The Two Basic Forms of Electricity Which Operate All Radio and Television Equipment

LESSON ND-2

SPRAYBERRY ACADEMY *of* RADIO

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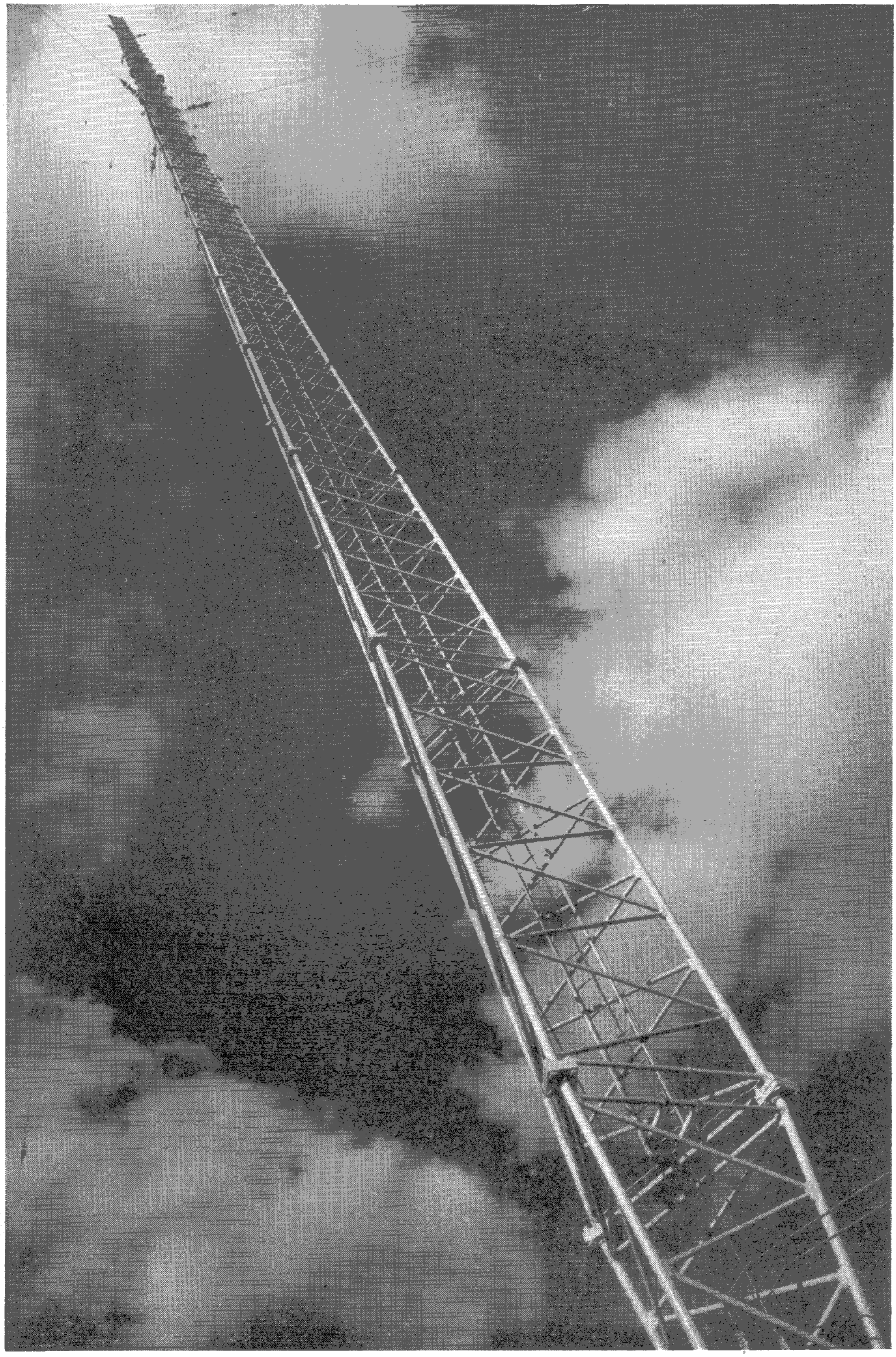
In this lesson you are going to learn much more about the mysterious force called electricity. It continues your basic foundation study and therefore you must give it your undivided attention. Put all the concentration of which you are capable into this entire lesson. This advice is given and emphasized not because the lesson is hard to study, but rather because of the importance of the subject. If you get the right foundation at the beginning you won't have the least trouble with other and more advanced subjects later on. Don't hesitate to take all the study time you feel is necessary for a complete personal understanding of the subjects covered.

Since radio and television are based upon certain fundamental electrical laws, it would be useless at this time to go right into the study of these subjects without first providing you with a basis for the advanced study. So, in this lesson you will study (from a general but not a detailed mathematical viewpoint) the two basic forms of electricity. (1) direct current, abbreviated DC or dc and (2) alternating current, abbreviated AC or ac.

Both forms of current are used extensively in radio and television equipment. There are certain basic reasons why both forms of current are necessary, as you will learn later on, when you begin the study of more advanced lessons. It is well to keep in mind the reasons why DC or AC is used, for it then makes clear in your mind why it is necessary for you to give these subjects careful study.

USES OF DIRECT AND ALTERNATING CURRENTS

First, consider direct current (or to use the more popular term DC) in simple general terms. This is known to flow in one continuous direction at a constant speed, along a suitable circuit. *In a stable circuit it does not vary in value.* It is important to remember the latter statement, so be sure to keep it in mind. Direct current is the type of current obtained from storage batteries, flashlight batteries, etc., and from certain types of mechanical generators, such as the common generator to be found on the average automobile. In radio and television DC is used to operate vacuum tube filaments and various other tube elements. In television DC is used at very high voltages to operate deflector plates of cathode ray tubes, etc. No attempt will be made at this time to explain



Westinghouse Photo

how all of this is done—the main point we want you to understnd right now is that there is a definite need and application for direct current. *Therefore, it is essential for you to study some of the basic laws which control it.*

Next, consider alternating current or AC in general terms. Unlike DC, alternating current does not flow continuously in one direction but it *doubles back and forth at regular intervals.* This type of current has definite advantages in radio and television—in fact radio and television would not be possible without AC, as you will learn later on, because all radio waves or signal voltages are based on the principles of alternating current. *This type of current cannot be obtained from a battery.* It must be generated from a device which has been especially designed to produce alternating current. Such devices are usually mechanical generators of one kind or another, although vacuum tubes can also be arranged to generate AC. High voltage AC is used in the power unit of most radio sets and it is also used at low voltages to heat the filaments of vacuum tubes. The modern superheterodyne radio includes at least one tube (oscillator) which generates a low voltage AC, and all radio signal voltages throughout the radio are of an AC type. It has one very important advantage over DC. Alternating current can be increased or decreased in value by means of transformers. This cannot be done with DC—it can only be reduced in value by means of resistors. *Direct current cannot be increased in value by any known method without changing its form.* The details of all of these things will gradually be made clear as you progress with your lessons. The most important thing for you to fully realize now is the fact that a basic study of AC is vitally essential before you get into the more advanced work. The other things which we have briefly mentioned in the foregoing general explanation will all fit in at the proper place in your studies as you proceed from lesson to lesson.

HOW ELECTRONS MOVE

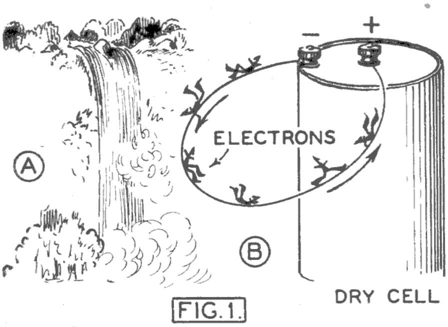
From your previous study you should now understand that electricity is a *dynamic movement* of electrons—that, in many ways, it is comparable to the flow of water in pipes. The *two* most important things to remember about this are:

(1) A force is required to move electrons.

(2) This movement is practically instantaneous.

The latter may be qualified by stating that the effect of the movement is practically instantaneous along the path over which the electrons travel. This is roughly analogous to the flow of water in pipes. When you open a water faucet, the *mechanical force* at the pumping station almost instantaneously causes water to flow all along the pipe—but it is the water already in the pipe that you see at this instant and not the water which is started at the pumping station. The same action holds true for the flow

☞ **Electrons built this 718 foot antenna tower! Without knowledge of electrons and their motions broadcast "waves" could not be radiated from such steel spires, and modern communications would cease to exist. This beautiful photo shows the antenna of KDKA at Pittsburgh.**



Unlike water, which flows from a high level to a lower one (A), electricity flows from negative to positive (B), or from "low" to "high".

of electricity. The force at the source simply sets the electrons in motion, and there is an electron movement all along the path of travel—this constitutes a flow of electrons. With this in mind you are now ready to consider the *direction of electron flow.*

ELECTRICAL CURRENT DIRECTION

Back in the early ages of mankind water was no doubt observed to flow from an upper level to a lower one, as for instance, from a mountain top down into a valley. Thus it probably became a fixed idea down through the ages that all liquids would naturally flow from a high level to a lower one. Now when man first began to get some factual knowledge about electricity, he probably thought of it as a natural, but invisible fluid. No doubt at that time it appeared most probable that this too flowed from a high level (in an electrical sense) to a low level. Early electrical experimenters soon discovered that gravitation did not affect electric current flow. They may have concluded that electricity and water differed in this respect. Yet not having any concrete evidence to the contrary, the chances are that they still thought of electricity as following the observed behavior of the flow of fluids. This probably led them to conclude that electricity flowed from a high pressure level which they called "positive" (from the Latin meaning of the word position) to a lower level of pressure which they called "negative" (also derived from the same Latin meaning).

For a long time then, from the early days of electrical research on down to more recent times, electricity was considered to flow from positive to negative. Before the formation of the *electron theory,* this idea that electricity (which was as yet an undefined from of energy) flowed from positive to negative was accepted as standard. Even today, in much of our present electrical literature, you will find this same statement. It is known now, however, that this original conception is false. It has been proved many times over in recent years that, in reality, current flow is from *negative* to *positive* (Fig. 1) just the reverse of the original conception.

As mentioned previously, electric current flow is not now considered as an invisible fluid but rather is thought of as being composed of a number of particles in *dynamic motion.* These particles are called *electrons* and they are assumed to make up what is now classified as the science of electricity. As a result of the discovery that the electron in motion, moving from atom to atom, actually formed electrical current flow, many exhaustive tests were conducted to determine the direction of motion. *Rectifiers,* which will permit the flow of electrons in only one direction, served to substantiate the electron theory. Because the electron is found in greater abundance at what was formerly chosen as the negative pole, it is considered to have a negative charge—or simply a charge by which the negative pole is identified.

The electron is considered to move dynamically from the negative pole of an electrical source to its positive pole; in other words, *from negative to positive.* A group of electrons, or *negative charges* as they are often designated, is simply called an electron current just as an immensely large group of molecules of water from a current of water molecules in a stream or river. For brevity, *electron current* is often shortened to *current,* which means exactly the same thing.

It is unfortunate that confusion exists in present day literature on the direction of current flow. However, it really makes very little difference to the practical radio man. Either conception of the direction of current flow will generally lead you to the same ultimate conclusion. But for consistency and accuracy in our lessons, we will consider current flow as being from negative to positive.

HOW ELECTRICITY IS MEASURED

In an electrical circuit it is not sufficient to simply say that there is so much electricity. You must know much more about it than that. In the case of a river or stream, to obtain some idea of its

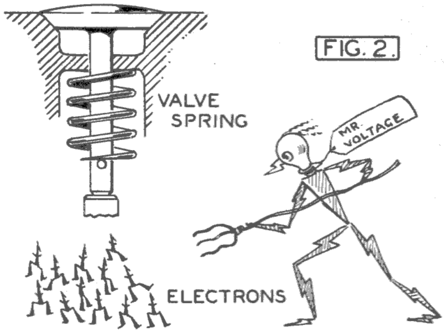


FIG. 2.

Power behind electricity is voltage, like the potential force in a valve spring, is ever-present, whether electrons move or not.

utility, you must know about the force driving the water and the amount of its flow. This pressure or force is known as *voltage.* Other terms used to identify voltage are *electrical pressure, electromotive force* (e.m.f.) *potential, etc.* The voltage is the available force which drives electrons—it actually produces a physical, mechanical or chemical force acting to move or displace electrons in a definite direction. This force may exist whether electrons are dynamically moving or not, just as a motionless spring or weight will act on an object with a definite force (Fig. 2). Electrical pressure or force called *potential* or voltage is always derived from some other form of energy *as it cannot be created.*

The next fact you should know about electricity is the quantity or amount of flow. It is quite easy to appreciate the fact that a very high water fall with but a little water cannot do much work. To determine the ability of the electricity to do work you must know the amount of electron flow, or the quantity of electrons set in motion. Thus to define quantity of electrons in dynamic motion the word *current* is used.

Again, the most perfect example or analogy of current flow is water flow. To get an idea of the *rate of flow* of water you must determine the actual amount of water passing any given point in a given time. One gallon of water flowing past a given point in a spillway in one hour would be quite different from one gallon per second. It is not the quantity of water alone that determines the actual measure of the current of water, but rather the quantity which flows past a point *in a given unit of time.* See Fig 3.

A quantity of electricity would naturally be a number of electrons, and a definite number of electrons make up a *coulomb* (the name given to a measure of electricity) just as a number of water molecules make up a pint of water. When this quantity of electrons, 1 *coulomb,* passes a point in an electrical circuit in one second, the rate of flow of the electron current is 1 *ampere.* To give you an idea of how small the electron is, the number of electrons forming 1 coulomb is calculated to be about 455,000,000,000,000,000. This number of electrons must pass every point in a circuit *every second* to form an electron current of 1 ampere.

There is no point in remembering this large number, but just fix in your mind the idea that an electrical current flow is the rate of a quantity of electrons *for a given unit of time.*

Electrical pressure or force, also called electromotive force (e.m.f.) is measured in *volts* (in honor of an Italian investigator by the name of Volta) just as weight or force

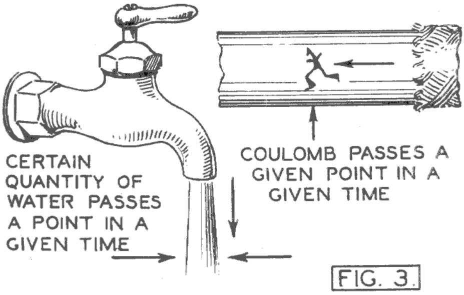


FIG. 3

Just as the rate of flow of water is determined by the quantity passing a given point in a certain time, so electric flow is determined by a coulomb passing a point in a circuit in a second.

is measured in pounds. Whereas, there are many units of weight or force, such as the gram, ounce or ton, there is only one unit of electrical force, *the volt.* (There are divisions or multiples of it such as a microvolt, which means a millionth of a volt).

Likewise, for rates of current flow the current unit *ampere,* is used in honor of the famous eighteenth century French scientist, Andre Marie Ampere.

The ampere, of course, *includes time* just as the expressions *miles per hour or gallons per minute do.* You know that an automobile does not have to travel 30 miles to have a rate of speed of 30 miles per hour. It is traveling at this rate each second or minute. In the same way, an ampere of current may be flowing at this rate for a fraction of a second or for any length of time.

You now have *the two foundation ideas about all electricity;* a force to move electrons (*voltage*) and a flow of electrons along a conductor (*current*). Obviously, the force or voltage pushes the electrons along, causing the current flow, but how much force is required for a given rate of flow of current, or how much current will be produced by a given force?

RESISTANCE AND OHM'S LAW

Current will flow through any substance, but it takes a great deal more force to make current flow at a specified rate in one substance than in some other. For example, you cannot say that it requires 1 lb. of force to move a paddle or oar in any medium at a certain rate. You probably know from experience that it requires much more force to move an oar in water than in air. Likewise, it would require still more force to move it in liquid tar and almost an indefinitely large force to move it if frozen in ice. Figure 4 portrays this graphically. On the other hand, if the oar is placed in a chamber from which the air has been pumped, it will move even more easily than in air. If you could obtain a perfect vacuum (total absence of air), no force at all would be required to move the oar.

Thus it is with voltage and current—the force (voltage) required to move electrons *depends on the nature of the substance through which they are moved.* It depends, as in the example of the paddle or oar, on the *opposition offered to its motion,* called *resistance.* Electrical resistance to the movement of electrons varies immensely from one substance to another and depends on the nature of each substance. You can measure this opposition or resistance so that you may tell how much effect a certain voltage will have on a number of electrons in various materials.

This is easy to understand, and you should have no trouble in seeing that the greater the resistance, the greater the voltage must be in order to keep the same amount of current moving.

Thus you will see that there is a very definite relation between *voltage, current* and *resistance.* A famous German scientist, Dr. G. S. Ohm, has reduced this relation to a very simple and definite form. From this form one of the most important and fundamental electrical laws is obtained, *Ohm's law.*

Dr. Ohm generated 1 volt and placed it across a circuit which was adjusted to carry exactly 1 ampere of current. The amount of resistance used he regarded as his stand-

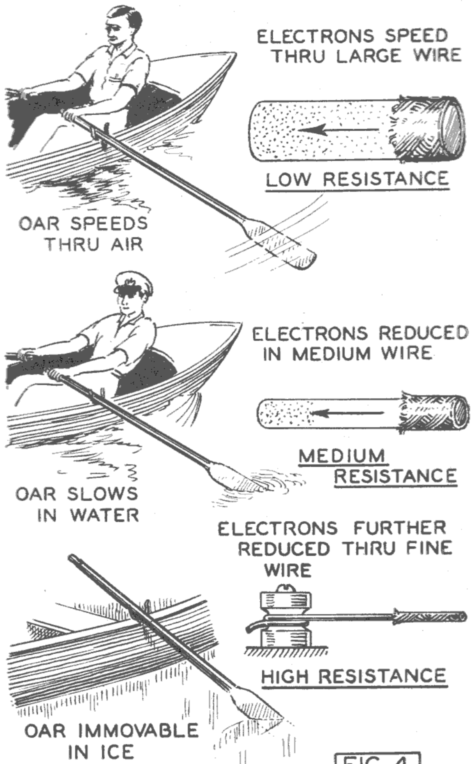


FIG. 4.

Resistance offered by various substances to electron current flow may be roughly compared to the action of an oar in different mediums. In air, as at top, there would be very little resistance to the oar's motion. In water, the oar is greatly impeded, in ice, immovable.

ard unit of resistance, and it has since been called an *ohm* in his honor. Thus, today a unit of *resistance* is known as 1 *ohm.*

Such a circuit will, therefore, pass, or permit to flow, 1 ampere of current under a pressure of 1 volt through a resistance of 1 ohm. This shows a very definite mathematical relationship. Actually, Dr. Ohm found that the *current in a circuit is directly proportional to the voltage and inversely proportional to the resistance.* This is the mathematician's way of stating this relationship in as few words as possible. The following word describtion gives the same relationship in more simplified terms. Note that this statement enables you to find the unknown value if you have two known values. Note further that this is given in three forms so that the unknown value in each case becomes (1) *voltage,* (2) *current,* (3) *resistance.*

Dr. Ohm found that:

(1) The value of the voltage in volts is *always* equal to the value of the current in amperes multiplied by the value of the resistance in ohms.

(2) The value of the current in amperes is *always* equal to the value of the voltage in volts divided by the value of the resistance in ohms.

(3) The value of the resistance in ohms is *always* equal to the value of the voltage in volts divided by the value of the current in amperes.

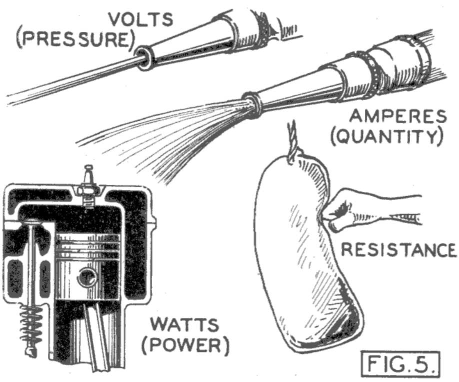


FIG. 5.

Meanings of the various terms used to define electron "performance" may be clarified by the above analogies. Volts, pressure of water in a hose; amperes, quantity of water flowing; Watts, "horsepower", as in an engine's cylinder; resistance is compared to a sandbag slowing or stopping fist.

The foregoing word statement shows the definite relationship of Ohm's law. However, practical radio men don't want to be bothered with such a long statement. A more convenient method has been adopted and you will find it more easily remembered. Instead of words to describe the relationship of Ohm's law, letters of the alphabet are used. The common method is to let E represent voltage (the E being the first letter of *electromotive force*). I represents current (in this case denoting the *intensity* of current flow. The letter R, of course, represents *resistance.* Ohm's law can now be stated very simply in *formula form* as follows:

(1) E equals I times R, or, $E = I \times R$ (volts).

(2) I equals E divided by R, or,

$$I = \frac{E}{R} \text{ (amperes).}$$

(3) R equals E divided by I, or,

$$R = \frac{E}{I} \text{ (ohms).}$$

Ohm's law in the foregoing form is one of the few basic electrical laws *that you should memorize.* You will have occasion to use it over and over again, so be sure to remember it, preferably by letters.

There is one more thing for you

to remember about Ohm's law, and that is, that it applies in every case where D.C. is involved and in a limited way for A.C. The difference with respect to A.C. will be explained in other lessons.

THE WATT, HORSEPOWER OF ELECTRICITY

Now that you have a conception of the nature of electricity in its fundamental form you are prepared to learn more about its usefulness. Whenever an electron or group of electrons move from one place to another, work is performed or energy is expended. You are, no doubt, quite familiar with the fact as applied to everyday life, that in moving an object from one place to another, work is performed. In fact, there is no possible way for anything to be moved from one place to another without performing work or expending energy in some form or another. A force is required in each case, and unless it acts to move something, no work is performed. Thus it is with electrons—for when they are moved from one place to another, work is always performed. When a large number of electrons are moved at great speed, more work is accomplished in a given time than if fewer electrons were moved or moved at a lower speed.

Reflecting from everyday experiences, you know that work may be done fast or slow, depending on the amount of power which is exerted to do the work. In an electrical sense, power may be increased by increasing either the voltage or the current. This has been proved time and again by experiment and mathematics. As a result of this proof another extension of Ohm's law has been made. It has been found that 1 volt multiplied by 1 ampere of current would serve well to equal 1 unit of power. This unit of power has been given the name of *watt* in honor of James Watt of Scotland. Thus you have another term to add to your store of electrical knowledge. In addition to remembering the meaning of *volts, current* and *resistance,* you should also remember that a *watt* means a unit of electrical power—representing the *amount of energy* consumed in an electrical circuit. See Fig. 5.

A lengthy word description and a short formula form may also be used to show the relation between voltage, current, resistance and power. The word description is as follows:

(1) Power equals the value of the voltage in volts, multiplied by the value of the current in amperes.

(2) Power also equals the value of the voltage in volts *squared* (to square a number, multiply that number by itself), divided by the value of the resistance in ohms.

(3) The third form: power equals the value of the current in amperes *squared,* multiplied by the resistance in ohms.

In formula form the same relation as already given would appear as follows:

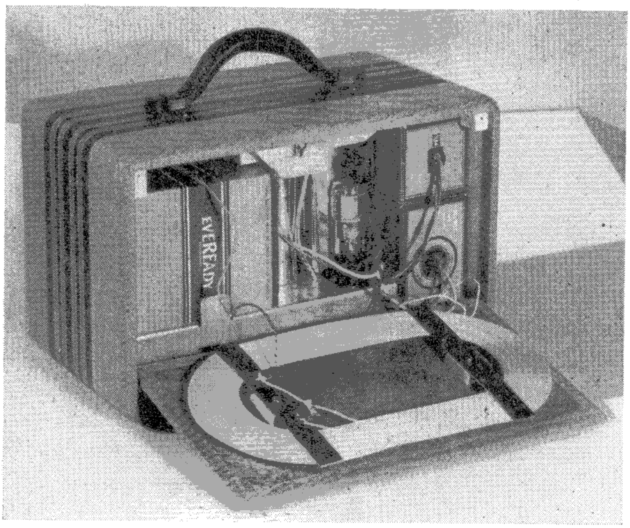
(4) $W=E\times I$

(5) $W=\frac{E^2}{R}$

(6) $W=I^2\times R$

Where:

W=power in watts.
E =voltage in volts.
I =current in amperes.
R =resistance in ohms.



Two types of current are employed to operate radio and television equipment, direct (DC) and alternating (AC). The common small portable receiver at left uses both kinds—DC when working by its batteries, AC when plugged into the regular household current supply.

Photo Courtesy Philco

The small number 2 to the right and slightly above E and I indicates that these values are to be squared (See your SAR math book).

You should note particularly that three formulas are used in the foregoing. The reason three are necessary is because in each case *two values are known.* The third value is, of course, *unknown,* nor do you need to know more than two of the values in order to find the value of the power. Thus, in any DC type of circuit if you need to know the amount of power the circuit consumes, you can find it by simple arithmetic if you know any two of the three fundamental electrical units involved. In AC certain other things prevent formulas 4, 5, and 6 from holding true in every case. Those things will be taken up at the proper point in your studies.

In formulas 1, 2, 3, 4, 5, and 6 we have given you the fundamental relationship between the units of electricity of the DC type. The following formulas include the several variations of Ohm's law for DC, where power values are also included.

$$(7)\quad W = E \times I \text{ or } I^2 \times R \text{ or } \frac{E^2}{R}$$

$$(8)\quad E = I \times R \text{ or } \sqrt{W \times R} \text{ or } \frac{W}{I}$$

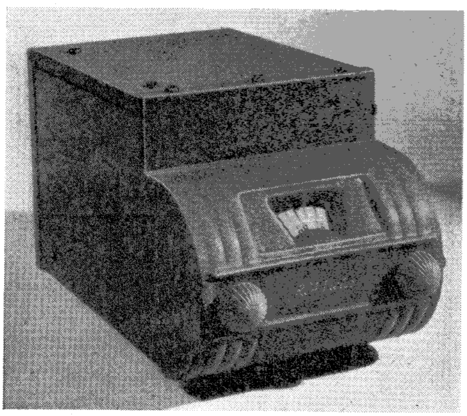
$$(9)\quad I = \frac{E}{R} \text{ or } \sqrt{\frac{W}{R}} \text{ or } \frac{W}{E}$$

$$(10)\quad R = \frac{E}{I} \text{ or } \frac{E^2}{W} \text{ or } \frac{W}{I^2}$$

The foregoing formulas combine the first six already given and places them all together with the power symbols, for easy reference. In using formulas 7, 8, 9 and 10 read across from left to right. For example, if your problem should involve I as the *unknown value,* read across from left to right, using Formula 9. For such a problem you must have two known values. For instance if you know the value of the voltage and the resistance select the formula $\frac{E}{R}$. If only the power and the resistance are known use $\sqrt{\frac{W}{R}}$. If the power and voltage are known use $\frac{W}{E}$. The following symbol √, is called a radical, and means that you are to take the square root of the value inside the radical. See your SAR math book for more information on squares and square root.

Ordinarily, you will not be required to make use of the power formulas in radio work except where you may need to calculate the power rating of a replacement part. These parts are usually designed in standard power ranges and all you need to do is to select the proper part from these manufactured standards. Thus, as you can see, these various formulas are included principally for reference.

You should now have a good understanding of the three main units of electricity. These are *voltage, current and power*. It is most important that you know just what these represent. If you have any doubt about their meaning, do not go on until you have restudied



RCA Photo

Automobile radios, like the model above, work on direct current, using the car's storage battery as the source of supply.

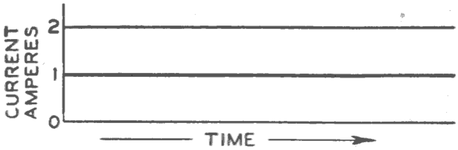


FIG. 6

what has been said about them. It is far better to spend a few extra hours of study at this point than to go on with only a vague idea of just what they represent. If you are satisfied that you have learned just what voltage, current and power mean, then you are ready to take up the study of *Alternating Current*.

ALTERNATING CURRENT

It has already been briefly mentioned that *direct current* (DC) flows along an electrical circuit in one direction—that is, the start of electron motion is at the negative terminal of the source of current. The effect of this electron motion is felt all along the electrical circuit from the negative to the positive terminal of the source—*but keep in mind that this is in one direction*. Also the *value* of the voltage and the current remains the same—that is, in any given circuit, once the voltage and current reach their maximum values, they maintain these values until the current is cut off. This is the type of current obtained from dry cells, storage batteries, etc.

In electrical literature this type of current is *represented* by a straight line as in Fig. 6.

Alternating current (AC) is very much different from direct current—not only in its direction of flow, but also in its behavior.

Also, it follows a different set of laws.

You can think of water flowing along a pipe in one direction and you can compare it to DC flowing in one direction along a wire circuit.

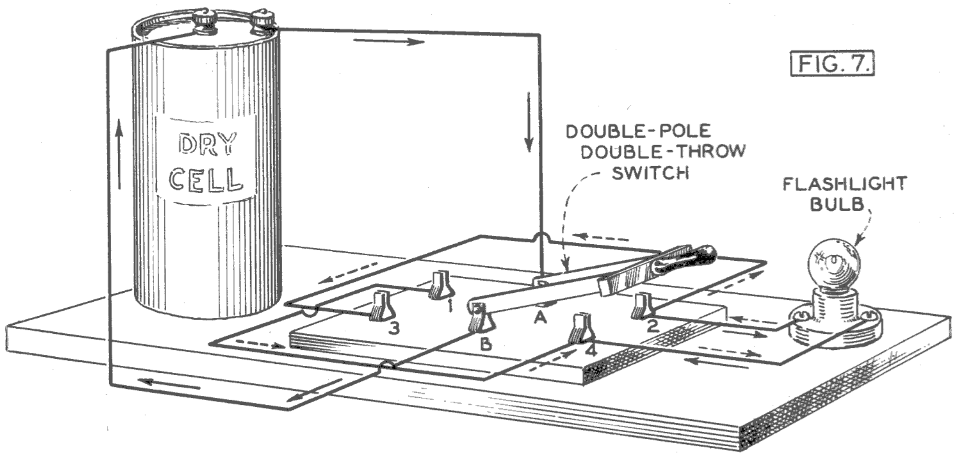
You can make from this a definite and rather complete picture in your mind about the general nature of direct current. When you consider *alternating current*, however, you cannot easily compare it to the flow of water because there is no water flow in nature which will correspond to the flow of alternating current. You must, therefore, think of AC in a different manner entirely. You must forget about the analogy of the flow of DC as compared to the flow of water and begin to think in more strictly electrical terms when you consider AC. This is an abrupt change in train of thought, but is something you can easily do if you will keep in mind what you have already studied.

It will help you in your elementary understanding of AC if you will remember at all times that AC follows a set of known laws. Thus, to understand AC, all you have to do is to learn these AC laws. Your understanding of the whole general subject will be easy and complete—you will learn step by step one subject at a time—each page will unfold more and more knowledge. In this way you'll gradually become the radio expert you want to be.

AC BACKS UP

Alternating current's most distinguishing characteristic is its reversal in direction of current flow. There are two things you must remember about alternating current; first, it is continually reversing. Its effect goes in one direction so far and then it stops and immediately its effect is exhibited in the opposite direction. This action is then repeated all over again continuously, one electrical impulse following another in regular order. *Second, the value of both the voltage and current is continually changing.* This, of course, is a natural consequence of the character of reversal in direction of current flow. It follows that, if the current starts out in one direction, and then stops and again starts in the opposite direction, that neither the voltage nor current can be constant *because in first starting out both have to start from zero.* Thus, it is easy to see that both the voltage and current must change simply because of the very character of starting and stopping. This is comparable to an automobile starting and stopping in that various speeds are required to complete the action. *You should, therefore, keep this important changing character of the voltage and current in mind at all times.*

A simple electrical circuit consisting of a switch, dry cell and flashlight bulb may be used to roughly illustrate how current may be made to reverse. This simple circuit is shown in Fig. 7. The center pole of the dry cell is positive and the one to the right of it is negative. (note from the solid arrows that current flows from negative to positive.) The heavy lines between the dry cell, switch and bulb represent wire circuits (a later lesson will explain more about wire circuits) and provides



The simple electrical circuit shown above demonstrates practically the action of alternating current in your home lighting circuit. Reversing the switch handle from contacts at right to those at the left of terminals AB causes the current flow to change direction, as indicated by solid and dotted-line arrows (see text).

an electrical path over which current may flow.

Note the switch has four contacts numbered 1, 2, 3 and 4 in Fig. 7. These are known as fixed contacts and do not move. In the center of the switch two other contacts (A) and (B) are provided, with metal blades attached to them. An insulated handle is attached to the other ends of the two switch blades which are movable. Thus, with the switch handle to the right contact (A) is made to touch contact 2 and contact (B) is made to touch contact 4. With the switch handle turned to the left contact (A) is made to touch contact 1 and (B) is made to touch contact 3.

The dry cell has its terminals connected to contacts (A) and (B) of the switch. The flashlight bulb is connected one terminal to contacts 2 and 3 of the switch while the other flashlight bulb terminal connects to contacts 4 and 1 of the switch.

With the switch handle turned to the right, an electrical circuit will be formed from the negative of the dry cell to contact (A), from there to 2, (to 3 also, but not used in this case) and then on through the flashlight bulb back to 4, (also 1 but not used in this switch position) to (B) and then to the positive terminal of the dry cell, thereby completing the circuit and causing the flashlight bulb to light. The solid arrows show the direction of current flow in this case.

Now, imagine the switch handle turned to the left. When this is done, electrical contact between (A) and 2 and between (B) and 4 is broken, thus interrupting the circuit. In the new position (A) will now touch 1 and (B) will touch 3. Thus, there is a new circuit from the negative of the dry cell to (A), to 1 (and 4, but not used in this case), and from there on through the flashlight bulb to 2 and 3, (but 2 not used in this case); to (B) and on back to the positive terminal of the dry cell again, completing a circuit and causing the flashlight bulb to light.

The arrows with dotted lines show the direction of current flow in this case.

Now, to get the complete picture of this action, note that with the switch handle thrown to the right, current flows through the flashlight bulb in one direction, as shown by the solid arrows. When the handle is thrown to the left, current flow is made to reverse from what it was before, as indicated by the dotted arrows. Note, too, that the direction of current flow from the dry cell itself has not been changed. The direction of current flow in the switch and flashlight bulb, however, is changed. This is caused solely by changing the position of switch contacts (A) and (B), first, to 2 and 4 and then to 1 and 3.

It should now be clear to you that it is easily possible to reverse the direction of current flow in a circuit. You should now understand also that throwing the switch handle in Fig. 7 from one position to the other rapidly several times in quick succession will cause an equal number of reversals of current flow. In fact, if you could manipulate the switch handle fast enough the flashlight bulb would appear to be lighted continuously, and would not appear to fail to light even though the circuit opened and closed several times per second. If the electric current in your home is AC, it too is interrupted several times per second, but the action is so fast you fail to notice that the lights are not on continuously. This is a practical example of the action of AC in your home.

The dry cell, switch and flashlight bulb circuit just outlined is a crude way to generate AC. There are other and more efficient ways of doing this, as you will learn later on. However, be sure to remember this elementary form of AC, because you will study much more about AC later on and you will need to keep this fundamental concept in mind all of the time.

FREQUENCY

The number of times per second that the current flows, reverses and starts in its original direction is called the *frequency* of the current. Instead of saying the number of times the switch handle flips over or the number of revolutions per minute (when referring to an AC generator), it is common practice in electrical language to say the number of *cycles* per second. The reason for this is that the word *cycle* best describes the action that takes place. *Cycle* means "a complete course of operations of some kind, returning unto itself and restoring the original state." Thus, you see that the word *cycle* is directly related to the AC action just described.

A frequency of so many "cycles per second" has been mentioned. Thus, for a given unit of time so many cycles may occur.

The fact that time is required to complete a cycle is sufficient proof that there is a definite relation be-

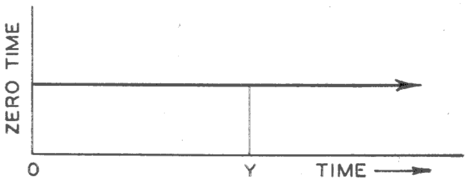
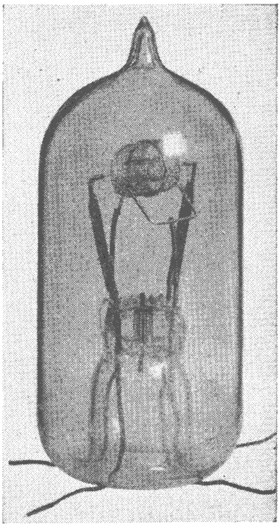
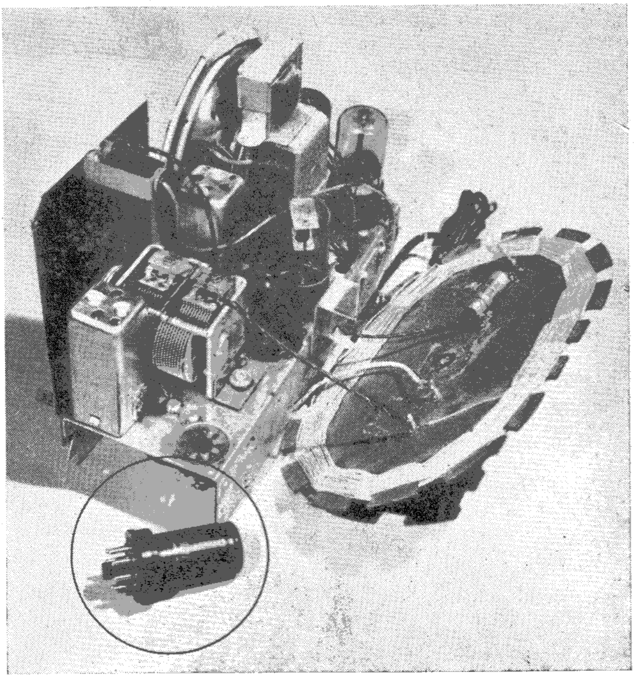


FIG. 8.



General Electric Photo



Two types of radio tubes that generate alternating current are the small ocsillator tube above and the small metal tube from a home receiver (in circle).

tween a cycle and time. When a number of cycles is referred to, *it must be remembered that this, in every case, means so many cycles per amount of time.* The unit of time in practically all electrical work is the second—1/60 of a minute. If in Fig. 7 the switch is reversed 100 times per second, the frequency of the current in the bulb circuit is 50 cycles per second. (Two movements of the switch form a complete cycle.) As a point of information, the frequency of the AC supplied to the homes (over the usual power lines) in the United States and Canada is 25, 40, 50 and 60 cycles per second. The 60 cycle frequency is the most common one in use in the United States. In other countries, the frequency varies over a wider range.

You will remember in a previous part of this lesson it was stated that not only did AC reverse its dection of flow, but also the value of the voltage and current were constanly changing. When AC first starts to flow in a circuit it does not reach a maximum value at the same time that it starts to flow. *It takes time for it to build up from a zero value to a maximum value.*

By now you no doubt realize that this matter of *time* is an important factor when considering AC. You should now also have a full realization that AC actually does reverse its direction of flow and that it takes a certain amount of time (no matter how small) for this action to take place. With this in mind, you will see it is possible to represent time and alternating current on paper in the form of a graph and the use of a word description.

Huge transmitting tubes for the U. S. Navy represent one of the many types of electronic devices required by modern warfare. These tubes make possible fast radio communication between ships at sea and shore stations.

THE TIME FACTOR

Electrical engineers have for many years represented time as a straight line as shown in Fig. 8. The long arrow pointing to the right represents the direction of travel (if it may be said that time has direction), with zero time indicated at the left as shown. *Zero time in this case represents any particular instant of time that you may wish to consider.* Any reference point of time to the right of zero represents time which has elapsed since the start of whatever time you may have chosen for zero. Thus, the point Y may represent $\frac{1}{2}$ second—likewise, any other point along the time line may be made to represent other periods of time. You see, then, how it is possible to represent time on paper. See your SAR math book on graphs.

It is desired to represent both time and AC on one graph or diagram, but before this is done one more fundamental point about AC should be explained. Since you know that AC reverses its direction of flow continually, it follows as logical reasoning that some standard method must be adopted to show current flow in each direction. Electrical men, long ago, adopted such a standard. They agreed to let a horizontal straight line (as along the line O to Y in Fig. 8), represent zero time for AC. They further agreed to show

A·C· CURRENT REVERSES DIRECTION
DURING EACH CYCLE

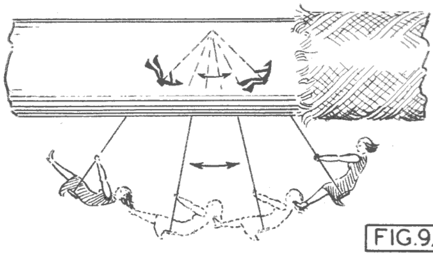


FIG.9.

Like a pendulum or a girl in a swing, AC current doubles back to complete its cycle.

values above this line as AC in one direction and values below the horizontal line as AC in the opposite direction. It then became necessary to give these values names for more clear identification. For values above the horizontal line the common agreement is to call them *positive*. Values below the horizon-line are called *negative*. Thus a complete cycle has one positive half-cycle and one negative half-cycle. Often these half-cycles are referred to as positive alternations or negative alternations. Another term used to mean the same thing, particularly in radio, is *wave form*. Rerefence may be made to one complete wave form (meaning a complete cycle), a positive wave form or a negative wave form. These terms all mean the same thing and refer to the fundamental cycle or parts of a cycle.

It is a common practice in drawing cycles or wave forms to start in a positive direction, showing all proper values above the reference line and then continuing with the negative below the reference line. This is not to say, however, that current flow is from positive to negative (the reverse of what you have previously learned in the SAR course). What it really means is that it has become common practice to designate the first half of a cycle as positive and the second half as negative. *The terms as used in this sense do not refer to the actual direction of current flow (with respect to polarity), nor do they mean that one half of a cycle has any more value than the other.* Both halves of the cycle have the same electrical value and both may be used to perform the same amount of work. In AC, as in DC, the actual direction of current flow is from negative to positive with respect to the individual charges of the electrons which make up the atoms of the conductor. *Always, whether reference is made to a positive or negative alternation of a cycle, current flow continues to be from a negative charge to a positive charge. The direction of alternation of the AC cycle (whether positive or negative) does not change this fundamental concept one iota.*

Be sure you do not confuse these two totally different ideas. *The positive or first half of a cycle and the negative or second half are merely names of the two halves of the cycle. No reference whatever is meant to the actual direction of*

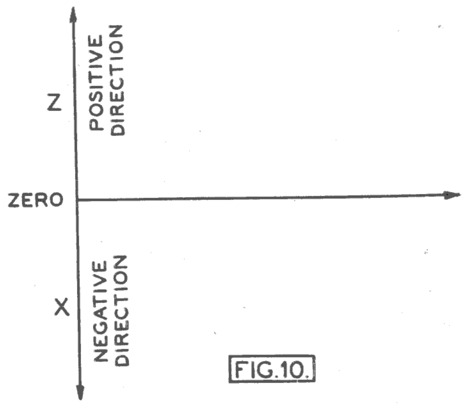


FIG.10.

current flow. In an AC cycle, it is the force that drives or pushes electrons from atom to atom (making up the current flow) that reverses, and not actual current flow direction. Think of this force as being exerted in one direction on a group of atoms and then being suddenly applied on the other side of the atoms and you will better understand the idea. (Fig. 9).

DIAGRAMMING THE AC CYCLE

You are now ready to study positive and negative alternations of AC in graph or diagram form. Refer to Fig. 10. Let the straight horizontal line represent zero, then let positive values be represented

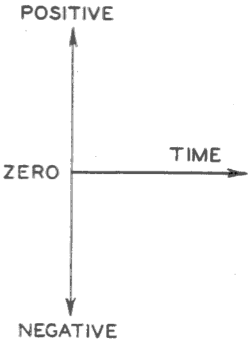


FIG. 11.

above the zero line and negative values below the zero line. Let Z represent a positive value of 10 and also let X equal a negative value of 10. This is entirely arbitrary—other values besides 10 could also be assigned to the points X and Z if you wanted to use other values. *In fact, the positive and negative lines could be so divided that almost any point along them could be evaluated.* This is often done in different kinds of electrical work, as you will have occasion to observe as you progress with your studies.

You will note the vertical line X to Z in Fig. 11, has been assigned AC values in positive and negative directions of the cycle. The horizontal line extending from the center of the vertical line from left to right may be arbitrarily divided into units of time. Thus, one graph may be used to show the relation between two values—in this case time and the cycle (see your SAR book on mathematics for more detailed information). Further along this subject will be described more thoroughly.

Right now, consider the manner in which electrons move in producing alternating current. To get a detailed understanding of this action refer to Fig. 12. Here is an extension of the principles already mentioned. The idea of this figure is to show the movement of *one electron* through one and one-fourth cycles of AC. The vertical lines numbered 1 through 20 represent time and an *imaginary single wire.* One electron is used and you may assume the use of one wire for clarity. The vertical lines represent the same wire but spread out across the page in 20 different time positions, so that the position of the single electron in the wire may be shown with reference to time. This single electron is used as an example to show what happens to *all electrons* in the wire. Actually, of course, there are many billions of electrons in the wire all undergoing pressure (voltage) from the AC generator which is providing the AC driving force.

As you will learn later, the par-

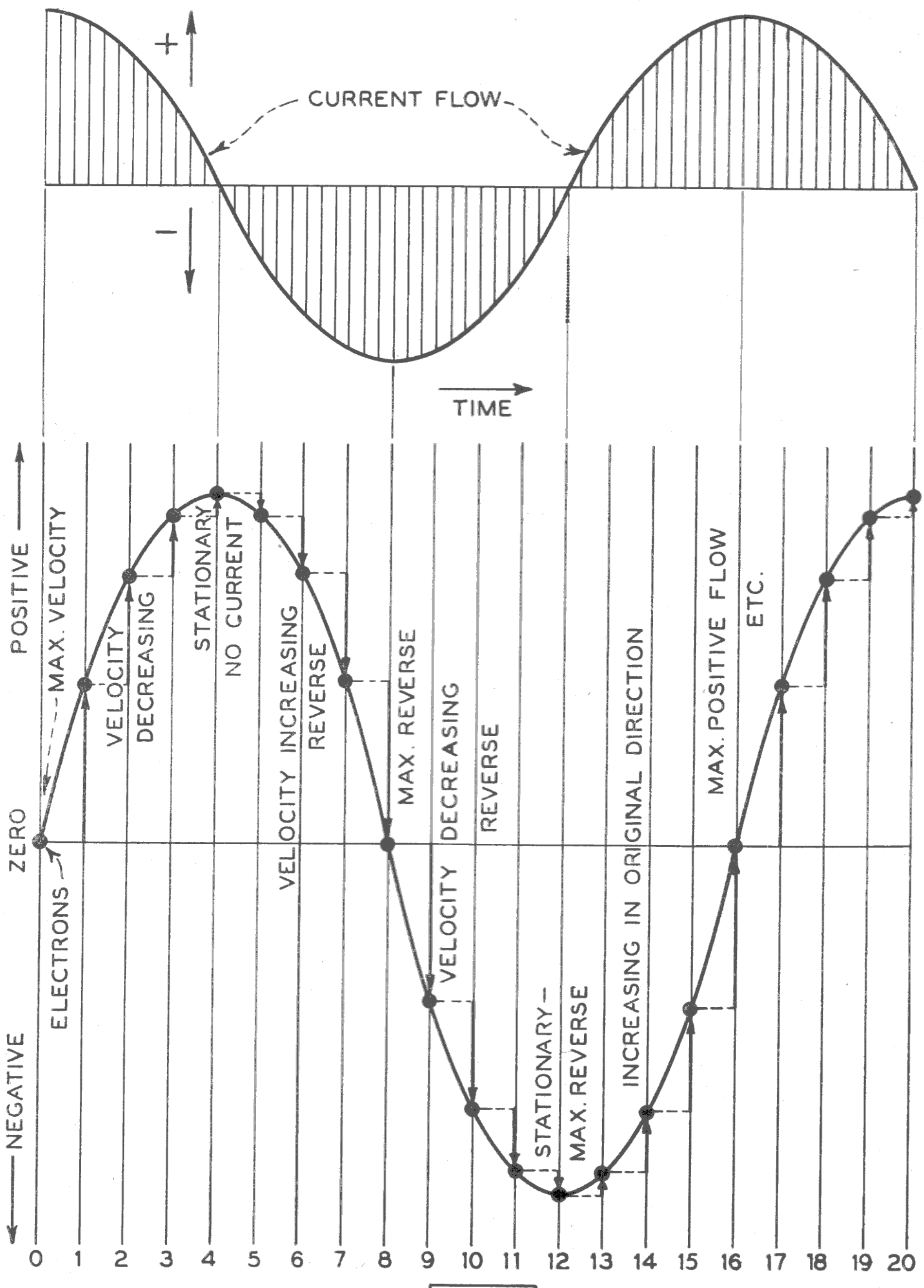
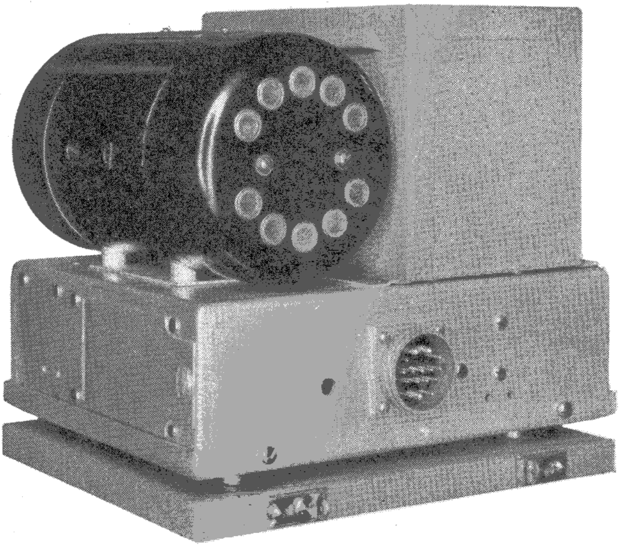


FIG.12.

The AC cycle diagrammatically illustrated. During the tiny fraction of a second required for the electrons to complete one cycle they move through an infinite number of time positions.



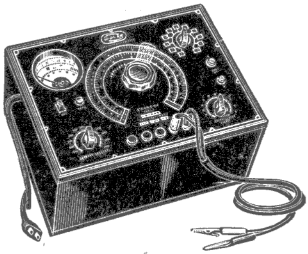
The photo at left shows a modern radio airplane transmitter power supply unit. It includes a generator and elaborate filter with voltage divider to distribute voltage for the various transmitter circuits.

ticular form of the curve in Fig. 12 is the way the usual AC wave form is shown. Note that it rises from zero at the horizontal line in a *positive direction,* increases up to a maximum and then decreases to zero (at the 8th time division). It then begins to increase in a *negative direction* and continues this to the 12th time division, where it again starts to decrease towards zero and finally reaches zero at the 16th time division, thereby completing one cycle. Another one-fourth cycle is shown where the curve increases up to the 20th time division—again starting to form a cycle in the positive direction. Now, return to the electron and imaginary wire and see what happens to them as AC is generated.

Between zero and the first unit of time, the electron has moved a considerable distance upward. It must be understood that all of the free electrons in the circuit move in this manner at practically the same instant. During the next unit of time, the free electron has moved a smaller distance, until at the fourth unit of time it momentarily *stops.*

From the fourth unit of time to the eighth the electron returns to the zero horizontal line. In doing so, *it increases in speed to a maximum.* The lengths of the arrows along the time division lines are a symbol of this increasing speed. Note that as time progresses from 4 to 8 the arrows get increasingly longer and note, too, the greatest increase in speed or velocity is between the 7th and 8th time division. Compare this to the velocity between time divisions 0 and 1, 8 and 9, 15 and 16 and 17. In each case you will note that it is the same. From this, it is obvious that an AC wave form has uniformity and is similarly related to its other corresponding parts. It should now be clear to you that if an electron moves increasingly farther in a circuit for equal units of time, it must accelerate or increase in speed. This is exactly what happens in portions of an AC cycle and it is an important point to remember—more about this later.

From time divisions 8 to 12 the opposite effect occurs. In this case, there is a decelerating effect —that is, a slowing down until at 12, the electron momentarily stops. *The rate of decrease* between 8 and 9 is the same as the *rate of increase* betwen 7 and 8. This,



Later on in other lessons you will start the study of the condenser which is a fundamental unit of radio circuits. The above view shows a tester used to test condensers. It employs what is known as a bridge circuit and uses a sensitive meter to indicate the condition of the condenser. Courtesy of Solar.

again, shows the uniformity of the AC wave form.

From the 12th to 16th time divisions exactly the same action as between 4 and 8 in the other half of the cycle (positive direction). takes place. Here again, there is an accelerating action in which the velocity progressively increases. Note, however, that this time the negative half of the cycle is being completed.

The action between the 16th and 20th time divisions corresponds exactly in every way to that taking place between zero and the 4th time divisions. To identify the cycle and parts of it, note that from zero to 8 is one-half cycle in the positive direction, and from 8 to 16 is one-half cycle in the negative direction. Then, from zero to 16 is one complete cycle. From 16 to 20 is one-fourth of a cycle in the positive direction. Be sure to study the AC wave form in Fig. 12 until you thoroughly understand its general form and manner of action. Much of your future study will be based on this fundamental concept and you should not pass on until you are satisfied with your understanding of it.

CURRENT FLOW AND WAVE FORM

Since you should now have a basic concept of an AC wave form you are ready to learn more about the nature of the actual current flow. Just above the wave form which you have just been studying in Fig. 12, you will note there is another shaded wave form identified as the *current flow intensity. The most important thing for you to understand about this second wave form is that it represents the rate of current flow.* It does not show a true picture of the actual current wave form because, in reality, the wave form of the current itself would appear exactly like the larger voltage wave form shown in Fig. 12 under the conditions assumed for this example. Later on in other lessons you will learn that the current wave form may have a different shape than the voltage wave form which generates it. That, however, is getting ahead of the story, so you should continue the study of the current flow intensity as shown by the smaller shaded wave form in Fig. 12.

Keep in mind that this particular current wave form is intended to show the rate of change of current *flow only.* To help in your understanding of this, think of the larger wave form as a voltage which is generating the current flow. Now, again refer to the larger or voltage wave form. Note that from 0 to time division 4 there is a decelerating action wherein the velocity progressively decreases, indicated by the progressively shorter arrows along lines 1, 2, 3 and 4. The unit of time remains the same *but the rate of velocity changes.* This can only mean that the *rate of current flow* changes. Thus, instantaneously after the wave form starts (with reference to zero or starting time) *the rate of current flow is maximum.* As time goes on from zero to the 4th time division the rate of current flow becomes progressively less, until at 4 the current flow has momentarily stopped. The shaded curve between 0 and 4 shows exactly how the rate of current flow progressively decreases for ¼ cycle in a positive direction.

The next points to observe *on the current intensity curve* are between time divisions 4 and 12. This represents two fourths of a voltage cycle—one-fourth of which is in the positive direction and one-fourth in the negative direction. These two-fourths of a cycle show a decelerating action (from 4 to 8) and an accelerating action (from 8 to 12). Thus, from 4 to 8, the rate of current flow gradually increases from zero at 4 to a maximum at 8. From 8 to 12, there is a decelerating action in that the rate of current flow gradually decreases to zero. From 12 to 16 again there is an accelerating action in that the rate of current flow progressively increases from zero at 12 to a maximum at 16.

As stated before, from zero at the left over to 16 farther to the right, one cycle is completed. However, one more quarter cycle is shown from 16 to 20 so that you may get a complete picture *of the rate of current change or rate of electron movement* for a complete wave form consisting of one complete negative and one complete positive alternation. This complete wave form of the rate of current change corresponds to time divisions from 4 through 20. The other one-fourth wave form from zero to 4 merely serves to show the rate of current change from the beginning of the voltage cycle to the first point of zero current change, which corresponds to time division 4.

Now, from the preceding description, you will note these facts. First, when the voltage is zero, *the rate of current change is maximum.* Second, when the voltage is maximum, *the rate of current change is zero.* This you can prove by comparing the voltage and *rate of current change* wave form at time divisions zero, 4, 8, 12, 16 and 20. This has been proved over and over again by experiments and mathematics, so you can accept it as a fact, or basic law.

Before leaving Fig. 12, there is just one more thing you should thoroughly understand about it. We have repeatedly referred to the *rate of change of current flow.* Also, we have referred to zero rate of current changes as at points 4, 12 and 20. *This does not mean that the actual value of current is zero at these points.* Actually the current may have values of 10, 20, 50, 100 or any other value at these points but the rate of change at these points will always be zero. At all other points on the wave form, there will be a changing current value. It is important that you do not confuse the rate of current *change with the real value of current at these points* on the wave form.

With the foregoing explanation clearly in mind you are ready to take up the study of an AC wave form in which actual current values are considered rather than the *rate at which current changes* in an AC cycle.

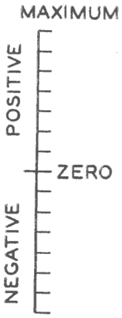


FIG.13.

TIME RELATION TO AC CYCLE

You no doubt now thoroughly understand the principles of representing time and positive and negative values of AC in graph form. If the principles of representing both time and AC in graph form are combined it will be possible to get a concrete representation of AC per unit of time. To do this it is first necessary to lay out a time base by drawing a horizontal line. A vertical line is next drawn to represent positive and negative values of AC. The result will appear as in Fig. 13. Next divide the horizontal time line by using vertical lines across it. The positive and negative vertical line, to the left in Fig. 13, is then divided by horizontal lines across it. (See your book on mathematics and graphs for more detailed information on the construction of graphs.) Next assign values to the time base line. Let the complete time line represent one second, and divide this line into 20th seconds. Then assume that the *maximum value* of AC will be 5 amperes. If this is done, can you then divide the positive and negative lines into units representing amperes. With this done you will have something that you can work with—a graph of an AC wave form as in Fig. 14.

Following standard practice, assume the AC starts out in a positive direction. If it reached its maximum value as soon as it started it would be at point 5 on the positive scale—but this is not what happens. If the divisions on the time line represent 20th seconds, then at 1/20th of one second, the AC will have reached a positive value of 1.54. Although this is an exact mathematical value (by use of trigonometry) you can see from observation that at the 1/20 time division the current is slightly more than 1.5 amperes. As 1/20 of one second has elapsed since the start of the AC, it follows then that the actual value will have to be somewhat to the right of zero time, or more exactly, at the 1/20 time division. Thus, you cannot read the increase in AC value directly on the zero vertical line—but must refer to the 1/20 vertical time line.

After 2/20 of a second of time has elapsed, the AC value will be slightly less than 3 as shown (2.94 actually) and will be read farther over to the right, since more time has elapsed since considering the 1/20th time position. Similarly, the 3/20 and 4/20 time positions would be read still farther to the right, as in each case 1/20 more of time has elapsed. At the 5/20 time

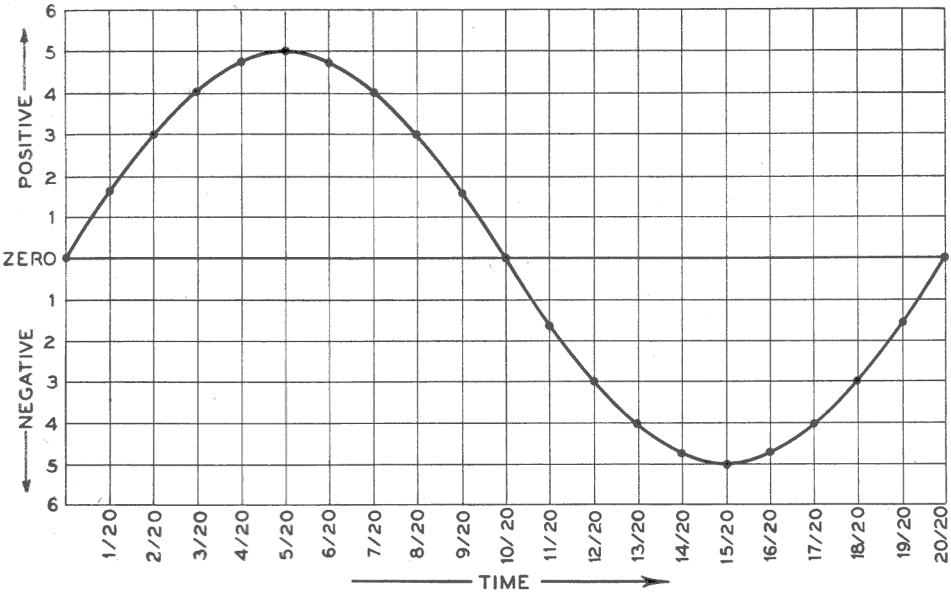


FIG. 14.

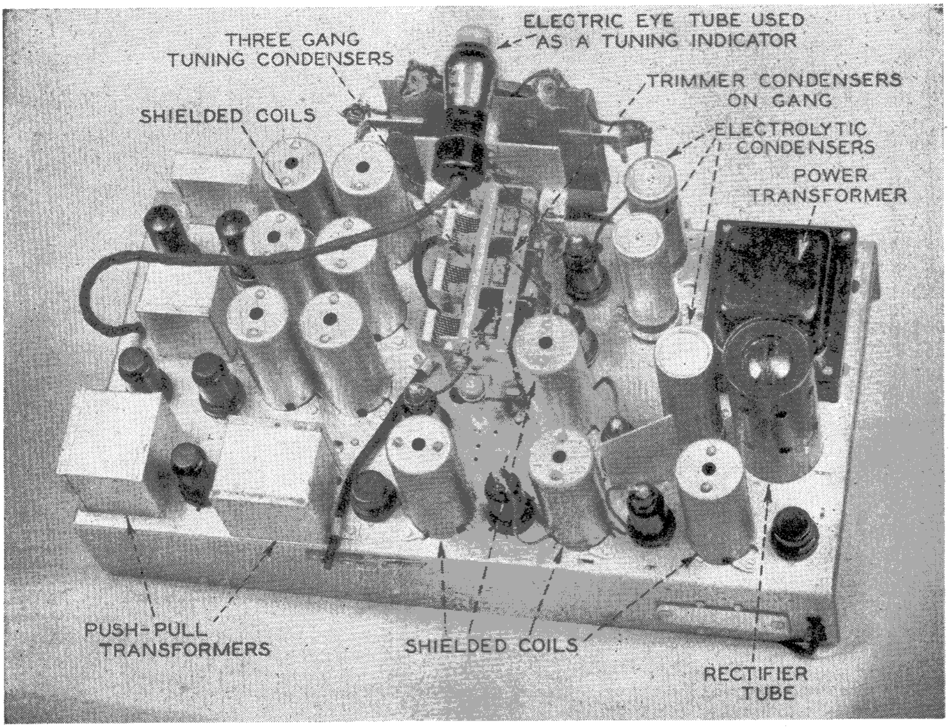
division, the AC has reached its maximum value (zero rate of change) and begins to decrease toward zero (note that the zero, 10/20 and 20/20 time positions are all equal to zero values of AC.)

The reason the AC is now decreasing toward a zero value is that the electrons are coming to rest—slowing down—and will reverse their direction of flow. It takes just as much time for the AC to *decrease* from maximum to zero as it does for it to increase from zero to maximum. Thus, the decrease must be read still farther to the right in relation to time. (Note however, the complete uniformity of the wave form.)

The following groups of two time positions have the *same value of* current flow—1/20 and 9/20 2/20 and 8/20; 3/20 and 7/20; 4/20 and 6/20. The only difference between them is the time element.

When the AC reaches the 10/20 time position, it has reached a zero actual value and is now ready to again increase from a zero to a maximum value—but this time in a negative or opposite direction. It now goes through the same procedure as for the positive half of the cycle. That is, it starts at zero and reaches a negative value of 1.54 at the 11/20 time division and a negative value of approximately 3 at the 12/20 division. It continues to increase in reverse or negative value until it reaches the maximum value of 5 amperes at the 15/20 time division. At this point, it starts to again decrease toward zero, and finally reaches zero again at the 20/20 time division.

The AC has now completed one cycle, and immediately starts to do the same thing all over again—hence there is no need of any further description of its action.

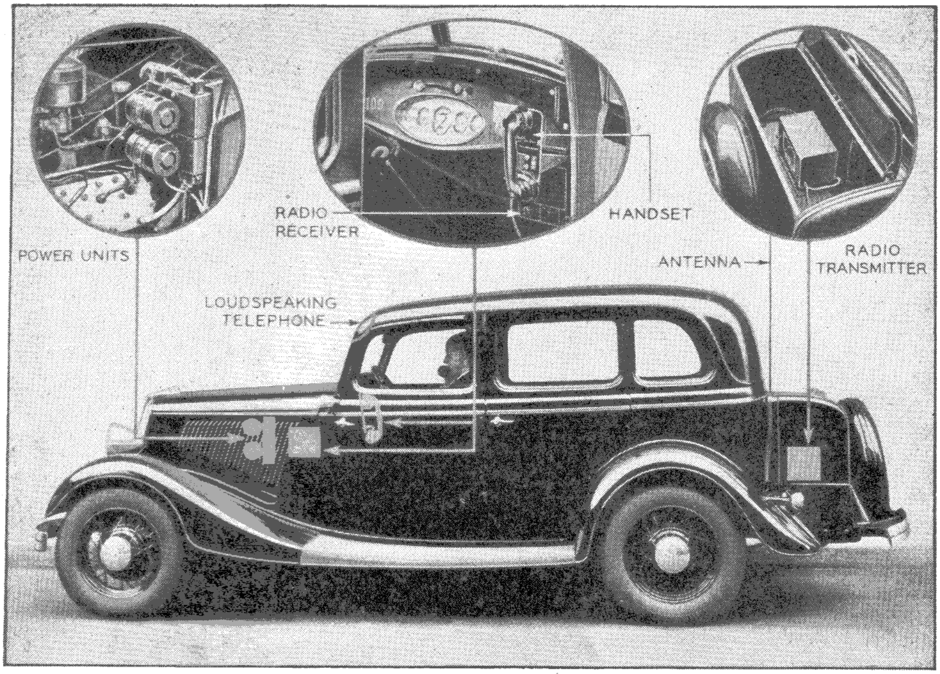


Top chassis view of a 15 tube superheterodyne receiver, with various important components labeled. These will be taken up individually in later lessons.

If it were not for the time element involved, an AC cycle could be represented as a straight vertical line as shown in Fig. 13. That is, AC would increase in value from zero toward maximum in one direction, then it could be represented as going back over the same line of travel to maximum in the other direction. It is perhaps fortunate that time must be considered for it permits spreading out the line of travel so that it may be seen from beginning to end.

Note in Figs. 12 and 14 dots have been placed on the voltage curves at the points where the different time intervals occur. This was done in order that you might visualize the value of AC in relation to time. *Actually the complete curve represents the value of AC at any given instant of time.* Thus, instead of having a series of dots with space between them (the space in this case representing other intervals of time), there is a continuous curved line which shows the actual *form* of the AC from the beginning of a cycle to the end.

While it has required quite a bit of space to describe this action, you must remember that in reality *it occurs very fast*—on the usual 60 cycle power lines, one cycle is completed every 1/60 of a second. When you stop to think just how short is one second of time, you can begin to appreciate at what speed the cycle is completed when the frequency is 60 cycles *per sec-*



WESTERN ELECTRIC PHOTO

Two-way police radio equipment operates on ultra high frequency channel, with transmitter unit held to its frequency by precision crystal. Lifting telephone from instrument panel automatically starts transmitter.

ond. This is a relatively low frequency when compared to radio frequencies. Later on you will learn that it is possible for many, many millions of cycles per second to occur.

IMPORTANCE OF WAVE FORM

In school, you probably studied about graphs. You will remember that graph was a "layout" on paper whereby it is possible to show the relation between two or more quantities. One cycle as laid out in Fig. 14 is, of course, a graph. In this figure, time is plotted against positive and negative values of AC.

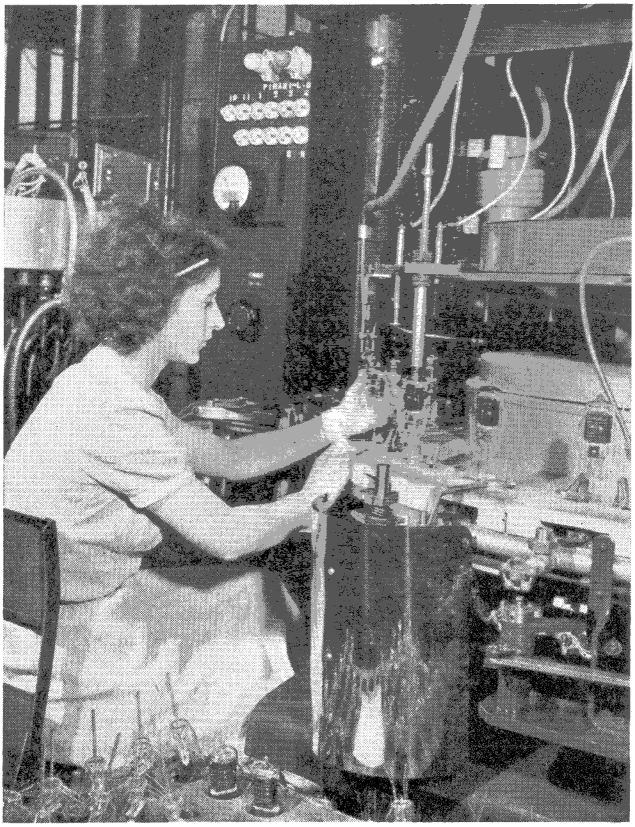
In other electrical and radio literature you will see one or more cycles of AC laid out in a manner very similar to Figs. 12 and 14. However, time and values of AC are not usually indicated, because in most cases, AC values and values of time are not greatly important (there are instances where values are indicated, but the occasion is rare). As a rule, you will be more interested in the *wave shape or wave form* as you will see in progressing from one lesson to another. So, if you see AC wave forms in other lessons without time and positive and negative divisions or scales, just remember these are not always necessary.

BASIS OF RADIO

All of radio is based on the AC principle of progressive changes in value of voltage and current as one or more cycles are completed. If you are able to visualize this action and are able to remember it, then you have the basic knowledge so necessary to the understanding and application of radio principles. Right now you may not be able to realize the full significance of the latter statement, but as you progress with your studies, you will more and more understand just what is meant.

As already stated, radio is based upon a limited number of Electrical Laws. Once you understand and memorize these laws then you also understand radio. You will perhaps realize this better if you compare it to your early attempts to learn arithmetic. At first, the *whole* of arithmetic may have seemed difficult. Just remember however, that you did not learn its principles as a whole, but studied it one subject at a time. When you were through, you had a good understanding of addition, subtraction, multiplication, division, etc. You will study radio principles in the same way. When broken down, subject for subject, the study of radio actually is a very interesting and informative pleasure.

You will, therefore, appreciate the fact that radio principles cannot be learned all at once. There is always the ever important time element. In this lesson you have seen that time is an important factor in the consideration of AC. You should also realize that time is just



Radio tubes during manufacture. They are placed on an automatic exhausting machine which creates an almost-perfect vacuum within the tubes. Each tube undergoes a dozen heating and pumping operations, and at the end has only one out of every 1,520,000 air molecules left inside.

as important in the learning of radio principles as it is in other things. Give yourself time and don't be afraid to go slow with these first few lessons. Try to visualize the principles of the things you study—think about them over and over again. Get the *key* thoughts to each subject and you cannot help but learn radio.

In this lesson you have studied the principles of both DC and AC. From this study, the following terms should be familiar and you should understand just what they mean. If you do not have a good understanding of them, restudy this lesson until everything is clear.

Direct Current (DC)

Polarity (Negative and Positive Values)

Alternating Current (AC)

Time Element	*Resistance*
Cycle	*Power*
Frequency	*Watt*
Voltage	*Alternation*
Ampere	*Wave Form*
Coulomb	*Curve*

FUTURE LESSONS

Your Sprayberry radio training follows a time tested plan which experience has proven to be right because it produces results which, after all, is the test of any training. Over the years, Sprayberry training has been gradually built to its present perfection. As a result, you get the benefit of all this experience and will study the essential elements of radio in such a way that you won't have to wade through a mass of unessentials to reach your ultimate goal. Perhaps you can not appreciate this now but as time goes on, and as you make steady progress with your lessons, you will come to realize the value in training that you are getting.

So at this point we are going to give you a preview of the lessons which are to follow this one in order that you may have a general idea of just what is ahead in your training. Your next lesson is the third in the series and treats *lines of force* of which there are two kinds. These are called *electromagnetic* and *electrostatic*. Electromagnetic lines of force have to do with the magnetic energy associated with coils of wire. The type of coils you will be most interested in are those which are used to form parts of tuned circuits, choke coils, speaker coils, etc. These are known under several names, such as radio frequency, oscillator, first detector, intermedite frequency and audio frequency coils or transformers. Then there are other special types, such as loading coils, iron core choke coils, electromagnets, etc.

The latter portion of the third lesson deals with electrostatics which has to do with the *elements of condensers*. These are used for many varied purposes in radio. Some of the more common uses for condensers are for tuning coils, coupling between stages, filtering, blocking direct current, etc. This part of the lesson merely serves as an introduction to this important subjct. The eighth lesson takes up the subject in detail after other necessary things have been introduced.

These questions are designed to test your knowledge of this lesson. Read them over first to see if you can answer them. If you feel confident that you can, then write out your answers, numbering them to correspond to the questions. If you are not confident that you can answer the questions, re-study the lesson one or more times before writing out your answers. Be sure to answer every question, for if you fail to answer a question, it will reduce your grade on this lesson. When all questions have been answered, mail them to us for grading.

QUESTIONS

No. 1. In which direction do electrons flow along a conductor?

No. 2. Can resistance completely stop all current flow if there is a voltage present?

No. 3. Is it possible for the resistance value (that is, changes in resistance value) to affect the power in a circuit?

No. 4. Describe how electrons move for direct current and give the same description for alternating current.

No. 5. Refer to Fig. 14. At what time intervals does the current completely stop flowing (zero current)?

No. 6. In Fig. 14 the positive and negative vertical numbers represent amperes. Study this figure and give all the time intervals when the current is flowing at the rate of 4 amperes in either a positive or a negative direction.

No. 7. Why is it that you can determine all you want to know from AC by studying only one cycle?

No. 8. What is meant by the expression—"This generator is capable of producing a frequency up to 100 cycles"?

No. 9. If the voltage in a circuit is 20 volts and the power is 6 watts what is the resistance of the circuit?

No. 10. Does an alternating current circuit always have the same polarity?