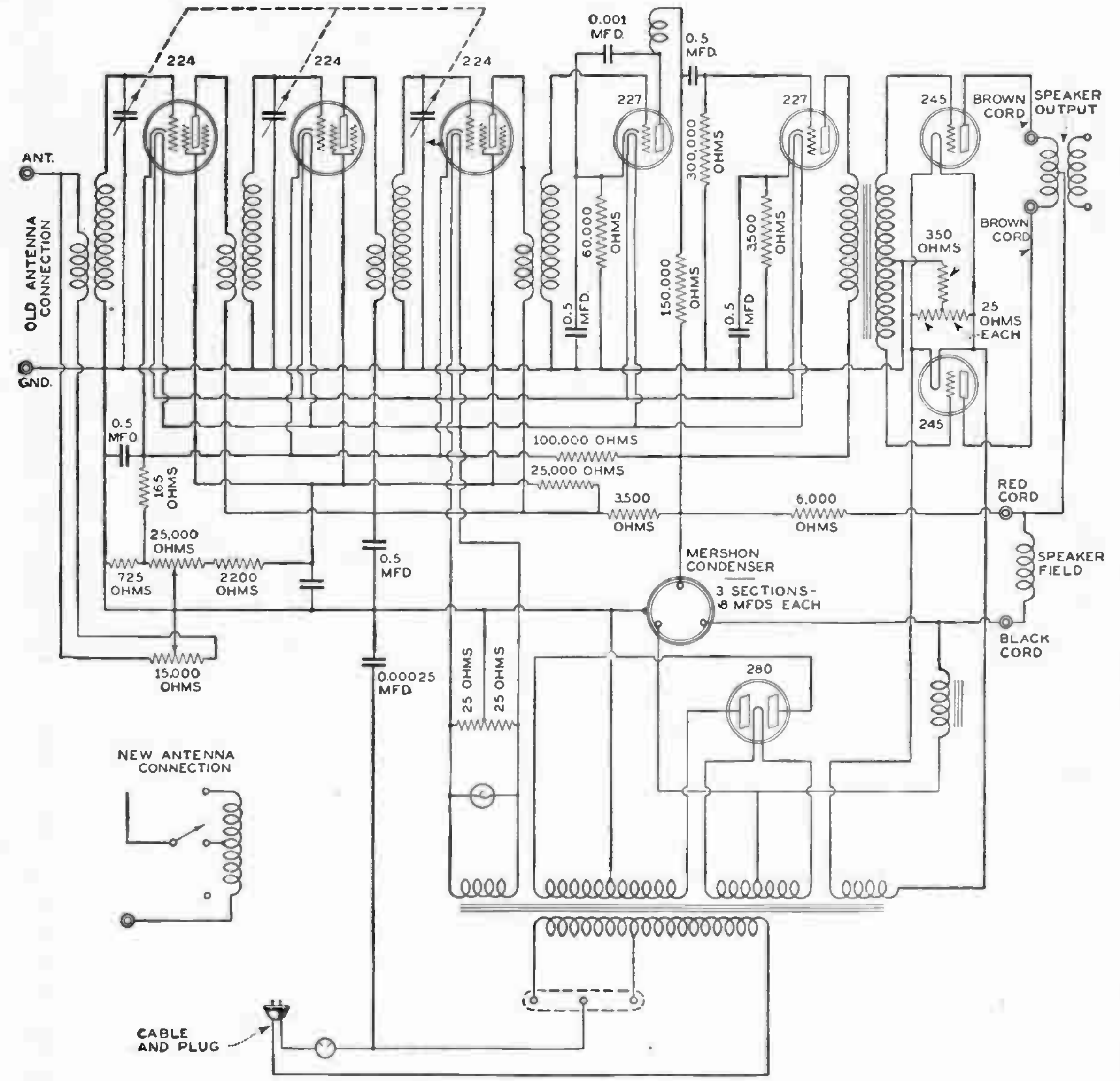
FADA MODELS 16, 17 AND 32



A three-stage tuned-radio-frequency amplifier is used in this set. It is interesting to note that the input circuits of the r.f. tubes are connected across only part of the tuned circuits. Neutralization is accomplished by connecting the neutralizing condenser from the grid of a tube to the secondary of the following r.f. transformer. The volume control is connected across the antenna-ground circuit.

Radio Broadcast's Set Data Sheets

CROSLEY MODELS 40-S, 41-S, 42-S, AND 82-S



THIS RECEIVER incorporates an eight-tube (including rectifier tube) circuit which employs three stages of tuned radio-frequency amplification, an untuned detector stage, and two stages of audio-frequency amplification, the second of which is a transformer-coupled push-pull stage. The first audio-frequency stage is resistance coupled to the detector stage. Screen-grid tubes are used in the radio-frequency stages.

Receivers having serial numbers prefixed with "GC", "GCA", "GCB", or "GCC" have volume controls composed of two rheostats operated simultaneously. One of these is shunted across the antenna coupling coil primary so as to regulate the strength of signal passing through this coil. The other is used to control the potential of the screen grids in the radio-frequency tubes. Receivers of serial numbers other than above have a volume control consisting of but one rheostat, controlling the potential of the screen grids.

The filament supply for the heater-type tubes (that is, the 224-type tubes used in the radio-frequency stages, and the 227-type tubes used in the detector and first a.f. stages) is obtained from a winding on the power transformer. A 50-ohm potentiometer is shunted across the filament supply leads for these tubes, and the middle tap of the potentiometer is connected to the chassis. The dial light is also shunted across these leads. The filaments of the 245-type output tubes are supplied from another winding on the power transformer. The 50-ohm potentiometer shunted across these leads has its mid-point connected through an 850-ohm resistance to the chassis. A third winding on the power transformer supplies current to the filament of the 280-type rectifier tube. The high potential plate supply taps on this winding.

A centertapped high-voltage winding on the power transformer supplies power to the plates of the 280-type tubes. Each end of this winding is connected to one of the plates of the 280-type rectifier tube, so that full-wave rectification is obtained. The tap of this winding is connected to the chassis, which thus acts as the low-potential side of the plate supply. As stated above, the high-potential lead of the plate supply is connected to the transformer secondary supplying power to the filament of the 280-type rectifier tube. This lead is connected through an iron-core choke coil to the "Black" terminal on the receiver. Two sections of the Mershon condenser are connected to the terminals of the choke coil so that the condenser and choke act together as a filter system. When the Dynacoil loud speaker is connected to the receiver, its field coil is placed between the terminals marked "Black" and "Red." Thus the entire plate current from the high-potential lead of the plate-supply circuit passes through the field of the Dynacoil. The plate supply for the two 245-type output tubes is obtained through a connection inside the Dynacoil loud speaker from the field coil of the loud speaker to a mid-tap on the primary side of the built-in output transformer.

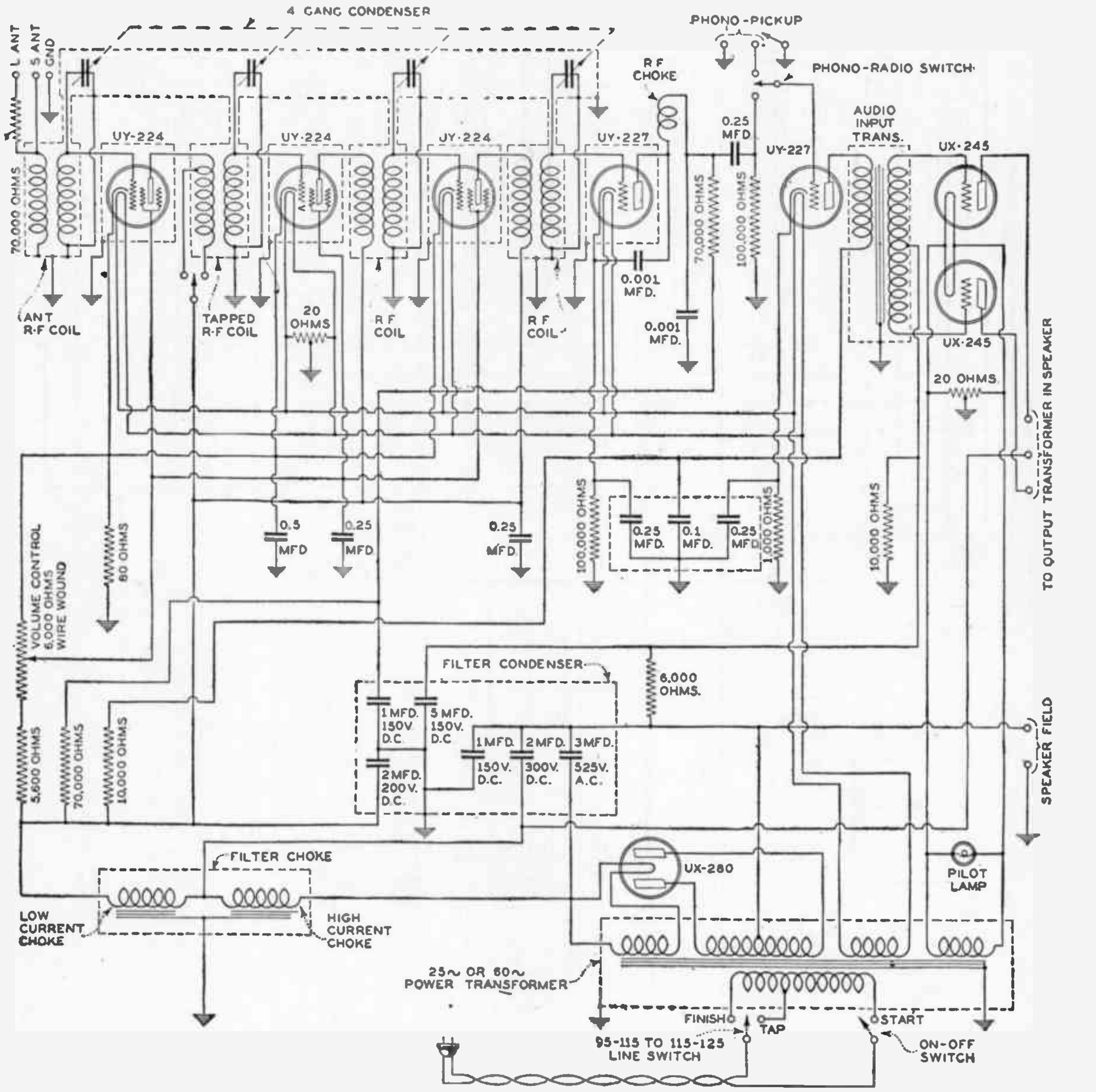
READINGS WITH JEWELL ANALYZER MODELS 198 AND 199

		Tube Out		Readings With Plug in Socket of Set and Tube in Tester							
Type of Tube	Position of Tube	A Volts	B Volts	A Volts	B Volts	C Volts	Cathode-Heater Volts	Normal Plate mA.	Plate Grid Test	Plate Change mA.	Screen Grid Volts
224	1st R.F.	2.60	180	2.40	175	1.5	1.5	1.5	4.0	2.5	70
224	2nd R.F.	2.60	180	2.40	175	1.5	1.5	1.5	4.0	2.5	70
224	3rd R.F.	2.60	180	2.40	175	1.5	1.5	1.5	4.0	2.5	70
227	Det.	2.60	100	2.45	100	12.0	12.	0.2	0.3	0.1	
227	1st A.F.	2.65	220	2.45	180	15.0	12.	4.0	5.0	1.0	
245	2nd A.F.	2.55	265	2.30	240	48.0		26.0	30.0	4.0	
280	Rect.	5.60		5.00				100.0			

Line voltage = 117.5. Set on high voltage tap. Volume control position maximum.

Radio Broadcast's Set Data Sheets

ERLA MODEL 224 A.C. SCREEN-GRID RECEIVER



The circuit of this receiver chassis employs three stages of tuned-radio-frequency amplification with four tuned circuits and uses three 224-type screen-grid tubes. The detector is a 227-type tube operated in a grid-bias or plate-rectification circuit. In the first audio-frequency stage a 227-type tube is employed with resistance-coupled amplification. In the output stage two 245-type tubes are used in a push pull. Reference to the diagram will show that two antenna connections are provided. For most purposes the "S. Ant." connection should be used as it provides the greatest sensitivity, but if a very long antenna is used, connection should be made to the "L. Ant." post. It will be noted that the "L. Ant." connection consists of a resister (attenuator) in series with the "S. Ant." connection. This serves to cut down the signal pickup and consequently the noise level when a very long antenna is used.

The local-distance switch functions to tap the primary coil of the first r.f. transformer. When in the tapped or "local" position the amplification is decreased. This setting is best for most local stations as that proper control of volume is obtained. By moving this switch to the distance position extreme sensitivity is obtained, but if powerful local stations are tuned-in improper volume control action is obtained for these strong signals tend to overload the screen-grid tubes.

The volume control consists of a 6000-ohm wire-wound potentiometer connected so as to vary the screen voltage on the screen-grid tubes. In combination with this volume control a single-pole, double-throw toggle switch is employed to throw the receiver from "phonograph" to "radio." When the control is turned all the way to the left the input to the resistance-coupled a.f. stage is switched from the output of the detector circuit to the phonograph pick-up jacks on the rear of the chassis. It will be noted that a small clip-type switch is connected across one of the jacks and the chassis frame. This clip should be connected in this manner when the pick-up unit is not inserted in the jacks, as otherwise a hum will be evident when the volume control is set so that the receiver is in the phonograph position. This hum results from having the input circuit of this first a.f. tube open.

A small toggle switch located alongside of the 280-type rectifier tube is used to tap the primary of the power transformer. The approximate line voltage ranges for the two positions of this switch are shown. It is well to keep this switch in the 115–125-volt position wherever possible.

The loud speaker used with this receiver is of the electrodynamic type and contains in its assembly the output transformer for coupling the output of the two 245-type tubes to the moving coil of the loud speaker. The field of this loud speaker has a d.c. resistance of 1000 ohms and is designed to carry 100 milliamperes. All connections from the loud speaker are made by means of a five-conductor cable and the special five-prong plug which avoids any danger of improperly connecting the loud speaker to the receiver.

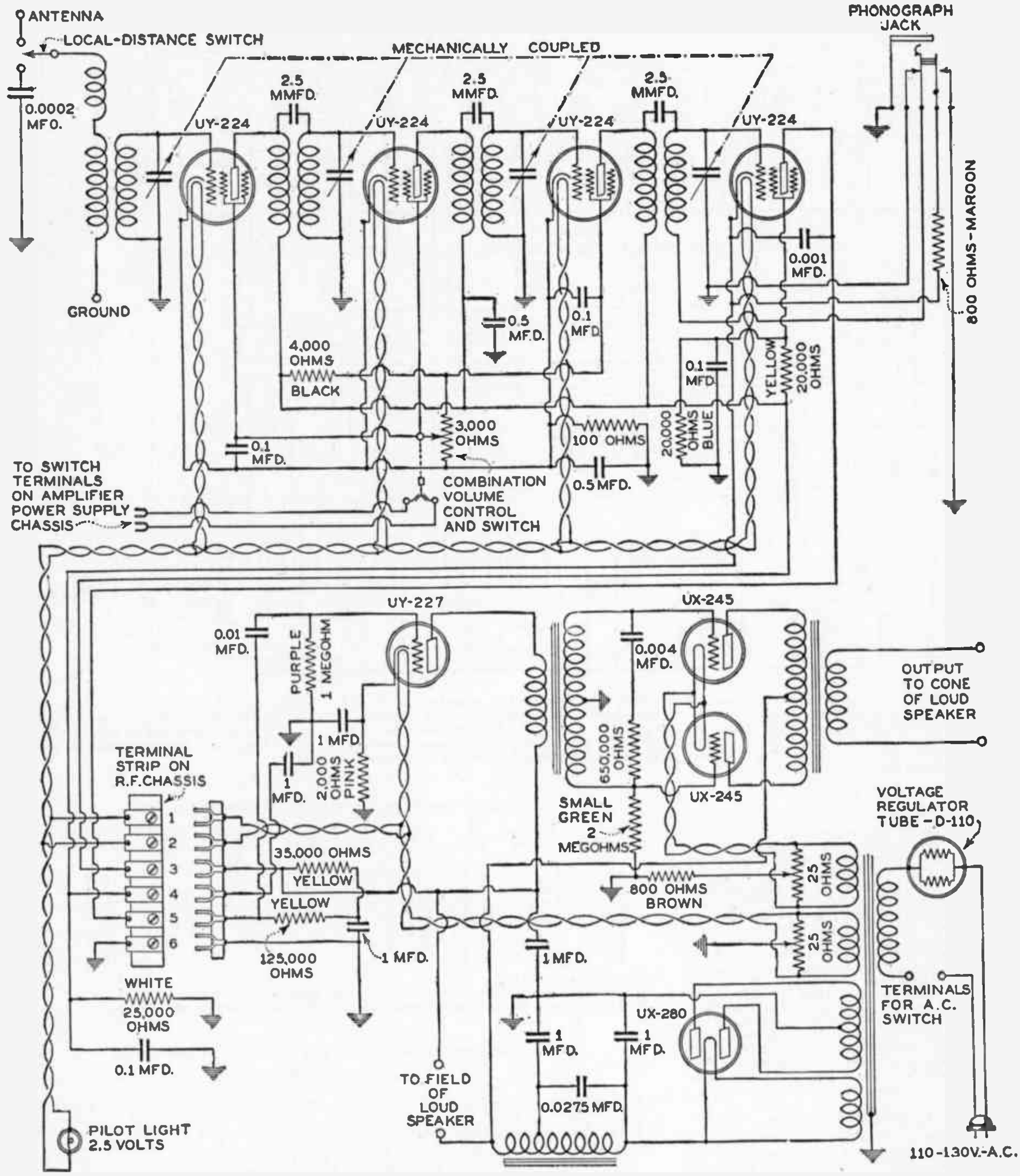
Average Voltage Readings

Position of Tube	*Type of Tube*	*Fil. Volts (A.C.)*	*Screen-grid to cathode volts*	*Plate to cathode volts*	*Ground to cathode volts*	*Grid to filament volts*
Rectifier	280	4.8 to 5		340 to 360		
2nd A.F.	245	2.4 to 2.5		240 to 250		45 to 50
1st A.F.	227	2.35 to 2.4		90 to 100	4.5	
Det.	227	2.35 to 2.4		60 to 75	6 to 7.5	
R.F.	224	2.35 to 2.4	75 to 80	160 to 170	1.5 to 2	

(The above are based on a line potential of 110 volts and the switch in the 95–115 position, no signal and volume control at maximum.)

Radio Broadcast's Set Data Sheets

BREMER TULLY MODELS S-81 AND S-82



THE CHASSIS used in the Models S-81 and S-82 receivers is designed for the new a.c. screen-grid tubes. The radio-frequency circuit consists of three stages of tuned and shielded high-gain amplification using the a.c. heater-type screen-grid tubes (224). By the use of localized shielding and proper grounding (each rotor section of the tandem condenser assembly is individually grounded even though the rotors are electrically connected in a common grounded steel shaft) the chassis and tubes are made accessible and are unencumbered by unnecessary shielding. All wiring is rigidly secured in position under the automobile-type steel chassis and protected from interstage reaction by the use of secondary aluminum shields. All r.f. coils are matched to a standard and are interchangeable. Volume is controlled by increasing or decreasing the screen-grid voltage. A local-distance switch controls the sensitivity.

The power detector uses the grid-bias method of demodulation instead of the condenser-leak method. This is possible because of the tremendous amplification secured in the radio-frequency amplifier. The power detector is a screen-grid tube.

The power detector is automatically biased for use as an amplifier for the reproduction of phonograph music when the magnetic pick-up unit is plugged into the jack provided at the rear of the r.f. chassis. Any good high-impedance pick-up unit provided with a volume control may be used.

AVERAGE VOLTAGE READINGS

Type of Tube	Position of Tube	A Volts	B Volts	C Volts	Normal Plate mA.
227	1st R.F.	2.5	150	12	5.5
227	2nd R.F.	2.5	150	12	5.5
227	3rd R.F.	2.5	150	12	5.5
227	Detector	2.5	45	0	3.4
227	1st A. F.	2.5	145	9	3.6
245	1st P-P	2.4	240	27	30.0
245	2nd P-P	2.4	240	27	30.0
280	Rectifier	5.0			
D98	Ballast				

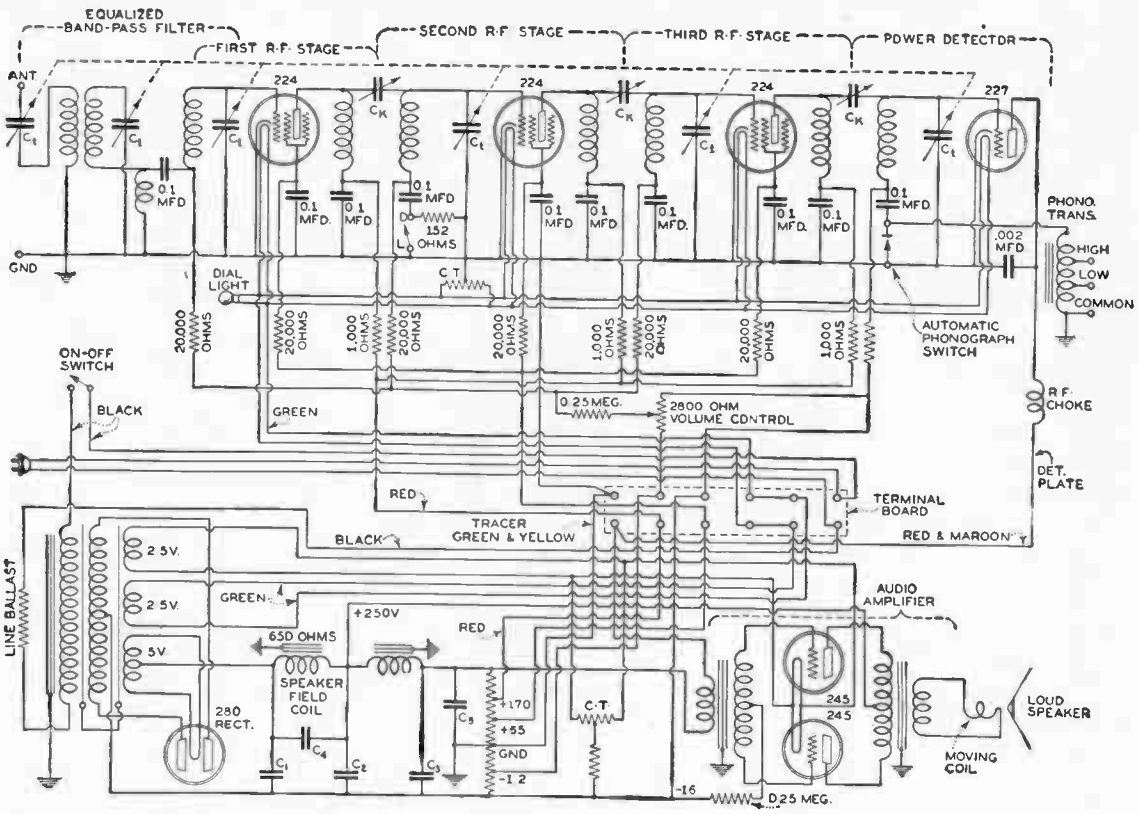
The audio-frequency amplifier consists of two stages. The first stage of amplification is resistance coupled to the detector tube, and employs a heater-type tube of the 227 type. The power amplifier employs two 245-type tubes in a push-pull amplifier circuit. All amplifying tubes and the detector tube have automatic grid-bias control which compensates differences in current drain from the rectifier system.

The power pack supplies all required voltages to the seven receiving tubes and energy for the field of the electrodynamic loud speaker. The Duresite type No. 110 voltage-regulator tube maintains a constant voltage across the primary of the power transformer, and protects the other tubes in the receiver from line voltage changes between 98 and 130 volts.

The direct current filter system is tuned to remove all trace of a.c. ripple. The loud speaker field acts as an additional choke in the filter system, and also furnishes the necessary resistance to reduce the high voltage for the two 245 tubes to the correct value for the r.f. and a.f. amplifier tubes.

Radio Broadcast's Set Data Sheets

GREBE SK-4 SUPER-SYNCHROPHASE RECEIVER



THIS RECEIVER consists of a three-stage screen-grid r.f. amplifier, a type 227 detector, and a push-pull output stage using two 245-type tubes supplying power to an electro-dynamic loud speaker. The receiver contains several unusual features.

R.F. Amplifier

Preceding the first screen-grid radio-frequency amplifier tube is a band-pass filter circuit consisting of two tuned circuits coupled by both capacity and inductance. Tuning condensers associated with these band-pass circuits are marked Ct on the diagram and these circuits function to prevent any signals other than those from the desired station from being impressed on the grid of the first r.f. amplifier tube. Highly selective circuits of this type are used, especially in connection with the screen-grid r.f. amplifiers, because these tubes tend to produce cross-talk. Cross-talk is eliminated if the circuits preceding the first tube are sufficiently selective to prevent practically all signals other than the one desired from being impressed on the first tube. To obtain this high selectivity simple tuned circuits might be used but these would produce sideband suppression. By the use of band-pass circuits, high selectivity without sideband suppression is obtained.

Impedance Coupling

The following tubes in the r.f. amplifier are impedance coupled, that is, a tuned circuit is in the plate circuit of each tube. The plates are choke fed and the tubes are coupled to the tuned circuits through small adjustable condensers, Ck. The condensers are, of course, properly adjusted at the factory and need only be altered in the event that the set has been tampered with or the adjustments have been altered due to rough handling.

Detector Circuit

The detector, using a 227-type tube, is of the plate-detection type. In the grid circuit of the detector tube a phonograph pick-up transformer is connected with two taps to make it suitable for use with either low- or high-impedance pick-up units. In normal operation as a radio receiver this transformer is shorted out of the circuit by the phonograph switch. When the set is to be used with a phonograph pick-up unit this switch is opened and the phonograph pick-up transformer is thereby connected in series with the grid circuit of the detector.

A.F. Amplifier

The two 245-type power tubes obtain a.f. signal voltage from the secondary of the a.f. transformer, the primary of which is connected in the plate circuit of the detector tube. Since push-pull amplifiers sometimes have a tendency to oscillate, a ¼-megohm resistor is connected in series with the center tap of the secondary of the transformer. This resistor prevents the circuit from oscillating but has no effect on the audio-frequency characteristics of the amplifier.

READINGS WITH WESTON SET TESTER MODEL 547

Type Tube	*Tube Position*	*A Volts*	*B Volts*	*C Volts*	*Screen Volts*	*Screen Current*	*Cathode Volts*	*Normal mA.*	*Grid Test mA.*
224	1 R.F.	2.4	155	0.2	38	0.5		2.8	32.0
224	2 R.F.	2.4	150	0.2	38	0.5		2.8	3.0
224	3 R.F.	2.4	150	0.2	38	0.5		2.8	3.5
227	Det.	2.4	180					0.5	1.4
245	P. P.	2.4	225	*				37.0	42.0
245	P. P.	2.4	225	*				37.0	42.0
280	Rect.	4.9						50.0 per anode	

Line Voltage = 116
*No bias reading at socket due to resistance in series with grid.
Bias can be read with voltmeter lead connected between filament and chassis.

READINGS WITH JEWELL SET ANALYZER MODEL 198

Type of Tube	*Position of Tube*	*Tube Out A Volts*	*Tube Out B Volts*	*Readings with Plug in Socket of Set and Tube in Tester* A Volts	*B Volts*	*C Volts*	*Cathode Heater Volts*	*Normal Plate Volts*	*Plate mA. Grid Test*	*Plate Change mA.*	*Screen Grid Volts*
224	1 R.F.	2.7	195	2.35	188	14		0	2.0	2	57
224	2 R.F.	2.7	195	2.35	188	14		0	2.0	2	57
224	3 R.F.	2.7	195	2.35	188	14		0	2.0	2	57
227	Det.	2.7	195	2.35	210	x		0.8	0.8	0	
245	1 A.F.	2.7	270	2.35	245	x		30.0	34.0	4	
245	2 A.F.	2.7	270	2.35	245	x		30.0	34.0	4	
280	Rect.	7.0		5.2		x		90.0			

Line Voltage = 120. Volume control position Min.*
Note: x Resistors in circuit prevent readings.
Note: *224 plate curreut read with volume control at maximum position.

READINGS WITH A SUPREME RADIO DIAGNOMETER

Type Tube	*Tube Position*	*A Volts*	*B Volts*	*C Volts*	*Screen Volts*	*Nor'l mA.*
224	1 R.F.	2.4	155	0.2	38	2.8
224	2 R.F.	2.4	150	0.2	38	2.8
224	3 R.F.	2.4	150	0.2	38	2.8
227	Det.	2.4	180			.5
245	P. P.	2.4	225	*		37.0
245	P. P.	2.4	225	*		37.0
280	Rect.	4.9				50.0

Line Voltage = 116
*No bias reading at socket due to resistance in series with grid. Bias read with voltmeter lead connected between filament and chassis.

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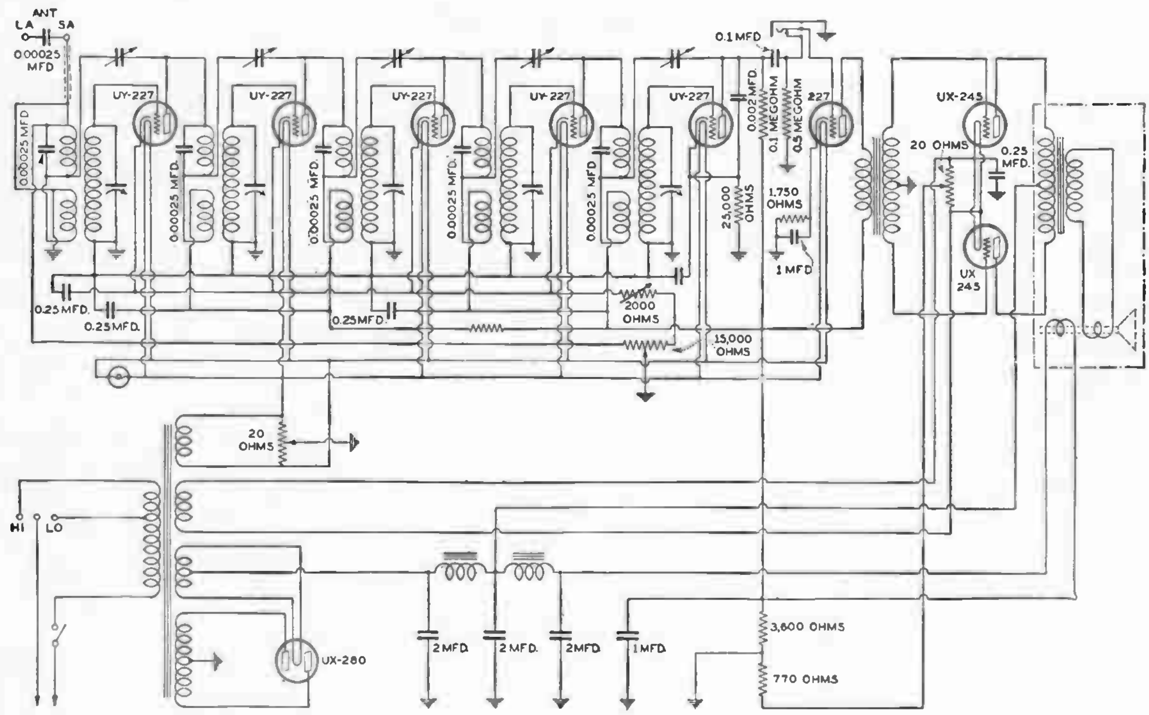
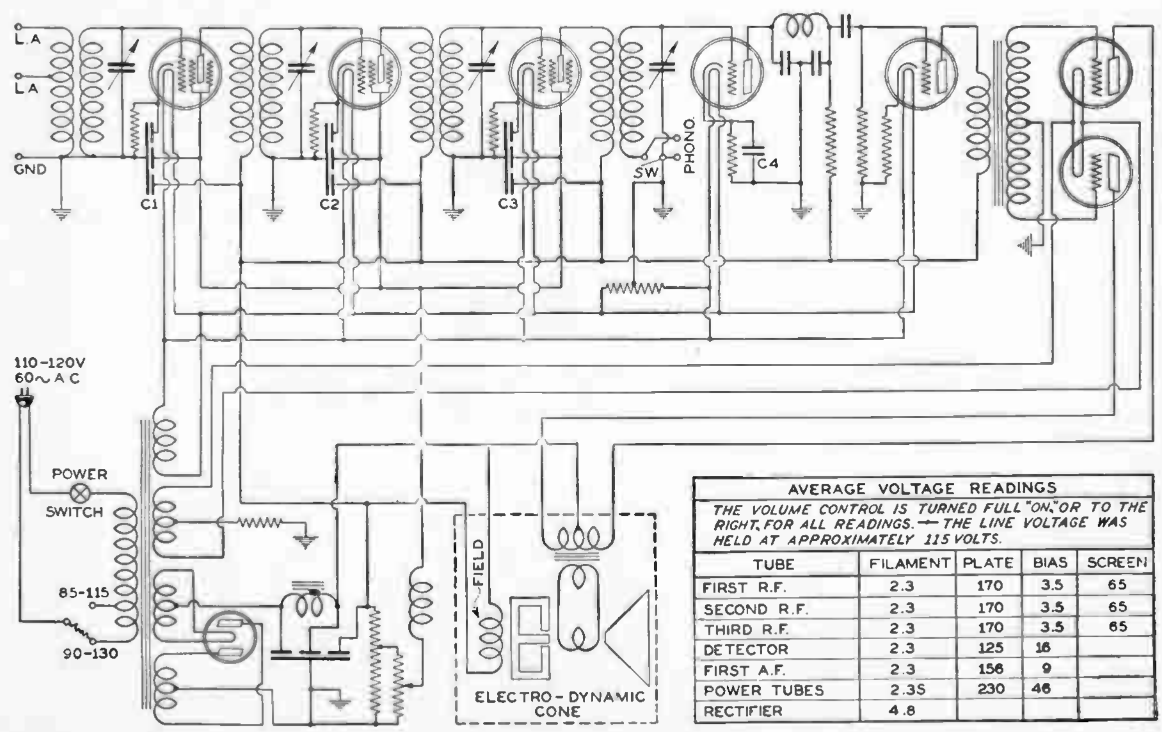
THE BALKEIT MODEL C

An interesting feature of this receiver is the use of double primaries on all of the radio-frequency transformers. In all cases the two primary windings are connected in series and an 0.00025-mfd. fixed condenser is connected across one of the primaries. These two windings are used to obtain uniform r.f. gain over the entire broadcast band, the capacity shunted winding being most effective at low radio frequencies and the unshunted winding being most effective at high radio frequencies, thus the inefficiency of each winding is compensated by the other.



THE KENNEDY CHASSIS NO 10

This is a screen-grid receiver using three 224-type tubes as r.f. amplifiers followed by a C-bias detector, one resistance-coupled a.f. stage, and one transformer-coupled a.f. stage. Note the r.f. filter in the detector output consisting of an r.f. choke and two fixed condensers, such a filter being essential when the detector is resistance coupled to the following amplifier tube.



AVERAGE VOLTAGE READINGS				
THE VOLUME CONTROL IS TURNED FULL "ON," OR TO THE RIGHT, FOR ALL READINGS.—THE LINE VOLTAGE WAS HELD AT APPROXIMATELY 115 VOLTS.				
TUBE	FILAMENT	PLATE	BIAS	SCREEN
FIRST R.F.	2.3	170	3.5	65
SECOND R.F.	2.3	170	3.5	65
THIRD R.F.	2.3	170	3.5	65
DETECTOR	2.3	125	16	
FIRST A.F.	2.3	156	9	
POWER TUBES	2.35	230	46	
RECTIFIER	4.8			

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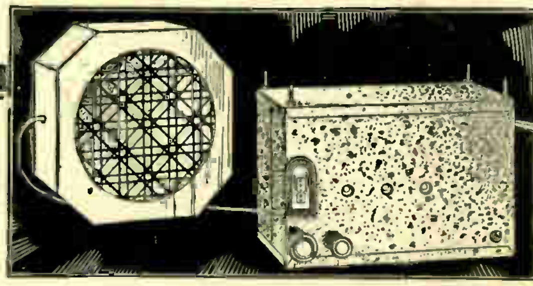
SM

You'll Put *This* Auto-Set In Your *Own* Car!



On the market the first of June, the S-M 770 Auto-Set has proven itself to have *everything!*

1. SENSITIVITY—2.5 to 14 microvolts per meter (an average of 8 over the broadcast band). That's *one* of the things that makes possible real console-model reception.
2. THREE SCREEN-GRID TUBES and '71A 2nd Audio—giving you console-model *wallop.*
3. SCREEN-GRID POWER DETECTION—as you know, *five times* better than a '27 detector!
4. POSITIVE TUNING—directly through a regular S-M 810 illuminated drum dial, eliminating dubious control through a "remote" shaft—another feature exactly like the finest console.
5. SMALL SIZE—12 inches long by 7½ inches high and 6¼ inches deep—a pocket edition expressly designed for its job.
6. NO CUTTING UP THE CAR—mounts on brackets under the cowl to the right of the driver's seat—dial and controls easily seen and accessible.
7. VIBRATION-PROOF—tests over hundreds of miles of rough back-country roads have proven this Auto-Set to be trouble-proof and shock-free.
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9. STURDY—cabinet built of heavy sheet steel.
10. RESISTANCE-COUPLED DETECTOR—giving fidelity fully equal to modern full-size receivers.

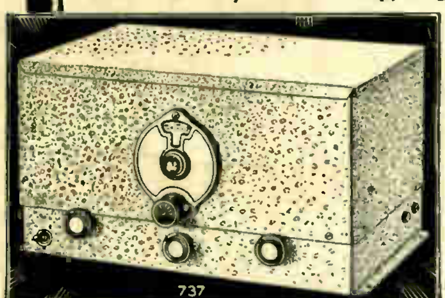
The Auto-Set was designed by the world-famous Silver-Marshall laboratories to give absolutely *everything* regardless of price—but look at the prices:

770 Auto-Set, receiver only, RCA license. Price $79.50 list. Parts total $61.40. (Tubes required, 3—'24, 1—'12A, 1—'71A.)

771 Auto-Set Accessories, including all installation equipment but batteries, tubes and speaker. Price $17.50 list.

870 Automotive Magnetic Speaker (9½" wide by 3" deep). Price $15.00 list.

And a Big Power Amplifier with Twice the Wallop!



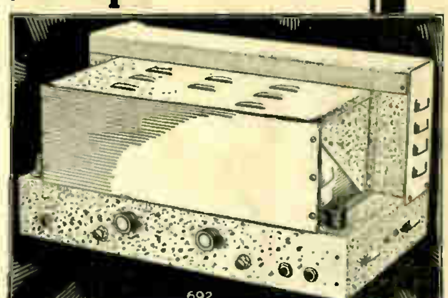
737

For Short Waves: The Bearcat

The first all-modern short-wave receiver—a. c. with built-in power supply, gang condenser, and 2 s.g. tubes. Single tuning dial—you can spread the crowded ham bands by a twist of the wrist—no tools required. Treat yourself to a short-wave set that will "get Prague" whenever Prague can be got. S-M 737—wired complete, $139.60 list. Component parts total $109.60.

The S-M 692 Amplifier combines perfect fidelity of tone with twice as much amplification as any other three-stage amplifier available today! Its unusual fidelity is due to uniform amplification of the higher harmonics in the 5000 to 10,000 cycle range. While most amplifiers cut off fairly abruptly around 5000 cycles, the 692 has as much amplification at 10,000 as at 400. The low-frequency end is exceptionally good, too, the curve going below 30 cycles and giving no peak in the 60 to 300 cycle range.

The 692 gets its power from any 105-120 volt, 50-60 cycle, a. c. source and has a voltage amplification of 4000 (72 d.b.) which comes primarily from the use of an a. c. '24 screen-grid tube in the first audio stage. It has an input circuit of "universal" type and will operate directly out of any pickup of 200 to 10,000 ohms. Completely wired and tested, less tubes, $245 list.



692

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.... No. 19: 692 Power Amplifier.
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