The GENERAL RADIO EXPERIMENTER

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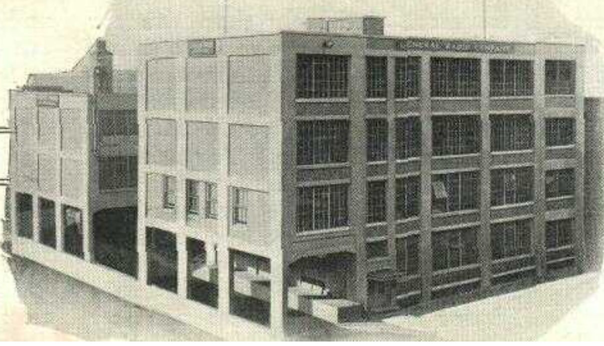

Announcing a New General Radio Service for Experimenters

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 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.

The EXPERIMENTER

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

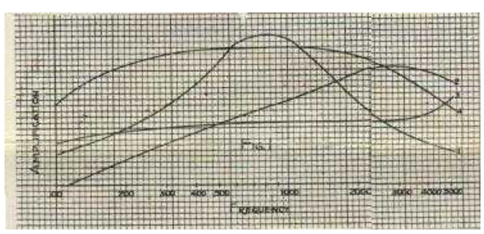

Fig. 1. A group of representative transformers. The superiority of the new types (curves 3 and 4) is marked.

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.

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-

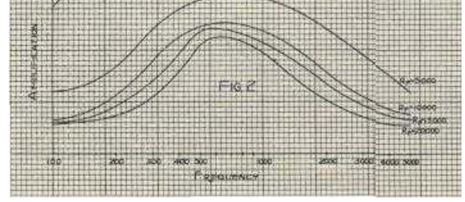

Fig. 2. The result of varying plate impedance on a transformer of low primary impedance. When the plate impedance equals that of the ordinary receiving tube (12,000-15,000 ohms) the curve is badly peaked.

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 1 5,000 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 1 5,000

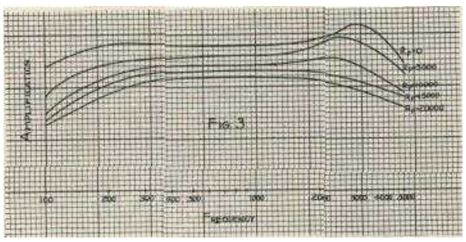

Fig. 3. The effect of plate impedance on the operation of a transformer of high primary impedance. The curves of Fig. 2 and 4 show the importance of making measurements with a resistance in series with the transformer primary. Otherwise an entirely false impression may be conveyed.

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.

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 1 5,000 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

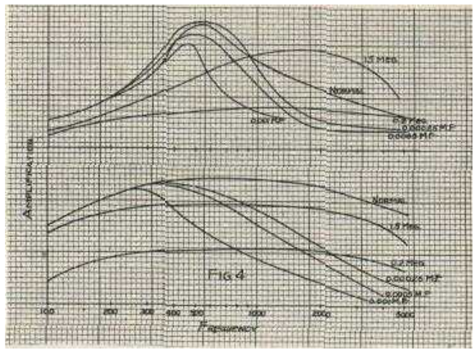

Fig. 4. A group of curves showing the effect of shunting various devices across the transformer secondary. The upper group were taken with a poor transformer, the lower on the newer types.

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.

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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