NATIONAL RADIO INSTITUTE

Complete Course in PRACTICAL RADIO

Radio-Trician
(Trade Mark Reg. U. S. Patent Office)

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POWER SUPPLY APPARATUS FOR TRANSMITTING TUBES

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POWER SUPPLY APPARATUS FOR TRANSMITTING TUBES

From our previous studies we have learned how the vacuum tube could be used as a generator of oscillations. In this use of the vacuum tube we made mention of the necessary plate, filament and grid voltages. However, we did not go into detail as to how these voltages were secured and the apparatus necessary in providing these voltages.

The purpose of this lesson is to explain in detail how these voltages are secured; also the apparatus necessary to make these applicable for use with the vacuum tube as a generator of oscillations.

When studying receiving sets and receiving tubes we found that it was necessary to supply the plate with **direct current.** If the plate voltage supplied to radio or audio frequency amplyfying tubes in a receiving set is alternating or pulsating, there will be a humming or throbbing noise present in the loud speaker output. It is the same with the tubes that are generating the oscillations in a transmitting set, except that the output is not connected to a loud speaker. Nevertheless, the net result is the same.

If alternating current should be applied to the plate of a tube generating oscillations, the plate current would be flowing only one-half the time. When the alternating current was trying to flow in the opposite direction it would be blocked. Therefore the wave generated and sent out by the transmitter would be pulsating or interrupted. If the frequency of the A. C. applied to the plate were 60 cycles per second then there would be 60 groups of waves sent out each second with spaces between each group equal to 1/120th of a second. This would cause a humming noise in the output of the loud speaker at the receiver. From this it can be understood that the tube acting as the generator of oscillations at the transmitting station must be supplied with direct current. This direct current must be as nearly constant as possible.

Just previously we learned that if alternating plate current is applied to the generator tube (commonly called the oscillator tube) groups of waves are sent out. It therefore seems reasonable that if the plate current furnished the oscillator tube is direct, but varies in value (that is, it is not constant), we should expect practically the same results at the receiving station. Such is the case. A humming noise would be heard in the loud speaker of the receiver, the frequency of which corresponds to the frequency in variation of the oscillator plate current.

Here we have a simple but very important fact. Remember this always for it is one of the basic principles of radio transmission. Any variance in the oscillator plate current causes corresponding variance in the plate current of the amplifying tubes at the receiving set. If the varying current applied to the oscillator tube is at an audio frequency, then an audible sound will be heard at the loud speaker. If the oscillator plate current varies at some radio frequency then no sound will be heard in the speaker because it is above the range of audibility.

The intentional varying of the oscillator plate current at an audio frequency so as to cause some audio frequency sound to be heard at the receiving set loud speaker or headphones, is called modulation. We learned how the receiving set made use of this modulation in order to reproduce sounds. Later when we study this subject in another text we shall see just how it is accomplished at the transmitter.

In the preceding paragraph we said that modulation was the intentional varying of the oscillator plate current. From this we could infer that there are forms of undesirable modulation. This is also the case.

Most of us have noticed a slight humming noise in the loud speaker when the receiver is tuned to some transmitting station and no one is speaking, singing or playing before the microphone. All stations do not have this. The transmitting station should not always be blamed for in some cases the receiving set is at fault. When it does originate in the transmitter, it is the result of a fluctuating voltage being applied either to the grid or plate of some tube or tubes. Later we shall see the reason for this.

This undesirable modulation is generally spoken of as "a ripple in the carrier wave" or "noisy carrier." The carrier or carrier wave is the wave that is transmitted by the ether and is the result of the oscillator tube impressing high frequency oscillations on the antenna. In Fig. 1 is shown how the carrier wave is represented together with the modulated carrier, and a carrier with a ripple in it.

From our preceding lesson we learned that transmitting tubes require high plate voltages and in some cases considerable current. For instance the UV-207 twenty kilowatt tube requires 15,000 volts on the plate and consumes on the average of two amperes when oscillating. It is not therefore reasonable to expect that this much power can economically be supplied by batteries. Some low power transmitting stations have used batteries for this purpose, but ordinarily other apparatus is employed.

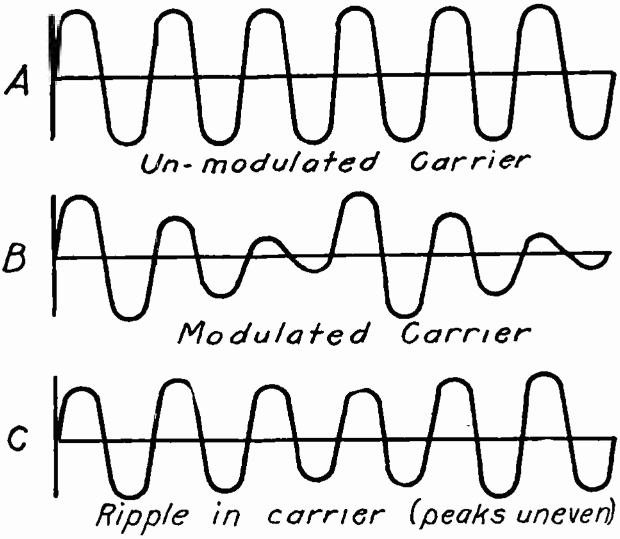


Fig. 1

Before taking up the detailed study of how the plate current supply is obtained let us first consider the filament supply.

THE FILAMENT SUPPLY

From our study of the previous lesson we learned something of the voltage and current that is required by the filament of large transmitting tubes. We shall now learn how this is supplied. But before doing so let us learn more about the nature of the filament and some of its characteristics.

The filament inside a power tube is one of the most precious parts of the whole transmitting set, due to the high cost of large transmitting tubes. Having as it does, only so many hours to live and this life in some cases being quite costly, extraordinary care should be observed to prolong the filament life. There are several ways in which this may be effected and the more important methods will be explained here.

Either alternating or direct current may be used to heat the filament, but as we shall later see, alternating current presents some desirable characteristics over the use of direct current. In small receiving tubes direct current is usually furnished by a battery but owing to the greater amount of filament current required for transmitting tubes, this source of supply cannot be successfully used except for the smallest types. When using this form of filament supply direct current generators of the correct power output are relied upon. Where the local lighting company furnishes alternating current, an alternating current motor is used to drive the direct current generator, thus converting the power. Such an arrangement is known as a motor-generator, one form of which is illustrated in Fig. 2.

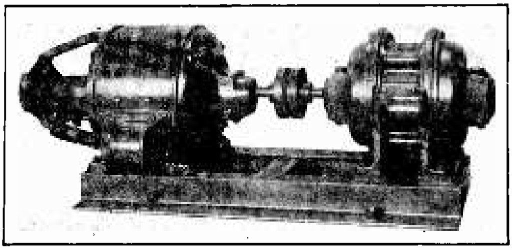


Fig. 2—Filament motor-generator set

When using alternating current for the filament supply there are two general means of securing the correct voltage and current. We can use a step-down transformer and reduce the voltage of the local power supply to the correct amount. Also we can again use a motor-generator driving the motor with the current obtained from the power mains and using the motor to drive an alternating current generator, or alternator as it is usually referred to, to supply the low voltage alternating current. This method is widely used by high power stations where large power tubes are used owing to high current at a low voltage required by the power transmitting tubes.

Let us now see why alternating current presents some advantages over direct current for a filament supply. It has been determined by theory and experience that the life of a filament will be considerably lengthened if it is heated by A. C. instead of D. C. When direct current is used as a source of supply the current flows through the filament in one direction only. Due to the voltage drop along the filament, the negative end of the filament is at the highest potential, since this is the end the electrons enter in passing through the filament. The electrons in the filament wire itself are then gradually driven towards the positive end and in time the negative end becomes partially inactive as far as electron emission is concerned. Thus there is not a constant and equal emission along the filament as it ages. Furthermore since the plate current flows through the filament the unequal distribution of emission is further increased.

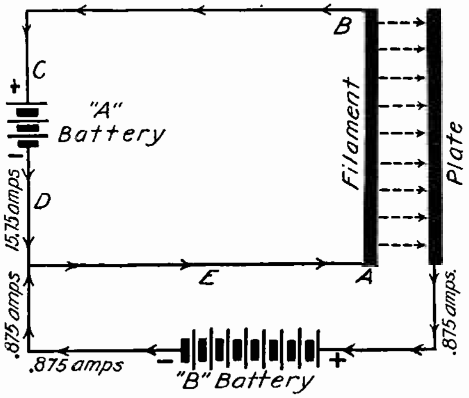


Fig. 3

4

In small receiving tubes the plate current is generally very small while in power transmitting tubes the plate current is considerable, being as high as two amperes in the 20 K. W. (kilowatt) type. The plate current has therefore quite an effect on the filament in transmitting tubes. Where a high plate current is present, the emission of electrons from various parts of the same filament differs very much. The filament current (hence filament temperature) is much greater at one end of the filament than at the other. As the filament does not give appreciable emission until it is quite hot, we may have a condition such as shown in Fig. 3. In this figure the arrows indicate the direction of electron flow. The filament is shown straight in order to further demonstrate the case.

The 1 K. W., UV-851 tube has a normal plate current of .875 ampere and a filament current of 15.75 amperes. From Fig. 3 it can be seen if a filament ammeter is placed at either C or D and the filament current adjusted to 15.75 amperes it would seem that the filament was being operated properly. According to the above conditions if the ammeter was placed at E the filament ammeter would register 16.625 amperes on account of the plate current flowing through this part of the circuit. End B of the filament is at a much lower temperature than end A, and is contributing a smaller amount of the plate current, as its emission is lower due to lower temperature. End A on the other hand, is furnishing most of the plate current and is also being operated at a higher temperature. The effect is, of course, to overheat that part of the filament where the current is greatest, causing it to burn out at that point before it should.

Most tube manufacturers take this into consideration in rating the tube so that the tube should be operated with the proper filament current including the plate current, but still this leaves the other end of the filament operating at a lower temperature.

When supplying the filament of a transmitting tube with A. C. and the plate circuit with D. C., if the negative side of the plate supply and grid return are connected directly to one of the filament terminals, there will be as previously explained, a crowding of current in the part of the filament next to this terminal. The alternating filament heating current in this part of the filament will alternately aid and oppose the plate current. As a result the plate current will be slightly modulated or varied, which will cause the emitted wave from the station to have a decided modulated A. C., hum, even if pure D. C., is used for the plate supply current.

THE FILAMENT CENTER TAP

In order to obviate the troubles just mentioned, the negative terminal of the plate supply and grid return should be connected to the midpoint of the filament. This would cause the plate current arriving on the two halves of the filament to become balanced so that the filament alternating current would no longer modulate the plate current. The crowding of current at any one point on the filament would also be much less.

The filament has only two connections, one at each end. In order to secure the advantage of this scheme other arrangements must be made.

The simplest arrangement for obtaining the desired result is shown in Fig. 4(A). Here a resistance is connected across the filament with the midpoint forming the common connection for filament, grid return and the negative terminal of the plate voltage supply. Since this resistance is across the filament supply transformer a current will flow through this resistance. Therefore it must be high enough to prevent any great amount of current from flowing. On the other hand the plate current must also flow through this resistance and it must not be so high as to interfere with the plate current flow.

A better arrangement is shown in Fig. 4(B). In this case the secondary of the filament transformer has a center tap. The grid return and negative terminal of the plate supply are then connected to this tap. An important point which should always be remembered is that the secondary of the filament must be designed to withstand the high-plate voltage, since the positive terminal of this high voltage connects to the plate and the negative terminal to the secondary center tap of the filament transformer. This voltage being applied to the filament transformer, the plate current must pass through at least a part of it. In designing such a transformer this must be considered and the insulation of the winding and the insulation between core and winding must be sufficient to withstand this voltage without breaking down.

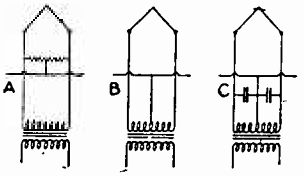


Fig. 4—The center filament tap

Both of the methods so far described have some disadvantages. It is not desirable to uselessly waste energy by connecting a resistance across the filament and thus inserting resistance in the grid return and path of the plate current. Neither is it desirable to force all radio frequency currents in these circuits to flow through the filament transformer secondary winding. The result of such procedure is usually punctured insulation of the secondary winding.

By inserting by-pass condensers having a lower reactance than the secondary to the flow of these radio frequency currents they can be kept out of the secondary winding. This arrangement is shown in Fig. 4(C). This method is in general use and offers the best solution to the problem. The capacity of the by-pass condensers should not be lower than .002 mfd., and any capacity between this and 1 mfd. will suffice. If the filament transformer is located some distance from the tubes, the by-pass condensers should be connected near the socket terminals so as to by-pass the radio frequency currents without having them flow through all the filament wiring.

PLATE SUPPLY OF TUBE

The plate supply system to transmitting vacuum tubes is one of the most important units of the whole transmitting system. We have previously seen that this plate supply must be continuous direct current with as little variation in the amount of current flowing as possible. For very small transmitting sets, batteries either of the dry cell or storage type are sometimes used. However, as the size of the transmitting equipment is increased, the use of batteries for plate supply becomes less desirable. There are a few broadcasting stations that use batteries as the plate supply, but most of these stations are owned by battery manufacturing concerns who desire to demonstrate the fact that it is possible to use batteries. The disadvantage of having to keep storage cells charged and the great number required, can easily be appreciated. It is necessary to have two sets of batteries so that when one is being charged, the other can be in operation and vice versa.

We can, therefore, disregard this form of plate voltage supply except in conjunction with very small transmitting stations. Practically speaking, the three types of plate voltage supply now in general use are divided as follows: Motor-generator, pre-
X5K rectified alternating current, and self-rectified circuits.

We shall take these up in detail and discuss the problems involved in each in their order.

MOTOR-GENERATOR SYSTEM

Where low voltage direct current only is available, a motor-generator is a necessity in order to step up the voltage to the required amount. Suppose the commercial lighting current is 110 volts direct current. In this case, the motor-generator would be a necessary adjunct if the plate supply voltage is higher than this amount. Since power tubes require considerable voltage on the plate and since a direct current cannot be stepped up by means of a transformer, we must rely upon a motor-generator. For amateur work, the motor-generator presents a very feasible plan for obtaining the high-voltage plate supply. This applies even though alternating current is available. We shall learn later that in order to convert alternating current into direct current for the plate supply, some form of rectifier and filter are necessary. When using a motor-generator, the high voltage plate supply can be obtained regardless of the form of commercial current available.

For commercial work, such as in commercial code stations or broadcasting stations, the use of a motor-generator for this form of plate supply is limited to some of the smaller power sets. When using a voltage on the plate of the transmitting tube much greater than 3,000 volts, the size and cost of the motor-generator increase considerably. For instance, in the case of the 207 type of transmitting tube, a plate voltage supply of 15,000 volts is required. A 15,000 volt direct current generator capable of generating enough current would not only be very large, but its cost would be considerable. There is a slight loss in the transformation of energy and the motor-generator is not excepted. The motor of the motor-generator would, therefore, consume a great deal of current. In most cases, it is desirable to eliminate as much rotating machinery as possible. Rotating machinery sometimes creates considerable vibration and this might be an undesirable feature around a transmitting station.

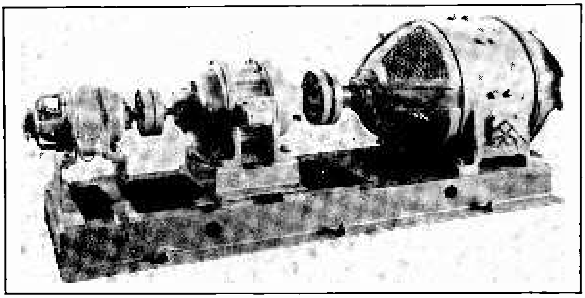


Fig. 5—Three-unit plate motor generator set

In Figure 5 is shown a typical motor-generator suitable for use with some of the smaller transmitting tubes either for amateur, commercial code or broadcasting station use.

PRE-RECTIFIED CIRCUITS

This form of plate supply is by far the most practical for large transmitting stations where the plate voltage is very high. Its most desirable characteristics are: Freedom from rotating machinery and vibration; ease of operation when once installed; very little attention required while in operation; and ease of starting and stopping the operation of the system. One of the main disadvantages of this system is due to the fact that its cost is considerably higher than some of the other forms of converting alternating current to direct and the amount of apparatus required. This type of plate supply is not as efficient as a motor-generator, but this factor becomes less as the voltage is increased due to the increasing cost of a motor-generator system.

The pre-rectified system of plate voltage supply consists essentially of apparatus which may be divided into three general classifications as follows: The power transformer, the rectifier, and the filter. Each of these will be taken up in order and described in detail.

THE POWER TRANSFORMER

The function of the power transformer is to change electric power at one voltage and current to power at another voltage and current. The transformed power may be greater or less than the voltage of the source depending upon the use of the transformer and the line voltage and plate voltage desired. Since transmitting tubes generally require a plate voltage higher than the voltage of the source, a power transformer generally assumes a step-up voltage ratio.

The input winding connects to the source of supply and is called the primary winding. The output connects to the load or rectifier and filter and this winding is called the secondary. Any transformer may be used for either step-up or step-down work by reversing the connections to the primary and secondary. To avoid confusion when referring to a transformer it is always best to refer to the transformer windings as high voltage or low voltage windings instead of primary and secondary unless it be known whether the transformer is of the step-up or step-down variety.

The exact characteristics of the transformer are governed by the type of current supplied to the input winding. Most transformers that amateurs build are for use on 110 volts 60 cycle supply. The number of turns necessary on the 110 volt winding depends upon the quality of the iron core used and on the cross section to the core. Silicon steel is best for the transformer core material. Various types of iron and steel possess different characteristics with regard to the density of the lines of force per square inch in the core material. A silicon steel core which has the capability of 50,000 lines per square inch should be used. This is the basis of the flux density (number of lines of force per square inch) that is used in all of the calculations following. The size of the wire used in the windings depends on the current consumed in the input and the current expected to be drawn from the output winding. This will vary with the load (that is, the amount of power consumed and withdrawn from the transformer).

A circular mil is the area of the cross-section of a wire 1/1000th of an inch in diameter. When a small transformer is built to handle a continuous load, the copper wire in the winding should have an area of 1,500 circular mils for each ampere to be carried. For intermittent use, 1,000 circular mils per ampere is permissible. The diameter of the wire and the circular mils of such wire can be obtained from an ordinary wire gauge which is supplied by most wire manufacturers and is shown in a great many texts.

TABLE 1

DESIGN DATA FOR CLOSED CORE TRANSFORMERS

Input (Watts)	Full-load Efficiency	Size of Primary Wire	No. of Primary Turns	Turns per Volts	Cross-Section Through Core
50	75%	23	528	4.80	1¼" x 1¼"
75	85%	21	437	3.95	1⅜" x 1⅜"
100	90%	20	367	3.33	1½" x 1½"
150	90%	18	313	2.84	1⅝" x 1⅝"
200	90%	17	270	2.45	1¾" x 1¾"
250	90%	16	248	2.25	1⅞" x 1⅞"
300	90%	15	248	2.25	1⅞" x 1⅞"
400	90%	14	206	1.87	2" x 2"
500	95%	13	183	1.66	2⅛" x 2⅛"
750	95%	11	146	1.33	2⅜" x 2⅜"
1000	95%	10	132	1.20	2½" x 2½"
1500	95%	9	109	.99	2¾" x 2¾"

The transformer uses a little energy to supply losses in the core and windings. Due to the resistance of the windings, and to the magnetic leakage path, the voltage of the secondary may drop materially under load. Poor regulation, as this is called, is sometimes useful in a special transformer. In filament heating and plate supply transformers, the windings are arranged compactly, making good solid joints in the core, using large low resistance wire in the windings, and keeping the length of the magnetic path fairly short and of good cross-section. This will keep the secondary voltage quite constant under load.

A table is given showing the best size wire and core to use for particular transformers. The figures in the table refer to 60-cycle transformers. The design of 25-cycle transformers is very similar. A slightly higher flux density is permissible. Because the frequency is much lower, the cross-sectional area of the iron must be greater (or the number of turns per volt correspondingly larger). Otherwise, the inductance of a certain number of turns will be too low to give the required reactance at the reduced frequency. If one builds the core so that its cross-section is 2.1 to 2.2 times the value of area worked out from the table, the same number of turns of wire may be used in a primary coil for 25-cycle operation.

Suppose it is desired to build a plate transformer for two UX-210 (7½ watt) tubes. The general practice is to supply two of these tubes with about 100 milliamperes at 500 volts. Allowing about a 50% voltage drop in the rectifier and filter, this means that the voltage supplied by the output winding should be approximately 750 volts. A transformer built for this voltage can be used with a resistance in the input winding to make an additional voltage drop if it is necessary to work with just one tube or lower voltages to prevent heating. With one tube the current required will be less and the regulation will be better. Since the voltage output of the transformer must be 750 and the current consumed is approximately 100 milliamperes, then 750 times .100 equals 75 which is the output wattage of the transformer.

The table gives us the probable efficiency of about 85% or 90% for small transformers of this size. It will be noticed as the size of the transformer is increased, the efficiency will jump considerably. An efficiency greater than 95% is hardly ever obtained.

The number of turns in the secondary winding is governed by the number of turns in the primary and the desired secondary voltage (in this case 750). Before the number of secondary turns can be found out, we must know how many turns per volt there are in the primary. This can be found by dividing the number of primary turns by the primary voltage which is given directly in the table. The number of turns for the secondary can now be found by multiplying this figure by the desired secondary voltage. As the power output of the transformer is 75 watts, the number of secondary turns can now be found (750 times 3.95 equals 2963 turns). The size of wire to be used in the secondary depends on the secondary current and the current density can be found in the same way from a wire table. For this lay-out of equipment, look for a size of wire for the secondary that will safely carry 100 milliamperes (.1 ampere). This will be found to be No. 30 B & S gauge wire. It is a good idea to add three to five per cent of the number of secondary turns to the winding to make up for the voltage drop that will occur at full load due to the transformer losses and regulation (105% times 2963 equals 3110 turns.)

Another convenient formula which can be used to roughly determine the details for a given transformer can be obtained from the following:

$$T = 7.5 \text{ x } \frac{E}{A}, \qquad A = 7.5 \text{ x } \frac{E}{T}, \qquad E = \frac{TA}{7.5}$$

In the above formula, the letter T represents the number of turns of wire, E equals the voltage applied to the winding, A equals the area of core in square inches, and 7.5 is a constant that is used when the frequency of the current applied is 60 cycles per second. If the frequency is 25 cycles per second, then the constant 9 should be used instead of 7.5, and when the frequency is 12 cycles, 25 should be used.

Although this is a very crude formula and cannot be used when designing complicated transformers, it will serve the purpose of the average person desiring to design a small power transformer for his own use. For instance, suppose that it is desired to design a 10-to-1 transformer to be used for a filament lighting transformer and that the area of the core is 2 inches square. This would give us an area of 4 square inches. From the above formula in which

$$T = 7.5 \text{ x } \frac{E}{A}$$

we can find the number of turns necessary. If the voltage applied to the primary is 110 volts, we then have

$$T = 7.5 \text{ x } \frac{110}{4} \text{ which equals 206.}$$

This is the number of turns that will be necessary for the primary when using a cross-section area of 4 square inches for the core. If we use a step-down transformer having a ratio of 10 to 1, then there should be one-tenth the number of turns in the secondary as in the primary, or 20.6 turns in the secondary.

It must be borne in mind that the usual step-up power transformer employed consists of a center tap secondary. In this case it will be necessary to use twice the number of turns in order to gain the full voltage required due to the fact that the transformer is tapped at the center. Thus, there are only one-half as many turns acting for each half of the cycle as there would be if the transformer were not center tapped.

THE RECTIFIER

The function of the rectifier is to convert alternating current into as near continuous direct current as possible. Very few rectifiers will convert alternating current into direct current which does not have some varying characteristic or pulsation. Also, different forms of rectifiers possess different characteristics, some being very good rectifiers while others are very poor.

There are two forms of rectifiers in general, the single wave and the full wave types. In the single or half wave type, a pulsating direct current is the result. By looking at Figure 6(B) it will be noticed the current is flowing only one-half the time and corresponds to only one-half the cycle as represented in the alternating current. The result then of the half-wave rectifier is that it cuts off the alternating current when it tries to reverse and flow in the opposite direction. This leaves a pulsating direct current. In the full wave type of rectifier both halves of the alternating current are made use of. The connections are so arranged that when the alternating current tries to reverse its direction of flow, it is made use of to have more nearly a continuous direct current. This is clearly shown in Figure 6(C).

There are two general types of rectifiers which are in use at the present time. There are several other forms of rectifiers and these are not nearly as widely used and our discussion will be confined to these two major types as follows: The chemical or electrolytic rectifier and the tube rectifier.

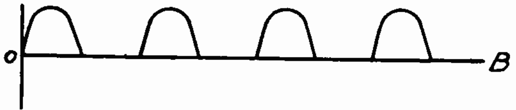
THE CHEMICAL OR ELECTROLYTIC TYPE

The chemical or electrolytic rectifier is a very cheap type and is widely used by amateurs desiring to hold down the cost of the apparatus. It is used very little in commercial work for several reasons, such as the bulkiness of the jars required, the inefficiency of the system, and the care required while in operation and maintenance.

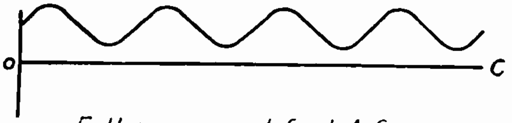
For an amateur station, the electrolytic rectifier is one of the best. It is bulky and sloppy, but works well. It usually consists of a jar in which some chemical substance is used as an electrolyte and two rods or plates of different metallic characteristics. One very simple type of electrolytic rectifier consists of a chemically pure aluminum rod and an iron or lead rod and a solution of soda or borax as an electrolyte.

Chemically pure aluminum is hard to obtain, while the lead or iron element is plentiful and cheap. In designing a chemical rectifier, sufficiently large jars should be used to prevent undue heating of the solution. Allow forty or fifty volts to a jar and a current density of not over forty milliamperes per square inch of aluminum sheet. Chemical rectifiers of this type are very cheap and are easy to filter. They must go through a process of forming before they are ready for operation and special care must be used in first forming an electrolytic rectifier, especially if the cells are formed in series across a high voltage transformer. When the rectifier jars are connected across a source of voltage such as the transformer secondary, current will be quite high until the film which forms on the plate is partially completed. Lamps or other resistances in series, closing the circuit for a few moments at a time, should be incorporated in the forming process until the current drawn from the transformer or other

Un-rectified A C



Half wave rectified A.C



Full wave rectified A C

Fig. 6

voltage source is not above its rated capacity. The maximum current density should not exceed the normal operating density and the jars must not be allowed to heat as the film on the aluminum plate begins to break down at about 120 degrees Fahrenheit. If there is sparking, the rate must be reduced, as the film on the aluminum will be destroyed as fast as it is made. A well-formed aluminum electrode will be smooth and have a thin, dull, white surface.

There are several electrolytes or solutions which may be used in the rectifier. A dilute solution of sodium bicarbonate (ordinary baking soda) gives good results and is quite inexpensive. A ¼" layer of transformer oil should be poured on top of the solution to reduce evaporation. Sodium-ammonium phosphate and sodium-potassium tartrate are also good but more expensive. The use of borax requires a saturated solution—that is, as much borax should be dissolved in the water as the water will take. If baking soda is used, there will be a heavy, white precipitate formed at the aluminum electrode which will settle at the bottom. As this does not appear after the aluminum is formed, an old solution can be used for forming and the electrodes put in a clean solution afterwards. Lead and iron are not satisfactory for use as auxiliary electrodes in an aluminum rectifier that has an organic solution, but they work well with a borax solution or with a dilute baking soda solution. A carbon auxiliary electrode is satisfactory when an organic rectifier solution such as tartrate, acetate, or citrate is used.

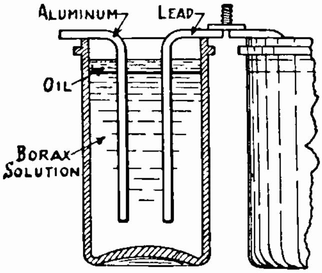
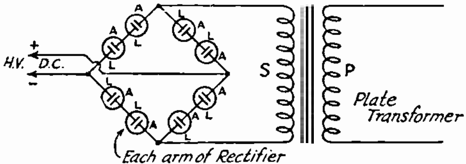


Fig. 7—Cross-section of an electrolytic rectifying jar

When a good large filter is used, there is a "back voltage" or counter electromotive force from the charge left in the filter condenser which has an effect in the rectifier circuit as soon as the circuit is broken. When a key is used as in a code station, this condition becomes more pronounced. This counter voltage is applied to the rectifier at the same time the transformer is applying high voltage alternating current to it. This may make the voltage per jar too high so that some of the aluminum film breaks down, sparking and making a noise that does not filter out easily. A few more jars added to a rectifier will usually cure this trouble permanently. The transformer voltage that causes break-down is always at the peak of the A. C. cycle which is nearly one and one-half times the effective value of voltage at which A. C. circuits are rated.



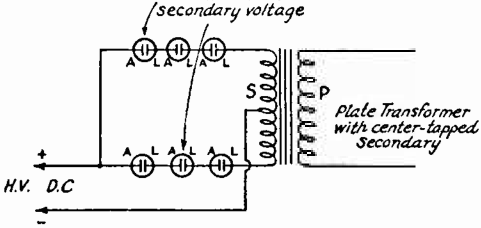
Each arm of Rectifier has ½ total secondary voltage impressed on it.

BRIDGE-CONNECTED LEAD-ALUMINUM RECTIFIER

Fig. 8

Diagrams of connections are shown in Figures 8 and 9. An example of designing an electrolytic rectifier might also be useful. Suppose we have two UX-210 tubes to supply and each normally takes 45 milliamperes of plate current; that makes 90 milliamperes which they are using. Our transformer, let us say, gives us 550 volts on each side of the center tap. Assuming 100 milliamperes maximum load, 100 divided by 40 gives us 2½ square inches of aluminum that must be immersed in each jar to carry the current. 550 divided by 50 makes 11 jars necessary for each leg of the rectifier. We should use 12 jars to give the necessary 10% safety factor. Some jelly tumblers may be pressed into service to hold the solution. A small rack and some wooden pieces holding the electrodes and jars will complete the outfit.

Each arm has total secondary voltage



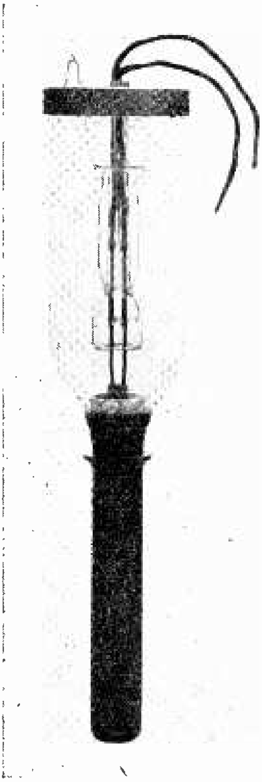
CONNECTIONS OF CHEMICAL RECTIFIERS

Fig. 9

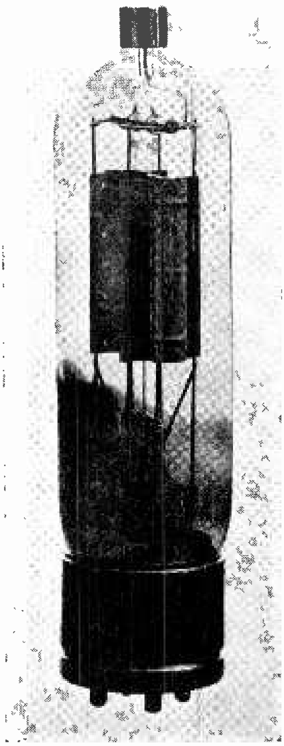
+
8
2

TUBE RECTIFIERS

A vacuum tube rectifier has a somewhat greater first cost and replacement cost than an electrolytic rectifier. It does not require any forming process or much care while in operation. It is also convenient and in large transmitting stations occupies less space than some of the other types of rectifiers. In fact, in the large installations the vacuum tube is depended on as the rectifier. The electrolytic rectifiers for small amateur stations have condenser characteristics and are cheaper in first cost. The tube rectifiers come next in ease of filtering.

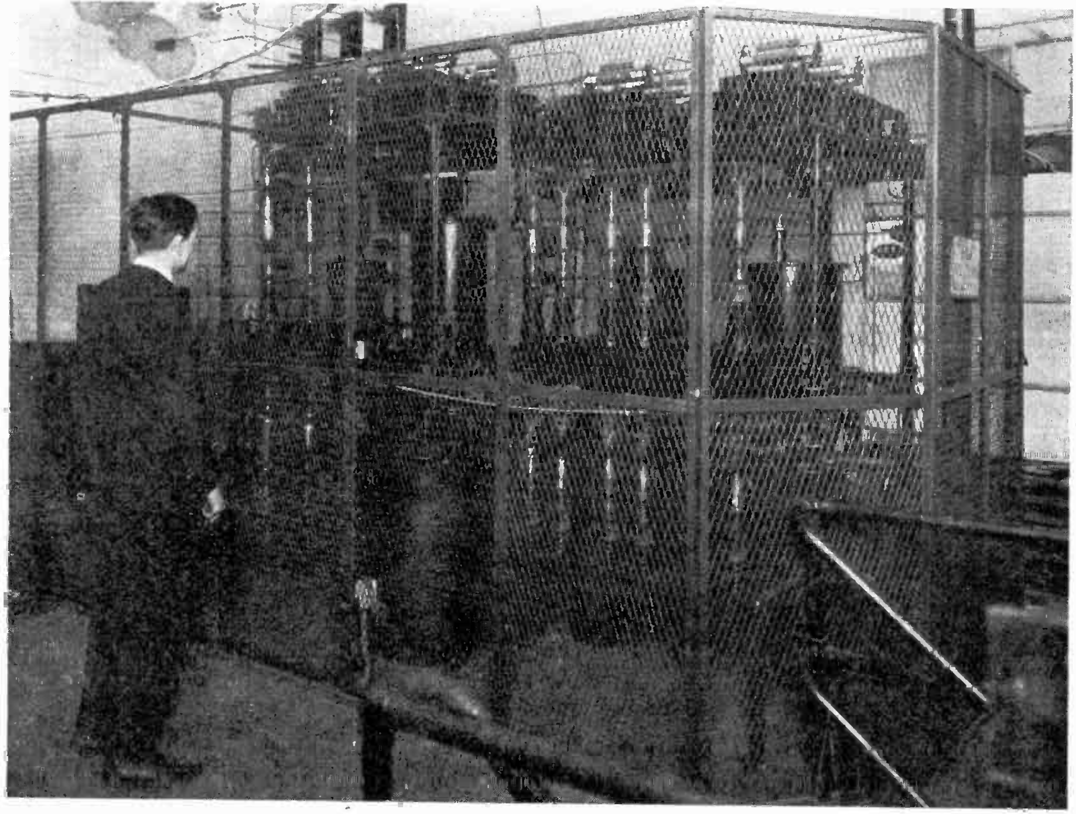


UV-214 Rectron



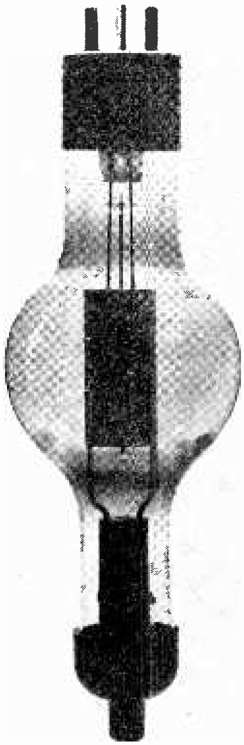
UV-217-C Rectron

The two-element vacuum tubes for rectifying are known as Rectrons. The filament gives off electrons when heated and current can only flow through the tube in one direction. The rectifying circuit is similar to that used in the chemical rectifier. The filaments are always at plate potential and the low voltage

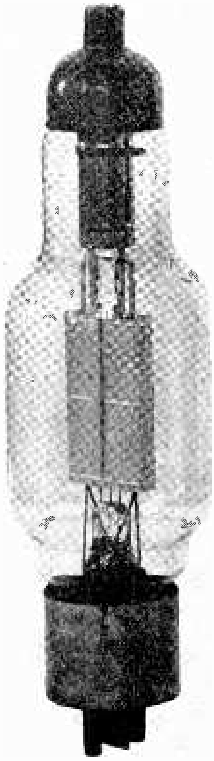


View of rectifier assembly at Station WGY winding of the filament transformer must be insulated from the high voltage. Separate filament transformers should be used for the rectifier and oscillator tubes.

The Rectron tubes are manufactured in appropriate sizes for use with the corresponding oscillator tube and the two element Rectron costs about three-fourths as much as the same size three element oscillator tube. The efficiency of the electrolytic and tube rectifier is rather low, for which the loss in heating the rectifier solution and the plate of the Rectron, and the power consumed by the filament of rectifying tubes is responsible. Tube rectifiers have a larger voltage drop across the rectifier unit than have chemical rectifiers.

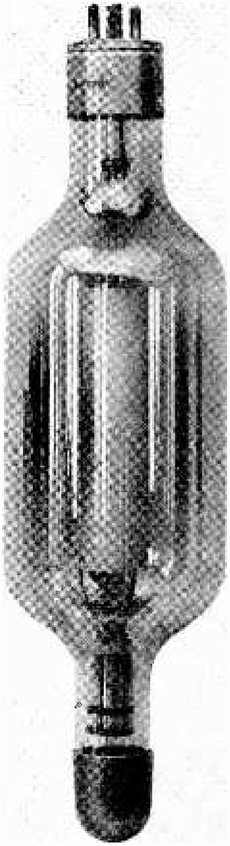


UV-218 Rectron



UV-1651-A Rectron

Most of the first cost in connection with tube rectifiers goes into the extra filament heating equipment. For a sending set using one or even two UX-210 tubes, a couple of 216-A Rectron tubes will be an excellent investment. Since tubes requiring less filament current have come on the market, all types of tungsten filament tubes have become of less importance.



UV-219 Rectron

In very low power sets some of the gaseous conduction rectifier tubes that are used in "B" eliminators may be used as rectifier tubes. Even the whole "B" eliminator assembly may be used if the voltage required by the transmitting tube is low enough to come within the scope of the eliminator.

A table giving the characteristics of the various Rectron tubes is shown on this page.

THE FILTER

As previously explained, the function of the filter is to smooth out any alternating current fluctuation that may be present either in the rectified output current or in the current supplied from the motor-generator. This fluctuating current is often referred to as the ripple.

Direct current generators operating under normal conditions have three sources of disturbance, i. e., commutator ripple, slot ripple, and the noise of the moving contact. The armature windings are a series of coils around the iron armature, forming one large coil, with taps brought out to the commutator segment. Voltages induced between the commutator segment are not equal, and vary as the armature revolves. When certain coils are nearest the field poles of the generator, the induced voltage is maximum and when a particular armature coil is at right angles to the fields, the voltage is minimum. This is very similar to the series-parallel battery connections where there are different voltages present in different parts of the circuit. As a brush leaves one segment and passes to the next segment of the commutator, the voltage changes slightly. The resultant ripple in the voltage is known as commutator ripple.

9

TABLE II

							Filament			
Tube Number	Voltage Input	Voltage Output	Normal Plate Current amps.	Plate Dissipation	Max. Plate Current amps.	Filament Volts	Current amps.	Filament Type	Height Inches	Diam. Inches
UX-213	440				.065	5.0	2.00	XL		
UV-214	18000	15000	3.0	10 K.W.		22.	52.	Tung.	18.75	4.1
UV-216	550				.06	7.5	2.35	Tung.		
UX-216B	550				.065	7.5	1.25	XL		
UV-217A	1500		.20		.20	10.0	3.25	XL		
UV-217B	5000	5000	.075	100 W.		10.0	3.25	XL		
UV-217C	3000		.150	100 W.		10.0	3.25	XL	8.5	2.0
UV-218	16000	15000	.166	350 W.		11.0	14.75	Tung.	15.6	5.0
UV-219	17500	15000	.833	1 K.W.		22.0	24.50	Tung.	22.4	6.0
UV-1651	2500			250 W.		11.0	14.75	Tung.		
UV-1651A	2500			200 W.						

As each slot of the armature passes a pole tip, there is a slight interruption of the field at this point. Each surge in the field slightly changes the value of the voltage induced in the coils. The resultant ripple is known as slot ripple.

The infinitesimal sparking on the commutator caused by microscopic unevenness in the surfaces of both the commutator and the brushes produces an audible noise in the transmitter. This noise is generally not very even due to the fact that the unevenness of the brush and commutator surfaces does not cause regular sparking.

For the commutator ripple, the frequency can be determined as follows:

$$FC = \frac{\text{number of segments x RPM}}{60}$$

The frequency of the slot ripple may be determined from the following formula:

$$Fs = \frac{\text{number of slots x RPM}}{60}$$

The ratio of the ripple voltage to maximum voltage for A. C. generally equals about 200%. The ratio of ripple voltage to maximum voltage for rectified alternating current generally equals about 100%. When using small motor-generators, the average ratio of total disturbance as just outlined in the previous paragraphs is in the neighborhood of 9/10 of 1%.

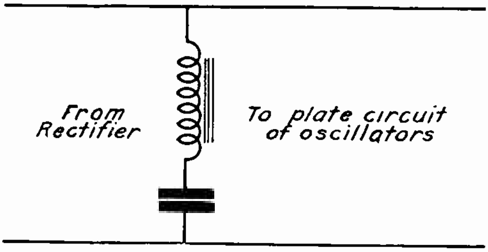


Fig. 10—Series resonant circuit

The simplest effective step towards ripple reduction is the condenser across the line. The direct current with a slight ripple component finds two separate paths back to the voltage source; one through the condenser and the other through the load impedance. Both paths offer impedance. If the low impedance is the plate circuit of the vacuum tube, this impedance will be in the order of 10,000 ohms for the smaller tubes. This impedance insofar as a ripple frequency is concerned remains constant. The path through the condenser is different, since its impedance will decrease as the frequency increases. That is, the higher the frequency, the more ripple current it will by-pass. The 1 mfd. condenser across a small generator with a commutator ripple of

2802 and a slot ripple of 934 will produce very satisfactory results. The function, then, of the condenser is to by-pass any remaining alternating current or ripple voltage.

Since the function or the reaction of an inductance inserted in a line is that of a choking effect, we can further increase the function of the filter by inserting an inductance in series with the line after the condenser across the line. The amount of ripples suppressed by the inductance depends upon the frequency of the ripples and the value of the inductance.

There are several forms of filters. In Figure 10, we have what is known as the series resonant circuit and in Figure 11, we have a parallel resonant circuit. A choke and a condenser connected in series as shown in Figure 10 will offer high impedance to all frequencies except one, i. e., resonance frequency (Fr). The formula for the resonant frequency can be obtained from the well-known formula where F equals

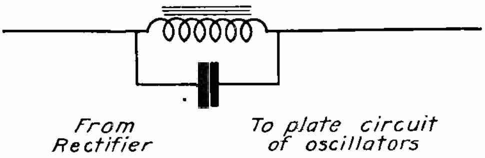


Fig. 11—Parallel resonant circuit

$$\frac{1}{2n} \text{ x } \sqrt{LC}$$

This resonant frequency, **practically speaking**, will pass with an impedance of the resistance of the choke only, which is better than with a condenser alone if the resistance is small, but the impedance will be high for frequencies above and below resonance. When an inductance and capacity are connected in parallel as in Figure 11, the reversed characteristics of Figure 10 will prevail. In Figure 11, all frequencies will pass except those near resonance. For resonant frequency, it will be a dead stop except to supply the losses which are, technically speaking, negligible.

The effective application of these resonant circuits in a basic form to generators is rather limited. One for slot ripples and one for commutator ripples will be required, either one of which will be very effective in reducing moving contact disturbances. They are so very discriminate that a slight variation of speed, such as caused by varying the load, would require adjustment.

In a circuit containing constant values of inductance and capacity in series, the distribution of the voltage across the various elements will be dependent upon the impressed frequency—that is, in Figure 12, for a constant ripple voltage, the voltage across the condenser will vary for various frequencies. The ripple voltage across the condenser is the ripple voltage across the tube. For high impedance loads across the condenser, such as a tube, this voltage rises to several times the value of the initial voltage. The peak of this rise is reached at a frequency slightly less than resonance. With increased frequency beyond resonance, this voltage decreases rapidly, soon becoming a small fraction of the impressed voltage. The amplitude of the fluctuation of the current through the plate circuit will vary with the voltage.

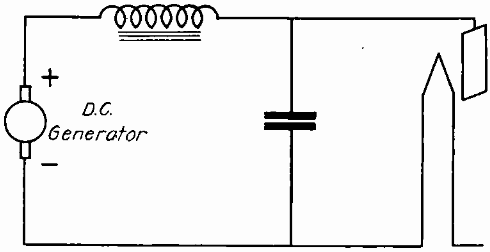


Fig. 12

In Figure 13 we have the so-called T type of filter. It consists essentially of two inductances in series with a condenser connected across the line from the midpoint of the two inductances. It would at first thought seem that the addition of this inductance would further reduce the voltage across the plate. It does reduce this voltage, but it also increases the frequency of the cut-off point—that is, the point at which the filter chokes refuse to pass current at a certain frequency.

The PI type of filter is illustrated in Figure 14 and is one of the simplest and most economical types of filters. For the motor-generator type of supply, it is ideal. Properly built, it is the most effective of the smoother type; that is, its filtering effect is not critical. It functions at all frequencies above the cut-off or resonance point. The lower this cut-off point and the sharper and more rapid the reduction beyond this point, the better the filter is. This means that as large condensers and chokes as are practical, from an economical standpoint, should be used. A general idea of the functioning of this type may be obtained by considering it to be divided into two parts. A is a condenser across the generator or voltage supply terminals. Its effect on the plate circuit is small. Its effect on the minute ripples in the generator is tremendous. It breaks them down, lowering them to a negligible amount. B takes what little disturbance is left and reduces it due to the choking effect of the inductance and the by-passing effect of the second condenser. One or two, 1 mfd. condensers and a 1 to 10 henry choke, makes a good filter for telegraphy and telephony work when using a motor-generator as a source of voltage supply. Larger condensers and chokes will, of course, increase the filtering effect and become necessary when using rectified alternating current.

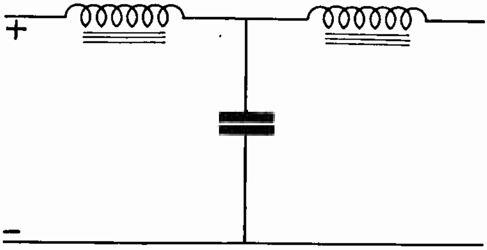


Fig. 13—T type of filter

The single section of the PI type of filter as shown in Figure 14 should be adequate when using small motor-generator sets. For rectified alternating current, several sections are generally necessary. There are some combinations such as belt-driven generators. With surges caused by belt slots, the separately excited generator with a large ripple in the excited path, or the generator bushing with an A. C. supply in series with it, will need a little more elaborate filter. This may be accomplished by adding other similar filter sections in series with the first. The first section reduces the disturbance a certain per cent. The next section reduces the ripple that the first passes, approximately the same per cent that the first reduced the original ripple. This action continues with each added section. The sections should be added value for value, that is, the inside condensers will be twice the outside ones and the inductances should all be equal.

The PI type of filter just described while excellent for continuous waves and some forms of phone modulation is not suitable for the Heising modulation. As we shall learn in a later lesson, the large condensers at the output side of the filter tend to short circuit the modulated voice frequency. This may be overcome by the addition of a small choke, 5 to 10 henries, in the plate lead directly after the filter, followed by a small condenser not over .005 mfd. across the line.

The condensers used in the filter are generally purchased ready to install. In some cases, it is necessary to build the chokes or inductances used in the filter. The Table No. III, shown on page 28, will give the average constructor some valuable information in regard to constructing chokes to be used in filters to accomplish certain results.

Wire with thin insulation should be used to make an economical design. Large wire uses up a great deal of space without giving much inductance. It is best to wind directly on the core with just a single layer of tape between if possible. More insulation will be required for chokes that are to be placed in a high voltage supply line, but this should not be any thicker than is absolutely necessary. Before starting a winding on the core, put some cotton strips along it and fasten some heavy cardboard or thin micarta end flanges in place. After winding the coil, the tape can be tied over the coil to keep the wire from spreading. Too much tape should not be put on or the coil will not keep cool under load conditions.

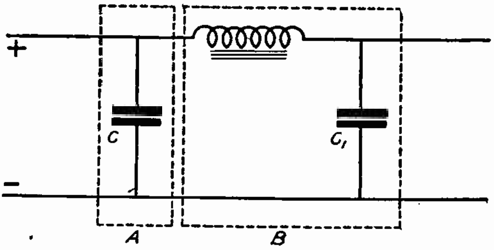


Fig. 14—P1 type of filter

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10

The wire sizes in the table are conservative and 10% more current can be passed continuously and even more than this intermittently. Heavy flexible leads should be soldered to the ends of the coil and taped down to prevent their breaking off.

TABLE III

Current Capacity Amps.	Core Size Cross Section	Inductance Henrys	No. Turns (N)	Feet of Wire	Resistance (D.C.)	Weight of Copper	Core Dimensions		Pounds
							Long Piece	Short Piece	
All wound with 33 enamelled wire									
0.05	½x½	0.5	1600	400	82.5	1.0oz	½x1.6	½x .50	0.30
		1.0	2300	615	127.0	1.5oz	½x1.7	½x .55	0.31
		5.0	5200	1670	345.0	4.0oz	½x1.92	½x .75	0.37
		10.0	7600	2640	545.0	6.5oz	½x2.1	½x .85	0.41
		15.0	9500	3510	725.0	8.5oz	½x2.2	½x .85	0.43
	¾x¾	5.0	3500	1310	271	3.25oz	¾x2.4	¾x .75	1.0
		10.0	5000	2000	411	5.0oz	¾x2.5	¾x .75	1.0
		15.0	6300	2630	544	6.5oz	¾x2.6	¾x .75	1.05
		20.0	7600	3280	678	8.0oz	¾x2.7	¾x .85	1.1
		50.0	14000	7000	1445	1LB 1oz	¾x3.0	¾x1.0	1.25
	1x1	10.0	3800	1760	364	4.25oz	1x3.0	1x .75	2.1
		15.0	4800	2310	478	5.5oz	1x3.0	1x .75	2.1
		20.0	5700	2800	580	6.75oz	1x3.1	1x .75	2.2
		50.0	11000	6130	1270	15.0oz	1x3.5	1x1.0	2.5
		100.0	18000	11000	2280	1LB 10oz	1x3.8	1x1.1	2.75
	2x2	100.0	8900	7700	1590	1LB 3oz	2x5.5	2x1.0	14.5
All wound with 30 enamelled wire									
0.10	½x½	0.5	1600	450	46	2.2oz	½x1.6	½x0.63	0.31
		1.0	2300	700	72	3.5oz	½x1.75	½x0.70	0.35
		5.0	5200	1950	200	9.5oz	½x2.10	½x0.95	0.43
	¾x¾	1.0	1500	540	56	2.7oz	¾x2.10	¾x0.63	0.87
		5.0	3500	1470	151	7.2oz	¾x2.5	¾x0.80	1.05
		10.0	5000	2250	230	11.0oz	¾x2.6	¾x0.95	1.12
	1x1	5.0	2600	1250	130	6.1oz	1x2.8	1x0.75	2.0
		10.0	3800	1940	200	9.5oz	1x3.0	1x0.85	2.2
		15.0	4800	2550	260	12.5oz	1x3.1	1x0.90	2.25
	2x2	10.0	1900	1500	160	7.5oz	2x4.66	2x0.60	11.5
		15.0	2400	1900	200	9.5oz	2x4.75	2x0.66	12.3
		20.0	2900	2400	250	11.5oz	2x4.85	2x0.75	12.5
		50.0	5300	4600	480	1LB 6.5oz	2x5.50	2x0.95	14.0
		100.0	8900	8300	860	2LB 8 oz	2x5.90	2x1.15	16.0
All wound with 26 enamelled wire									
0.25	½x½	0.5	1600	550	22.5	7oz	½x2	½x .85	0.40
		1.0	3200	1350	55	1LB 1oz	½x2.5	½x1.10	0.50
	¾x¾	0.5	1000	390	16	5oz	¾x2.3	¾x0.71	0.96
		1.0	1500	640	26	8oz	¾x2.5	¾x0.83	1.05
	1x1	1.0	1100	530	22	6.5oz	1x2.9	1x0.75	2.10
		5.0	3700	2260	92	1LB 12oz	1x3.6	1x1.20	2.7
	2x2	5.0	1300	1050	43	13oz	2x4.9	2x0.80	12.7
		10.0	2000	1750	71	1LB 6oz	2x5.2	2x1.0	13.8
		15.0	3300	3060	125	2LB 6oz	2x5.5	2x1.1	14.7
		20.0	4000	3820	156	2LB 15oz	2x5.6	2x1.2	15.2
	3x3	10.0	1300	1510	62	1LB 3oz	3x6.9	3x0.8	39
		15.0	1600	1900	77	1LB 7oz	3x7.0	3x0.85	40
		20.0	1900	2300	93	1LB 12oz	3x7.1	3x1.09	41
		50.0	5000	6600	270	5LB 2oz	3x7.8	3x1.35	46
		100.0	8400	12000	485	9LB 3oz	3x8.3	3x1.65	50
All wound with 23 enamelled wire									
0.50	½x½	0.5	3200	1700	35	2LB 10oz	½x3	½x1.45	0.62
	¾x¾	0.5	1480	735	15	1LB 2oz	¾x2.9	¾x1.1	1.26
		1.0	3000	1800	37	2LB 13oz	¾x3.5	¾x1.5	1.6
	1x1	0.5	800	410	8.5	0LB 10oz	1x3.0	1x0.85	2.2
		1.0	1600	945	19	1LB 8oz	1x3.5	1x1.0	2.5
		5.0	7800	7000	143	10LB 14oz	1x5.2	1x2.2	4.2
	2x2	1.0	560	460	9.4	0LB 12oz	2x4.9	2x0.75	12.7
		5.0	1800	1700	35	2LB 10oz	2x5.5	2x1.15	15.0
		10.0	3800	4100	83	6LB 6oz	2x6.2	2x1.5	17.3
	3x3	5.0	860	1000	21	1LB 10oz	3x7.1	3x0.85	40.0
		10.0	1840	2350	48	3LB 10oz	3x7.5	3x1.15	43.5
		15.0	2620	3500	71	5LB 7oz	3x7.8	3x1.4	46.0
		20.0	3500	4850	99	7LB 8oz	3x8.1	3x1.5	48.0
		50.0	8700	14000	282	21LB 8oz	3x9.3	3x2.3	58.0
		100.0	16700	31000	620	47LB 5oz	3x10.5	3x3.1	68.0

TEST QUESTIONS

Number your Answer Sheet No. 33—2 and add your
Student Number

Never hold up one set of lesson answers until you have another set ready to send in. Send each lesson in by itself before you start on the next lesson.

In that way we will be able to work together much more closely, you'll get more out of your course, and better lesson service.

No. 1. What is modulation?

No. 2. Give the plate voltage and plate current of a UV-207 tube.

No. 3. What is a motor-generator?

No. 4. Draw a diagram illustrating the best way to connect the grid return and the negative of the plate supply to the filament of a transmitting tube using A. C. on the filament.

No. 5. Name three types of plate voltage supply generally used for transmitting tubes.

No. 6. Give three advantages of the pre-rectified system of plate supply.

No. 7. Name the two general types of rectifiers.

No. 8. What should be the size of the aluminum electrode of a chemical rectifier if it is desired to obtain 80 milliamperes of current from the cell?

No. 9. Name the three sources of disturbance which affect the output of a motor-generator.

No. 10. Draw a diagram of the filter described in this lesson which is best suited for filtering the output of a motor-generator.


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