# INTRODUCTION

Since the discovery of electricity, a great deal has been learned about it and many ways have been devised to use it in performing tasks which were formerly done by hand, or other cumbersome methods. Electricity has made possible the introduction of many labor-saving devices such as electric light, electric power for motors, and electric heating units.

Electricity, as it is used to power cranking motors for engines, makes starting of engines much easier and less hazardous than the previous hand cranking method. The modern gasoline engine could not be run without electricity to furnish the spark to ignite the fuel in the cylinder. These and many other applications of electricity are used on our modern tractors and farm equipment.

On the following pages is a discussion of the fundamental principles behind the application of electricity to tractors and farm equipment. It is the aim of this manual to present these fundamentals in a manner which will make the farm equipment service man better able to understand the operation of the electrical equipment on farm machines. An understanding of the material covered in this basic manual will enable the service man to understand better the service procedures covered in service manuals on electrical equipment.

# FUNDAMENTALS OF ELECTRICITY

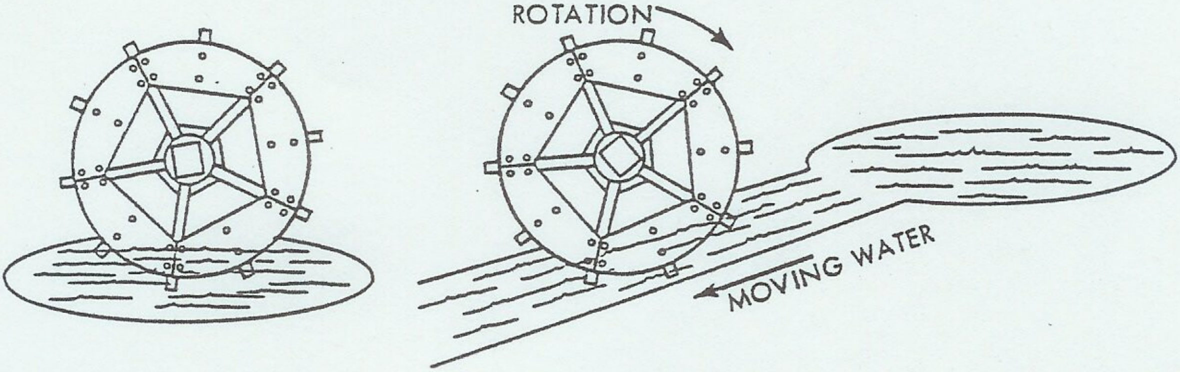
## Definition of Electricity

Electricity can be defined briefly as a form of energy. Since energy is the capacity for doing work, it follows that electricity, if properly harnessed, can perform work. This work can take the form of motion as in the case of electric motors, or heat as in electric heaters, cigarette lighters, etc. or it can produce light as in a light bulb.

## Nature of Electricity

In order to have a better understanding of how electricity can be used to perform work. we need to know something about the nature of this form of energy. No one knows specifically what electricity is. Electricity is present in everything, for example, our body, clothes, paper, furniture etc. The reason that we are not aware of its presence is because it is not in motion.

Electricity can be compared with water. For example, if we were to place a water wheel in the middle of a pond, the wheel would not turn, but if we place the wheel in a position where water can flow past the blades, the wheel would turn. (Illust. 1.) The motion of the water causes the wheel to turn. The same is true of electricity, when we put it in motion we can obtain work from it.




Illust. 1

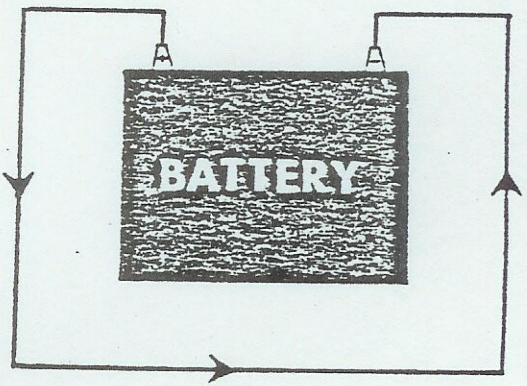
In order to get the water wheel to move, it was necessary to have a current of water flowing; and so it is with electricity. There must be a "current" or "flowing" of electricity before we can get any work out of it.

To continue our water analogy, we know that in order to move the water to perform work, it is necessary to have a trough or pipe to carry the water from the source to where it is used. So it is with electricity, it must also have a path to follow. This path is called a conductor. This conductor can be made from any material which will conduct electricity. Some of these are, copper, aluminum, steel or iron.

Electric current will flow in a conductor provided there is a pressure forcing the electricity to move. This pressure is called electromotive force or voltage. The amount of pressure or voltage which is required to make the current flow in a conductor varies depending upon the amount of resistance in the conductor. There is resistance to current flow in the conductor just as there is resistance to the flow of water in a pipe.

## ELECTRICAL CIRCUIT

Electricity can be made to flow in a conductor provided there is pressure (voltage) applied. This is true provided that the conductor is arranged to provide a continuous path from the source of electricity back to the source. This conducting path is called an electric circuit. To illustrate this, let's use a source of electricity that we are all familiar with, a storage battery. The storage battery is a chemical source of electricity. As we know, this battery has two posts or terminals, one of which is marked "positive" (+) and the other "negative" (—).




Illust. 2

If one end of a wire is attached to the positive terminal "A" and the other end to the negative terminal "B," we will have created an electric circuit and current will flow through the wire (Illust. 2). This is true because we have created a continuous path from the positive terminal of the battery through the wire and back to the battery at the negative terminal. The direction of current flow will be from positive to negative.

## RESISTANCE

Any conductor has resistance to current flow, so it is necessary to overcome this resistance with pressure (voltage) to make the current flow. With a given pressure (voltage) such as is produced by the battery, the amount of current which will flow will depend upon the amount of resistance in the circuit. The more resistance there is in the circuit, the less current will flow and conversely the less resistance in the circuit, the more current will flow. In order to perform work with electricity, it is necessary to put it in motion (that is) we must have current flowing in a sufficient amount to do the work required. Therefore, it is necessary to pay close attention to the amount of resistance present in a circuit.

## FACTORS AFFECTING RESISTANCE IN A CIRCUIT

There are a number of factors which affect the amount of resistance in a circuit and these must all be considered when setting up an electrical circuit to do a particular job.

For example, the simple circuit in Illust. 2 has only the wire conductor to cause resistance to current flow. In this case, the factors affecting the resistance are:

1. The material from which the wire is made.

   Metallic substances such as copper, aluminum, steel or iron are good conductors. This is because they have a relatively low resistance to current flow. These materials, therefore, are often used as conductors. Copper is by far the most commonly used because it has a low resistance to current flow and is relatively cheap. Copper is also desirable for conductors because it is soft and bends easily without breaking. This simplifies forming the conductor in the shape desired to make up a circuit.

   Most metallic substances have a relatively low resistance to current flow and may, therefore, be used as conductors. Engine blocks or the frame of a tractor can be used as conductors and often are used to reduce the amount of wire necessary to complete circuits.

2. Diameter of Conductor.

   Another factor which affects the amount of resistance present in the wire used in Illust. 2 is the diameter of the wire. It has been determined that the larger the wire, the less resistance to current flow will be present. Therefore, if a circuit must carry a large amount of current, a wire of large diameter should be used.

3. Length of the conductor.

   The total resistance of a circuit depends also on the length of the wire since a given amount of resistance per unit length is present. This being the case, the length of the wire becomes an important factor when considering the current carrying capacity of a circuit.

4. Temperature of the conductor.

   When the temperature of a conductor increases, the resistance also increases in direct proportion, that is, for each degree rise in temperature of the conductor, there is a corresponding increase in the amount of resistance. This fact makes it important that the conductor be of sufficient size to carry the current required without heating.

## OTHER TYPES OF CONDUCTORS

We have considered up to this point resistance as it exists in a wire conductor such as used in the simple circuit shown in Illust. 2. However, the conductor need not necessarily be a wire. It can be the frame of a machine or unit of a machine. It can also be a liquid. The liquid in a storage battery is a conductor of electricity. Even air will conduct electricity but the resistance is so high that it takes a great deal of pressure (voltage) to make the current flow.

## INSULATORS

We have considered materials with relatively low resistance which are used as conductors of electricity, but what about other materials with high resistance to current flow. Many materials have such a high resistance to current flow that no current will flow through them unless the pressure (voltage) is very high. This makes them of little value as conductors. Many of them do have a value however, to prevent current from flowing in the wrong path. Electric current will flow through the material offering the least resistance. Therefore, it is necessary to use a material of high resistance around conductors to prevent the current from deviating from the path provided. This material is called insulation.

Rubber, fabrics, glass, enamel, and air are examples of good insulators and are commonly used for that purpose. These materials have such a high resistance to current flow that a thin layer around a conductor will prevent current from straying from its normal path. Air, while it is a good insulator, is not too practical for insulating wires because it will not support the wire and keep it away from other conductors.

## Measurement of Voltage, Current, and Resistance

In order to properly use electricity and control it for our use, it is necessary to have some means of measuring voltage, current and resistance of the various components. We have said that electricity will flow in a conductor as a current of water flows, provided there is pressure, which we have called voltage, present to make it move. The unit of measurement for this is called the "volt." The unit of measurement of current is called the "ampere" and the unit of measurement of resistance is called the "OHM." The relationship between these three factors is very definite and conforms to a very definite rule known as "OHMS LAW." This rule states that the electrical current through a conductor equals the pressure divided by the resistance. In terms of the electrical units of measurement, this may be stated as:

$$\text{AMPERES} = \frac{\text{VOLTS}}{\text{OHMS}}$$

By means of this equation if two of the quantities are known, the third can be calculated. It follows then that we must have some way of measuring at least two of these factors.

In order to make these measurements, it is necessary to have instruments which will measure volts and amperes. These instruments are called voltmeters and ammeters, or a combination of both. Most modern meter movements are of the moving coil type which consists of a permanent horse shoe or hoop shaped magnet and a movable coil. Current flowing through the movable coil reacts with the permanent magnetic field causing the coil to rotate against a light spring tension. The relative movement of the coil is in proportion to the amount of current flowing in the windings. A pointer attached to the coil moves across a calibrated scale indicating the amount of current flowing in the coil. See Illust. 31.

The same meter movement can be used for either a voltmeter or an ammeter. It becomes a voltmeter when connected in parallel with the circuit, and an ammeter when connected IN SERIES with the CIRCUIT.