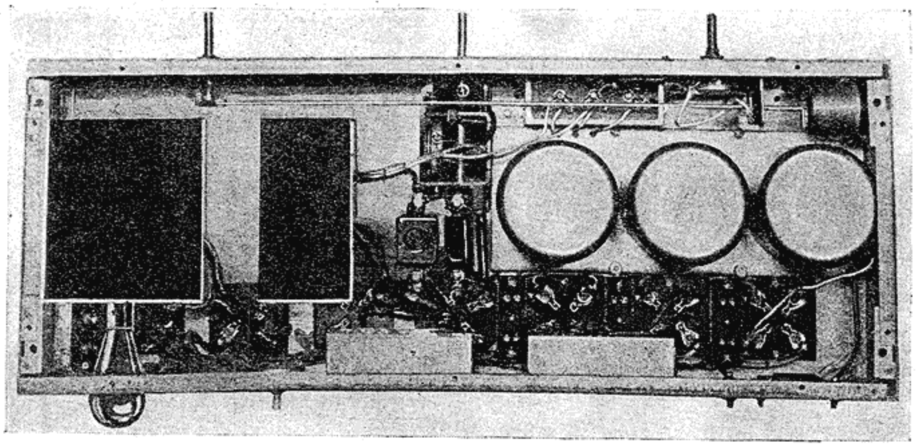
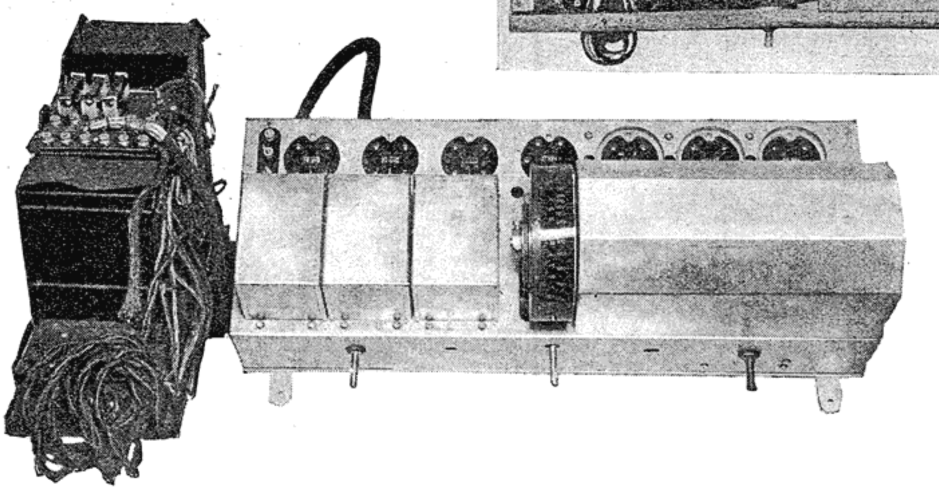
Eliminating the

By
Benjamin F. Miessner





(Left)—A standard manufactured chassis with its power pack at the left. (Above)—Underside view of the same chassis after the entire original power pack had been eliminated. The two black boxes contain all of the apparatus required—utilizing the Miessner system — to give even better performance

In my last instalment of this series, appearing in the April number of Radio News, the evolution of the a.c. powered, B-C supply system from the old "brute-force" type to the more modern types was described.

The first step in this evolution, characteristic of the old B-C eliminator antedating the self-contained electric sets, completed the filtering equally for all tubes, before division of the total output voltage into the various portions required for B and C voltages of the different tubes.

The second step differed from the first only in that each tube or group of similarly operated tubes, such as the radio-frequency and first audio-frequency group, produced its own bias by the flow of its plate current in a bias resistor.

The astonishing thing about these circuits is the wastefulness of filter apparatus. In the first place, the current for the power tube or tubes, taking from one-half to three-fourths of the total rectified current, is filtered just as well as that for the detector tube, notwithstanding the fact that the detector current requires from one hundred to five hundred times the filtering because of the succeeding amplification or, to put it in another way, if the detector current is filtered sufficiently well to eliminate its hum, then the power tube current has been filtered from one hundred to five hundred times too well!

Viewed from another angle, our astonishment grows apace. In a modern set with -45 power tubes in push-pull, the total tube load may be 100 milliamperes, of which the -45's take about 60 milliamperes, the radio-frequency and first audio-frequency tubes about 18 milliamperes, the detector tube only 2 milliamperes, and the voltage divider about 20 milliamperes. Here only two per cent. of the total load requires a high degree of filtering, eighteen per cent. a medium degree and sixty per cent. a low degree, whereas the twenty per cent. taken by the voltage divider really requires none, since it is wasted. Here ninety-eight per cent. of the current is filtered to the very high degree required by the detector's two per cent. when it need only be 1/200th as good! And the eighty per cent. taken by power tubes and loss resistor is filtered as well as the eighteen per cent. taken by radio-frequency and first audio-frequency tubes, when it need only be about 1/10th as good! And yet one can hardly find a radio magazine today which does not print diagrams of this very type as used or recommended by companies or engineers, or technical writers.

The first step in my system was directed at this wasteful use of filter apparatus. In Fig. 2 I show the essential details of my circuit arrangement embodying what I call "proportioned filtration." The voltage-dividing resistor, that waster of our costly filtered current, is replaced by series resistors (or chokes, if desired) in which the filtered current loss is reduced to a minimum. They perform the double function of voltage regulators and filter devices. Here we note three filter stages in series: one, for the power tube stage, which is no better than necessary for it; two, for the radio-frequency and first audio-frequency tube group, which adds the required increased filtering to that of the first stage for these intermediate tubes; and three, for the

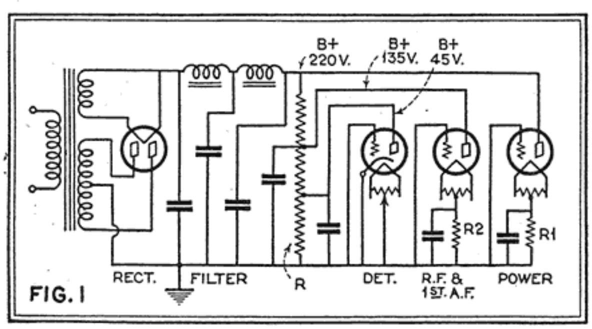
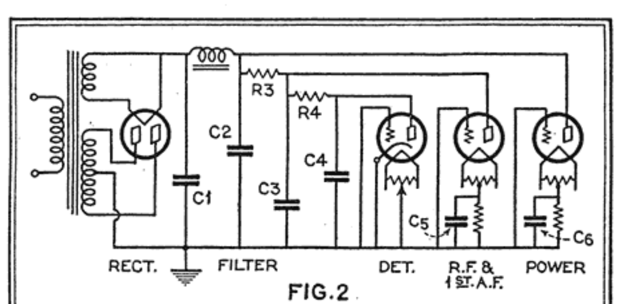


Fig. 1—A modern fundamental filter circuit

Fig. 2—These changes effect an improvement over the circuit shown in Fig. 1



Hum

*How the Bad Features of the Old Power Supply Systems Were Eliminated and a Greatly Improved Circuit Substituted**

Benjamin F. Miessner standing beside an Oscilloscope which is employed in studying hum phenomena. The note books contain more than two thousand pages of notations, photographs and curves of this inventor's discoveries

detector, wherein the additional filter stage R4 C4 adds just enough filtration to that of the preceding two stages to clear the detector of hum. It may be noted here that the resistance values used are determined by the operating B and C voltages of the tubes they supply, and the filtering is regulated by proper choice of capacity. Further, the amount of filtering required for the power tube is determined by adjustment of filter elements while its grid input is short circuited. When this adjustment is completed the short circuit is removed and placed across the input to the first audio-frequency tube to keep out detector hum. Then the filter elements R3 C3 are adjusted for the first audio-frequency tube hum, amplified by the second audio-frequency tube or tubes. It may here be remarked that if the radio-frequency tubes have the same degree of filtration as the first audio-frequency tube, and the latter does not hum, then no difficulty with "B" ripple as a cause of carrier modulation hum in the radio-frequency tubes should be expected.

Finally, the first audio grid input short circuit is removed and placed across the detector grid input, while the third filter stage constants are adjusted for operating voltage and hum.

This series filter system has many advantages over the earlier "brute force" types previously discussed, and is much more efficient and economical.

It will be noted that this circuit eliminates all loss current, provides proper voltages for all tubes, regulates the filtering for given tubes to a degree determined by succeeding application, and eliminates the couplings between grid and plate circuits of different tubes previously noted.

With a circuit of this type it is ordinarily possible to produce better results with about one-third the amount of filter apparatus required by the first type, and with about one-half the amount required by the second.

If this last arrangement has filter elements so proportioned that hums from all tubes due to filter ripple are equally low and unobjectionable in a loud speaker, we may proceed further to reduce the required amount of apparatus. This may be accomplished by reducing inductance or capacity in the first filter section so that the power tube develops a hum having a magnitude five or ten times the tolerable limit; that is to say, about one volt, if the predominant frequency, as usual, is 120 cycles. This is done also in the second filter stage, feeding the first audio tube, so that this produces a one-volt hum in the plate circuit of the power tube. If now the phases of these two hums be reversed 180° in the plate circuit of the power tube, by properly poling the second audio primary and by regulating the resistance R3 and condenser C3, these two hums may be neutralized. I call this type of neutralization "interstage hum bucking."

Hum may likewise be introduced in the detector stage by filter reduction and neutralized in either the second audio or power stages; or it may be added to or subtracted from the first audio hum, and the residual neutralized in the power stage.

If, as is usual, the radio tubes obtain their grid and plate voltages from the same points supplying the first audio tube, the best plan is to provide sufficient filter apparatus in the

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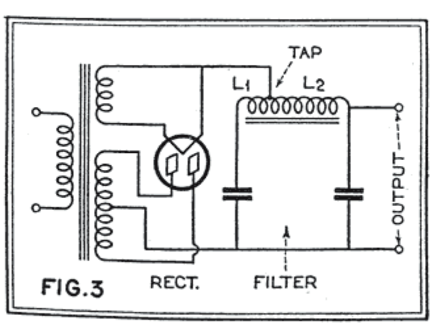
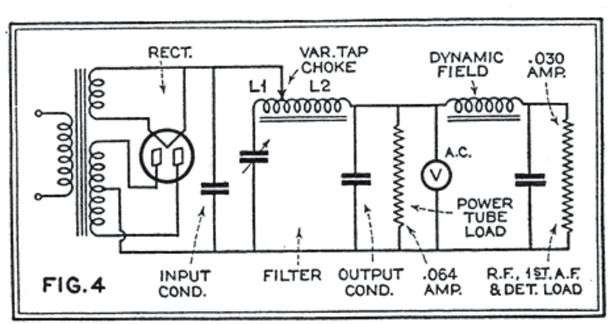


Fig. 3—Much smaller filter element values are made possible by the Miessner "tapped-choke filter"

Fig. 4—The circuit employed in measuring filter ripple and from which the curves in Fig. 5 were made



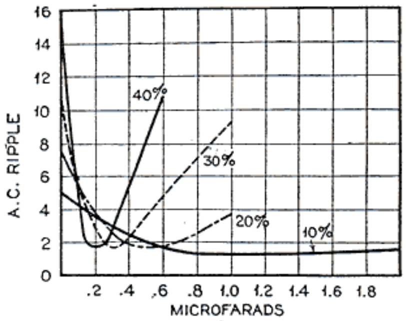


Fig. 5—Ripple measurement curves made with circuit shown in Fig. 4. The ordinates are arbitrary measures of ripple and the abscissae are variable condenser capacities

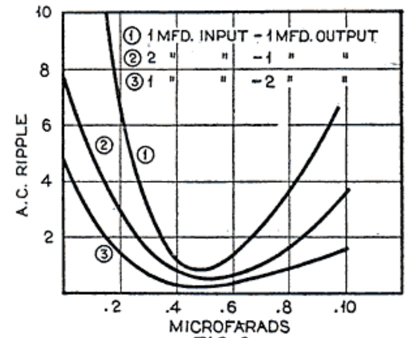


Fig. 6—These curves indicate that changes in input and output capacities do not affect the adjustment of the neutralizing condenser

second filter stage to prevent the introduction of hum by all of these tubes, and then to neutralize the power stage hum by that of the detector stage. Otherwise modulation hum may appear.

A purely audio hum without r.f. carrier can also be neutralized by carrier modulation, caused by insufficient filtration of the radio tube current. In this case the receiver may possess a strong hum when no carrier is received, which will disappear when a carrier, whether modulated or unmodulated, is tuned in at the transmitter. The disadvantage of this scheme is that unless the audio hum be adjustable, the neutralization is complete only when the carrier input to the detector tube has a particular amplitude. This, as before mentioned, results from the fact that the carrier modulation amplitude is governed both by the receiver modulating influence and the strength of the carrier in the receiver itself.

In resistance-coupled amplifiers, such, for example, as the new Loftin-White circuit, the interstage coupling is of correct phase to produce this interstage bucking. It is necessary in amplifiers of this type only to regulate correctly the amplitudes of the hums by filter design to get neutralization. I am informed by Mr. Loftin that the low hum output of their amplifier is due largely to this and another of my bucking schemes, to be described later as "hum feedback," wherein the normal grid voltage ripple produced by the plate current ripple in a bias resistor, by the B supply is increased to a point where it neutralizes the plate ripple.

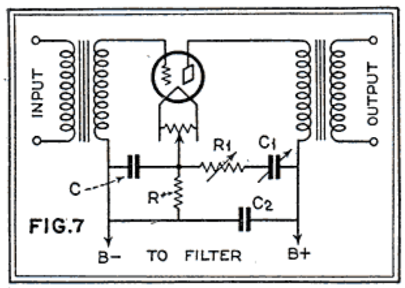


Fig. 7—This form of hum neutralization in a receiver circuit, instead of in the filter, is capable of surprising results, and is applicable to a single tube or a group of tubes obtaining their plate and grid-bias voltages from a common point

This is done by means of a condenser, or condensers and resistance, connected in series between B+ and the cathode of a given tube or group of tubes, so as to develop a ripple current in the bias resistor from B+ to B. When the phase of the ripple voltage across this bias resistor is correct and its amplitude, multiplied by the amplification factor of the tube, is equal to the plate ripple, neutralization occurs, and no ripple current flows through the tube, which behaves as if only the decomponent of plate and grid voltages were present. This will be described in detail later.

Another form of interstage bucking occurs in most receivers with one or more filament potentiometers. Assuming that fixed mid-point potentiometers or filament windings are used for power tube and first audio and r.f. tubes, and that an adjustable potentiometer is used for the detector heater, it is observed that a fixed mid-tap will provide minimum hum with only a small proportion of tubes, so that for most tubes it is somewhat out of adjustment, thus causing a 60-cycle voltage to be introduced in the grid of the particular tube or tubes which it serves. An adjustable detector heater circuit mid-tap may be made to neutralize the hum so introduced, by setting up the same type of hum in the detector stage. This, when amplified into the grid circuit of the first audio tube, will, if correct in phase, wave form and amplitude, neutralize the first-mentioned hum. The detector hum phase may be reversed and its amplitude regulated merely by adjustment of this detector potentiometer. The same effect may be secured by using the adjustable potentiometer in the first audio stage instead of the detector. Sixty-cycle induction hum can also be neutralized to some extent in this manner.

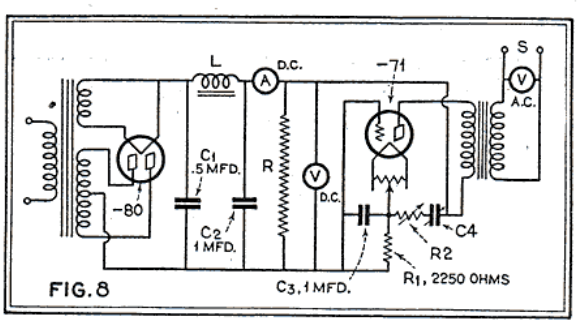


Fig. 8—The alternating ripple voltages are applied to both the grid and plate, but since they are neutralized at every instant no a.c. current can flow through the tube. Curves illustrating the performance of this arrangement appear in Figs. 9 and 10

Tapped Choke Filter

Another method of considerably increasing the effectiveness of a given amount of filter apparatus, or of reducing the amount of apparatus required for a given output ripple, is what I call a "tapped choke filter." This circuit is illustrated in Fig. 3. Here the rectifier is connected to the filter choke at some point near one end, the filter condensers being connected to the ends of the choke winding. An input condenser may also be connected across the rectifier if desired. This circuit ordinarily will reduce the ripple output by a factor of five to ten over that obtained with the same choke and condensers connected in the usual manner. Or, conversely, it will provide just as good a filter with considerably smaller values of the filter elements.

The increased filter action is due to a neutralizing effect between the a.c. components of the two portions of the choke. That is, a rather strong a.c. current component flows through the portion marked L1, the coupling of which to L2 neutralizes to a large degree the a.c. voltage component therein, so that the output a.c. component is reduced.

Curves showing the performance of this circuit accompany this article. These curves were made by Mr. Arthur B. McCullah of the Gulbransen Radio Corporation of Chicago and are here included by his kind permission. The circuit arrangement used is shown in Fig. 4. It will be noted that an input condenser is connected directly across the rectifier, that the vacuum-tube voltmeter for measuring the filter ripple is connected across the power tube load, and that the d.c. current in the filter is 94 milliamperes. You will note further that the condenser conected to the beginning end of the choke is variable.

Fig. 5 shows, for several tap-points on the choke coil, the effect of changing the variable condenser. The per cent. designations refer to the percentage of total turns in the input side of the choke coil. The ordinates are arbitrary measures of ripple, and the abscissæ are capacities of the variable condenser in microfarads.

You will note that while low ripple levels may be obtained with capacities as low as two or three-tenths of a microfarad, not much variation from the best value can be tolerated without increasing the ripples.

As the tap percentage increases the capacity increases and becomes much less critical. A 20% tap appears to be quite effective without critical condenser value.

In Fig. 6 is shown a family of curves indicating that the adjustment of the neutralizing condenser is not affected by change of input or output capacities.

Further tests have shown that if the full choke coil be used in a normal filter circuit, more than twice as much filter capacity is required to reduce the ripple to a given level.

This type of filter stage may of course (*Continued on page* 957)

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be used singly or in series with others of the same or of different types. If the condenser across the rectifier be omitted, an additional advantage is obtained in that the rectifier load due to such a condenser is greatly reduced, and the rectifier tube life prolonged. In a particular very popular receiver using a two-microfarad condenser in this position, and having a filter output direct current of 70 milliamperes, the a.c. current through this input condenser was also 70 milliamperes, thus doubling the load on the rectifier tube. Another valuable advantage of the tap choke filter is therefore evident. I have developed many modifications of this arrangement wherein choke coils of successive filter stages are coupled for hum reduction; and wherein filter chokes are coupled to audio transformers or other audio-frequency coupling devices for the same purpose, and having the same general effect.

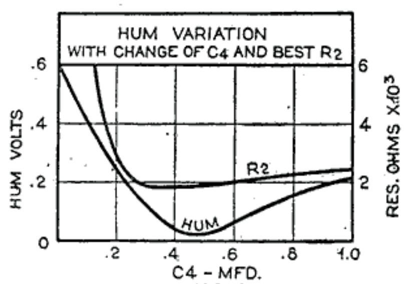

FIG. 9.

Hum voltage may be computed from these curves which were made using the circuit in Fig. 8

Neutralization by Hum Feedback

Another method of hum neutralization, which I term "hum feedback," is capable of very surprising results. It is used not in the filter, but in the receiver circuit. The circuit arrangement as applied to a single tube or group of tubes obtaining plate and grid-bias voltages from the same points, such as the first audio and all-radio tubes as a group, is shown in Fig. 7.

Here a tube is shown with input and output coupling devices, B voltage being obtained from the receiver filter output, and C voltage being obtained from the voltage drop, produced across the grid bias resistance R by the plate current of the tube. A condenser C is connected across this resistance for signal by-pass, first to keep this resistance out of the

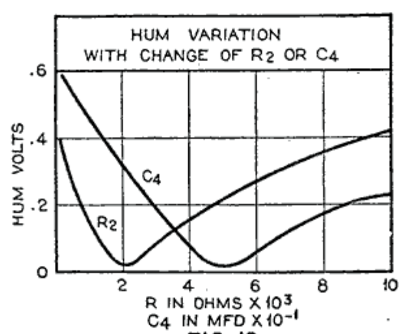

FIG. 10

These two curves show the resistance and condenser tolerances with a neutralizing factor of approximately 60

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signal output circuit, and secondly to prevent the signal voltage drop across it from introducing degenerative effects in the grid circuit of the tube. Condenser C2 is the normal combined filter and filter by-pass condenser. So far this is a normal and well-known circuit. If a strong ripple component is present across the B current input—that is, across C2—this ripple voltage will drive a corresponding ripple current through the tube superimposed on the d.c. current driven through it by the d.c. voltage. This a.c. current component will develop a corresponding voltage across the secondary of the output transformer, which will ultimately appear in the following reproducer as a loud hum. If the tube be used for radio-frequency amplification the carrier will be modulated and, after detection and amplification, the hum will likewise appear.

If now condenser C1 and resistance R1 be connected and properly adjusted, the hum will completely disappear without harming the normal signal amplification of this amplifier stage; as a matter of fact it will actually be improved, because the plate circuit signal current will have another path from output transformer B+ to the tube filament, in parallel with that already provided through C2 in series with C and R in parallel. Furthermore, the signal thus by-passed through C1 R1 cannot cause a degenerative effect because it does not flow through R and C, as does that portion flowing through C2. The action of this circuit is as follows: a path for the a.c. component only of the B current is provided across B+ B— through C1 and R1, and thence through C and R in parallel. Since C and R are included in the grid circuit of the tube, the a.c. ripple thus developed will produce a ripple voltage of a magnitude, phase and wave form determined by C1, R1, R.C. and the corresponding characteristics of the ripple voltage across B+ B—. When C1, R1, R and C are properly chosen, the neutralization is of a very high order. It will be seen that the effect of C1 and R1 is to introduce into the grid circuit of the tube a ripple voltage of the same wave form but of opposite phase, and having an amplitude less than that of the plate ripple voltage by a factor equal to the amplification factor of the tube. Both grid and plate, therefore, have the alternating ripple voltages applied, but these are neutralized at every instant, so that no a.c. current can flow through the tube because of them, and only the direct component of the grid and plate voltages remains effective to permit current to flow. Since the signal input voltage is applied to the grid alone, it can and does produce a corresponding alternating signal current component in the plate circuit which appears in the output for further amplification, speaker operation or any other desired function.

Some curves showing the performance of this arrangement may be of interest. The data for them were obtained with the circuit arrangement shown in Fig. 8.

A -80 full-wave rectifier tube is shown normally energized by a power transformer. It operates into a single-stage filter consisting of a one-half microfarad condenser C1, a choke coil L, having an impedance of 23,600 ohms at 120 cycles and 31 milliamperes of d.c. current, followed by a one-microfarad condenser.

A d.c. milliammeter is included in the filter line to the load, which consists of the load resistance R and the -71 power tube shown. The load current was 31 milliamperes. A d.c. voltmeter across the load resistance indicated the d.c. voltage, which was 220 volts. The -71 tube has no signal input, but was provided with a proper output transformer connected to a Western Electric 540-AW speaker, and a vacuum tube voltmeter as shown. The grid bias resistance was 2,250 ohms, and its bypass condenser C3 was one microfarad. An adjustable mid-point potentiometer was included and carefully adjusted for minimum hum. The hum feedback condenser C+ and resistance R2 were both variable.

In Fig. 9 I show in the curve marked "Hum," with ordinates at the left in volts, the variation of hum output with simultaneous variation of the hum feedback elements C4 and R2. Variation of R2 is indicated in the curve labeled R2, whose ordinate scale in ohms is at the right. The abscissæ scale is in microfarads for capacity of the variable condenser C4. For any given point on the hum curve, the capacity of C4 is given by the abscissæ corresponding to the ordinate of this point. The resistance value for this hum point is obtained from the intersection of the ordinate with the resistance curve. Thus, for 3/10 microfarad and 2,000 ohms the hum voltage is .16 volts or 160 millivolts. The unneutralized hum—that is, the hum with C4 equalling zero—is 600 millivolts, while the least hum, obtained with ½ microfarad and 1,900 ohms, was only 10 millivolts. This residual hum was caused almost altogether by the a.c. filament excitation of the tube.

In Fig. 10 I show in the curve labeled R2 the hum variation with variation of R2 alone, C4 being fixed at one-half microfarad; in the curve labeled C4 I show the variation of hum with variation of C4, the resistance being fixed at 1,900 ohms. The abscissæ of curve C4 indicate tenths of a microfarad, whereas for R2 they indicate thousands of ohms. These two curves show the resistance and condenser tolerances with the neutralizing factor here indicated, which is about 60.

This circuit may be used with equal advantage in audio or radio-frequency amplifier tube circuits. I have obtained with some forms of it neutralizing factors as high as ten thousand. That is to say, an output hum of about 50 volts, that is 50,000 millivolts, could be reduced to one of about 5 millivolts when the circuit constants were carefully adjusted. I have developed many variations of the hum-eliminating methods heretofore described, and also many other methods, the presentation of which must be reserved for some future time.