NATIONAL RADIO INSTITUTE

Complete Course in
PRACTICAL RADIO

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

LESSON TEXT No. 6

(3rd Edition)

RADIO BATTERIES, CHARGERS AND POWER UNITS

Originators of Radio Home Study Courses
···Established 1914···
Washington, D. C.

"I will study and get ready, and maybe some day my chance will come."—*Abraham Lincoln.*

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A Personal Message from J. E. Smith

No one ever accomplished anything worth while without sufficient exercise of the will.

You must first develop a deep desire to know certain facts, to become an expert in a particular field. You must determine that you will master all the subjects which will help you in your aim in life.

Other men have done what you are undertaking to do, and have counted their achievement the most valuable of their lives. Determine to complete the job in spite of hardships which may be in your way. Don't admit that you are a poorer man than the young fellow across the street who is achieving success for himself. If he can make a success so can you.

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Complete Course in Practical Radio

NATIONAL RADIO INSTITUTE WASHINGTON, D. C

RADIO BATTERIES, CHARGERS AND POWER UNITS

This is the last of the lessons of this practical radio course which will be devoted to what we have called our "bird's-eye view" of radio. In these six lessons, with which we have begun our course, you will have learned quite a lot about radio; you are probably surprised yourself, at the speed and ease with which you quickly became acquainted with what is going on in a radio receiver.

But one thing we wish to warn you against; do not think that you know much about radio. So far in these first few lessons, you have merely "scratched the surface." *These lessons are intended to be only an introduction to a complete study of radio, which you will get in all the lessons that follow.* But if you have studied these lessons carefully, and have mastered all that is in them, then, with the aid of the Practical Work Sheets which the National Radio Institute supplies, you ought to be able to do valuable and practical work on ordinary radio receivers.

We shall now consider the matter of battery charging, which is quite an important item in connection with the operation of radio receivers.

BATTERY CHARGERS

As you know a storage battery is used to light the filaments of the electron tubes, and in some cases to supply current for the magnetizing coils of loud-speakers.

An average size storage battery will gradually lose its charge in a month or two, depending on how much the receiver is used, and then it will not be possible for it to sufficiently light up the tubes. Then the battery must be charged.

For this reason a number of small battery chargers have been placed on the market, which are in very wide use. You may raise the question, why does not the operator of the set simply connect his battery to the house lighting system and charge it from that source of electric power. The trouble with this is that the storage battery requires *direct* or *constant* current for charging while the house lighting system is generally operated with alternating current. There are only a few places left where lighting and power lines are supplied with direct current. Where this is the case the problem is rather simple, and it is not even necessary to buy apparatus for charging batteries, as the apparatus can be easily constructed by the operator himself.

Therefore, let us take the simpler case first. Suppose you live in a district where the house lights are connected to a *direct current* supply. This supply is generally about 110 volts. The charging voltage for a battery must be a little higher than the voltage which the battery is supposed to deliver. Thus, since our storage battery is supposed to deliver 6 volts, we use a charging voltage of about 8 volts. The problem is then, how to get 8 volts from 110 volts. As you have learned sometime ago, in any circuit which carries a current, we have a certain voltage impressed on that circuit, which is used up in the various parts of the circuit. For instance, if we have a filament of 20 ohms resistance connected in series with a resistance of 4 ohms, and these are connected to a battery of six volts, 4/24ths of the voltage will be used up in the resistance, and 20/24ths of it will be used up in the filament. That is, 4/24ths of 6 makes 1 volt lost in the resistance, and 20/24ths of 6 makes 5 volts used up in the filament.

Now we can use the same principles in connection with our charger. Having 110 volts to begin with, let us suppose we wish to charge our storage battery at a rate of 5 amperes, which is sufficiently high for most purposes. *Of course, the greater the charging current the faster the battery will charge, but in the case of ordinary home charging it is not well to go above 5 amperes.* Remember that we need about 8 volts as the charging voltage. We must now find how much resistance we must place in the circuit. Now look at Figure 1.

If we have an original voltage of 110 volts, and we want only 8 volts, it is clear that we have to lose 110 — 8 or 102 volts in the resistance. Next, if we want a charging current of 5 amperes, we can find the resistance required by dividing the voltage by the amperes.

$$\text{Ohms} = \text{Volts} \div \text{Amperes} \qquad (1)$$

Therefore we get 102÷5 or 20.4 ohms, as the resistance we require in the circuit. The next step in the problem is to find a resistance of that value which will be able to carry 5 amperes without getting too hot, for you remember we spoke some time ago about the heating effects that electric currents produce in conductors.

Fortunately, we have such resistances very close to us and easy to get. These are the ordinary incandescent lamps used in your house for lighting purposes. A 50 watt lamp has a resistance of about 242 ohms, and a 100 watt lamp has a resistance of 121 ohms. So all we have to do is to take ten 50 watt lamps and connect them in parallel, or take five 100 watt lamps and connect them in parallel. The circuit then looks like that shown in Fig. 2, where we have shown five 100 watt lamps for limiting and controlling the current.

Now, in many cases it is not necessary to use such a high charging rate as five amperes. If the battery is put on charge often enough, a two ampere charging rate may be sufficient. In that case you can work out the number of lamps required, just as we have done above. This may be done in a simpler way by remembering that every 50 watt lamp we add increases the charging rate by about ½ ampere. Therefore, if we want a charging current of 1 ampere we use two 50 watt lamps. If we want a current of 2 amperes we use four 50 watt lamps. Or, if we want to use 100 watt lamps instead of 50 watt lamps, we simply count 1 ampere to each lamp.

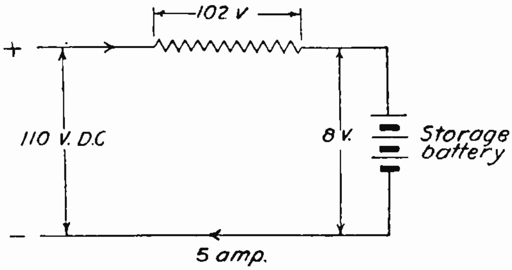


Fig. 1—Circuit Diagram for Charging a Storage Battery from a 110 Volt D. C. Line.

You must remember, in all this we are considering charging only one storage battery at a time. If we want to charge two batteries at the same time, each of these being a 6 volt storage battery, we must allow about 16 volts for the charging voltage instead of 8 volts.

When charging two batteries, they are connected in series. Requiring 16 volts for charging, the voltage drop in the lamps must be 110 — 16 or 94 volts. For a two ampere charging current the resistance must be 94 ÷ 2 or about 47 ohms. The nearest we can come to this with the lamps is to use three 100 watt lamps in parallel, which will give a resistance of 121 ÷ 3 or 40.3 ohms. The charging current will then be slightly greater than 2 amperes, but will be satisfactory. If we wish, we may use six 50 watt lamps, which will give the same charging current as three 100 watt lamps.

MECHANICAL, BULB AND ELECTROLYTIC RECTIFIERS

All this is a very simple matter, but when it comes to charging batteries in places where we have alternating current instead of direct current, the problem is much more difficult. We cannot then use a simple method like the one described above, but must use a special instrument called a *rectifier*, which will take the alternating current and break it up, so that instead of flowing into the battery at one instant and out of it at the next, the current is *always* flowing into it.

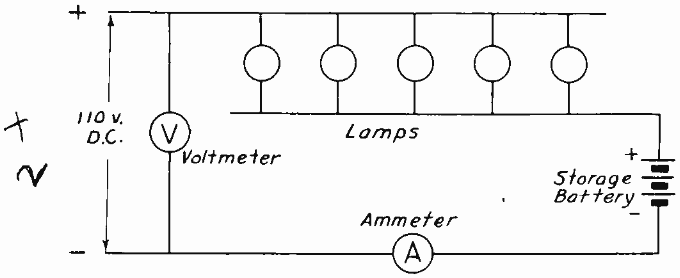


Fig. 2—Charging Storage Battery, Using Lamps as Charging Resistance.

Suppose we think of what an alternating current is. It is a current which reverses its direction of flow regularly so many times a second; in the case of house lighting systems it generally reverses 60 times a second. Hence it is called a 60 *cycle current*, or its *frequency* is 60 *cycles per second*. Suppose now we have a battery connected to the line, and that at a certain instant the current from the house line is flowing *into the positive* terminal of the battery. Now, suppose again that when the current reverses and tries to flow *out* of the positive terminal of the battery, that we open a switch. Then the current cannot flow out of the positive terminal. In other words, if we open the circuit every time the current begins to flow out of the positive terminal of the battery, we shall never have any current flowing in that particular direction. On the other hand, since we always allow the circuit to remain closed when the current is flowing *into* the positive terminal, it is plain that this is the only way in which the current can flow through the battery.

Of course it will then flow in *"jerks"* or *"impulses,"* but as far as concerns the charging of the battery, this will be satisfactory, and the battery will charge up. This is the way in which the *"mechanical"* rectifiers work. There is just such a switch as we have mentioned here, which, however, operates automatically. Every time the current begins to flow in the wrong direction this switch opens, and every time the current is in the right direction the switch is closed.

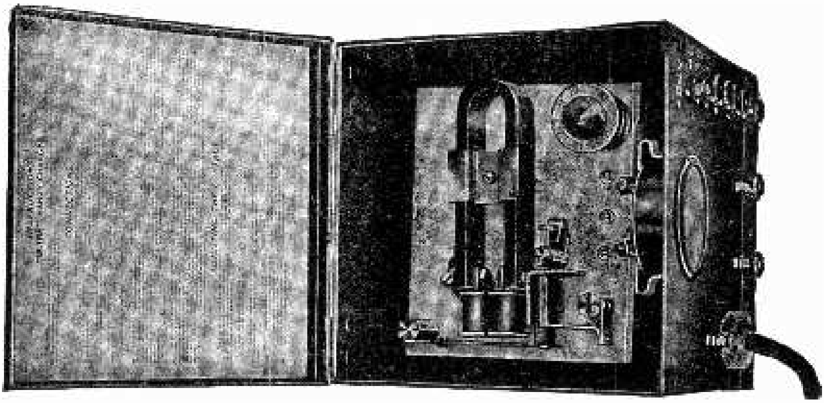


Fig. 3—Picture of a Mechanical Rectifier Charger With Cover Removed.

MECHANICAL RECTIFIER

The simple diagram of such a *"mechanical rectifier"* is shown in Fig. 4. This illustration is not a complete diagram, but is merely a *skeleton diagram,* which will be sufficient at the present time for explaining how the rectifier works. The alternating current (60 cycle) enters the transformer, at the top of the diagram. In the transformer the voltage is "stepped down" to whatever voltage is necessary to work the charger and charge the battery; as we have seen before, we require about 8 volts for charging, so that we may require a few more volts to operate the charger. The total voltage in the secondary winding of the transformer (marked S) may therefore be about 10 volts. The primary winding of the transformer (marked P) is connected to the house lighting circuit.

The alternating current flowing in the secondary winding of the transformer also flows through the magnetizing coil and the strength of this current is regulated by the resistance R_1. When the current from the transformer to the battery is of the correct polarity to charge the battery, the contacts close and the current flows to the battery. But when the supply line reverses its polarity, the contacts open so that the battery cannot be discharged.

The name *armature* is given to the part of the charger that vibrates. A spring supports the armature and when there is no current flowing, prevents it from coming in contact with a piece of carbon, which is held in an adjustable clamp. The screw is for the purpose of adjusting this piece of carbon so that when the charger is not in operation it is at the right distance from the armature.

A fuse is generally used in the circuit, which is a small piece of material which melts easily and breaks the circuit when an excessive current flows, which might damage the charger or the battery. The ammeter is an instrument which tells us how much current is flowing at any time.

You will also note that in the diagram of Fig. 4 there is included a permanent magnet M. You may suspect therefore that the operation of the charger is very similar to that of a diaphragm type of loud-speaker unit. Such is the case, as we shall see.

Since the magnetizing coil is connected directly to the secondary of the transformer, when the primary is connected to the house lighting circuit there is always an alternating current flowing in this coil. The coil, therefore, has a *magnetic field* which alternates as the current alternates, first in one direction, then in another.

Now, the permanent magnet always attracts the armature with the same force. The screw is adjusted so that the armature is not quite touching the piece of carbon. Therefore, when the magnetic field of the coil is in such a direction that it aids the field of the permanent magnet, the attraction on the armature is greater than it was, and the armature is pulled over and makes contact with the carbon. While the current is in this direction, therefore, and the contact is closed, the current can flow into the battery.

But when the alternating current through the coil is in such a direction that the field of this coil *opposes* the field of the permanent magnet, it is clear that the attracting force on the armature will be less than is required to pull it over, and the spring will keep it from making contact with the carbon. When this happens no current can flow into it, since there is no complete circuit to the battery. As a result the charger automatically breaks the circuit when the current is in the wrong direction, and closes the circuit when it is in the right direction.

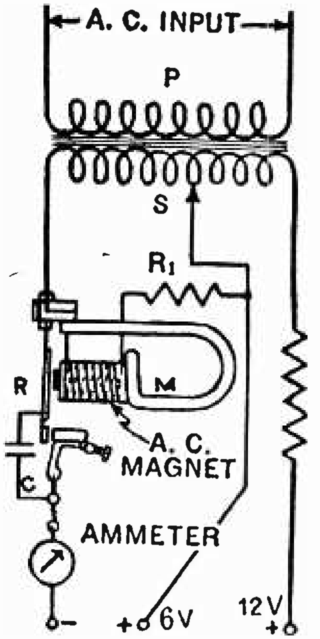


Fig. 4—Wiring Diagram of a Simple Mechanical Rectifier.

You will notice there are three terminals to the charger at the bottom of the diagram of Fig. 4. When there is one battery to be charged, it has its negative terminal connected to the — terminal of the charger, and the other is connected to the terminal marked 6V. When there are two 6 volt batteries to be charged they are connected in series. Then the negative terminal of the battery is connected to the — terminal of the charger and the other terminal of the battery is connected to the 12V+ terminal of the charger.

The chargers are so designed that it is not necessary to adjust anything on them excepting the screw, which regulates the position of the carbon contact. Very little difficulty is experienced with good mechanical chargers, the only servicing that they ever require being an occasional replacement of the piece of carbon, which gradually wears out, due to rubbing of the armature, and an occasional spark. A good charger should not spark at the contacts and when it does spark, it is an indication that the charger is not working properly.

BULB RECTIFIER

There are two other types of chargers which we will review rather quickly at the present time, for we shall study them in more detail in a later lesson. We must introduce them here in order to make our bird's-eye view more complete. You must remember that all rectifiers work in the same manner; they all break the circuit when the current to the battery is in the wrong direction, and complete the circuit when the current is in the right direction. If you keep this in mind you will not have much trouble in understanding how chargers work.

4 The first of these two types, which we shall consider, is the "*bulb*" type of rectifier. There are several of these on the market, all of which use the same kind of bulb or tube, called the "*tungar*" bulb. A tungar bulb is an electron tube which has a filament and a plate, but no grid. It also has inside the glass envelope argon gas. This differs from the electron tubes used in amplifiers for all the gas or air has been removed from these as is possible to remove.

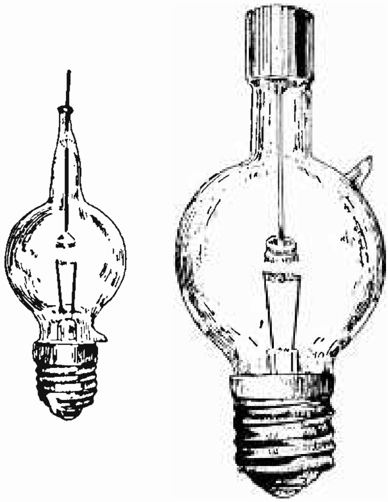


Fig. 5—Small and Large Size Tungar Rectifying Bulbs.

The diagram of one of the rectifiers which uses the tungar bulb is shown in Fig. 7. The 110 volt A.C. line of the house lighting system is connected as before, to the primary winding of the transformer, marked P. The lower alternating voltage is delivered by the secondary winding, marked S. Connections are made to a small part of this secondary winding, as at "a" and "b," where a voltage is taken off to furnish current for lighting the filament of the tungar tube.

5 The plate (or anode, as it is also called) of the bulb, is connected to the — terminal of the charger, and the other side of the transformer secondary is connected to the + terminal of the charger. The + terminal of the battery to be charged is connected to the + terminal of the charger, and the — terminal of the battery is connected to the — terminal of the charger. A fuse is included in the + side of the charger.

The operation of the tungar charger depends on the fact that the tube will only allow current to pass in one direction.

This is because the heated filament gives off electrons, while the cold plate does not.

When the filament is heated and a difference of potential exists between the plate and filament an electric current will flow between the plate and the filament.

If an alternating current is impressed across the plate and filament, a current will only flow when the plate is positive. When the voltage reverses its polarity, no current flows and thus the negative half-waves are suppressed.

ELECTROLYTIC RECTIFIER

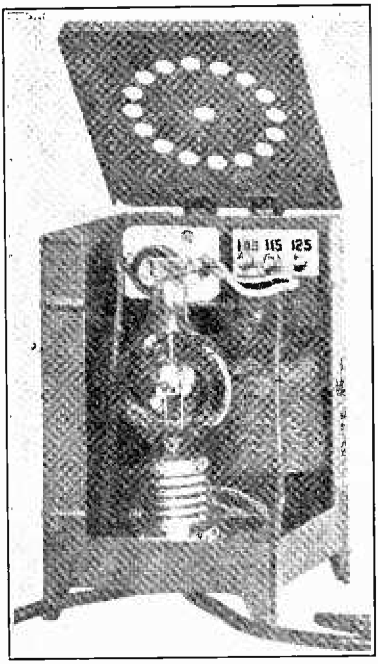


Fig. 6—General Appearance of a Commercial One Tube Rectifier with Two Sides and Top Removed.

The last type of rectifier or charger which we shall study is known as the *"electrolytic"* 4 rectifier. This type of rectifier is widely used, especially for *"trickle"* charging. The word *trickle* indicates exactly what it means; the charging rate is made very small, so that the current merely trickles into the battery, and hence the battery charges very slowly. When a trickle charger is used, it is necessary to have the battery on charge at all times when the radio receiver is not in use. This is easily done by throwing a switch when you have finished using the set.

There is not a great deal known about the way in which electrolytic rectifiers operate. The circuit diagram of this type of charger is shown in Fig. 8. Note that the diagram is about the same as that of the bulb rectifier. The house line is connected to the primary of the transformer P. In the secondary circuit of the transformer there is connected the electrolytic rectifier. This consists of some kind of a container, such as glass, which cannot leak or be attacked by acids, and in it are placed two pieces of metal. The container is then filled with a certain liquid called an *"electrolyte."*

There are various combinations of metals and electrolytes which may be used, but the best of these, and the most widely used are:

+ 6 Aluminum rectifier: plates of aluminum and lead, with a solution of borax in water.

Tantalum rectifier: plates of tantalum and lead, with a solution of sulphuric acid in water.

The latter type of electrolytic rectifier is also known as the Balkite rectifier. The lead plate is in both cases the negative (—) terminal of the charger and the other plate is the positive terminal.

+ 5

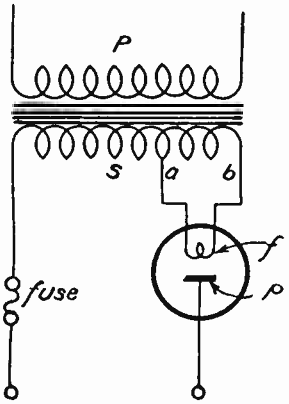


Fig. 7—Diagram of a Charger Using Tungar Bulb.

The electrolytic rectifier, if well constructed, should not require much attention. It is necessary to replace the water which evaporates out of the electrolyte, just as it does in a storage battery, but in the average electrolytic rectifier used for trickle charging, this need be done hardly more than every two or three weeks, and in many cases less frequently than this. It is well not to place the electrolytic rectifier very near to heaters or radiators, as the water will evaporate more quickly. When used for charging batteries at other than trickle rates (which are generally about ½ ampere or less)—say at one or two amperes, the electrolytic rectifier, especially the aluminum type, is apt to give trouble, due to the chemical formation of salts on the jars, which may creep over the sides of the jar as they accumulate, and may then do damage to furniture and carpets, etc. It is well to place electrolytic rectifiers (and storage batteries too), in glass or porcelain pans, which will prevent acid and salts from doing damage to the home.

If you should accidentally spill acid on the floor, rug, or furniture, the best thing to do is to run for the ammonia bottle as quickly as you can, and douse the acid with it. Sulphuric acid is very destructive, and is also dangerous;

pure sulphuric acid may give you very serious burns if you are not careful. Pure acids are not used in batteries or rectifiers, but they are mixed with water. In this state they are not quite as dangerous, but it is best to be very careful. If you should get some acid on your hands, apply ammoninum hydroxide, or bicarbonate of soda immediately. This will take care of dilute acid all right, but you are in for a lot of trouble if you get pure acid on your skin. Fortunately, it is never necessary for you to use pure acid, unless you should some day go into the battery charging business. As we said before, the acids you will use are generally diluted in water.

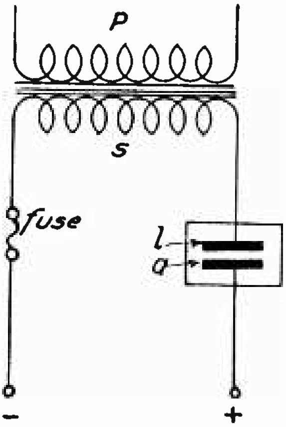


Fig. 8 — Diagram of a Charger Using Electrolytic Rectifier.

Now, before we go into the subject of battery eliminators, you should learn something about batteries.

CHEMICAL CELLS

Look at Figure 10. Here we have shown a very simple form of cell. It consists of a copper plate and zinc plate. These two are placed in a solution called an *electrolyte*. The copper plate and the zinc plate are called electrodes. In this simple cell the electrolyte is salt dissolved in water. Ordinary table salt will do the trick very well, but it has been found that a salt known as *sal ammoniac* is better. When such an arrangement is set up, it is found that the copper plate becomes positively charged and the zinc plate becomes negatively charged. We could connect to this cell then, as we see in Fig. 11, any kind of a circuit through which a current can

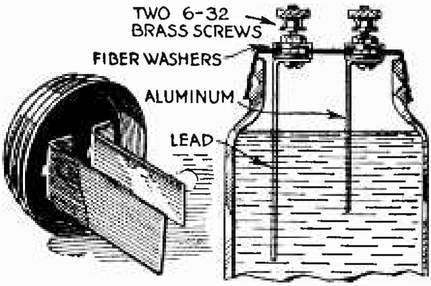


Fig. 9—Electrolytic Rectifier.

flow. The circuit shown, consists of a resistance R and the filament of an electron tube F.

The instant we connect a circuit to the cell, a chemical action starts in the cell, and it is this chemical action which furnishes the electric power which the circuit takes from the cell.

Now, since we have the chemical energy of the cell continually being changed into electrical energy while the circuit is connected, there must be an end to it sometime, when the chemical energy of the cell is all used up. This actually happens. The chemical energy is furnished by the salt and the metals. So when these are used up, we cannot obtain any more energy from the cell. The zinc electrode and the salt in the electrolyte combine chemically; the zinc is gradually eaten up by the salt solution. After a while, in order to make the cell continue working, it will be necessary to replace the zinc electrode and the electrolyte. This is what we have to do with "wet cells," which are merely glass jars in which we place the carbon and zinc electrodes and the sal ammoniac electrolyte.

RADIO BATTERIES

"Dry cells," such as we use to operate radio receivers, work in the same way. There is a carbon and a zinc electrode in each cell. As a matter of fact, a zinc container takes the place of the glass jar. This is shown in Fig. 12. The electrolyte is not now a solution, but rather a paste. It is made in the form of a paste so that it holds the liquid and does not leak. After the cell is put together, the whole thing is sealed at the top with pitch or sealing wax, so that the liquid will not evaporate and allow the paste to dry out.

This is the way in which ordinary dry-cells are made: "B" batteries are made the same way, a number of these small dry-cells being connected together and the whole outfit being enclosed in the same cardboard box. See Fig. 13. With care, "B" batteries should last quite a long time, especially if the receiver which they are to operate is well designed. But we must be careful to not make them furnish currents of more than perhaps 40 milliamperes, for if we do, the batteries will not last very long. This fact must be carefully remembered, especially when power tubes are used in the radio receiver. When these are used, be sure that the proper "C" battery voltage is applied, for it will be remembered that the "C" battery keeps down the current in the plate circuits of the tubes.

There are other things used in the construction of dry batteries which we have not mentioned, and we will not study now; we will learn about these things when we come to study batteries in detail, in a later lesson. The things we have spoken of above are the main things to be remembered in connection with all batteries.

In the *construction of a cell of a storage battery, we have two electrodes and an electrolyte.* The storage battery which is mostly used today is the *"lead"* battery, because the plates (or electrodes) are made of lead. One of these plates is coated with a chemical called *lead peroxide,* while the other plate is a spongy lead. The electrolyte is a solution of *sulphuric acid* in water. The chemical action going on in the cells changes the coating of lead peroxide into lead sulphate, just as the chemical action in the dry cells changes the chemicals in that type of battery. The action is very much the same. In the dry cells, however, the electrodes and electrolyte are so cheap and easily obtained that we rarely ever try to *recharge* the cells, or renew the electrodes and the electrolyte. We simply throw away the worn out dry cells and buy new ones.

X 8

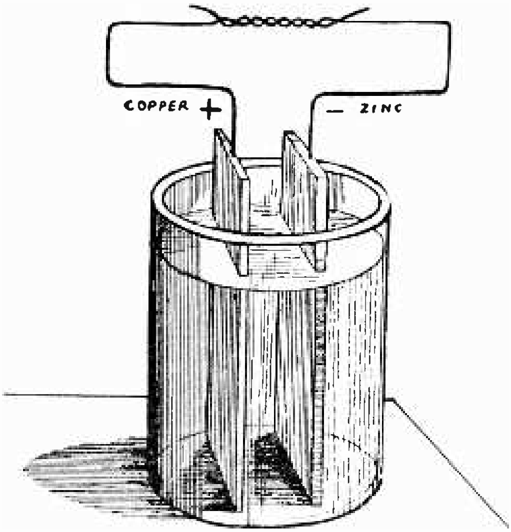


Fig. 10—Simple Chemical Cell. Two or more of these cells joined together would be a battery.

The lead plate storage batteries are expensive, however, so instead of throwing them away when they are worn out, we put them into good condition again by reversing the action, that is by charging them, either at a charging station or by using the house current and a rectifier. When the battery was being used, you will remember, the chemical action caused the lead peroxide to change into lead sulphate. Now, when the battery is being *charged,* this lead sulphate changes back into lead peroxide again.

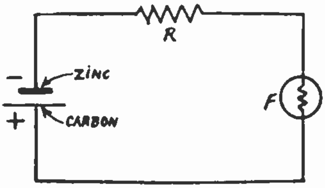


Fig. 11

The electrolyte does not have to be removed very often, however. If the battery is in good shape, all that the electrolyte loses is water, and this is certainly cheap enough. It loses the water by evaporation. But it does not lose the acid. So in using a storage battery, we must be careful to look at it about once every two weeks, to see if it needs any water. If we can see the plates (or electrodes) sticking up out of the electrolyte, it is time to add water. The electrolyte should always cover the plates completely by about a quarter of an inch. And be sure to remember, never use any kind of water but *distilled water.* Never mind what your friends tell you; they may use water out of the hydrant, but sooner or

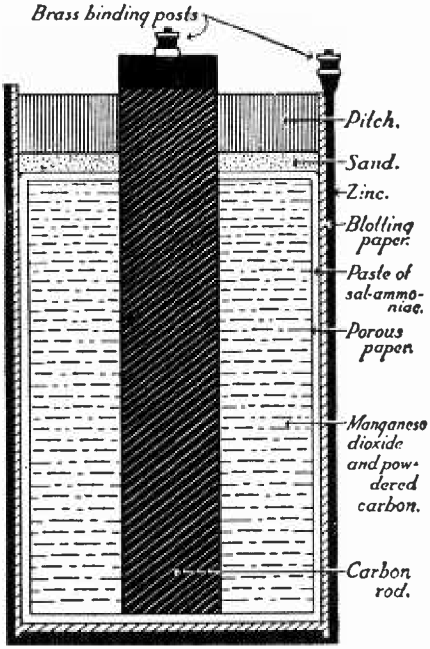
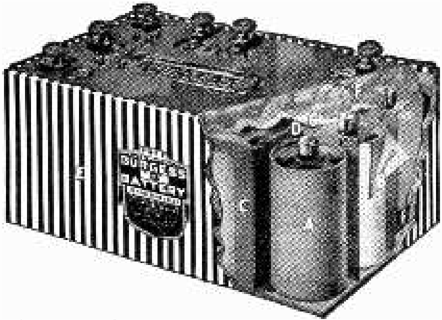


Fig. 12—Cross-Section View Showing Inside of a Dry Cell.

later they are going to spoil the battery by having a lot of *sediment* or dirt collect at the bottom of the battery.

Next we must learn how to connect batteries to the radio receiver. As you have already learned, it is necessary to have several different voltages for the different parts of the radio receiver. For instance, the voltage often used on the radio-frequency amplifier is 67½ volts, on the detector 45 volts, on the first audio-frequency amplifier 90 volts, and often on the second audio-frequency amplifier 135 volts. And finally, as you already know, we usually have to have a voltage of 6 volts to light the filaments of the tubes.



"A"	One-piece seamless zinc can.
"B"	Moisture-proof wrapper.
"C"	Sealing material between cells.
"D"	Waterproof partition between cells.
"E"	Heavy waterproof non-metallic insulating material.
"F"	Heavy triple seal over the top.
"G"	Webbing between seals.

Fig. 13—22.5 Volt "B" Battery, used with Vacuum Tube Receiving Sets. The Battery Consists of a Number of Small Dry Cells Connected in Series.

You have also learned something about the amount of current that must be furnished by these batteries. If we have a six tube receiver, each filament taking a current of ¼ ampere, and all these filaments are connected in parallel, as is usually the case, it is clear that the total current taken from the 6 volt battery is 6 x ¼ or 1½ amperes. Therefore the battery which lights the filaments must be capable of furnishing a current of that amount. As we have said before, we cannot expect the small cells to furnish this current as they would not last long. So as a rule we use a storage battery to light the filaments of the tubes.

Fig. 14—45-Volt "B" Battery.

Now, as to the "B" batteries. These are generally made in "blocks" of 45 volts each, and the middle of each block has a separate connection to the batteries, so that we can use either half of the cells in the block, thereby obtaining 22½ volts, or we can use all of them, obtaining 45 volts. This is illustrated in Fig. 14. The negative (—) terminal is at the one end of the block; then there are 11 cells connected in series, giving a total of 16.5 volts for the first tap. (Each cell gives 1.5 volts and 11x1.5 = 16.5 volts). Then we have another cell connected in series with the 11 others. This gives us the 18 volt tap. Another cell added in series gives 19.5 volts, another cell in series gives us 21 volts and still another cell in series gives us 22.5 volts. In other words, we use 15 small cells in the "B" battery block to give us the 22.5 volts. After the 22.5 volts tap there are 15 more cells added in series,

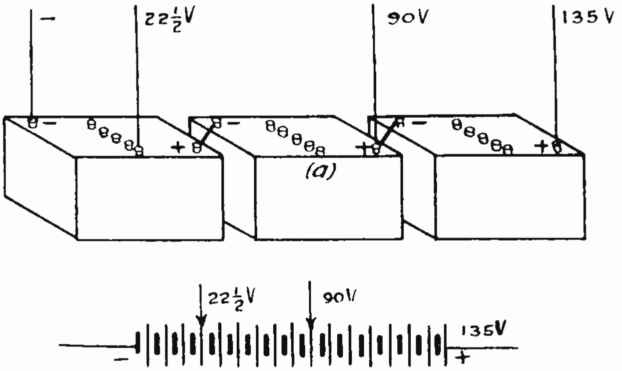


Fig. 15—Three 45-Volt "B" Batteries, Showing Taps Taken Off for 22½, 90 and 135 Volts.

making a total of 30 cells, which gives 45 volts as the total voltage of the block. The reason why the 16.5, 18, 19.5, 21, and 22.5 volt taps are furnished is that many detectors are operated on voltages of about those amounts. These taps are furnished so that we can pick out the exact voltage which makes the detector work best.

But this only gives us 45 volts; we really need 90 volts and 135 volts. How are we going to get all this? The answer is simple; merely connect together several of these 45 volt block, in series. Two of them in series will give 45 + 45 or 90 volts, and three in series will give 45 + 45 + 45 or 135 volts. The diagram of connections is given in Fig. 15, with the schematic way of representing it. It must be clear to you that there are other combinations of voltages that you can use. For instance, if we wanted to operate our radio-frequency amplifier tubes on 67.5 volts, we would connect them to the tap marked (a) in Fig. 15.

The connections of the "A" battery, that is, the storage battery, are very simple. An ordinary 6 volt storage battery is shown in Fig. 16. It consists of 3 cells, each cell furnishing 2 volts, so that 3x2 gives us six volts for the complete battery. One terminal of the battery is marked + (positive) and the other terminal is marked — (negative). We simply connect the binding post on the set marked + to the plus terminal of the "A" battery, and the — binding post on the set to the — terminal of the battery.

This will be sufficient about batteries for the present. As we have stated before, we shall study batteries quite in detail in a later lesson. But before we leave the subject, it may be well to mention that "C" batteries are exactly the same as "B" batteries in construction, excepting that they are smaller.

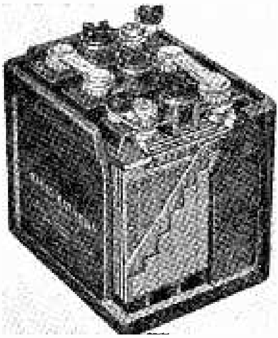


Fig. 16—Cross-section of Lead plate Storage Battery.

Next we go on to the subject of "B" battery eliminators.

BATTERY ELIMINATORS

The simplest kind of "B" battery eliminator is that which can be used in districts where the house lighting circuit carries *direct current*. This is the same kind of current that the "B" batteries furnish, so the problem is mainly to obtain the proper voltages from the house lighting system. The voltage of the system is 110 volts or thereabouts. This voltage can be used for operating the audio-frequency amplifiers without change.

Besides this voltage for the audio-frequency amplifiers, we need a much lower voltage for the detector, 22.5 or 45 volts, and a voltage of about 67.5 volts for the radio-frequency amplifiers. The problem then is to get these other voltages. This can be solved in a manner similar to the way in which we solved the problem of the direct current charging circuit for charging storage batteries. We can place resistances in series with the line and the receiver, and so adjust these resistances as to furnish the voltages which we require to operate the set.

Suppose you look at Fig. 17 for a moment. This will explain the method very easily. First we have to find out how much resistance is required in the connection which goes to the R. F. amplifier (R. F. is an abbreviation for radio-frequency). Next we have to know how much current the radio-frequency amplifier tubes take. As a rule this should not be high; we may assume that about 5 milliamperes is the most they will take in a well designed receiver. Suppose also that the receiver is designed to have the R. F. tubes operate with 67.5 volts on the plates. This is all the information we need in order to find out how much resistance we need at R in Fig. 17.

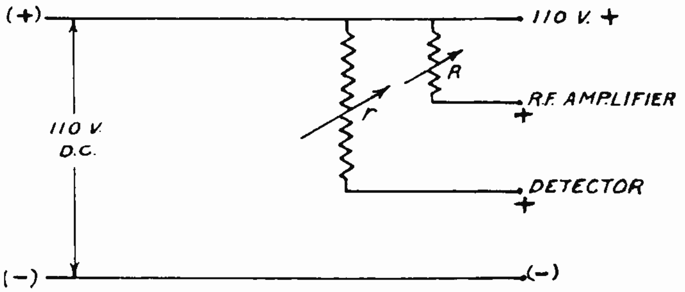


Fig. 17—Illustration Showing How Various Voltages are Obtained From 110 Volt D. C. Line.

Now to begin. Since we have an impressed voltage of 110 volts and we need only 67.5 volts, the resistance must be of such a value that it makes up for the difference. This difference is

$$110 - 67.5 = 42.5 \text{ volts} \qquad (2)$$

In other words the resistance must use up that amount of the voltage. Now, if this is so, then knowing what current it must carry, we can find the value of the resistance by the old rule:

$$\text{Ohms} = \text{Volts} \div \text{Amperes} \qquad (3)$$

The resistance must carry 5 milliamperes. A milliampere is 1/1000th of an ampere, so that 5 milliamperes is

5/1000ths or .005 of an ampere. Therefore, the resistance required is

$$R = \frac{42.5}{.005} = 8500 \text{ ohms} \qquad (4)$$

Next we must find the resistance to be placed in series with the detector tube. This tube will rarely take more than about 2 milliamperes, or 2/1000ths or .002 of an ampere. Let us suppose that this tube is to be operated with 45 volts on its plate. Then the voltage drop required in the resistance is given by

$$110 - 45 \text{ or } 65 \text{ volts} \qquad (5)$$

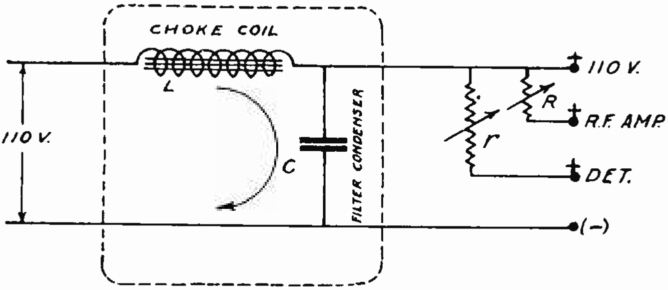


Fig. 18—One Section Filter Arrangement for 110 Volt D. C. Line.

This much voltage must be used up in the resistance r in Fig. 17. The value of the required resistance can be obtained the same as above, that is

$$R = \frac{65}{.002} = 32{,}500 \text{ ohms} \qquad (6)$$

It is practically impossible to buy resistances which have these exact values, so the way we do it is to buy *variable* resistances. These resistances come in *ranges* anywhere from zero to 150,000 ohms and upwards; that is, it is possible for us to adjust them to any value we want, or to any value which may work best. Therefore the problem is greatly simplified for us when we use variable resistances, and simply adjust them by *trial* until we find the adjustments that make the set operate best.

So what was thought a big problem at first turns out to be a simple problem after all; our great problem will be tackled next. As you probably know, the power which the electric company sends into your home or your shop, which furnished your power for lighting purposes, is generated in a dynamo at the company's power station. In this dynamo there are various things going on which make the current slightly irregular. Why and how this happens we shall learn in a later lesson. At one instant, there is a sudden but slight jump or increase of current. Next there is a sudden but slight decrease. And these jumps or irregularities do not follow each other in any regular order. They are very small jumps, so small that you can not notice the effect in the way your incandescent lamps light up. But they are there, nevertheless, for when we try to operate such an extremely sensitive thing as a radio receiver on such a power supply, we can constantly hear an annoying noise in the loud-speaker. So, as far as our "B" battery eliminator is concerned, it will not work in the simple form shown in Fig. 17. We must modify or change this arrangement in some way, so as to get rid of this noise, which is due to the variations in the generator.

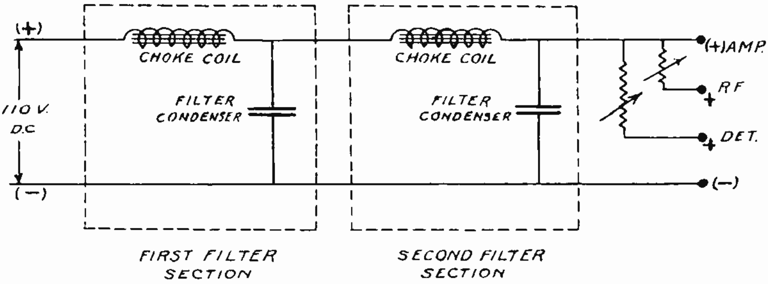
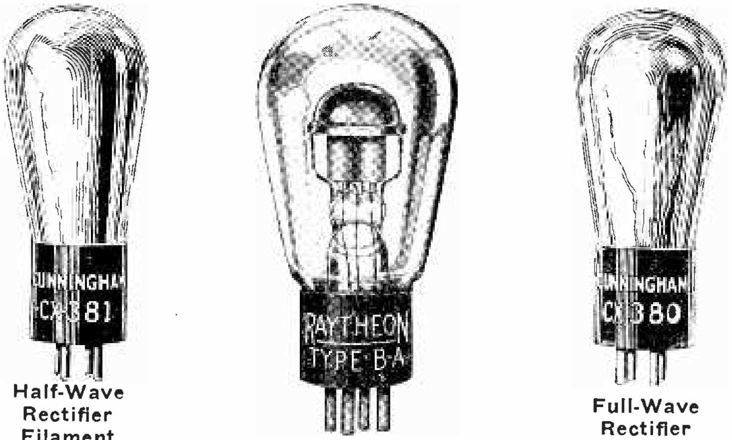


Fig. 19—Two Section Filter for 110 Volt D. C. Line.

As you recall, sometime ago, when we were learning about condensers and coils, we explained how the coil tries to keep up the current when it is decreasing, and how it tries to hold it down when it is increasing. We also explained how the condenser acts in just the reverse manner. It tries to increase the current further when it is increasing, and to decrease it more rapidly when it is decreasing. It seems, therefore, that some good might come if we should connect a condenser and coil in the circuit of Fig. 17, as this might cut out the noise or the hum. This is exactly what we have done, as is shown in Fig. 18.

In this figure we have connected a very large coil in series with the 110 volt line, and have connected a very large condenser across the line. The large coil tries to slow down the slight changes in the current, and the small changes that do get through the coil are hurried up by the condenser. The condenser, therefore, acts partly as a *short circuit* for these *ripples,* as the variations of current are called. It enables what little ripple is left after the greatest part has been ironed out by the coil, to return to the generator in the direction of the arrow, so that hardly any of the ripple can go as far as the radio receiver.

The large coil marked L is called a *choke* coil because it "chokes" out these ripples. The condenser marked C is called a *filter condenser.* The whole arrangement enclosed by the broken line in Fig. 18 is called a *filter,* because it "filters" out the ripples. Figure 18, therefore, represents a complete "B" battery eliminator, which can be used when the house lighting system is operated on *direct current. It cannot* be used with *alternating current.*



Half-Wave Rectifier Filament Type

Full-Wave Rectifier Gaseous Type

Full-Wave Rectifier Filament Type

Fig. 20—These Three Pictures Illustrate the Appearance of Rectifier Tubes Used in Power Units.

Sometimes, when the ripple is very bad, that is, when the variations of the current are rather large, the filter of Fig. 18 may not be sufficient. When this is the case, it is necessary either to use a larger choke coil and condenser, or to use *two filter sections.* Such a circuit is shown in Fig. 19, where the separate filter sections are enclosed by broken lines.

After all, the problem of the eliminator to be used on direct current systems is a small one. The next problem is to devise an eliminator which will supply direct current without a ripple, when it is operated on alternating current. Let us suppose that we have a source of direct current which has quite a large ripple in it. It makes no difference where we get it, we can always apply to it the filter system of Fig. 19, and finally get the ripple out of it. Of course we may have to use very large choke coils and condensers, but at least we can do it. The problem that remains is to find a means of changing the alternating current into at least some form of direct current.

Fig. 21—Picture of a Typical "B" Eliminator.

You remember that not long ago we learned about rectifiers? Remember how in one of these rectifiers, which are used for charging batteries, we used a tungar bulb which allowed the current to pass through it in only one direction? When the current tried to pass in the other direction it was blocked. So what we actually got out of the bulb was not a constant current, but a *pulsating* current. It would flow for an instant, say 1/120th of a second; then the next 1/120th of a second it would not flow. The next 1/120th of a second it would flow again, and in the same direction as before. So we have a current which flows in "jerks" or "spurts."

The tungar bulb will not operate well on the higher voltages needed for the plates of the electron tubes. It works only on low voltages such as are used for charging storage batteries. However, there are other tubes available, such as the Raytheon and filament types, which act in a different manner, but produce the same effects. They can furnish a pulsating current always in the same direction, when supplied with alternating current.

The Raytheon tube consists of three electrodes in its simplest form, one of these electrodes being rather large, and the other two, small. There is helium gas inside the tube. The current can flow only from the small electrodes to the large one, just as in the tungar bulb the current can flow only from the anode to the filament or cathode.

Figure 22 shows a typical circuit of a "B" eliminator. The transformer has impressed on one winding (the primary) the voltage of the house lines. It is so designed as to deliver from its secondary winding a voltage of somewhere about 450 volts. This is the voltage at which one type of Raytheon tube operates satisfactorily.

The particular Raytheon rectifier tube which is used has *one* large electrode and two small ones. In order to explain how it operates, suppose that at a certain instant the current is flowing in the transformer secondary in the direction of the arrow F. Now remember that the current can flow only from the small electrodes to the large one. Therefore the current can flow from A to B, and will then pass around the circuit in the direction of the arrow D and the arrow E, back to the center tap of the transformer.

Now suppose the next instant the current in the transformer secondary reverses, or flows in the direction of the arrow G. Then the current can flow through the tube only from C to B, and will travel around the circuit in the direction indicated by the arrows D and E.

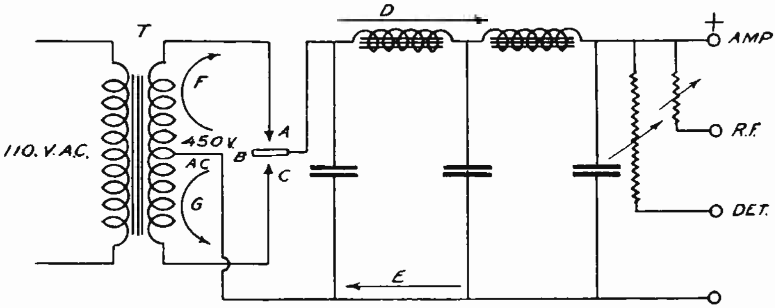


Fig. 22—Complete Circuit Diagram of "B" Eliminator.

+
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At one time we are using the voltage in the upper half of the transformer secondary and the electrodes A and B of the rectifier tube. At the other time, we are using the lower half of the transformer secondary winding and the electrodes C and B of the tube. In each case, however, it will be noted that the current always flows through the filter sections in the same direction, and consequently, after the ripple is filtered out, we shall have more or less pure direct current on which to operate the receiver.

The rectifier tube, which we have been discussing in the previous paragraphs, is the Raytheon type of tube, also known as the *cold cathode* rectifier, because the cathode, or large electrode is not heated. This is the electrode marked "B" in

Fig. 22. On account of this fact, it is necessary to introduce into the tube a gas which can be made capable of conducting electrons from one electrode to the other when the voltages applied to the tube are quite small. Let us first refresh our memory on the nature of an alternating current. Look at Fig. 23. This represents a wave of alternating current.

An alternating current or voltage is one which at a certain instant has a value of zero. Then, as time goes on, current begins to flow in a certain direction in the circuit, which we will call for convenience, the *positive direction,* and continually increases until it assumes a maximum value. Then it begins to decrease in value until it becomes zero again, after which it begins to flow in the opposite (or negative) direction, increasing in this direction until it again attains a maximum, and once again decreases to zero. In commercial alternating current circuits, this cycle of events is accomplished in 1/60th of a second, whence we call this a 60 cycle current or 60 cycle voltage.

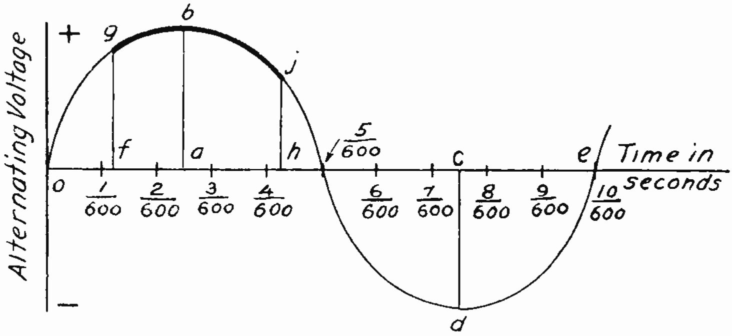

Fig. 23—An Alternating-Current Curve.

In Fig. 23 we have shown this whole cycle in the form of a curve or graph. The divisions marked off horizontally represent 1/600th of a second of time, so that 10 of these divisions represent 10/600ths of a second, or 1/60th of a second. The height of this curve at any point above or below the horizontal axis represents the voltage at any instant. For example, between 2/600ths and 3/600ths of a second after the start of the cycle, the voltage has its maximum, say 110 volts, indicated by the length of the line ab. Being above the horizontal line, we say the voltage at this instant is in the positive direction. Between 7/600ths and 8/600ths of a second after the start of the cycle, the voltage is again maximum, but this time it is in the negative direction, indicated by the line cd, Fig. 23. At the instant 5/600ths after the start of the cycle the voltage is zero; likewise at the end of the cycle, as at e.

Now, in the *cold cathode* type of rectifier, or the Raytheon tube, a certain voltage is required in order to *ionize* the gas within the tube, or to make it capable of conducting electrons. Therefore, at any time when the voltage is less than this, no current can flow through the tube. So, starting at the beginning of the cycle, as at O, Fig. 23, the voltage is zero, and the gas is not ionized. As time goes on the voltage increases, but still the gas does not become ionized until a certain critical voltage has been reached, which has the value, let us say, indicated by the line fg in Fig. 23. During the part of the cycle when the voltage is greater than this critical value, current will flow through the tube for the gas remains ionized, but when the voltage has decreased to a certain value again, the gas ceases to be ionized, and current ceases flowing. The voltage at which it ceases flowing is slightly less than the voltage at which it starts flowing, for it is easier to maintain the ionized condition than it is to start it. Hence the *cut-off*

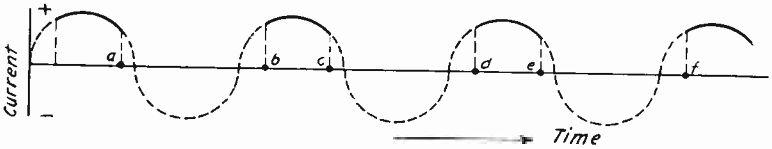

Fig. 24—A Rectified Alternating Current.

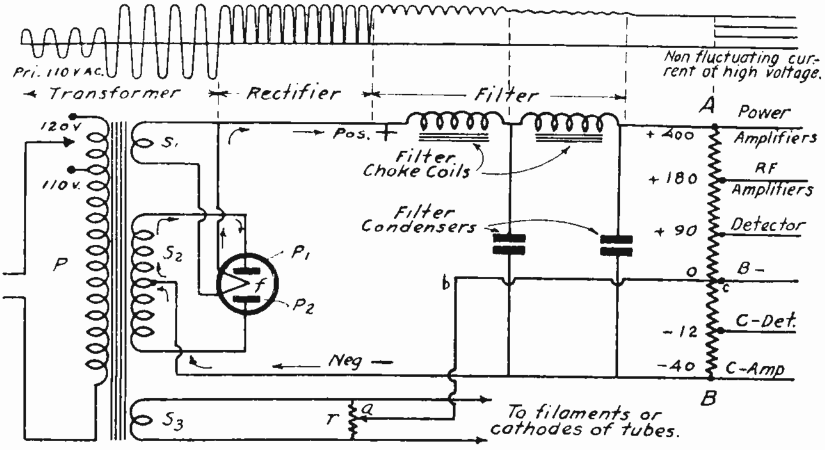

Fig. 25—Schematic Diagram of a Full-Wave Rectifier Power System.

voltage, as we call it, is less than the ionizing voltage, which is indicated in Fig. 23 by the fact that the point j is lower than the point g.

Of course, when the voltage is reversed no ionization can occur at all, regardless of the value of the voltage, so that current flows through the tube only during the short interval of time occurring between f and h in the figure. So you see, we have a pulsating current, which flows only for a short time during each cycle, always in the *positive direction,* and which is repeated from one cycle to another. The heavy part of the curve in Fig. 23 has this current varying with time during a single cycle. In Fig. 24 we have indicated the nature of the current over a number of cycles. It is clear that this is a pulsating current, since no current flows during the intervals of time ab, cd, ef, and so on.

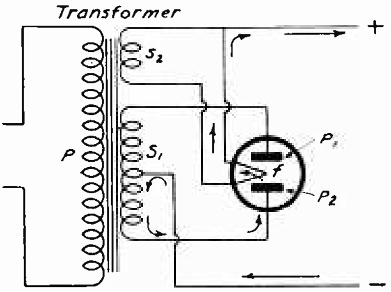

Fig. 26.

On account of this, for reasons which we shall learn later, it is a little difficult to properly filter out the noise or hum in circuits which use the cold cathode, gas filled rectifier. For this reason, the *hot cathode* type of rectifier is now used. This type of rectifier does not rely on the ionization of a gas and does not have critical voltages. Furthermore, current will flow through the tube during the complete half-cycle, the value of the current being simply dependent upon the value of the voltage impressed on the tube.

The *hot cathode* type of rectifier, just like the Raytheon, consists of a cathode and two other electrodes, but this time the cathode is a filament which can be heated by an alternating current passing through it. Figure 20 shows one of these tubes, known as CX-380. The tube has no gas in it, and it operates just like the other electron tubes we have studied previously. When the cathode is heated it emits electrons, and when one or the other of the additional electrodes is charged positively, it attracts the electrons to it and a current flows through the tube. Figure 25 shows the circuit arrangement. The primary "P" of the transformer is connected as usual to the house lighting circuit. The two windings going to the rectifier tube from the secondary side of the transformer, winding S_1 supplies the high voltage, which is to be rectified, and the winding S_2 supplies the alternating current for heating the filament (or cathode) f of the rectifier. The ends of the winding S_1 are connected to the two plates of the tube. The filament, being heated, emits electrons; during one-half the cycle the plate P_1 is positive, so that the current flows through the circuit in the direction indicated by the various arrows. During the other half of the cycle the plate

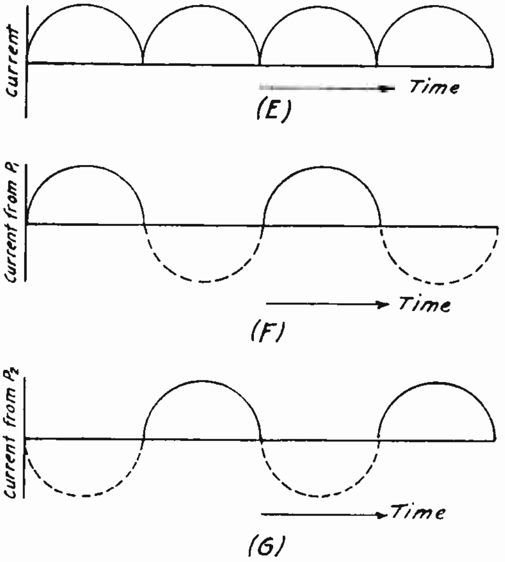

Fig. 27.

P_2 is positive, so that the current now flows in the direction indicated by the arrows in Fig. 26. In each case, you will notice, the current flows out of the rectifier and into the radio receiver at the + (plus) terminal, showing that our current is now unidirectional; that is, it always flows in the same direction. It, however, is not a constant current, but has the wave form indicated by the curve in Fig. 27-(E). Since current flows from each plate to the filament during only one-half the cycle, it is clear that Fig. 27-(E) is obtained by adding together the current waves of the two plates, shown in Figs. 27-(F) and 27-(G).

We have now found a means of obtaining a fairly constant direct voltage by means of which we can operate our radio receiver. It remains now for us to find a means of supplying current to the filaments of the electron tubes, so that we can dispense with the storage battery. This has been accomplished by designing tubes just for this purpose, and by adding other windings to the transformer for supplying the filament current.

There are several ways of obtaining the "C" voltages for the receiver, but for the present we will consider the rather simple method shown in Fig. 25. The output of the rectifier, after passing through the filter, sends current through a high resistance AB, which is variously known as the *output resistor* or *bleeder resistor*. Note that this is a different arrangement from that shown in Fig. 17. Many arrangements and combinations are possible.

There is a voltage of, let us say, 440 volts across the terminals of this resistor. If we require a "C" voltage of —40 volts on the grid of the power amplifier tube, we can call the lower terminal —40 volts. Then, 40 volts above this on the resistor wil be the B— connection, which goes to the cathodes of filaments of the tubes. If we are using a "C" bias detector, perhaps we need a bias of —12 volts on its grid. Then this connection is 12 volts down from B— on the resistor. For simplicity we have marked the B— connection as being at zero potential. Then the plate voltages are plus and the "C" voltages are minus. Various other connections can be made to the resistor, depending upon the voltages we require in the radio receiver. Several voltage taps are shown in Fig. 25. Bear in mind that many combinations of voltages may be used, depending upon the types of tubes used and the particular design of the set.

Before concluding this lesson there remains one thing to be pointed out. That is, when current flows from the output resistor to the plate of any tube and then to the cathode or filament of that tube, it must get back to the B— connection of the output resistor. In Fig. 25 we have shown the cathodes or filament connected to the transformer winding S_3, which supplies the alternating current for heating the cathode. We must therefore show a connection between this winding and the B— tap on the output resistor. This connection is generally made by placing a resistance r across the heater winding, as it is called, and connecting the midpoint of this resistance to the B— tap. This is the connection abc in Fig. 25.

We have now arrived at the end of our "bird's-eye view." By this time you have become acquainted with the fundamental ideas of radio. It is no longer a mystery to you, as you have learned that it is the result of a long period of development. They are the same as the fundamentals of electricity, which were learned years ago. Radiotelegraphy and radiotelephony are highly specialized branches of electrical engineering.

TEST QUESTIONS

Number your Answer Sheet 6—3 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.

1. What amperage should be used for charging a 6 volt storage battery at home?
2. Draw a diagram showing how to charge a storage battery from 110 volts D. C., using lamps in parallel for resistance.
3. What is the purpose of the ammeter shown in Fig. 4?
4. Name the three types of rectifiers or chargers mentioned in this lesson.
5. Draw a wiring diagram of a Tungar charger, naming the three principle parts of the charger.
6. Name the parts used in the two electrolytic chargers described in this lesson.
7. Of what is a dry cell made?
8. Describe the construction of a lead storage cell.
9. What is the purpose of the filter used in a battery eliminator?
10. Draw a complete circuit diagram of a Raytheon tube B-eliminator, showing all choke coils and condensers.


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