HAZARDS OF ELECTRICITY

The primary hazards associated with electricity and its use are:

- **SHOCK.** Electric shock occurs when the human body becomes part of a path through which electrons can flow. The resulting effect on the body can be either *direct* or *indirect*.

  - **Direct.** Injury or death can occur whenever electric current flows through the human body. Currents of less than 30 mA can result in death. A thorough coverage of the effects of electricity on the human body is contained in the section of this module entitled *Effects of Electricity on the Human Body*.

  - **Indirect.** Although the electric current through the human body may be well below the values required to cause noticeable injury, human reaction can result in falls from ladders or scaffolds, or movement into operating machinery. Such reaction can result in serious injury or death.

- **BURNS.** Burns can result when a person touches electrical wiring or equipment that is improperly used or maintained. Typically, such burn injuries occur on the hands.

- **ARC-BLAST.** Arc-blasts occur from high-amperage currents arcing through air. This abnormal current flow (arc-blast) is initiated by contact between two energized points. This contact can be caused by persons who have an accident while working on energized components, or by equipment failure due to fatigue or abuse. Temperatures as high as 35,000°F have been recorded in arc-blast research. The three primary hazards associated with an arc-blast are:

- **Thermal Radiation.** In most cases, the radiated thermal energy is only part of the total energy available from the arc. Numerous factors, including skin color, area of skin exposed, type of clothing have an effect on the degree of injury. Proper clothing, work distances and overcurrent protection can improve the chances of curable burns.

- **Pressure Wave.** A high-energy arcing fault can produce a considerable pressure wave. Research has shown that a person 2 feet away from a 25 kA arc would experience a force of approximately 480 pounds on the front of their body. In addition, such a pressure wave can cause serious ear damage and memory loss due to mild concussions.

  In some instances, the pressure wave may propel the victim away from the arc-blast, reducing the exposure to the thermal energy. However, such rapid movement could also cause serious physical injury.

- **Projectiles.** The pressure wave can propel relatively large objects over a considerable distance. In some cases, the pressure wave has sufficient force to snap the heads of 3/8 inch steel bolts and knock over ordinary construction walls.

  The high-energy arc also causes many of the copper and aluminum components in the electrical equipment to become molten. These "droplets" of molten metal can be propelled great distances by the pressure wave. Although these droplets cool rapidly, they can still be above temperatures capable of causing serious burns or igniting ordinary clothing at distances of 10 feet or more. In many cases, the burning effect is much worse than the injury from shrapnel effects of the droplets.

- **EXPLOSIONS.** Explosions occur when electricity provides a source of ignition for an explosive mixture in the atmosphere. Ignition can be due to overheated conductors or equipment, or normal arcing (sparking) at switch contacts. OSHA standards, the National Electrical Code and related safety standards have precise requirements for electrical systems and equipment when applied in such areas.

- **FIRES.** Electricity is one of the most common causes of fire both in the home and workplace. Defective or misused electrical equipment is a major cause, with high resistance connections being one of the primary sources of ignition. High resistance connections occur where wires are improperly spliced or connected to other components such as receptacle outlets and switches. This was the primary cause of fires associated with the use of aluminum wire in buildings during the 1960s and 1970s.

  Heat is developed in an electrical conductor by the flow of current at the rate I^2R. The heat thus released elevates the temperature of the conductor material. A typical use of this formula illustrates a common electrical hazard. If there is a bad connection at a receptacle, resulting in a resistance of 2 ohms, and a current of 10 amperes flows through that resistance, the rate of heat produced (W) would be:

$$W = I^2R = 10^2 \times 2 = 200 \text{ watts}$$

  If you have ever touched an energized 200 watt light bulb, you will realize that this is a lot of heat to be concentrated in the confined space of a receptacle. Situations similar to this can contribute to electrical fires.

EFFECTS OF ELECTRICITY ON THE HUMAN BODY

The effects of electric shock on the human body depend on several factors. The major factors are:

1. Current and Voltage
2. Resistance
3. Path through body
4. Duration of shock

The muscular structure of the body is also a factor in that people having less musculature and more fat typically show similar effects at lesser current values.

Current and Voltage

Although high voltage often produces massive destruction of tissue at contact locations, it is generally believed that the detrimental effects of electric shock are due to the *current* actually flowing through the body. Even though Ohm's law (I=E/R) applies, it is often difficult to correlate voltage with damage to the body because of the large variations in contact resistance usually present in accidents. Any electrical device used on a house wiring circuit can, under certain conditions, transmit a fatal current. Although currents greater than 10 mA are capable of producing painful to severe shock, currents between 100 and 200 mA can be lethal.

With increasing alternating current, the sensations of tingling give way to contractions of the muscles. The muscular contractions and accompanying sensations of heat increase as the current is increased. Sensations of pain develop, and voluntary control of the muscles that lie in the current pathway becomes increasingly difficult. As current approaches 15 mA, the victim cannot let go of the conductive surface being grasped. At this point, the individual is said to "freeze" to the circuit. This is frequently referred to as the "let-go" threshold.

As current approaches 100 mA, ventricular fibrillation of the heart occurs. Ventricular fibrillation is defined as "very rapid uncoordinated contractions of the ventricles of the heart resulting in loss of synchronization between heartbeat and pulse beat." Once ventricular fibrillation occurs, it will continue and death will ensue within a few minutes. Use of a special device called a de-fibrillator is required to save the victim.

Heavy current flow can result in severe burns and heart paralysis. If shock is of short duration, the heart stops during current passage and usually re-starts normally on current interruption, improving the victim's chances for survival.

Resistance

Studies have shown that the electrical resistance of the human body varies with the amount of moisture on the skin, the pressure applied to the contact point, and the contact area.

The outer layer of skin, the epidermis, has very high resistance when dry. Wet conditions, a cut or other break in the skin will drastically reduce resistance.

Shock severity increases with an increase in pressure of contact. Also, the larger the contact area, the lower the resistance.

Whatever protection is offered by skin resistance decreases rapidly with increase in voltage. Higher voltages have the capability of "breaking down" the outer layers of the skin, thereby reducing the resistance.

Path Through Body

The path the current takes through the body affects the degree of injury. A small current that passes from one extremity through the heart to the other extremity is capable of causing severe injury or electrocution. There have been many cases where an arm or leg was almost burned off when the extremity came in contact with electrical current and the current only flowed through a portion of the limb before it went out into the other conductor without going through the trunk of the body. Had the current gone through the trunk of the body, the person would almost surely have been electrocuted.

A large number of serious electrical accidents in industry involve current flow from hands to feet. Since such a path involves both the heart and the lungs, results can be fatal.

Duration of Shock

The duration of the shock has a great bearing on the final outcome. If the shock is of short duration, it may only be a painful experience for the person.

If the level of current flow reaches the approximate ventricular fibrillation threshold of 100 mA, a shock duration of a few seconds could be fatal. This is not much current when you consider that a small light duty portable electric drill draws about 30 times as much.

At relatively high currents, death is inevitable if the shock is of appreciable duration; however, if the shock is of short duration, and if the heart has not been damaged, interruption of the current may be followed by a spontaneous resumption of its normal rhythmic contractions.

Summary of Effects

We can sum up the lethal effects of electric current as follows:

- Current flow greater than the "let-go" threshold of an individual may cause a person to collapse, become unconscious and can result in death. The current flow would most often have to continue for longer than five seconds. Although it may not be possible to determine the exact cause of death with certainty, asphyxiation or heart failure are the prime suspects.

- Current flow through the chest, neck, head or major nerve centers controlling respiration may result in a failure of the respiratory system. This is usually caused by a disruption of the nerve impulses between the respiratory control center and the respiratory muscles. Such a condition is dangerous since it is possible for the respiratory failure to continue even after the current flow has stopped.

- The most dangerous condition can occur when fairly small amounts of current flow through the heart area. Such current flow can cause ventricular fibrillation. This asynchronous movement of the heart causes the hearts' usual rhythmic pumping action to cease. Death results within minutes.

- When relatively large currents flow through the heart area, heart action may be stopped entirely. If the shock duration is short and no physical damage to the heart has occurred, the heart may begin rhythmic pumping automatically when the current ceases.

- Extensive tissue damage, including internal organ damage due to high temperatures, occurs when very large currents flow through major portions of the body.

- There are recorded cases of delayed death after a person has been revived following an electrical shock. This may occur within minutes, hours or even days after the event has occurred. Several assumptions for such delayed effects are:

- internal or unseen hemorrhaging
- emotional or psychological effects of the shock
- aggravation of a pre-existing condition

In many accidents, there is a combination of the above effects, or additional effects may develop after the initial accident, thus making an accurate diagnosis quite difficult.