the GENERAL RADIO Experimenter

GR Exp Index 1926-

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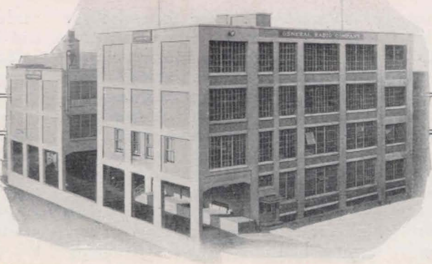
The GENERAL RADIO EXPERIMENTER



VOL. I NO. 1 JUNE, 1926

Announcing a New General Radio Service for Experimenters

There are many phases of radio—particularly concerning the development of apparatus and its application other than its more common uses in broadcast reception—in which there is considerable interest.

To supplement the technical information already contained in the leading radio magazines, the General Radio "Experimenter" will be issued every month to provide the experimenter with reliable data and helpful suggestions which may be put to good use in the home laboratory. It will also reveal some of the interesting information which extensive research in the General Radio laboratory has yielded.

The topic chosen for discussion in this issue treats upon a subject in which there is a wide interest, namely—**better quality of radio reproduction.**

The improvement in quality has come about principally thru the design of better tubes, audio amplifying transformers, and loudspeakers; the problem of particular interest to the General Radio Company being that of transformer design.

It will be remembered that in 1915 the first audio amplifying transformer having a closed core was introduced by the General Radio Company. At that time the closed core was looked upon as a radical departure from the open core type which had been the standard practice. It was not long, however, before this type of transformer was adopted by practically all radio manufacturers.

Be Sure To Return the Enclosed Postcard

"The Experimenter" will be published each month for the purpose of supplying unbiased information pertaining to radio apparatus design and application. We aim to treat fairly and thoroughly subjects of interest to experimenters. Only through your co-operation in sending us helpful suggestions and requests for articles on topics you wish analyzed can we accomplish our aim.

Our permanent mailing list to receive future copies of "The Experimenter" will be made up from the returned post cards. Assure yourself of receiving all future copies by mailing us your card today.

Improved quality of broadcasting, reproducing instruments, and better tubes made it quite desirable to improve transformer design still further and to meet new conditions the General Radio Type 285 transformers were developed.

In the article on transformer design contained in this issue C. T. Burke, of the Engineering Department, gives some very interesting and instructive data based upon numerous laboratory experiments in amplification and measurements of various types of transformers.

July Issue of "The Experimenter" to Contain Treatise on "B" Elimination

While complete battery elimination has not yet reached a stage where it is generally satisfactory for receivers employing various tube combinations, great strides are being made in that direction and today the "B" eliminator, because of its unfailing plate voltage and relief from the bother of continual battery replacements, bids well to eclipse to a large extent the use of "B" batteries.

Although the successful operation of a battery eliminator depends fundamentally upon the rectifying device, the use of well designed rectifier transformers and filter chokes is imperative.

Considerable research has been conducted in the General Radio laboratory upon this subject which has yielded a store of interesting information which H. W. Lamson, of the Engineering Department, will discuss in his article on "B" battery elimination in the July issue.

Future issues of the "Experimenter" will contain articles on popular engineering subjects and information concerning the development and processes of manufacture of various instruments.

It is hoped that thru this medium the experimenter may become more familiar with the underlying principles of apparatus design and application so that he may have a more complete and accurate knowledge of radio upon which to base his experimental activities.

Amplifier Ins and Outs

By C. T. BURKE, Engineering Department

"All that goes up must come down," is a familiar axiom. If we could establish for radio a parallel axiom, "All that goes in must come out," the radio millennium would be reached. Designers are steadily approaching this goal, and the progress of the last few years has been enormous. During the last year particularly has the swing been toward getting out more of what went in, rather than getting more in. That is, the fad for "getting" stations is passing. In its place is arising a demand for natural reproduction. This is a problem of getting out all that went in, for if some notes are subdued or lost, in passage through the set, the reproduced music will not sound natural. This newly critical attitude refuses to regard radio as a marvel, to be accepted in silent wonder in spite of any shortcomings. The radio set is forced to stand comparison with other forms of entertainment on its merits as a musical instrument. This attitude is the compelling force behind the recent great improvements in audio amplifying and reproducing devices.

The problem of "quality," by which is meant the accurate and faithful reproduction of the matter sent into the air at the broadcasting station, is three-fold, embracing tubes, transformers, and loudspeakers. As each phase of the subject is worthy of individual consideration, only the second, that of transformers, will be considered here. The other two should not be forgotten, however, for the amplifier cannot be much better than its poorest element. Perfect transformers will not compensate for improperly biased, overloaded tubes or a squawky loudspeaker.

As it is not possible to invite all my readers into the laboratory to hear the tests I am about to describe, it is necessary to devise a means of putting the result on paper, so that they can use their eyes to judge instead of their ears. The means of doing this is to reproduce the "amplification curve." The data for this curve is obtained by measuring the amplification at a number of frequencies. A curve is plotted of amplification against frequency, and as the principal source of transformer distortion is unequal amplification of different frequencies, a study of this curve shows even more definitely than the ear could, just what is the relative rating of two amplifiers. It is not necessary to have the curve a straight horizontal line, which would indicate the perfect amplifier. A variation of twenty-five per cent would not be perceptive to the average ear. The frequencies above five thousand may be lost without serious loss of quality. The curve should remain high for frequencies at least as low as one hundred cycles. Probably the most interesting part of the curve is that between one hundred and five hundred cycles. Most of the older transformers failed to amplify in this range, and its full amplification is essential to natural sounding music. In order to study this part of the curve, which is crowded at the lower end, more easily, a special method of plotting the curves has been resorted to. Instead of making the distance along the frequency scale proportional to frequency, it has been made proportional to the logarithm of the frequency. The effect is similar to that obtained with the "straight line frequency" condensers now so popular. The lower end of the curve is opened up, spread over more space.

Just how much transformers have improved during the last few years is apparent from the curves of figure 1, which show the characteristics of four transformers of different vintages. Transformers No. 1 and 2 are of the older types designed before the period of development of quality reproduction. No.'s 3 and 4 are both "new era" transformers. The difference between the new and the old is very noticeable. No. 1 has a marked peak at about eight hundred cycles. This frequency would be amplified to a much greater extent than those above and below, resulting in bad distortion. No. 2 lets through practically nothing under one hundred cycles and has but half its maximum amplification at four hundred cycles. Many frequencies that go into this amplifier do not come out. The result of this type of distortion, the loss of the low frequencies, is to give music a harsh mechanical sound. The transformers of curves 3 and 4 are a vast improvement over these earlier types, and are typical of several transformers making their appearance during the past year. The deviation of the maximum and minimum from the average amplification over this range is so slight as to be barely noticeable to the ordinary ear.

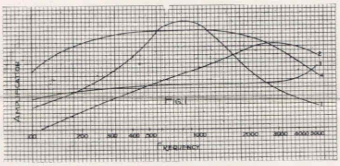


Fig. 1. A group of representative transformers. The superiority of the new types (curves 3 and 4) is marked.

An interesting and important fact is discovered when the turns ratio of these four transformers is considered. No. 1 had 8.5:1, No. 2, 3:1, No. 3, 2:1, No. 4, 6:1. Note that the 8.5:1 transformer has a lower amplification than the 6:1 over practically the entire frequency range, and at both ends passes below even the 2:1. Another interesting point is that the 3:1 transformer distorts to a much greater extent than the 6:1, despite the popular idea that low ratio transformers necessarily have better characteristics than those of high ratio.

It was not entirely without reason that high ratio transformers have been viewed with some suspicion. Notice again the curve of the 8:1 transformer. This is typical of the older style high ratio transformers. The loss of the high frequencies is easy to understand. The coil capacity acts as a bypass for these frequencies, short-circuiting them to ground. The loss of the low notes is due to the fact that the primary turns were kept low in order to get high turns ratio with a small coil. The result of this practice may be explained with the as-

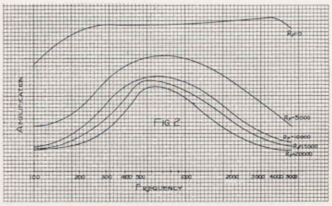


Fig. 2. The result of varying plate impedance on a transformer of low primary impedance. When the plate impedance equals that of the ordinary receiving tube (12,000-15,000 ohms) the curve is badly peaked.

sistance of the curves of Figs. 2 and 3.

In the audio amplifier, the transformer primary is connected in series with the plate impedance of the tube, which is about 15,000 ohms for the common types of receiving tubes. A considerable portion of the voltage supplied by the signal is used up in this impedance. The portion of the voltage left across the transformer primary depends upon the relation of transformer impedance to the total impedance of transformer and tube. Thus if the tube impedance is 15,000 ohms and the transformer impedance 30,000, two-thirds of the voltage will be impressed across the transformer primary. It will now be seen why a high ratio transformer sometimes gives less amplification than one of low ratio. Suppose a 5:1 transformer had 150,000 ohms impedance at a certain frequency. Another transformer with an 8:1 ratio has but 15,000 ohms impedance in the primary. Both are used with a 15,000 ohm tube, with 10 volts available. The 5:1 transformer will have 150,000/165,000 of 10 volts or 9.3 volts across the primary. Assuming no losses the secondary voltage would be 47 volts. Only 15,000/30,000 or 5 volts will be impressed across the primary of the 8:1 transformer, with a secondary voltage of 40.

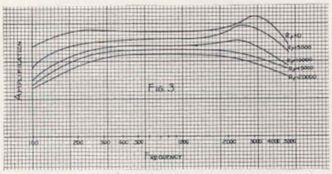


Fig. 3. The effect of plate impedence on the operation of a transformer of high primary impedance. The curves of Fig. 2 and 4 show the importance of making measurements with a resistance in series with the transformer primary. Otherwise an entirely false impression may be conveyed.

As the transformer impedance varies with frequency, while the tube impedance remains constant, the input to the transformer varies over the frequency range. This of course results in distortion (unequal output of different frequencies). Distortion due to this cause can be reduced by means of a high primary impedance. The input to the transformer cannot be greater at any frequency than the tube voltage. If at the lowest frequency it is intended to amplify, the transformer impedance is three times the tube impedance, the input will not be less at any frequency than 75 per cent the tube voltage, that is, not more than 25 per cent difference in amplification of different frequencies can occur. On the other hand, if the transformer has but half the tube impedance at this frequency, the difference will be 65 per cent.

The curves of figure 2 were taken on transformer No. 1, using different values of plate resistance. If the plate resistance could be reduced to zero, even this transformer would give little distortion. The curve becomes more and more peaked as the value of Rp is increased, and the amplification per stage is greatly lessened. In figure 3 is shown a similar group of curves for transformer No. 4. This is a transformer of high primary impedance, 155,000 ohms at 1000 cycles as compared to 15,000 for No. 1. It will be seen that while the curve is better for the lower plate resistances, the difference is much less marked than in the case of No. 1. The advantage of a tube of low plate impedance is obvious. That is one of the advantages of the new R. C. A. tubes.

We have shown the essential requirement of equal amplification of all frequencies to be a high and nearly equal impedance at all frequencies. This is accomplished by the use of many turns of wire, with a large core of high permeability steel, and by proper coil design, avoiding capacity that acts as a bypass for high frequency. This requirement may be met in a transformer of high ratio as well as one of low.

So far we have been dealing with the problem of the manufacturers. They have met it with surprising success as several of the new transformers show. It is up to the builder to make the best use of the manufacturers' efforts and not spoil the result by touches of his own.

Many radio builders think it an advantage to shunt their transformers with condensers or grid leaks. While this practice sometimes helped to improve quality with the old type transformers, with a transformer of good design it generally ruins quality.

A condenser across the primary of the first audio transformer is usually advisable, and may be as large as 0.005 microfarads without affecting the faithfulness of reproduction. Devices across the secondary are particularly harmful. Fig. 4 shows the effect of several sizes of condensers and grid leaks across the secondary. The effect of the condensers on transformer No. 1 shown in the upper half of the figure is to make still more marked the peak in the central portion of the curve. The high frequencies are cut off with increasing effectiveness as the size of the condensers is increased. It is interesting to note that at some frequencies resonance effects carry the curves with shunting condensers above the normal curve. The use of grid leaks improves the quality with this poor transformer. With a leak of 1.5 megohms, a curve similar to No. 2 of figure 1 is obtained. This curve is poor but somewhat better than the normal one. When the shunting resistance is reduced to 200,000 ohms a very flat curve is obtained, but the 8:1 transformer gives less amplification than a 2:1.

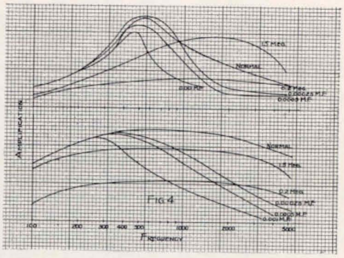


Fig. 4. A group of curves showing the effect of shunting various devices across the transformer secondary. The upper group were taken with a poor transformer, the lower on the newer types.

The effect of shunting condensers across the secondary of transformer No. 4 is similar to that observed in No. 1. The amplification of high frequencies is greatly reduced, with the point at which the curve falls coming farther toward the low frequencies as the condenser size is increased. The improvement in quality gained by shunting the secondary with a resistance is not so marked as with the badly peaked transformer. A great loss of volume is caused by this practice. With the 200,000 ohm resistance across the secondary the amplification is cut approximately in half, with no great improvement in quality.

The radio set can be made to reproduce music as faithfully as the average phonograph, or even more so. If this is to be accomplished the whole amplifying and reproducing system must be laid out with this purpose in view. Good transformers must be used, in the way the manufacturers intended them to be used. Tubes must be properly biased, and not overloaded, and finally, all other precautions are in vain unless a good reproducer is used.

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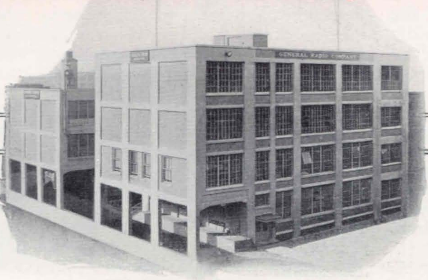
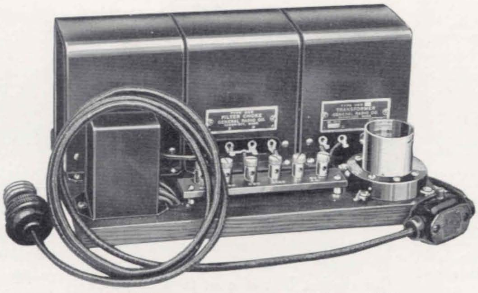


VOL. I NO. 2 JULY, 1926

The "B" Battery Eliminator

By H. W. LAMSON, Engineering Department

A careful study has recently been made concerning the design and operation of the "B" battery eliminator using either the Raytheon rectifying tube or the thermionic rectifier, as exemplified by the UX 213 Rectron.



Above illustration shows a Raytheon "B" battery eliminator constructed of all General Radio parts. Note neat arrangement of parts and compactness.

In order that an alternating current, such as that obtained from the ordinary AC lighting circuit, may be available for supplying the "B" battery power for a radio receiver it must first be rectified, that is, made unidirectional in character. One method of doing this consists of utilizing the limited "one way" conducting power of the rectifier tube. If this tube is operated as a "single wave" rectifier one-half of each cycle is suppressed so that, with a sixty cycle AC source, sixty unidirectional pulses of current are passed through the tube per second. Between every two of these pulses there exists a "dead" interval approximately one-half a cycle or 1/120 of a second long during which no current flows through the tube.

When the rectifier is of the "double wave" form 120 unidirectional pulses are passed per second. A double wave rectifier actually consists of two separate rectifiers built into a single unit. It is used in conjunction with a transformer having a center tap on the secondary coil. The two individual anodes of the tube are connected to the extremities of the transformer secondary coil while the common cathodes are connected through the output load to the center tap of the coil. In this manner one of the anodes passes the positive and the other the negative half of each cycle so that there are no "dead" intervals.

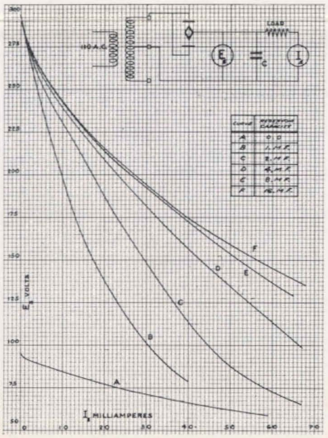


Fig. 1. Showing fall of output voltages as load is increased in single wave rectification using "Rectron" tube.

We shall first consider the "regulation characteristics" of the Rectron tube as a single wave rectifier. (See Fig. 1.) The curves show the fall of the output terminal voltage E_s as the load is increased. Load current I_s was measured with ordinary DC milliammeters while the terminal voltage was measured with a special DC voltmeter drawing only about one microampere per volt, a negligible load. When measuring a pulsating current both instruments give, ordinarily, an integrated mean value of current or voltage. The filaments of the Rectron tube may be conveniently heated by an additional low voltage secondary on the transformer delivering 2 amperes at 5 volts.

Curve A shows that the mean terminal voltage of the rectifier is very low due to the single wave rectification and that it falls with increase of load due to the internal resistance of the tube. When, however, a reservoir condenser of even a moderate value (curve B) is placed across the output the open circuit voltage jumps up to approximately the peak value supplied by the transformers. This is because a few instantaneous applications of this peak voltage are sufficient to force enough charge into the condenser to raise its potential to this value and, if this charge cannot leak away, due to the "one way" conductivity of the tube, the peak voltage is maintained when there is no external load. When, however, an external load is drawn from the tube the output voltage falls rapidly as the limited charge thrown on the condenser at the peak of every other half-cycle leaks away to supply the load current during the "dead" intervals. The remaining curves of Figure 1 show how increasing the capacity of the reservoir condenser serves to maintain the output voltage under a load, causing, thereby, a slower drop from the open circuit peak value.

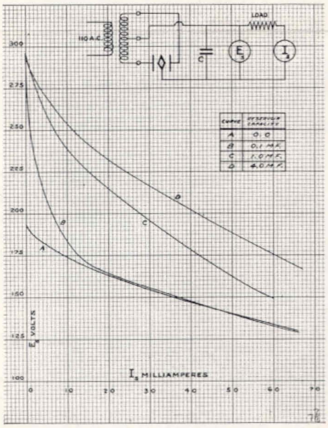


Fig. 2. Showing fall of output voltages with double wave rectification as load is increased using Rectron tube.

Figure 2 shows a similar set of curves for the Rectron tube used as a double wave rectifier. It will be noted that curve A (no reservoir condenser) is considerably higher than in Figure 1. This is, of course, due to the fact that mean values of 120 impulses are being measured, there being no "dead" alternate half cycles. As before, the addition of a reservoir raises the open circuit voltage to approximately the peak value of the transformer. The improvement in regulation and increase in capacity of reservoir is not so pronounced as in the case of the single wave Rectron. This is, of course, to be expected.

Figure 3 shows a set of characteristic curves taken in a similar manner with the Raytheon tube used "double wave." With no reservoir condenser (Curve A) the output voltage drops very sharply for the first few milliamperes of load and subsequently falls away more slowly. The introduction of a reservoir condenser raises the initial open-circuit voltage to a certain peak value. Increasing the reservoir improves the regulation, as in the case of the Rectron. A comparison of figures 2 and 3 shows that, with the same reservoir condenser, a given load may be drawn from the Rectron at a considerably higher voltage than in the case of the Raytheon. This is due in part to the fact that the Raytheon does not "break down" and pass current until a considerable fraction of the peak voltage is applied to it, causing thereby a greater drop of voltage in the tube.

Having rectified a sixty cycle alternating current into a pulsating current with a frequency of 120 the next step consists of "filtering" or smoothing out the impulses to give a steady flow of current into the load. Figure 4 shows a set of curves taken with the Raytheon tube using a one-section filter net work. This consists of a choke coil of approximately thirty henrys in series with the output load and two condensers, C1 and C2, connected in shunt across the line leading to the load. The choke coil offers a strong opposition to a pulsating current so that the successive impulses from the tube tend to pile up a charge on the reservoir condenser C1, which, however, immediately proceeds to discharge at a uniform rate through the choke with little difficulty, as the resistance of the choke to a steady direct current is comparatively low. A small amount of ripple, however, passes through the choke, but this is, to a large degree, absorbed by the reservoir action of the second condenser, C2. If we desire a more perfect filtering a two section filter composed of two chokes and three shunt condensers may be employed.

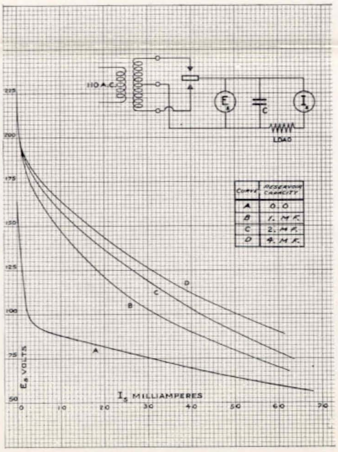


Fig. 3. Curves illustrate voltage drop with increased load using double wave rectification with Raytheon tube.

Referring again to Figure 4, the curve A shows a regulation obtained when each condenser has a value of 2 MF. Curve B shows the improvement in regulation when the output condenser, C2, is increased to 8 MF, while curve C shows the greater improvement obtained, on the other hand, by increasing the reservoir condenser to 8 MF. We see thus that the reservoir condenser is more important in controlling the regulation.

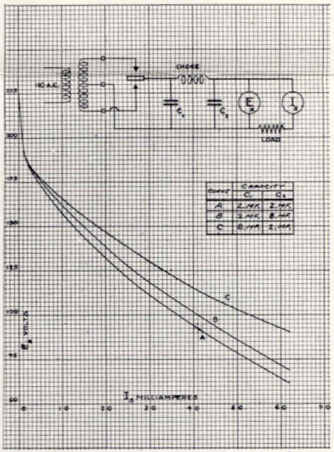
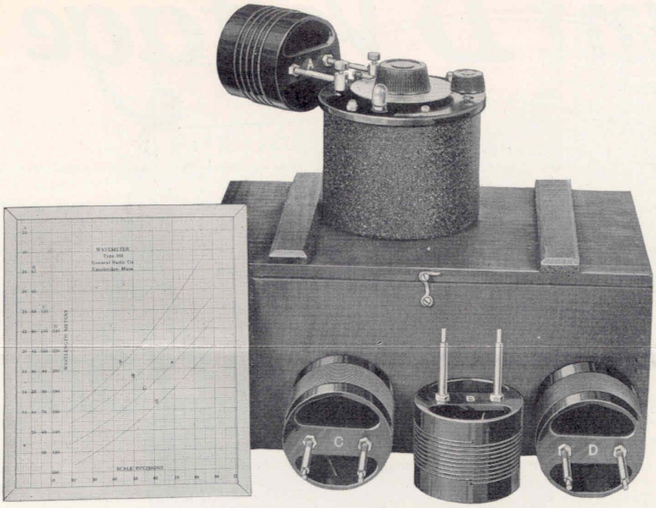


Fig. 4. Illustrating voltage regulation with various filter combinations using Raytheon tube.

Measurements of the ripple passing into the output load, made by means of an oscillograph, show, on the other hand, that the output condenser, (that directly adjacent to the load) is most effective in eliminating the ripple (hum) in the output. These considerations hold equally well with a filter of three or more actions.

Increasing the size of any one of the condensers improves both the regulation and the hum. However, a practical limit is soon reached at from three to four microfarads each in the three condensers of a two-section filter. Both experiment and theory verify the fact that, given a certain total capacity to the filter, the best regulation and the least hum are always obtained by dividing this total capacity into equal units, that is, making all the condensers of the same value. This applies to the hum actually coming through the filter and not to any ripple which may be picked up independently on a radio receiver fed by the eliminator. This latter point is being investigated at present.

A New Amateur Wavemeter



In the type 358 wavemeter, illustrated above, the General Radio Company presents a wavemeter particularly designed for amateurs.

For the lack of a more accurate standard of checking his wavelength the amateur has had to rely largely upon some one else receiving his signals to determine his wavelength.

Though this method is generally satisfactory the advantages of using a carefully constructed and accurately calibrated wavemeter are apparent without further comment; especially in view of the increasing interest in two way short-wavelength communication.

On the short wavelengths particularly, only a slight swing in wavelength is required to carry the note of a station beyond audibility—thus interfering with the quality and intensity of signals.

By using a reliable wavemeter the operator of a transmitting station may conveniently check his wavelength and consequently assure himself that his full power output is radiated on the wavelength he is intending to use.

The type 358 wavemeter is designed particularly for experimental use. As it covers a wavelength range of 15 to 225 meters it covers all the amateur bands in common use. In general appearance the 358 wavemeter is somewhat similar to the well known type 247 wavemeter and filter. The coupling coil of the latter has been dropped, however, and an indicating lamp has been substituted.

The wavemeter consists of a mechanically rugged coil of low loss construction, mounting directly on the binding posts of a shielded condenser. The condenser capacity is 125 MMF. Mounted on the condenser panel and connected in series between the condenser and coil is a resonance indicator in the form of a small lamp. The lamp socket is so arranged that it is short circuited when the lamp is removed.

The range 15 to 225 meters is covered by means of four coils, plugged into a condenser which is enclosed in a metal can. Unlike the type 247W meter which uses a direct reading dial with a multiplication factor for the various coils, the new instrument is supplied with a calibration curve for each coil, with an accuracy of 1%.

The coil ranges, providing adequate overlaps, are as follows.

Coil A	14 to 28
Coil B	26 to 56
Coil C	54 to 114
Coil D	105 to 220

Coil A, B and C are space wound on threaded bakelite forms. This assures accurate and permanent calibration.

The condenser, coils and chart are contained in a wooden carrying case which provides proper protection for the instrument when not in use.

The wavemeter complete, sells for $22.00.

A New Tube and a New Transformer

A new tube of great interest to all owners of storage battery sets has been announced by the Radio Corporation. It is the 200A detector tube. This tube is said to have all the good qualities of the old type 200 without its high current demand and sensitivity to plate voltage variation.

The new tube requires only one quarter ampere filament current at 5 volts, the same as the 201A type. The plate potential is not critical but 45 volts is recommended.

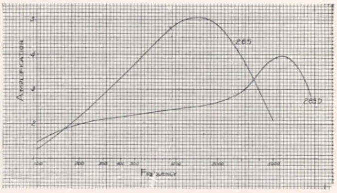
"The UX-200A has a greater sensitivity than any existing special detector tube," it is claimed. "It may be used in any receiver of the storage battery type without change or special adjustment." "Its internal resistance is such that it may be used with either resistance or transformer coupling. The new detector tube is absolutely stable and provides reliable operation at all times with no more critical adjustment than required with standard 'hard' tubes."

The tube data is as follows:
Design—same as standard UX 201A
Base—same as standard UX 201A
Filament voltage—5
Filament current—.25 amp.
Plate voltage—45 maximum
Plate current—2 milliampere
Plate impedance—28,800 ohms
Grid leak—2 megohm
Grid condenser—.00025 microfarads

Attention is called to the very high plate impedance of the 200A tube which makes necessary the use of a transformer particularly designed for it if good quality is to be obtained.

To meet this need, the General Radio type 285D transformer has been designed. This transformer has a sufficiently high input impedance to work efficiently with the new tube. Its characteristics are as follows:

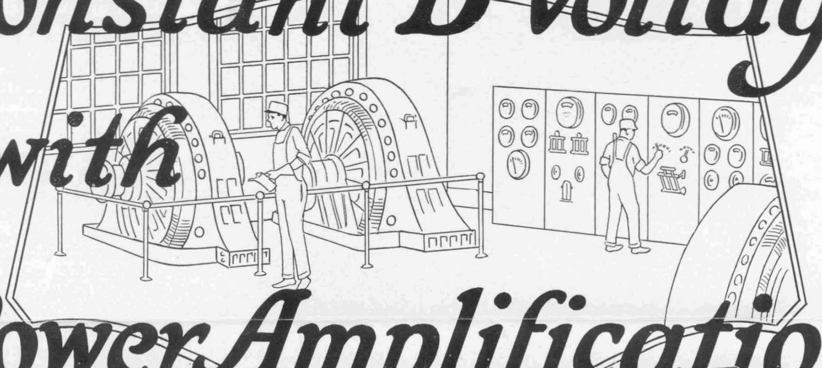
Pri. Imped. 375,000 ohms—Resist. 2200 ohms.
Sec. Imped. 3,000,000 ohms—Resist. 8300 ohms.
Turns Ratio 1:2.7

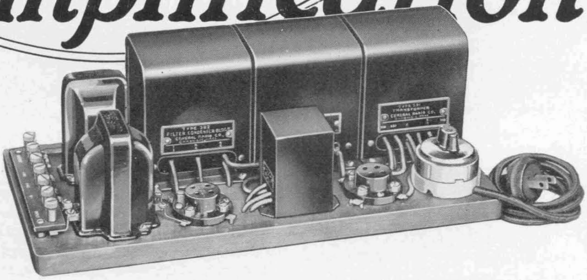


The curve above gives a comparison between the type 285D and the type 285 transformers, when both are used in the output of a 200A tube.

This advertisement appears in the August issue of Radio Broadcast, Popular Radio and Radio

Constant "B" Voltage with Power Amplification





For a dependable "B" eliminator—power amplifier unit which will enable your loudspeaker to deliver greater volume with a tone quality that is amazing, buy a General Radio Rectron "B" Eliminator—Power Amplifier kit and carefully follow the few simple instructions for assembling the unit.

Price of Kit, including all parts and drilled baseboard

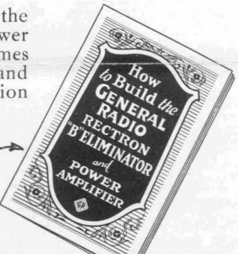
$47.50

A properly built "B" eliminator operated from the lighting circuit noticeably improves the consistent quality of reception. It provides a constant, silent flow of current that makes it as dependable as the power station itself.

Worry whether the "B" batteries are run down and their continual replacement is forever abolished by the use of a reliable "B" voltage supply unit. Once installed and adjusted is ready for years of constant service.

A Power Amplifier in conjunction with the "B" eliminator permits the use of a high power tube in the last audio stage. This overcomes the tendency toward tube overloading and removes the most common cause of distortion in loudspeaker operation.

Get this Booklet



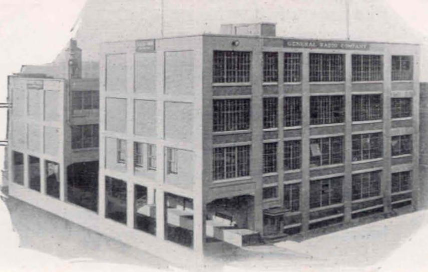
Ask your dealer or write today for our pamphlet "How to Build a Rectron "B" Eliminator and Power Amplifier."

GENERAL RADIO Co. Cambridge 39, Mass.

GENERAL RADIO
INSTRUMENTS

Behind the Panels of Better Built Sets

The GENERAL RADIO
EXPERIMENTER



L. I NO. 3 AUGUST, 1926

The Design and Use of the Speaker Filter

By H. W. LAMSON, Engineering Department

In the earlier days of radio broadcasting the chief aim of the average enthusiast was for DX, distance at any price. Thus the crystal detector, for many years an old standby, became superseded by the regenerative vacuum tube detector with its truly marvelous sensitivity. Before long the ever increasing number of broadcasting stations raised the demand for another important feature of a radio receiver—selectivity. This was accomplished by placing a tuned radio frequency amplifier between the antenna system and the detector element, as exemplified in the neutrodyne, superheterodyne and other familiar circuits.

In recent times a new demand has been made upon the radio art. Nowadays, when a considerable number of the major broadcasting stations are frequently tied together to transmit, in unison, programs of exceptional merit and wide popular interest, programs available literally to an audience of millions, the cry for DX has become more and more subjugated to the demand for quality, for faithful and realistic reproduction and sufficient intensity to produce a volume of speech or music customarily associated with grand stand and orchestra seats. Thus, attention is turned to the audio amplifier and interest has become centered upon power amplification.

For this purpose several new designs of vacuum tubes have been placed upon the market to be used in the last stage of the audio amplifier. Chief among these are the UX-120, a dry cell tube; the UX-112 and the UX-171, storage battery tubes; and finally the UX-210, a "high power" amplifier. Of this list the UX-171 and UX-210 are undoubtedly the best in their respective ratings. Each operates with a large plate voltage and, when properly biased, has a long straight-line operating characteristic which permits a wide range in volume while maintaining quality.

The Type 387 Speaker Filter

These power amplifier tubes, however, draw a noticeably larger plate current than such tubes as the UX-201A or UX-199, and this feature has necessitated, or at least made quite desirable, an additional piece of equipment in the power amplifier, whose chief function is to keep this direct current from passing through the speaker. Why is this desirable? Perhaps the two principal reasons are as follows:

1—If a steady direct current is passed through the loudspeaker the armature or diaphragm is deflected one way or the other so that an unsymmetrical strain is placed upon the vibrating system. Then, when a pulsating ripple of current (speech or music) is passed through the instrument, the restoring forces are unbalanced, the moving parts do not vibrate in strict accordance with the wave form of the current ripple, and distortion results. This effect is comparable to pushing against a piano string with the finger while striking the corresponding key.

2—If a direct current is passed through the loudspeaker certain parts of the magnetic system may become more or less saturated with magnetism, so that when a ripple of current is passed through the instrument the variations in the magnetic pull may not correspond in magnitude to the amplitudes of the current ripples. That is, a small ripple of current may produce a relatively large change in the magnetic force on the driving mechanism, again giving rise to distortion.

Either one of two different instruments may be employed for removing this undesirable direct current from the loudspeaker. These are known as the **output transformer** and the **speaker-filter.** The former is self-explanatory; the latter consists of an inductance choke which passes the DC plate current, but which offers a high impedance to the audio frequency currents, forcing them to pass through a condenser into the loudspeaker.

Figure 1 illustrates the use of the output transformer "T" between the amplifier tube "A" and the speaker "S." Figures 2 and 3 show the corresponding circuits of the speaker-

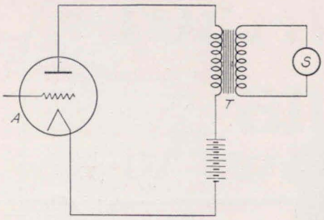


Fig. 1

filter, composed of the choke "L" and the condenser "C." The arrangement indicated in Figure 3 is preferable since, with the circuits as shown in Figure 2, the loudspeaker is at high potential with respect to ground, which is usually connected to the minus terminal of the "B" battery.

An investigation was recently undertaken in the General Radio laboratories to ascertain the best practical design for the elements of the speaker-filter. When it is recalled that the impedance or opposition to flow of alternating currents in a choke inductance increases with the frequency, while the impedance of a condenser decreases as the frequency rises, it will be apparent that the speaker-filter must be relatively more efficient for the higher pitched notes. Thus, if the inductance of the choke and the capacity of the condenser were both made too small a perceptible amount of low frequency current might pass through the choke and be lost to the loudspeaker.

At first glance the solution would appear to consist of making both "L" and "C" very large. Increasing the capacity of the condenser, of course, increases costs and at the same time increases the possibility of an accidental puncture or breakdown. Increasing the value of "L," while maintaining reasonable dimensions to the instrument, means more turns of finer wire. This, of course, introduces more resistance to the passage of the direct current so that less "B" voltage will be available at the plate of the amplifier tube. Then again, too many ampere turns on a given size core might tend to saturate the iron and reduce the efficiency of the choke. To ascertain the practical limits of design, three speaker-filters were constructed. Each contained a condenser of two microfarads capacity and each had an individual choke coil described as follows:

Speaker-filter "A"—Inductance 22 henrys, resistance 385 ohms.
Speaker-filter "B"—Inductance 50 henrys, resistance 745 ohms.
Speaker-filter "C"—Inductance 100 henrys, resistance 1,940 ohms.

For purpose of comparison, a standard design of output transformer "D" having a primary inductance of 0.9 henry (320 ohm resistance) and a secondary inductance of 0.6 henry (385 ohm resistance) was also used. The technique of the measurements is described below. Various pieces of equipment used in the study of loudspeakers were employed.

The audio frequency output from a "heterodyne beat oscillator" was amplified once by a small vacuum tube amplifier and then passed into a combination "B" battery eliminator and power amplifier. The output from the plate of the power amplifier tube could be passed at will through any one of the four instruments described above and then into a loudspeaker. This speaker was placed in a large sound-proof box, which contained also a pair of microphones used to pick up the sound emitted from the speaker. The pulsating currents from the microphones were then passed through a suitable transformer and rectified by a crystal so that their relative intensity could be measured on a millivoltmeter. Thus **comparative** measurements of the sound output of the loudspeaker could be made, using the different types of speaker-filter, etc.

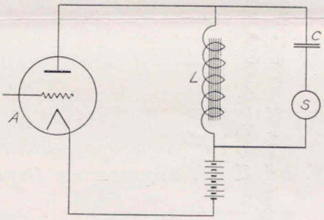


Fig. 2

To attempt to make measurements at a single pitch or frequency is difficult for several reasons. These objections were overcome by "wabbling" the pitch, that is, by varying the frequency repeatedly and regularly over a small range, perhaps twice a second. This was done by means of a small motor driven rotary condenser attached to the oscillator. This "wabble" produced a slight pulsating motion on the needle of the meter, but a mean reading could easily be obtained.

The first set of data were taken with a power amplifier employing the UX-171 tube and using as low a pitched "wabble" as would give a reasonable response to the loudspeaker. Readings were taken in succession on instruments "A," "B," "C" and "D," and then repeated in the same order perhaps a dozen times. This repetition was deemed necessary owing to the variability of certain elements in the circuit, noticeably the microphones. The readings on a particular instrument were then averaged to give a mean value which could legitimately be compared with corresponding values obtained with the other instruments. For purpose of comparison these values were expressed as ratios to the value obtained with the output transformer "D," which in every case proved to be the least efficient. The data given in Table I show the average ratios thus obtained with several makes of loudspeakers, all being of the cone type.

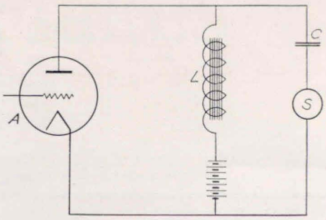


Fig. 3

TABLE I.

Type of Loudspeaker	Speaker Filters A	B	C	Output Trans. D
Erla	1.42	1.44	1.40	1.00
Musicone	1.27	1.28	1.32	1.00
West. Elec.	1.23	1.22	1.30	1.00
Acme	1.66	1.59	1.52	1.00

UX-171 with Low Pitched Wabble

In a similar manner comparative data were taken using the UX-171 tube by employing a high pitched "wabble." These ratios are given in Table II.

TABLE II.

Type of Loudspeaker	Speaker Filters A	B	C	Output Trans. D
Acme	1.28	1.26	1.28	1.00
West. Elec.	2.03	1.94	1.75	1.00
Musicone	1.32	1.31	1.31	1.00

UX-171 with High Pitched Wabble

A high power "B" eliminator and amplifier employing a UX-210 tube was then substituted for the UX-171 amplifier, and the data given in Table III. were obtained using a low pitched "wabble."

TABLE III.

Type of Loudspeaker	Speaker Filters A	B	C	Output Trans. D
West. Elec.	1.23	1.29	1.41	1.00
Acme	1.24	1.30	1.34	1.00
Erla	1.34	1.40	1.51	1.00
Musicone	1.38	1.55	1.76	1.00

UX-210 with Low Pitched Wabble

Lastly, the UX-210 amplifier was used with a high pitched "wabble," giving the data of Table IV.

TABLE IV.

Type of Loudspeaker	Speaker Filters A	B	C	Output Trans. D
Musicone	1.08	1.09	1.09	1.00
West. Elec.	1.04	1.05	1.05	1.00
Acme	1.20	1.21	1.23	1.00

UX-210 with High Pitched Wabble

Let us now examine these results which may, perhaps, be a bit surprising. It must be borne in mind that the figures give no indication of the relative merits of the cone speakers, but indicate merely a comparison between the various types of speaker-filters when used with a particular loudspeaker.

Table I shows that, with the low pitched "wabble," any one of the speaker-filters might be chosen as the best, depending upon the type of cone employed. The maximum variation (1.66 to 1.52) or 9 per cent. represents so small a difference that it could not easily be detected by ear. The relative efficiency of the filters and the output transformer, on the other hand, varies appreciably with the type of loudspeaker used.

Table II shows that, except in the case of the Western Electric cone, there is no appreciable difference between the speaker-filters when passing a high pitched note. As stated previously, this is to be expected on theoretical grounds.

With the UX-210 amplifier and a low pitched "wabble" the data of Table III shows a consistent improvement, favoring the Type C filter in each case. This improvement, however, is by no means pronounced, the greatest difference noted, 27 per cent. in the case of the Musicone, being an amount barely perceptible to the human ear.

Operating with the high pitched "wabble," the data of Table IV again offer no choice between the behavior of the filters.

It appears, therefore, that for all practical purposes the same intensity is obtained with all three types of speaker-filters. This being the case, it would then be desirable to use the Type A, which has the lowest resistance and hence leaves the highest voltage available at the plate of the amplifier tube and is, at the same time, least liable to core saturation.

A series of comparative measurements were then made between the A type of speaker-filter as described above and the A type of filter with the condenser increased to 6 MF. by the addition of a 4 MF. unit. Using various cone speakers with both high and low frequency "wabbles," it was found that the difference between the two capacities was less than the error of measurements, an entirely negligible amount, so that a condenser of 2 MF. proves to be quite large enough for the purpose.

Quartz Plates Available to Amateurs

After many disappointments, due to failures of sources of supply, the General Radio Company is now able to supply quartz plates for amateurs. These plates will be supplied for frequencies between 1750 and 2000 K. C. (171.4 and 150 meters). This will permit the use of the plates on any of the amateur bands by tuning to the proper harmonic.

Plates will be supplied as close as possible to specified frequencies in the above band. The frequency of each plate, measured to 0.25% accuracy, will be supplied with the plate.

The plates are somewhat irregular in shape from ½ to 1" in diameter. Faces are ground smooth and parallel, and the edges are bevelled. These plates are guaranteed to oscillate when used in a properly built holder, and kept clean. The plate voltage of the oscillator tube should be from 40 to 200. Puncture of the quartz plate due to excessive voltage is a characteristic of the material which cannot be prevented.

The plates as above described are supplied at $15.00 each, unmounted, post paid.

Notice

The expense of printing and mailing "The Experimenter" each month is too great to permit promiscuous circulation.

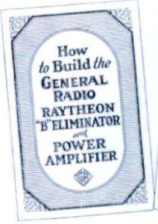
If you wish to continue to receive copies regularly and have not returned your post-card requesting that your name be placed on our mailing list, please write and have your name put on our permanent list.

Our permanent mailing list to receive all future copies of "The Experimenter" will be made up from returned post-cards and letters from experimenters who are anxious to avail themselves of the information contained in our new publication.

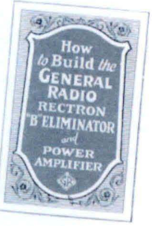
There is absolutely no charge attached to this service and we are very glad to extend all of our experimenter friends a permanent subscription for "The Experimenter" with our compliments.

Assure yourself of receiving all future copies by mailing us your card or writing us a letter today.

New Construction Literature on the Rectron and Raytheon Plate Supply and Power Amplifier Units Now Ready



How to Build the General Radio Raytheon "B" Eliminator and Power Amplifier



How to Build the General Radio Rectron "B" Eliminator and Power Amplifier

In addition to building and improving their sets the amateur builders this year will also turn their ingenuity to the construction of plate supply units and power amplifiers.

In order that the amateur builders may carry on this constructional activity without unnecessary bother in collecting the required material and information the General Radio Company has brought out both Raytheon and Rectron Plate Supply and Power Amplifier units in kit form, and has published construction booklets containing all instructions for building plate supply and power amplifiers using either rectifier tube.

In addition to schematic diagrams they contain full scale pictorial diagrams showing exact arrangement of parts and actual connections.

In general characteristics and operation these power kits are similar to the completely assembled Type 400, Plate Supply and Power Amplifier which uses a rectifier, the UX-213, and as an amplifier tube the UX-171 power tube.

Dealers will be able to obtain a quantity of the construction booklets for free distribution to their set-building customers on request to their jobbers or to the General Radio Company.

For All Popular Makes and Circuits
of radio receiving sets

A Constant "B" Voltage Supply Unit with Power Amplification

TYPE 400

Price **$68.**

The NEW GENERAL RADIO "B" Eliminator and Power Amplifier

Broadcast listeners everywhere are now demanding above all else "B" battery elimination and reception that is NATURAL.

The answer to this demand is the new General Radio Type 400 "B" eliminator and Power Amplifier which is designed to operate with all popular makes and circuits of radio receivers, regardless of whether they may be operated by storage battery or dry cell tubes.

Where A. C. 110-volt (60 cycle) lighting current is available the use of the Type 400 Unit is the most practical and satisfactory method of supplying all necessary "B" voltages. The Power Amplifier in conjunction with the "B" eliminator permits the convenient use of a high power tube in the last audio stage. This overcomes the tendency toward tube overloading and removes the most common cause of distortion in loudspeaker operation. An outstanding feature of the General Radio Type 400 "B" Power Unit is that it has no variable resistance voltage controls to get out of order and cause noisy reception.

Voltages in this unit are controlled by fixed resistances which are properly designed to make the Type 400 readily adaptable to all average receivers.

Once installed it requires no further alteration and is ready for years of unfailing service.

The Type 400 Unit is designed to use the UX-213 Rectron rectifier tube and UX-171 power tube in the amplifier.

Dealers, show this unit to your set owning customers, and you will interest them, demonstrate it and it will sell itself. Why not include a Type 400 Unit in every new installation?

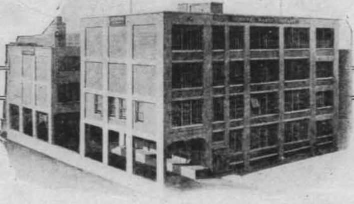
Place your initial order with your jobber now and be ready for the big popular demand for plate supply and power amplifier units.

GENERAL RADIO COMPANY CAMBRIDGE, MASS.

GENERAL RADIO
INSTRUMENTS

Behind the Panels of Better Built Sets

The GENERAL RADIO
EXPERIMENTER



OL. 1 NO. 4 OCTOBER, 192

The Status of "A" Battery Elimination

By C. T. BURKE, Engineering Department

The question most frequently heard at the New York Radio Show, just past, was, "How about A eliminators?" "B" battery eliminators were exhibited in great numbers and many varieties, but no "A" substitutes of general application appeared.

The problem of filament supply from alternating current is essentially different from that of plate supply. It is not a question of the power supplied, but the voltage at which it is supplied. The power required for filament supply ranges from 0.18 watt for the dry cell tubes to 9.5 watts for the 210, while the plate power for these tubes is .2 watt and 9 watts, respectively. The average set draws a filament load of about 7 watts and a plate load of perhaps 4 watts. There is not enough difference between the wattage requirements of plate and filament to involve great difficulty.

The essential difference between the plate and filament supplies is the supply voltage, which is about 100 for the plate as compared to 5 for the filament. As power in watts is equal to the current supplied, times the supply voltage, roughly twenty times the current is required to supply a given number of watts to filament as would be required at the plate. The great difference then between the demands of filament and plate supplies is not of power, but of current. Plate current supply devices are not called on to deliver more than 50 milliamperes, while the filament may draw two or more amperes.

Direct current power differs from alternating, in that power at high voltage and low current cannot be transferred into power at low voltage and high current without the use of rather expensive equipment. It is, therefore, necessary to use the D. C. power at the current and voltage supplied by the rectifier.

Rectification and filtering is generally necessary in order to use alternating current for filament supply. The last stage of audio amplification can be run with alternating current on the filament with excellent results. When the slight hum resulting from A. C. on the filament is amplified through successive tubes, it reaches an objectionable magnitude. Thus the use of raw A. C. is confined to the last tube. This is generally a power tube, and requires a greater filament supply than the others. Under certain conditions, where some hum is not objectionable, it may be possible to operate two stages of audio amplification on alternating current. The detector tube must have a supply of well filtered direct current.

The maximum current available from a single tube of the kinds popularly used in plate supply devices is about 85 milliamperes. This is the current required by a one tube set, employing a UX-199 tube. It is delivered at high voltage. If the set is so wired that the tubes are in series, any number (up to 50) UX-199 tubes may be operated from such a tube when supplied with a suitable transformer and filter. As the same unit is generally used for both A and B supply, it would be necessary to design transformers and chokes to deliver this current at about 220 volts in order to take care of the plate and grid voltage of the UX-171 tube. This is somewhat expensive, but by no means impossible. A rheostat of sufficient resistance and current carrying capacity is also required.

It will be seen that A elimination for UX-199 tubes is feasible. So far as the writer knows, however, there is no commercial eliminator for this service available. The field for such a device would be very limited, first because of the comparatively few sets using 60 mil tubes, and second because rewiring of the set is required. The making of individual installations of this kind, however, including building the unit, and rewiring the set, should prove a source of considerable profit to those dealers and service stations who undertake it. The same type of installation would not be entirely beyond the bounds of practicability with 201A tubes if a rectifier tube were available supplying 250 milliamperes. The chokes and resistances for this arrangement would present considerable difficulty. This would result in greater bulk, and materially greater expense than would the equipment for 199 tubes.

There are a number of low voltage rectifiers available which are used to charge batteries. The output of these units is ample to supply the filament current drain of any set, and they would be suitable for a general purpose filament supply.

The great obstacle in this case is filtering. The condensers in the filter act as reservoirs, storing surplus current during one part of the cycle and feeding it to the load at another. The large current required by the filament supply would require condensers of many times the capacity now required on plate supply units. The filter inductances also present a serious problem. The low voltage available from high-current rectifying devices permits a very small drop in the filter system. This requires chokes having very large wire and few turns. In order to get the proper inductances, and avoid saturation, the cores would have to be of very large cross section, and would require air gaps. Fortunately, as the current drain increases, the amount of inductance required for a given degree of smoothing decreases somewhat. Even allowing for this, the filter choke for a filament power supply to furnish 2 amperes would cost much more than do those for a plate supply. The condenser cost would be multiplied by an even greater proportion unless electrolytic condensers were used.

The cost of a storage battery is, of course, many times less than that of such a filter would be. This brings us to the trickle charger—battery combinations, which, while not a battery substitute, do provide a reliable filament source from the alternating current line. The trickle charger is probably at present and likely to remain for some time the most satisfactory general purpose filament supply. The use of UX-199 tubes in series will, however, prove interesting to the experimenter and to the service man.

Another type of A eliminator, in which dry batteries are used as filter condensers, is appearing this year. In this type a tungar rectifier is generally used. The filter consists of a choke of small inductance which can, therefore, be made with low resistance and dry cells in place of the filter condensers. A number of these devices will be on the market this year and they offer interesting possibilities.

In the meantime, tube manufacturers are at work on the problem of developing tubes which will not require A batteries. Various types of tubes have been suggested in which the heating current does not pass through the anode, and one such tube has been placed on the market. Further developments along this line are certain, and it is possible the final answer to the "A" eliminator question will be provided by the tube manufacturer.

What Tube Shall I Use in My Power Amplifier?

As there are two tubes available for use in the last audio stage where considerable power is desired with perfect quality, some question has arisen as to which of these tubes should be used in a given case.

The plate characteristics of these tubes (UX-171 and UX-210) or (CX-371 and CX-310) are as follows:

UX 171

Grid Volts	Plate Volts	Output Resistance	Maximum* Undistorted Output (Milliwatts)	Amplification Factor
16½	90	2500	130	3
27	135	2200	330	3
40	180	2000	700	3

UX 210

Grid Volts	Plate Volts	Output Resistance	Maximum Undistorted Output (Milliwatts)	Amplification Factor
4.5	90	9200	18	7.5
9	135	8000	65	7.5
10.5	157.5	7400	90	7.5
18	250	5600	340	7.5
27	350	5100	925	7.6
35	425	5000	1540	7.7

* Proper bias assumed.

Considering first the output resistance, it will be seen that it is lower for the 171 for all conditions of plate voltage. A low output resistance increases the energy transferred from the tube to the speaker, and in part compensates for the low amplification factor of this tube. The low resistance also results in a greater energy transfer at low frequencies, where loud-speakers are inefficient.

The input voltage which may be applied to a tube without causing grid distortion is fairly well indicated by the grid bias voltage. An inspection of the table will show that the 171 permits a greater input at 180 volts than does the 210 at 425 volts, and more than twice as much as the latter tube at 180 volts plate.

Considering next "maximum undistorted output," it is seen that the 171 will deliver about twice the power at 180 volts that the 210 will at 250 volts plate. At 425 volts the 210 will deliver somewhat more than twice the power than the 171 delivers at its maximum plate voltage.

The amplification factor of the 210 is greater at all voltages.

From the above data it is possible to deduce a few rules for the use of these two tubes.

Where the plate voltage available is less than 200, the 171 tube should invariably be used.

Where it is desired to obtain the greatest possible volume, as might be the case in a hall or large assembly room, the 210 tube should be used with 425 volts on its plate.

The 171 tube is the ideal type for use when it is desired to obtain the proper volume for a living room without the distortion resulting when 201A tubes are forced. The undistorted output is more than ten times that of the 201A. Its low output resistance makes it particularly well suited for working into a low impedance cone. When the input is sufficient to work it to its capacity, the power delivered is ample for home use.

In order to obtain results equivalent to those delivered by the 213 rectifier, two 216B rectifiers must be used to supply the high voltage required by the 210 tubes. A transformer secondary voltage of nearly 1000 volts is also required. It is felt that a unit of these proportions is an extravagant and possibly a dangerous one for home use. These considerations have led the engineers of the General Radio Company to build their power units around the 171 tube.

NOTICE

In order that the Experimenter may be published and circulated around the first of every month, the September issue has been omitted, and the October issue distributed earlier in the month than has been the custom in the past few issues. Future issues will be mailed out on or shortly after the first of each month.

The Vacuum Tube Bridge

By HORATIO W. LAMSON, Engineering Department

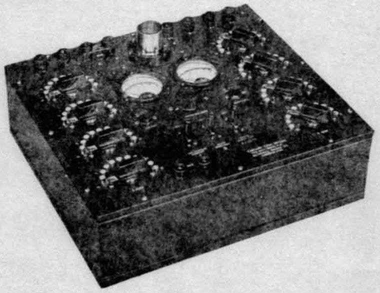


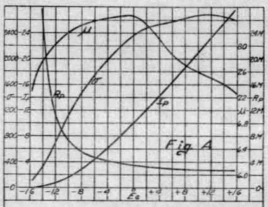
Figure 1. The Type 361-A Vacuum Tube Bridge Manufactured by the General Radio Co.

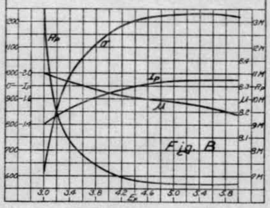
The uses of the three-electrode vacuum tube have become so manifold that the study of its various characteristics is of considerable importance. Several tube-testing devices, more or less elaborate in design, have been developed and placed on the market. These usually consist of a series of meters and rheostats, with or without enclosed batteries, and are designed to check filament power and to measure certain so-called "static characteristics," such as the joint emission to grid and plate or the steady plate current passing under any particular conditions of filament current or voltage, plate voltage, and DC grid bias. From characteristic curves obtained in this manner the "static amplification constant" and other data of value may be determined. Under certain conditions, however, the "dynamic characteristics" of a tube are of more fundamental importance. Chief among these are the Amplification Constant, the Plate Resistance, and the Mutual Conductance, which is the ratio of the former to the latter.

The actual value of the Amplification Constant, together with the variation of this quantity with different filament temperatures, plate voltages and grid potentials, is of paramount importance in determining the operating characteristics of a particular tube when used as a voltage amplifier. The Plate Resistance is more or less determined by the geometrical construction and the filament emission of the tube, so that any defect or abnormal variation in these factors may readily be detected by measuring this particular dynamic constant. Knowledge of the mutual conductance of a tube is important in determining its behavior as a power amplifier and as an oscillator.

To obtain such data it is necessary to supply an audio frequency tone source, preferably sinusoidal in character, to the grid of the tube and to make use of certain balanced-bridge measurements. Three circuits for measuring these tube constants are shown on page 203 of Van der Bijl's text book "The Thermionic Vacuum Tube." Beside the regular batteries and filament current controls, these circuits require two decade resistance boxes, three fixed resistances of 10, 100, and 1000 ohms respectively, a tone source and a pair of telephones. For accurate measurements it has been found beneficial to add a small variocoupler to introduce an inductive coupling between the tone source and the phones in order to counteract the effect of capacity between the tube elements.

These circuits may be set up with individual pieces of apparatus, but a higher degree of precision and better shielding, as well as freedom from other minor troubles, may be obtained by building the several parts into a properly designed bridge unit. Such a bridge is described more fully in the General Radio Bulletin 414.





The attached curves are given to illustrate data obtained with this bridge upon two different tubes. In the first set, marked "A," the grid bias was varied over a considerable range. In the second set, marked "B," the filament voltage was adjusted at various values. In either case the plate current Ip, the amplification constant Mu, the plate resistance Rp, and the mutual conductance Sigma, were measured directly on the bridge.

Referring to Figure A we see that the emission is practically cut off at sixteen volts negative on the grid, while no sign of saturation is reached at sixteen volts positive. The amplification constant remains essentially the same from 0 to about 9 volts negative, and then falls off as the plate current becomes abnormally low. With an increasingly positive grid the value of Mu falls away rapidly.

With a strong negative bias the plate resistance is of course, high, but this falls rapidly and becomes essentially constant for positive values of grid voltage. On the other hand, the mutual conductance rises rapidly as the negative bias is reduced and attains an approximately uniform value with the grid positive.

Figure B shows that the plate current rises with the filament temperature reaching saturation at about the rated filament voltage of the tube. The amplification constant is a maximum at the lowest workable filament temperature and falls off more or less uniformly as Ef is increased. The plate resistance remains constant down to 4.5 volts and then rises with increasing rapidity as the filament is cooled. The mutual conductance curve, of course, exhibits a reciprocal characteristic.

For All Popular Makes and Circuits *of radio receiving sets*

Type 405 Plate Supply

IMPROVED quality of reception, free from anxiety caused by steadily deteriorating "B" batteries is now possible thru the use of General Radio—Raytheon Plate Supply.

This unit operates on 110 volt (60 cycle) A.C. and provides voltages of 45, 90, 130 and 200.

Voltages are readily adaptable to all popular makes and circuits of radio receivers by means of fixed resistances which are tightly sealed from dust and moisture, thus eliminating bothersome and noisy tendencies of variable resistance voltage controls. The unit is contained in a metal case with attractive black crystalline finish, and has a conveniently located A.C switch.

Price, with BH Raytheon Tube..........$46.00

Type 400 Power Amplifier and Plate Supply

THE type 400 is similar to the above described unit except that it has the additional feature of a Power Amplifier and uses the UX-213 or CX-313 Rectron tube as a rectifier instead of the Raytheon.

A power amplifier in conjunction with the plate supply permits the convenient use of a power tube in the last audio stage, regardless of whether the receiver may be operated by dry cell or storage battery tubes—the filament current of the power tube being supplied by A.C. from the secondary of the rectifier transformer. The power stage overcomes the tendency toward tube overloading and removes the most common cause of distortion in loudspeaker operation.

The plate supply provides voltages of 45 and 90 for the receiver and 180 direct to the power tube, (UX-171 or CX-371) together with the proper bias for this tube.

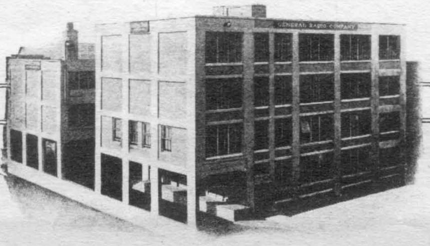
Price, without tubes..........$68.00

GENERAL RADIO COMPANY, Cambridge, Mass.

GENERAL RADIO
INSTRUMENTS

Behind the Panels of Better Built Sets

The GENERAL RADIO
EXPERIMENTER



VOL. 1 NO. 5 NOVEMBER, 192

An Effective Method of Measuring Amplification

By L. B. ROOT, Engineering Department

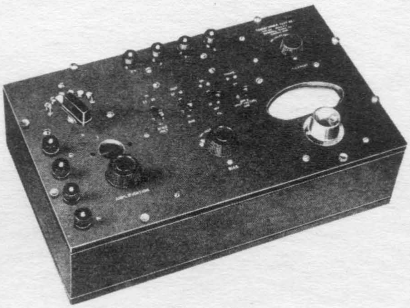


Figure 1
The General Radio Type 355 Amplifier Test Set

The first years of development in radio broadcasting were devoted mainly to the improvement of the sensitivity and selectivity of the receiver. The best set was the one that could pick up a station perhaps two thousand miles or more away, and amid tube hisses and crashes of static, enable a careful listener to discern the call letters. Perhaps a moment later the station had faded out completely, but the enthusiastic fan was happy in the knowledge that his set was capable of the unusual.

The trend of feeling toward distant reception has changed, and though there are many exceptions, the great majority of people are now content to listen to the nearby stations.

This change was brought about mainly by two things, the advent of chain broadcasting and the improvement in quality at both transmitter and receiver. The former made it unnecessary to go outside of one's immediate locality to listen to a good program by well known artists, while the latter gave such good reproduction from the local stations that more distant reception was decidedly unsatisfactory from the viewpoint of quality and certainty of nearly constant volume.

These developments have made the set manufacturer alert to design speakers that would more faithfully reproduce the studio program in the home. In order to do this, the audio frequency amplifier must do its part in passing the detector output to the speaker, increased in volume, but undistorted. It is here that poor quality generally, but not always, originates.

The Associated Manufacturers of Electrical Supplies were confronted with the problem of obtaining characteristic curves on transformer, impedance and resistance amplifiers. Several more or less satisfactory methods were in use, each having its advantages and disadvantages. Roughly they were divided into two classes, those methods which included the tube in the measurement, and those which did not. For simplicity, it was decided to eliminate the tube, and use for comparison, curves which showed the performance of the coupling device only.

Of course, it was necessary that operating conditions be closely approximated if not actually obtained, in order that comparisons might be fair.

The General Radio Type 355 Amplifier Test Set is built around that idea and permits the accurate determination of performance. It is as simple in construction and operation as is consistent with correct results. It permits testing with a resistance in series with the input circuit of the coupling device which corresponds to the plate impedance of any ordinary tube, and the corresponding direct current which that tube would draw in use. The output circuit carries a tube capacity not greatly different from most tubes, and this may be increased by adding a very small variable capacity if desired. Of course the secondary should not carry any direct current, and this condition is made certain by so designing the tube voltmeter that it is impossible to take amplification readings if the grid takes current.

The Test Set is nearly self-contained, having only a 6-volt storage battery and the source of audio frequency external to it. It may be used with any audio source, either variable or fixed in frequency. The General Radio Type 377 Oscillator is particularly suited to the purpose.

The diagram on page 2 shows the operation of the set when measuring transformers.

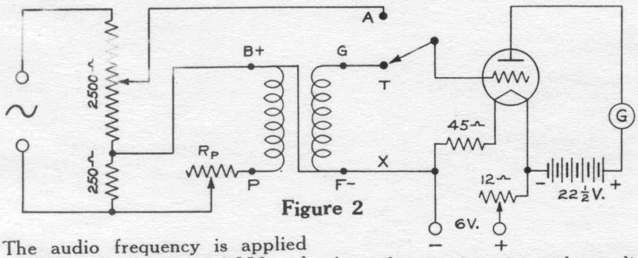


Figure 2

The audio frequency is applied across the two resistances of 250 and 2500 ohms respectively. The primary of the transformer is connected across the 250 ohm section, with the variable resistance Rp in series to represent the plate impedance of the tube with which the transformer is to be used. This may be 5000 to 25,000 ohms. The secondary is connected to a UX 199 tube which is being used as a tube voltmeter. A six-volt storage battery supplies the filament through a 45 ohm resistance, giving three volts across the filament and a three-volt negative bias on the grid. Even with the comparatively high bias and only 22.5 volts on the plate, some current will flow and deflect the galvanometer G. To correct this the suspension of the galvanometer is twisted so that it reads zero with the tube lighted. When the filament is out, the pointer goes off scale below zero, of course. This galvanometer is partly calibrated, in that the scale is marked to show the deflection obtained when one volt A. C. is impressed on the grid of the tube.

The 2500 ohm resistance is a potentiometer which has a direct reading scale, calibrated from 0 to 10, each main division corresponding to 250 ohms. The calibrated 1 volt point on the galvanometer applies only when the potentiometer reads 1. In this case it is obvious that the voltage across the transformer primary (including plate impedance Rp) is the same as that applied to the grid of the tube, and when the potentiometer reads 2, the voltage input is .5, etc. With this relation in mind, any reasonable input voltage may be applied using only the one known point on the tube voltmeter.

TRANSFORMER CHECKING

To check the amplification of a transformer the procedure is as follows. Suppose that the curve is desired at .5 volts input. Rp is set at a value corresponding to the plate impedance of the tube with which the transformer is to be used. The input frequency is set to a known value, and with the switch on point A, and potentiometer scale reading 2, the voltage is increased until the galvanometer indicates one volt. Then the switch is thrown to T, so that the vacuum tube voltmeter is excited by the transformer secondary and a certain galvanometer deflection is obtained. The switch is then returned to A and the potentiometer adjusted to obtain the same deflection as while on point T. The potentiometer scale reading now indicates the voltage amplification directly.

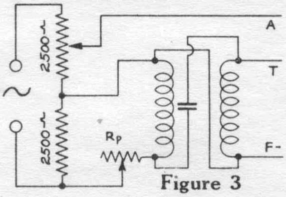


Figure 3

The sensitivity of the galvanometer is such that an input of more than about 1.7 volts will throw it off scale, and the grid of the tube will begin to take current. With many transformers, this situation does occur. This is remedied by cutting in an additional adjustable bias at the point X with a switch, permitting the reading of amplification up to 10, without any grid current being taken, even though the voltage may become quite high.

IMPEDANCE CHECKING

Impedance or resistance couplings are checked in a similar manner but with slight circuit changes.

A switch changes the input resistance connections as shown in fig. 3 Since the potentiometer is calibrated 0 to 10, the readings are now one-tenth of former indications and a one-volt input is obtained with the potentiometer scale reading 10. The procedure is now the same as before.

If desired, direct current may be used in the transformer or impedance to determine its effect on the resultant performance curve. Likewise, a tube may be connected across the secondary to determine the effect of capacity.

Attention should be called to the fact that the vacuum tube voltmeter is used only as a transfer instrument, so that changes in the tube characteristics, or the running down of batteries have no effect on the accuracy of measurement. These things will affect the calibration of the 1 volt point, but even large percentage changes of input voltage have little effect on the resulting curve.

The Test Set finds its greatest use in design work, either to determine the proper coupling device to use under certain conditions, or to develop the coupling unit itself. The rapidity with which points may be taken, makes it easy to plot many curves with only a small consumption of time.

Figure 4 shows curves on various transformer and impedances, taken with the Test Set.

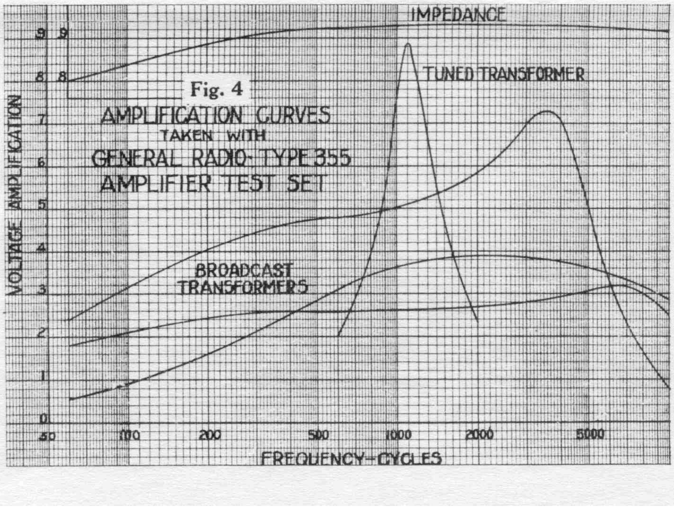


Fig. 4

Coil Calculations

By C. T. BURKE, Engineering Department

The experimenter has frequent occasion to design air core tuning inductances. As few have means of measuring the inductance of such coils after they are built, it is rather important to be able to predict the inductance of a specific coil, and conversely, to design a coil to have a given inductance.

The calculation of inductance for iron cored coils is impossible unless the permeability of the iron is known under the conditions existing when the coil is used. The design of air core coils, however, is relatively simple. Three variables are involved, the diameter of the winding, the length of the winding, and the number of turns. The generally accepted formula for the calculation of air core single layer solenoids is as follows:

$$L = \frac{0.0251\, d^2 n^2}{b}\ K \text{ microhenries}$$

d = diameter of the coil (in inches)
b = length of the coil (in inches)
n = number of turns
K = a constant depending on the ratio of the diameter to the length of the coil.

Inspection of the formula shows that the inductance is inversely proportional to coil length, that is, the longer the coil, for a given number of turns, the less the inductance. This is due to the fact that in a long coil, much of the flux surrounding wires at one end of the coil does not link turns at the other end. If inductance were the only consideration, coils should be bunched in the shortest possible length, but the requirements for low coil resistance forbids this. The inductance is proportional to the squares of both the diameter and turns, that is, doubling either turns or diameter multiplies the inductance by four. Other things remaining equal, a change in coil diameter may be compensated for by a proportionate change in the number of turns.

The effect of changes in coil diameter and coil length are considerably modified by the constant K, which depends on the ratio of coil diameter to coil length. K is an empirical constant, i.e., is not a function of the coil dimensions, but has been determined by experiment. Since the value of K increases, as the ratio of diameter to length decreases, the constant tends to lessen the reduction of inductance as the coil is lengthened.

For accurate calculations, a table of the values of K is required. Such a table is contained in Circular 74 of the Bureau of Standards.* This book contains a great deal of valuable information and formulae, and is worth many times the price to anyone interested in radio laboratory work. Formulae are given for many types of coils other than the single layer solenoid.

The coil formula can be greatly simplified by choosing coil dimensions. If both length and diameter of the coil are always the same, the formula reduces to a very simple form, depending only on the number of turns.

For the standard General Radio Type 277 form, wound full length, the formula reduces to:

$$L \text{ (in microhenries)} = n^2 \times 0.000059$$

In order for this formula to apply, the coil must be wound the full length of the form, spaced if necessary.

It is often convenient or necessary to use a coil length different from the 277 form. A chart (Page 4) has been prepared, giving the solution of the formula for the case where diameter=2.75 inches. This chart will be found sufficiently accurate for most purposes. As it is nearly always desired to design a coil to tune to a certain wave length with a given capacity, a chart for computing the required inductance has been combined with the inductance chart.

The inductance chart consists of curves of inductance against turns for various coil lengths. The inductance scale runs to 600 microhenries and 100 turns. The right hand scale, running to 30 turns, may be used for lower inductances. The inductance scale is divided by 10 when using the 1 to 30 scale of turns, that is, 64 turns on a 2-inch coil would give 240 microhenries, while 21 turns on the same length coil would give 24 microhenries inductance.

The use of the charts is simple and obvious. The inductance chart may be used either to determine the inductance of a coil already built, or to give the number of turns required to obtain a desired inductance. In the former case, the number of turns and the length of the winding are learned. Project horizontally along the line corresponding to the number of turns until the curve for the proper coil length is reached, then project vertically to the scale of inductance. Thus, 40 turns, on a winding 1½ inches long, gives an inductance of 115 microhenries. For smaller coils, use the right hand scale of turns. When using this scale of turns, inductance values read on the scale must be divided by ten. Thus, 5 turns on a winding ¼-inch in length gives 4 microhenries inductance.

In designing a coil, the desired inductance and the length of the winding must be known. The procedure is then similar to that for the determination of inductance. The table of wire data accompanying this article will be found of use in calculating the coil length from the wire size.

SIZE B. & S.	TURNS PER INCH				
	Enamel	Single Silk	Double Silk	Single Cotton	Double Cotton
20	29	27	25	27	25
21	32	30	27	30	27
22	36	34	30.5	34	30
23	40	38	34	37	32
24	45	43	38	41	35
25	50	47	41	45	38
26	57	52	45	50	41
27	64	58	50	55	45
28	71	64	53	60	48
29	81	71	58	65	51
30	88	80	66	71	55

Considerable variation from the figures in the table may be expected, depending on the tension under which the coil is wound. If it is desired to wind a coil to tune to a certain wavelength with a given condenser, the upper part of the chart

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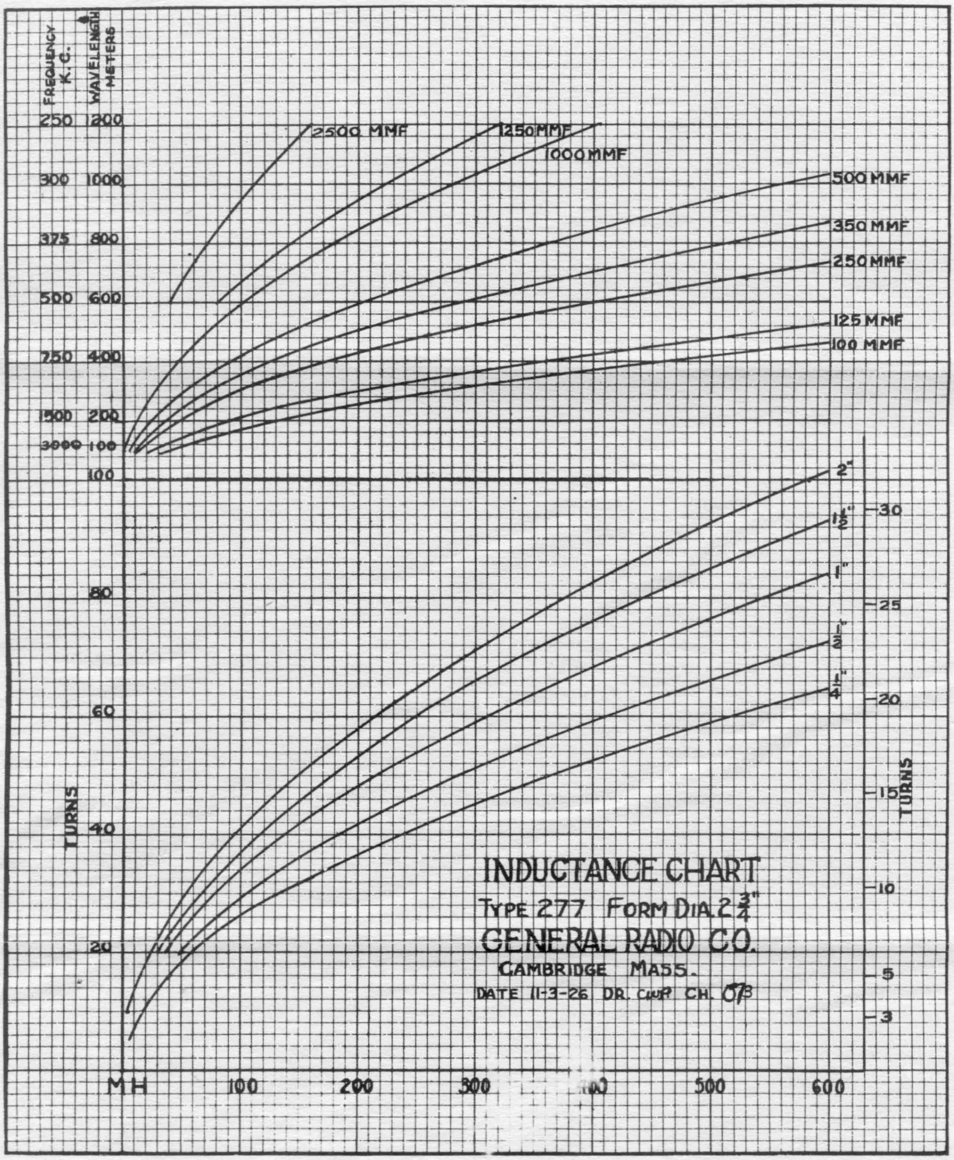
*Obtainable from the Superintendent of Documents, Government Printing Office, Washington, D. C. Price $ .60.



is used. A scale of frequency is shown beside the wavelength scale for convenience.

Suppose it is desired to tune to 500 meters with a 350 MMF condenser. Project horizontally from the 500 meter mark on the diagram to the curve for 350 MMF. Project down from the point of intersection into the inductance chart, and find that the turns required ranges from 45 with a ¼-inch winding length to 72 with a winding length of 2 inches. It should be possible to determine the winding length within a quarter of an inch from the wire data, and the coil is thus approximated within a turn or two.

The range of the chart may be extended by dividing the scales. Remembering that wavelength is proportional to the square root of the product of inductance and capacitance, it is obvious that the wavelength scale can be reduced to read to 120 meters by dividing the capacity and inductance scales also by 10. The right hand scale of turns is then used.

To find the turns required for tuning to 60 meters, project horizontally along the 600 meter line to the 2500 MMF curve and down to the inductance scale (e.g., 2 inches winding length). Projecting horizontally from the intersection to the **Right Hand** scale of turns, and find nine turns required.

The GENERAL RADIO
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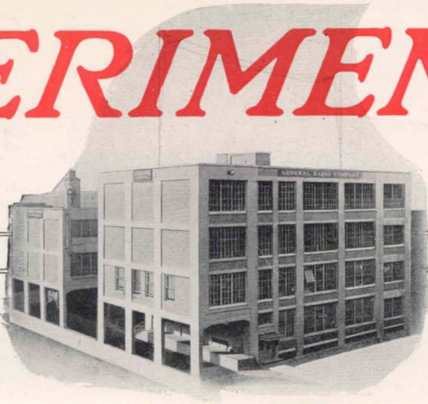


OL 1 NO. 6 DECEMBER, 1926

Design and Testing of Plate Supply Devices

By P. K. McELROY, Engineering Dept.

Part I—*Design*

[*Editor's Note: The following is the first of two articles on plate supply devices. Each article is complete in itself, but the second article will be clearer if the first article has previously been read, and if it may be at hand for ready reference when reading the second. The second article will appear in the January issue of the Experimenter.*]

I. Design

The manufacture of plate supply devices for radio receiving sets involves many problems of design, production, and testing. It is the aim of this article to acquaint the readers of the Experimenter with some of these problems and with our methods of meeting them.

Design problems are to a great extent affairs of theory and the laboratory, where experimental models are built and tried out to check theory and develop finished design preparatory to production.

Production problems are myriad and never are at an end, but they are of such nature as to be of little interest to readers of this article. Suffice it to say that varied means must be found, and found quickly, to solve these production worries as soon as they arise, in order to maintain the standard of the finished product as well as sufficient volume of production to meet market demands.

Perhaps testing may be considered a production problem, since it keeps up the standard of the finished article and, paradoxical as it may seem, speeds up production by enabling correction of defects to be made when correction is most easy, i.e., before assembly is entirely completed. If, in reality, the subject of testing is only a problem of production, at least its size and its interest warrant its treatment as a separate field.

Before proceeding to a detailed consideration of design and testing, it will be well to review briefly the more important divisions into which fall the circuits of plate supply units. Asking the indulgence of those to whom these circuits are familiar, we will briefly, so as not to be tedious, offer to those not conversant with these devices a simple explanation of their schematic operation. Referring to figure 2,

(a) is the actual wiring of a typical plate supply, and (b) is a schematic showing the functions of the corresponding divisions of the circuit (a).

The Transformer both heats the filaments and furnishes stepped-up high-voltage alternately to the plates of

The Rectifier, through which current can pass in only one direction. This current, a pulsating direct current of 120 pulsations per second (for a 60-cycle supply line), passes on to

The Filter. This is a "brute-

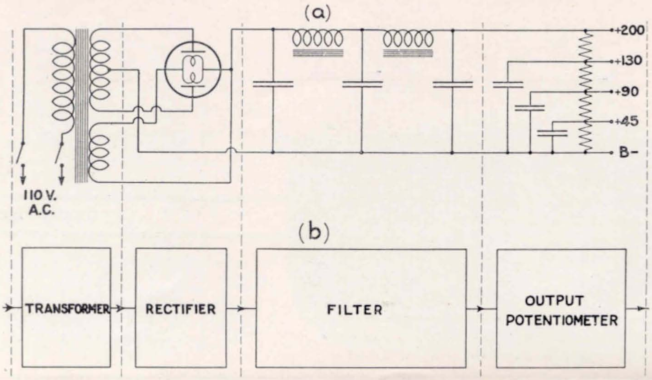


FIG. 2

force" or untuned filter. The pulsating D.C. delivered by the rectifier is equivalent to the sum of an average D. C. and the superposed pulsating ripple or A. C. of a frequency of 120 cycles per second. The D. C. component goes through the filter practically unchanged, being impeded only by the ohmic resistance of the two choke coils. The pulsating ripple, however, is by-passed by each filter condenser and held back by each choke coil in turn until, at the end of the filter, practically no ripple is present in the output, which is impressed across

The Output Potentiometer, which apportions the total voltage in a correct manner to supply various voltages as customarily required by plates of vacuum tubes in receiving sets. This division also contains fixed condensers to by-pass around the resistance of the potentiometer the A. C. energy, either radio or audio, from the receiving set. The plate supply unit is, in effect, a "B" battery of quite high internal resistance, and the by-pass condensers reduce the coupling between tubes operated from the same voltage tap by reducing the effective impedance common to the plate circuits of those tubes.

With this short resumé of the functions of the various parts of a plate supply unit, we proceed to considerations of the design of a unit having the following desirable general features and characteristics:

1. **Pleasing appearance.**
2. **Convenience of installation.**
3. **Economy of manufacture as well as economy of space occupied.**
4. **Safety.**
5. **Simplicity of operation and installation.**
6. **Load capacity.**
7. **Freedom from hum and other extraneous noises.**
8. **Flexibility or universality of application.**
9. **Good quality of audio output from receiving set or power unit.**
10. **Permanence and long life.**

These problems have been met in our units as follows:

1. Pleasing appearance has been striven for by making harmonious the general external proportions and mechanical design of the case and by applying to the case a durable finish which will harmonize well with its surroundings.

2. The 110-volt supply cord and the binding posts for external connections have been arranged close together on the rear of the instrument to facilitate connection in the least conspicuous place of the wires leading to the unit. The switch, however, is placed on the end of the case so as to be readily accessible.

3. The case has been made as small as possible consistent with reasonable ease in assembling parts and soldering connections. The sockets, resistance unit and audio transformer are placed in the rear or open compartment, while the remaining parts—condensers, chokes, transformers, etc.—are more easily assembled in less space in the compartments which are later sealed with wax. The final design represents a compromise between the two aims, economy of space and manufacture.

4. Safety has been attained by enclosing and shielding all parts in a well-ventilated metal case which is itself well insulated from the live parts within. Protection from the high voltages of the D. C. output is obtained by the use of bakelite binding posts, the engraved tops of which cannot be removed. Since these plate supply units cannot supply through their secondary circuits sufficient current to burn out the filaments of even 199 type tubes, should the "B" voltage by accident be applied across the filament terminals, care has been taken to insulate well the primary coil from the secondary coils so that there is no chance for the great primary energy to flow in secondary circuits, to the danger of filaments.

5. Installation involves only the insertion of tubes into the correct sockets, the connection of the supply cord to a 110-volt 60-cycle line, and the connection of the various binding posts to the corresponding terminals on the receiving set. Operation involves only the turning on or off of the 110-volt supply switch. Simplicity of operation is due to the use of a fixed resistance across the whole output of the filter circuit, tapped at the correct points to supply the various "B" voltages commonly used. These resistance taps are so proportioned that the voltage at any tap is, under all normal load conditions, near enough to the nominal voltage for all practical purposes. The elimination of variable voltage controls simplifies enormously the operation of the unit. Also, where tubes with filaments are used, correct voltages are applied to the filaments directly, eliminating filament rheostats that require adjustment. Thus, once installed, the unit may be forgotten, except to be turned off and on, and, nowadays, even that may be accomplished automatically by the use of a control relay (many of which are now on the market) actuated by the filament current from the "A" battery.

6. Load capacity, subject to limitations of rectifier tube ratings, is insured by generous proportions of power transformer coil and core, choke coils and cores, and resistance units.

7. Freedom from hum, even under heavy current drains, demands good choke coils of large current-carrying capacity (i.e., free from magnetic saturation at high currents) and allows no skimping of condenser capacities in the filter circuits. Enlarging the capacity of the last condenser of the filter is most effective in reducing hum in the output. The use of full wave rectification, i.e., rectifying both halves of the alternating current wave, produces better filtering action since the fundamental frequency of the pulsations is 120 instead of 60 cycles, and the higher frequencies are better removed by

the filter. Noises common to variable resistors of the carbon type (the only kind practicable to cover the range necessary if a variable resistor is to be used in a plate supply unit output circuit) are eliminated by use of fixed wire-wound resistances, in which only the best of resistance wires are used.

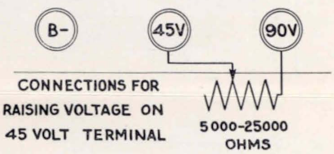
8. Flexibility of application of the unit demands good regulation of voltage at all voltage taps, i.e., the voltage must vary as little as possible with the current drawn from the unit. Good regulation of the low voltages in the output circuit can not be had unless the total voltage from the filter as applied to the output circuit has itself good regulation. The use of full-wave instead of half-wave rectification and the proper distribution of a sufficient number of microfarads in the filter circuit combine to improve very considerably both the voltage output and the regulation of that voltage. Large capacity of the first filter condenser following the rectifier is most important for obtaining high voltage and good regulation from the filter output. Good regulation of the lower voltages in the output circuit is obtained by properly designing the resistances of the potentiometer across the output so that the variation of the voltage at any tap from no load to a maximum is small, and the voltage is at no time very far different from its nominal value. In general, the smaller the resistance across the output, the better the voltage regulation of the various taps, but there is a happy medium beyond which too large a proportion of the output is diverted through the resistance and too little is available for "B" supply. In general, we have followed the principle of making voltages high rather than low, realizing that the high voltage can easily be cut down by the use of an external resistance in series with the load across any tap which may be high, while there is no remedy whatever if the voltage across any tap is very much too low. With this end in view the output potentiometer has been designed and the high transformer secondary voltages have been made as large as tube ratings will allow.

9. Good quality of audio output and freedom from receiving set oscillation is obtained by placing a sufficiently large by-pass condenser between each "B plus" tap and the "B minus" lead. Large capacity of the last condenser of the filter is important to maintain quality of reproduction. If the capacity is too small, currents of low frequencies in the power tube, which must be large if they are to actuate the loudspeaker audibly, are liable to modulate the output of the whole unit, thus spoiling the quality. In the power amplifier units it is also found that a by-pass condenser across the biasing resistance of the amplifier tube is necessary in order to achieve best quality of reproduction. In accordance with present accepted practice, the input to the power amplifier tube is through a good audio transformer and the output through an output transformer or speaker filter to remove the D. C. component of the plate current. It has been found also that better results and quality are obtained when the power amplifier has a separate feed circuit across the output in parallel with the output potentiometer. We have also found, as described in the accompanying article on page 4 by Mr. Lamson, that biasing by using the voltage drop across a resistance in the plate circuit gives superior results by compensating somewhat for changes in plate voltage due to different load conditions on the unit.

10. Permanence and long life of the unit mean satisfied owners and a saving of expense to the manufacturer for replacements and repairs. Great care in manufacturing is necessary to prevent failures in service. Non-corrosive fluxes must be used, soldered joints must be firm mechanically and of low electrical resistance, and the whole assembly must be kept clean of bits of metal, solder, or the fine cut-off short ends of stranded lead wires, so that troublesome short circuits may be avoided. Surplus flux must be wiped off of joints to prevent corrosion and appearance of slovenly workmanship. Waxes used for sealing uncased parts must have sufficiently high melting points so as not to melt under the heat developed in continuous service and must not be heated so hot when being melted as to become carbonized or to injure the paper condensers when poured around them. All leads between parts must be well insulated from the case, cores, and each other. Perhaps the most care is required in the selection of the paper condensers since the failure of only one condenser (out of six or eight in a unit) is sufficient to render the whole unit useless. This makes it imperative that condensers having a large factor of safety be employed, and that they be handled carefully to prevent their contamination by moisture or soldering flux, or injury by mechanical abrasion before they are finally hermetically sealed into place.

Simple Method for Increasing Voltage at 45V Tap Where Current Drain is Heavy

Several cases have arisen of sets having an unusually heavy drain—5 to 10 milliamperes—on the 45-volt terminal which were not properly handled by the G. R. power units. This situation is very easily met by means of a resistance connected as shown in the above diagram. This should have a range of 5,000 to 25,000 ohms. A resistance similarly connected between the highest voltage output (B plus terminal or output transformer) and the 90-volt terminal may be used if this terminal must carry an abnormal load.



A fixed resistance may be substituted for the variable one when the proper value has been ascertained, in order to keep the unit quieter.

On plate supply units having a 130-volt tap, the voltage on the 90-volt tap will be affected less if the variable resistance is connected between the 45- and 130-volt taps.

Correction of Error in November Issue

November Experimenter, Page 4, Column 1, for 500 meters, read 500 kilocycles (600 meters). Column 4, last paragraph should read "To find the turns required for tuning to 60 meters with a 250 MMF condenser, project to, etc."

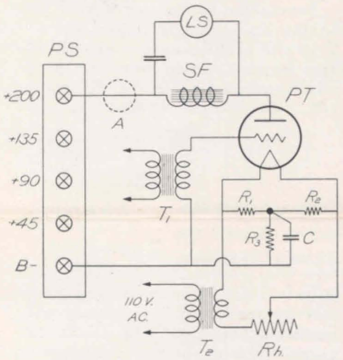
NOTICE TO RADIO EDITORS

Inasmuch as our permission has been requested by several radio editors to publish material contained in various copies of the "Experimenter," we wish to make this announcement.

Permission is hereby granted to radio editors of newspapers or magazines to reprint any or all of the material contained in this monthly publication, provided due credit is given the General Radio Company. Photoprints of any of the illustrations and diagrams will be sent on request free of charge to recognized radio editors.

Biasing the Power Amplifier Tube from the Plate Supply Unit

By HORATIO W. LAMSON, Engineering Department



After the radio fan has banished the need for "B" batteries by the use of some form of plate supply or "B" eliminator he becomes seized, perhaps, with the desire to do away with the "C" batteries, especially those of relatively high voltage required to bias the power tube in the last stage of the audio amplifier. If the plate supply outfit is capable of providing an over-all voltage equal to the normal plate voltage of the tube plus the required grid-bias voltage, this may readily be accomplished, provided a separate source of power is at hand for heating the filament of the power tube.

The circuits and equipment for doing this are indicated schematically in the figure. PS represents the terminal panel of a typical plate supply unit. PT is the power tube in question, for which T1 is the customary input transformer. SF is a speaker-filter in the plate circuit of the tube to keep the direct current from passing through the loudspeaker LS. This filter may consist, perhaps, of a thirty henry choke used in conjunction with a 2 MF condenser, or it may be replaced by an output transformer which will serve the same purpose.

An ordinary bell ringing transformer, T2, connected to the A. C. house mains, may be employed to heat the filament of the tube, using a suitable rheostat, Rh, to control the filament voltage. In this way no storage battery is required for the power tube, which makes it possible to add a stage of power amplification directly to a radio set employing only dry cell tubes.

Directly across the filament terminals are connected two resistances in series, R1 and R2. These may be from thirty to fifty ohms each. Their exact value within this range is immaterial but it is essential that they be closely equal to each other so that their center point is "equally distant" from the tube filament terminals. Between this center point and the B- terminal of the plate supply a third resistance, R3, is connected. This is known as the "biasing resistance" and it should be directly shunted with a condenser "C" of 1 MF capacity.

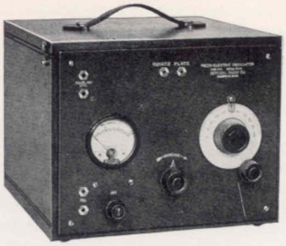
Examination of the figure will show that the plate emission current of the tube is obliged to pass through the resistance R3, and that the location of the grid return is such that the grid will be biased negatively with respect to the center of the filament, by a voltage very closely equal to the IR drop of the plate current through the resistance R3. In other words, the tube is biased by its own plate current. This is advantageous in that any change in plate voltage is compensated by a proportional variation in grid bias, thus maintaining automatically the correct relation between the two.

The by-pass condenser C is desirable to reduce the A. C. coupling between the grid and plate circuits of the tube, due to the resistance R3, which is common to both circuits.

The value of the biasing resistance depends, of course, upon the tube used and the voltage available at the plate supply terminals. By inserting a milliammeter at A the bias may be computed as described above or it may be measured directly by means of a high resistance voltmeter connected across the terminals of R3. If desired, this resistance may be an adjustable unit having an operating range of 500 to 5,000 ohms.

In general, it is not advisable to attempt to bias any but the last audio tube in this manner. Other tubes requiring a biasing battery should be provided with dry cell units. These tubes rarely require more than a few volts, which may conveniently and economically be supplied by small-sized flash light cells which, since they supply no current, will last throughout their normal shelf life.

A "Rock-Bottom" Standard



The importance of keeping all radio stations exactly on their assigned wavelengths has become vital. With the great number of stations operating at present, there is no vacant space between their assigned waves, and if a station is off its assigned wave it is interfering with another. The resultant effect is most unpleasant, as any of us can testify.

To help in the relief of this acute situation, the General Radio Company has designed an instrument known as a Piezo Electric Oscillator, the operation of which depends on a plate cut from a quartz crystal.

It has been discovered that when a plate, cut and ground from a piece of quartz crystal, is properly connected in a vacuum tube circuit, the quartz absolutely controls the oscillating frequency of the circuit. The quartz can be ground to any frequency (wavelength) desired, and is as unchanging as the rock from which it was cut.

The instrument shown above is a commercial adaptation of this principle. It consists of a quartz plate, and the necessary tube circuit, mounted in a cabinet. By means of this instrument, with a plate ground to the wavelength at which the station operates, its wavelength may be kept very constant, checking it frequently against the standard. A number of the larger broadcast stations are using this system to keep from straying over the fence of their frequency channel. A few stations have gone further and are using the quartz plate to control their transmitter directly.

The adoption of quartz standards promises much for the elimination of interference due to stations being off their wavelength. The older types of wavemeters were easily thrown out of adjustments by temperature changes and sometimes the calibration was affected by the treatment received in shipment. The quartz plate standard elminates both of these difficulties.