cost of the lower voltage filter condensers which can be used with the lower voltages, and the elimination of any need to use resistors either at point "X" (the most desirable point at which to use resistors to cut down the voltage input to the filter circuit when necessary), or at point "Y" or "Z."

Once the characteristics of the voltage divider, chokes, rectifier, voltage reducing resistors and transformer have been decided upon, the requirements of the condensers to be used can be determined.

The voltage ratings of the condensers required will depend on the voltages which obtain between the leads across which the condensers are to be connected. The voltages across these points will vary at different points of the filter and will depend to a considerable extent on the characteristics of the current at each step, because the current in the filter circuit is not a pure continuous current, but a pulsating current which approaches a continuous current to an extent which is dependent on the filtering in the circuit.

While the average D.C. voltage across points "A" and "B" of Fig. 1, in the case we have been considering (using a full wave CX-381 rectifier and a transformer with 600 volts A.C. each side of center tap), may be 660 volts, the peak voltage of the pulsating current may rise to about 1.4 times the A.C. voltage supplied by the transformer, i.e., 600 times 1.4 or 840 volts. When a resistor is used at point "X," reducing the average D.C. voltage across the condenser to 495 volts, the peak voltage across the condenser will be considerably reduced because of the drop through the resistor. In the first case therefore, under working conditions with the unit drawing 75 milliamperes, with a resistor at "Y" or "Z" the use of an 800-volt D.C. working voltage condenser would not be sufficient, while in the second case, when using the resistor at "X" an 800-volt condenser is more than ample. Here again the resistor at "X" acts as an automatic voltage regulator at the peak voltages and currents.

Another factor which must be considered is the fact that the total current of 75 milliamperes is not drawn immediately by the load, which may have a slight time lag, before the tube filaments of the receiver heat up and draw current. This is especially true in the case of the C-327, CX-310, CX-350 and CX-345 tubes which require an appreciable time to heat up.

If we consult the curves of Fig. 4, we find that at lower loads, (the minimum which will be drawn by the power unit being limited by the bleeder current in the voltage divider), of about 20 milliamperes, the voltage output of the rectifier, with an input of 600 volts A.C. per anode may rise to almost 740 volts D.C. with a practically steady peak voltage of somewhat less than 840 volts (600 times 1.4). This steady voltage applied to the condenser, because of the more nearly continuous current characteristics at low load, is more damaging than the peak voltage obtained under load. The consequences of operating a receiver without a load are evident if condensers of insufficient safety factor are used in the case just cited. Fortunately, with CX-310 tubes, the overload is only for a very short time and since Aerovox condensers are conservatively rated so that a condenser rated at 800 volts D.C. will easily withstand voltages up to twice that value or up to 1,600 volts for comparatively long intervals, no harm will result. The application of twice the D.C. working voltage for 15 seconds is the standard retest voltage applied to Aerovox condensers before they are passed by the testing department, although they will stand much higher transient or flash voltages.

Under the "no load" conditions mentioned, with a current flow of 20 milliamperes due to the bleeder, the drop due to the resistor placed at point "X" in Fig. 1 would naturally be lower than the drop with an average current of 75 milliamperes. With a possible peak voltage of 840 volts between points "A" and "B" and assuming that the peak tube current reaches 2.5 times the load current or 50 milliamperes, the peak voltage across the condenser when using the resistor at "X" would be in the neighborhood of 738 volts, practically the D.C. output of the rectifier at a load of 20 milliamperes.

At the second section, the filtering provided by the choke "CH1" plus the resistance of the choke will limit the voltage across "C2" to almost steady continuous current of a value about equal to the D.C. input to the filter. A 600 volt D.C. working voltage condenser at "C2" under the "no load" condition constitutes an overload on the condenser and may result in breakdown if kept up for a long period.

When using C-327 tubes throughout in the receiver, with CX-345 power tubes in the power amplifier, it is especially important to use condensers of sufficiently high rating to stand the temporary "no load" conditions of steady high voltage under which the filter will be called upon to operate because of the appreciable time lag of the receiver and amplifier tubes.

The same thing is true of the bypass condensers, used across the 90-volt, 135-volt and 180-volt terminals of heater type tubes such as the C-327 and the A.C. screen grid tubes. Unless a bypass condenser of about 300 volts and in some cases higher D.C. working voltage is used, trouble may be experienced due to the use of 200 volt D.C. working voltage condensers because of the temporary higher voltages which will obtain at those taps until the tubes heat up.

To sum up briefly, most economical design and efficiency in long tube and condenser life demands that the power pack be designed to fit a particular receiver or group of receivers having practically the same current drain. In designing the power pack the current drain of the receiver, plus the current allowed as a bleeder current should constitute the "load" upon which the design of chokes, filter condensers, rectifier and transformer should be based.

Where a "standard" transformer is employed as for instance for experimental use or in custom set-building where the design of a special transformer is not practical, the voltage should be reduced at the input to the filter (point "X" in Fig. 1), so as to reduce the voltage across the filter condensers and thus improve the life of the rectifier and the filter condensers.

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Overlooked Factors Which Cause Grief in the Design of Power Supply Units

By the Engineering Department, Aerovox Wireless Corp.

To get maximum efficiency both from the standpoints of first cost and maintenance it is important that power supply units which are to be used with a particular receiver or amplifier be designed to give an output just sufficient for the load imposed. If the power unit does not deliver the required output, the receiver will not operate at maximum efficiency. The drain of a higher current than that for which the power unit is designed is bound to result in excessive heating and possible breakdown.

On the other hand, if the capacity of the unit is larger than that required by the load, some means, usually resistance, must be used to take up the excess.

To supply too little results in impaired operation. To use a transformer and rectifier arrangement which supplies too much results in needless cost in the transformer, reduced life of the rectifier, increased cost of chokes, resistors, and filter condensers, and is analagous to using brakes instead of the accelerator to maintain any desired speed of a car.

The determining factor in the selection of the proper power transformer, rectifier, filter and to some extent voltage divider design to use, is the load which is to be imposed on the power supply unit by the receiver, amplifier, filter and voltage divider of the power unit.

The first step therefore, before attempting to design a power supply unit is to determine the load, this to include the total current to be drawn by the receiver and the amplifier. To this should be added the bleeder current of the voltage divider The voltage divider should be designed to give a bleeder current of about 20 milliamperes if no regulator tube is employed and about five milliamperes if a regulator tube is used. When a regulator tube is used, another 30 milliamperes should b allowed for it at the 90-volt tap.

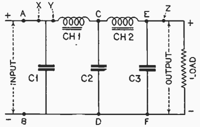

Fig. 1

If we are using a receiver with a push-pull amplifier employing CX-310 tubes or their equivalents, the total current drain of the receiver and amplifier may run from 50 to 56 milliamperes, depending on the tubes and voltages used in the receiver. If no regulator tube is used an additional 20 milliamperes for bleeder current will bring the total load to 70 to 76 milliamperes. If a regulator tube is employed, five milliamperes for bleeder current and 30 milliamperes for the regulator tube will bring the total up to 85 to 91 milliamperes.

It is also important to know at what output voltage this total current should be supplied. The voltage desired at the output will be the plate voltage necessary for the power tubes, plus the maximum grid bias voltage required. In this particular case if we consider operation of the CX-310 tubes at 400 volts with a grid bias of 35 volts, the total voltage will be 435 volts.

With these figures (these will vary with different circuits and tube combinations), as a starter, we can proceed to design the power supply unit to give the required output voltage and current.

The most important thing to consider next is the filter choke. The usual circuit arrangement uses two chokes and these must be capable of carrying the output current.

The current flowing in the complete circuit is kept constant by the load, while the voltage at the different points of the circuit will vary depending on the voltage drop caused by the resistances in the circuit.

If we consider a typical receiver and amplifier using two CX-310 tubes in push-pull as drawing 75 milliamperes (including bleeder current), at a total output voltage of 435 volts, the voltage measured between points "E" and "F" of the filter circuit, shown in Fig. 1, should be 435 volts at a current drain of 75 milliamperes. The filter chokes in this particular case should be capable of passing at least 75 milliamperes without undue heating. Because of the resistance introduced by chokes "CH1" and "CH2" there will be a voltage drop between points "A" and "E" which will depend on the resistance of the chokes and the current flowing in the circuit. The resistance of these chokes as made by some of the leading transformer and choke coil manufacturers, varies but a good average for a choke designed to carry 75 milliamperes and having an inductance of 30 henries would be in the neighborhood of 400 ohms. Since there are two chokes connected in series, the voltage drop from "A" to "E" with a current flow of 75 milliamperes would be .075 times 800 or 60 volts. The voltage input to the filter therefore as measured between "A" and "B" would therefore have to be 435 volts (output required), plus the drop which will take place through the chokes, 60 volts, or a total input of 495 volts.

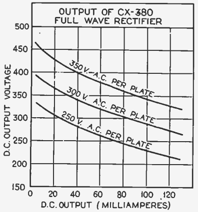

Fig. 2

It is therefore necessary to use a transformer and rectifier arrangement capable of providing an output of 495 volts at a current drain of 75 milliamperes.

The first step therefore is to find a rectifier which is capable of such an output.

A glance at the curves of a CX-380 rectifier, for use with the conventional filter circuit of Fig. 1, shows (see Fig. 2) that this rectifier is out of the question for this unit. At a current drain of 75 milliamperes, the maximum voltage which can be obtained with this type of rectifier, even when using the maximum 350 volts per anode on the rectifier, is only about 375 volts, a value that is entirely too low.

Figure 3 shows the curves for a CX-381 tube when used as a half wave rectifier. The CX-381 rectifier is capable of supplying up to 85 milliamperes (the maximum current which the tube manufacturers recommend for this type of tube when used as a half wave rectifier), but it is not desirable to use it so close to its maximum output. It is also advisable to use a full wave rectifier wherever possible in preference to a half wave rectifier to get quieter operation.

Figure 4 shows the curves for two CX-381 tubes connected to give full wave rectification. It can be seen that at a current drain of 75 milliamperes it is possible to obtain a D.C. output voltage of approximately 660 volts by applying a voltage of 600 volts A.C. to each anode by means of a conventional power transformer designed to provide a secondary voltage of 600 volts each side of center tap.

If a voltage of 700 volts A.C. is applied to each plate of the rectifier tubes by means of a transformer designed to give 700 volts each side of center tap, the output voltage delivered by the full wave rectifier will be approximately 775 volts D.C.

Since the D.C. input voltage required to the filter is only 495 volts in the case we are considering, it is easy to see that both of these transformers will give a higher output than is necessary, an output which must be cut down if it is impossible to obtain a transformer desired to give a lower secondary voltage, either by introducing additional resistance in the filter circuit to reduce the rectifier output voltage (input to the filter), to 495 volts at a current drain of 75 milliamperes, or by drawing additional current at the output so as to cut down the output voltage of the rectifier to the required value.

If we start with the assumption that we are to keep the current drain constant (the most desirable method), it is an easy matter to determine the additional resistance required in the filter circuit to reduce the voltage at the output to the required value.

If we assume, in this particular case, that we are using a transformer designed to give 600 volts each side of center tap and which when used with a full wave rectifier employing CX-381 tubes will give an output of 660 volts at 75 milliamperes, it will be necessary, in order to reduce the 660 volts to the 495 volts required to use a resistance of 2200 ohms. This will produce the necessary 165-volt drop with a current of 75 milliamperes.

This resistance should be introduced at the point "X," next to point "A" of Fig. 1, since in that way the voltage applied across condenser "C1" will be 165 volts less than would be the case if the resistance were introduced in the line after the condenser connection (point "Y"). Of course the same effect, that is of lowering the voltage at the output of the filter at the required current drain, could be obtained by introducing the resistor at point "Z" next to the output. However, in the latter case, the voltage across condensers "C1," "C2" and "C3" would be higher, and more costly condensers of higher voltage ratings would have to be used to withstand the higher voltages.

In the other system, that of designing the voltage divider to take up enough extra current to keep the voltage input to the filter circuit such that the drop across the chokes will give the required output voltage across points "E" and "F," it is necessary to start at the rectifier circuit to calculate the voltage divider necessary to take up the extra current.

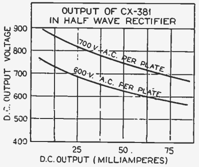

Fig. 3

If, as we have seen, we use a full wave rectifier with a transformer which applies 600 volts to each plate, it is possible to obtain an output of 100 milliamperes at a voltage output of 650 volts D.C.

If the output of the rectifier is 100 milliamperes at 630 volts, chokes "CH1" and "CH2" must now be designed to carry the extra current. Their resistance will depend on their design but the average resistance of chokes of this type may run to about 200 ohms. It might be mentioned that this additional current carrying capacity is obtained either by using much larger chokes to get the same inductance or by reducing the inductance of the chokes to permit the use of the heavier wire without unduly increasing the cost.

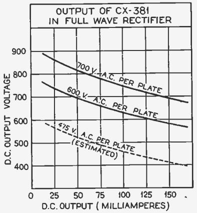

Fig. 4

At 100 milliamperes current, the drop in voltage through the two chokes will amount to 40 volts (.100 times 400). This will give 100 milliamperes at 590 volts output from the filter. The voltage can be reduced to 495, the required value by using a resistor at "X," "Y" or "Z" to produce the required drop of 95 volts or by increasing the resistance of the choke coils to produce an additional drop of 95 volts. Since all that is necessary for the receiver, amplifier and bleeder current is 75 milliamperes, it is necessary to dissipate, in some way, the additional current represented by the 25 extra milliamperes.

This can be done by providing an additional bleeder current, either by connecting a resistor directly across the output of the filter or by designing the voltage divider so as to draw this additional current.

If the first filter condenser is connected directly across the output of the rectifier, the peak voltage to which it may be subjected may run as high as 600 times 1.4 or 840 volts, requiring the use of 1,000 volt condensers, the next standard size above 800 volts.

Taking into consideration the additional cost of the transformer to supply voltages that are higher than necessary, the lower life of the rectifier tubes when operated at high voltages, the need for higher voltage condensers, larger chokes and heavier duty voltage divider, it is easy to see the disadvantage of using transformers which are not designed to give the minimum output voltage necessary to produce an output of the required voltage and current characteristics, especially if the extra current is to be dissipated at the output of the filter.

Another very important advantage of using the resistor at point "X," Fig. 1, is the increased life of the first filter condenser which it makes possible.

While oscillograph records of the conditions which would obtain at a load current of 75 milliamperes have not been plotted, the records for a current drain of 125 milliamperes, as given in the Cunningham Tube Data Book, are available and will serve to illustrate the action.

The oscillograph record in question, shown in Fig. 5, shows that while the load current may be only 125 milliamperes, the tube current during the complete cycle may run as high as 310 milliamperes. When a resistor is employed at point "X" of the filter circuit as shown in Fig. 1, the voltage drop across the resistor will increase considerably at the higher peak currents because of the heavier current flow, thus reducing the peak currents and voltages which would otherwise be applied across the filter condenser. To cite a concrete instance, let us consider the case shown in Fig. 5. At the normal load current of 125 milliamperes, the drop produced by the use of, let us say, a 500 ohm resistor, would be 62.5 volts. If the D.C. output of the rectifier were 600 volts (the D.C. output of a full-wave CX-381 rectifier with 600 volts A.C. per plate), the input to the filter would be reduced to 537.5 volts. When the current through the tube rises to 310 milliamperes keeping practically in step with an increase in the pulsating D.C. peak voltage to about 800 volts, the drop across the resistor at this current will rise to 155 volts so that the maximum voltage applied across the first filter condenser, "C1" will be limited to 800 minus 155 or 645 volts, instead of the 800 volts peak voltage that would be applied if the resistor were placed at point "Y" or "Z" of Fig 1, in which position it would merely act on the filtered D.C. current. This action of course would apply with equal effect on the power supply unit we have been considering. In any case, the peak voltage applied to the first filter condenser when using a transformer of higher voltage than the required minimum, to give the required input voltage to the filter, can be kept down to the maximum peak voltage that would be applied if the proper transformer were used, provided the resistor is placed at "X" instead of at "Y" or "Z."

The importance from a saving in condenser life and reduction of possible breakdown cannot be overestimated.

Of course the ideal method would be to design the transformer especially for the power unit and receiver in such a way that the secondary voltage, each side of center tap would be just sufficient to give an output of 495 volts from the rectifier. To do this in the particular case we are discussing would require a transformer providing a voltage of between 450 and 475 volts A.C. each side of center tap (estimated from the curve for 600 volts A.C., see Fig. 4). The maximum voltage would then be 475 x 1.4 or 665 volts instead of 600 x 1.4 or 840 volts as would be the case if a 600 volt transformer were used with the resistor at "Y" or "Z" in Fig. 1. The advantages to be gained by applying a lower voltage to each plate of the rectifier system are longer life for the rectifier tubes, which give longest life when operated at lower voltage and at current drains well below their maximum outputs and also lower cost of the transformer, lower

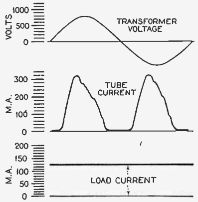

Fig. 5