JOHN FRYE

Essential to the technician's safety is a thoroughgoing knowledge of the potential dangers of electric current.

ELECTRIC SHOCK

"BET you can't guess where I was last night," Barney said to his employer. "I'd probably do better predicting the course of a Mexican jumping bean," Mac growled without looking up from the TV set he was aligning.

"I was at a Red Cross class learning how to apply artificial respiration to a victim of drowning or shock."

"Fine, but what brought this on?"

"I may as well tell you. Last week when I was servicing that photoelectric counter at the spring factory, I darned near electrocuted myself. I'm not used to working on a wet cement floor, and I carelessly got hold of the hot 120-volt lead. For the first time in my life I couldn't let go, but fortunately I staggered backward and broke the connection. See what it did to my finger?"

His extended forefinger revealed a narrow, deep burn edged with whitened, blistered skin.

"Still smells like a butcher-shop incinerator," Barney said, sniffing the wound and wrinkling his nose in distaste; "but I decided that if I were going to spend the rest of my life working in a snake house, I'd better learn the poisonous and the harmless snakes and provide myself with some snake-bite serum. That's why I've really been boning up on just how electric shock injures or kills a human being. Also, when I found out that artificial respiration is the best method of reviving a victim of shock, I went to the Red Cross to learn the modern methods of restoring breathing."

"You know you're busting to tell me what you've learned," Mac said, laying down his soldering gun and reaching for his pipe; "so why don't you sound off?"

"I thought you'd never ask!" Barney exclaimed, heaving himself up on the workbench. "In the first place, it's the electric current that does the damage. Of course, we know current is a function of both voltage and resistance, but the resistance of the human body varies so widely it's impossible to tag one voltage as 'dangerous' and another as 'safe.' People have been killed by less than 50 volts and have survived contact with several thousand volts.

"The resistance of the human body to electric current is divided between internal resistance, such as would be measured between two flayed areas of the body, and skin resistance. Internal resistance varies from about 100 ohms between the ears—and no cracks about the vacuum between *my* ears increasing this value—to about 500 ohms from a hand to a foot. Skin resistance varies from about 1000 ohms for wet skin to more than 500,000 ohms for dry skin. The skin area in contact with the voltage also affects this skin resistance. For example, a man sitting in a grounded tub of water with one hand on the hot side of the a.c. line may present no more than 500 ohms total resistance to the voltage present between the hot wire and ground.

"Electricity damages the body in at least three ways: (1) it harms or interferes with proper functioning of the nervous system and heart; (2) it subjects the body to intense heat; and (3) it causes the muscles to contract. The first effect probably accounts for the most deaths. Normally, the heart contracts at a rate of about 65 beats per minute at the dictation of a built-in pacemaker. Electric current interferes with this pacemaking activity in two possible ways. The current may produce 'ventricular tachycardia' in which the heart beats very rapidly with greatly reduced efficiency that cannot sustain life for long. At currents between 100 and 200 ma., 'ventricular fibrillation' is induced in which the heart produces weak, random contractions that render it nearly useless for circulation of the blood."

"What happens with still more current than 200 ma.?"

"Oddly enough, the victim's chances may be better with the higher current because it causes clamping of the heart muscles and prevents the deadly fibrillation. One writer says that if the heart is exposed to this 100- to 200-ma. current, no power on earth can save him from the resulting fibrillation and death, but I think this needs some qualifying. I know that in certain types of heart surgery ventricular fibrillation has been deliberately induced for a certain length of time so that the quiet heart can be operated upon; then, another shock of a different sort has been used to restore the heart to normal operation. If this 'de-fibrillation' equipment could be used quickly enough on a shock victim, his life might be saved.

"But let's go back to the effect of rising current. At 1 ma., the victim may feel no more than a tingling of the skin. Higher current can cause muscular contractions severe enough to break bones, and it produces a loss of voluntary control over the muscles that freezes a victim to the source of current. A man normally can free himself from a current of 9 ma. or less; a woman, from 6 ma. or less.

"The electric current deadens the center in the brain that controls breathing. At 30 ma., breathing becomes labored and it finally ceases completely at values approaching 75 ma. At or about 100 ma., ventricular fibrillation begins. Beyond 200 ma. the heart muscles are clamped."

"What about really heavy currents measured in amperes?"

"We know about the effect of these from autopsies performed on criminals executed in the electric chair. In a typical execution, 2000 volts single-phase a.c. is applied to moistened sponge-lined electrodes fastened to the shaved head and one leg. Immediately the voltage is dropped to 500 volts and then raised and lowered at 30-second intervals for a total application of two minutes, during which period the current varies from 4 to 8 amperes. There is little doubt circulation and respiration cease at the first contact, and it is believed consciousness is blotted out instantly. The temperature of the body rises abruptly. A temperature of 128°F has been measured at the site of the leg electrode 15 minutes after the execution. The blood is profoundly altered biochemically."

"Let's change the subject," Mac said with a little shiver. "I imagine the path through the body has lots to do with the shock danger."

"And you're right. A current passing from finger to elbow through the arm may produce only a painful shock, but that same current passing from hand to hand or hand to foot may well be fatal. That's why the practice of keeping one hand in your pocket while working on high-voltage circuits and standing on an insulating material is a good one.

"A.c. is said to be four to five times more dangerous than d.c. For one thing a.c. causes more severe muscular contractions. For another, it stimulates sweating that lowers the skin resistance. Along that line, it is important to note that resistance goes down rapidly with continued contact. The sweating and the burning away of the skin oils and even the skin itself account for this. That's why it's extremely important to free the victim from contact with the current as quickly as possible before the climbing current reaches the fibrillation-inducing level.

"The frequency of the a.c. has lots to do with the effect on the human body. Unfortunately, 60 cycles is in the most harmful range. At the house-current frequency, as little as 25 volts can kill. On the other hand, people have withstood 40,000 volts at a frequency of a million cycles or so without fatal effects."

"Well, now that we have the victim thoroughly shocked, what can we do to revive him?"

"Apply artificial respiration at the earliest possible minute and keep applying it until a doctor pronounces the victim dead. In one study, about three out of four who received artificial respiration within *three* minutes of the shock lived; but of those who got it *four* minutes after the shock, only 14% survived. In another study involving 700 victims, 479 had stopped breathing, 323 of those were saved by artificial respiration. Most recovered in 20 minutes, but some took as long as four hours to start breathing on their own. It may even take as long as eight hours to revive a victim, and during this period no pulse may be discernible and a limb-stiffening condition similar to rigor mortis may be present. These are manifestations of shock and are not to be taken as evidence the victim has died."

"Well, this has been a most illuminating conversation," Mac said, knocking the ashes from his pipe against the heel of his hand. "Let's see if I can recapitulate your major points:

"1. A very little current can produce a lethal electric shock. Any current over 10 ma. will result in a painful and serious shock.

"2. Voltage is not a reliable indication of danger because the body's resistance varies so widely it's impossible to predict how much current will be made to flow through the body by a given voltage.

"3. The current range of 100- to 200-ma. is particularly dangerous because it is almost certain to result in lethal ventricular fibrillation. Victims of high-voltage shock usually respond better to artificial respiration than do victims of low-voltage shock, probably because the higher voltage and current clamps the

eart and hence prevents fibrillation
"4. A.c. is more dangerous than d.c.
nd 60-cycle current is more dangerou
ıan high-frequency current.
"5. Skin resistance decreases whe
ıe skin is wet or when the skin area i
ontact with a voltage source increases
t also decreases rapidly with continue
xposure to electric current.
"6. Prevention is the best medicin
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eed to take hold of *both* 120-volt wire
o kill yourself. Touching the hot wir
hile in contact with a good ground wil
y you just as quickly.
"7. In case a person does suffer a se
ere shock, it is important to free hin
om the current as quickly as can b
one safely and to apply artificial respir
tion *immediately*. The difference of
ew seconds in starting this may spell lif
r death to the victim. And keep up th
rtificial respiration until a physicia
ronounces the victim dead."
"Hey! That's excellent," Barney ap
lauded. "I didn't know you were sucl
good listener. I thought you were jus
talker. I might conclude by saying tha
bout 750 persons died from electri
hock in industry last year, as did 15
ho were electrocuted in the home. Con
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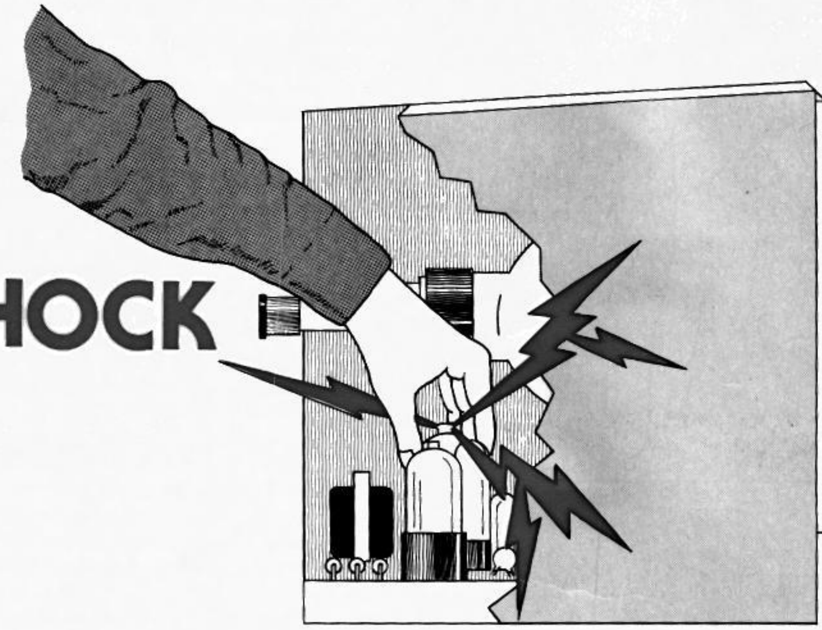
f its danger, that's not very encour
ging."
"No, but I think it's the old story c
amiliarity breeding contempt," Ma
aid. "Working with electricity day afte
lay, we tend to get careless until a
xperience such as you had in the sprin
actory wakes us up. It could well be tha

All About ELECTRIC SHOCK



All about electrical shock, and how it can affect your body.

RAY FISH, Ph.D., M.D.

MOST OF US ARE FAMILIAR WITH THE effects of a mild electric shock—the sharp sting, the tingling sensation. The effects of a severe electric shock, however, can be much more devastating, even fatal. In this article, we are going to take a look at electric shock, and how it does its damage.

All about shock

Put quite simply, electric shock is the passage of a current through the body. The human body, as shown in Fig. 1, can be modeled as a network of resistances. Simply touching a voltage source is not sufficient to cause a shock (see Fig. 2-*a*). That's because, no circuit is completed. For current to flow, another part of the resistance network that is the body must be in contact with a ground or a different voltage level (see Fig. 2-*b*).

To understand more about the effects of shock, it is sometimes more useful to construct more detailed models of the body. Consider the model of an arm shown in Fig. 3. An electric shock that is applied between the hand (R_{SKIN-1}) and the elbow (R_{SKIN-2}) must pass through three separate resistances. That's because, in addition to the resistance presented by the forearm, R_{FA}, the skin surface at the hand and the elbow also resist current flow. And even more complex electrical models of the body are often made. In those models, the body is broken down into more separate parts. The parallel resistances of bone, blood vessels, nerves, and other tissues are modeled by additional resistors. The different ways that high-frequency currents are passed through various tissues can be modeled by using capacitors and inductors. For our purposes, however, the simple models we've shown you thus far are sufficient

The resistance to current flow at the skin surface depends on a number of factors. The area of contact is important. A flat piece of metal held against the skin will affect the resistance; pushing harder lowers the resistance. You can prove that to yourself by holding onto the leads from an ohmmeter. Holding them loosely will yield a reading of about 50,000 ohms; holding them more tightly will yield a reading of 10,000 ohms.

The surface of the skin is dry compared to lower layers, which causes it to offer a higher resistance. In order to reduce skin resistance, the top dry layer can be partially rubbed off with little discomfort.

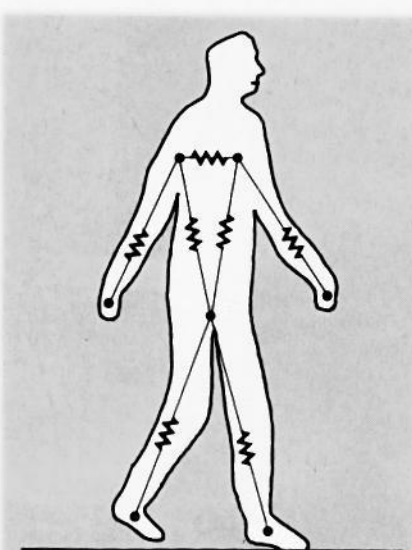


FIG. 1—A PERSON CAN be modeled as a network of resistances.

The skin surface can also be made more conductive by moistening it with water. Electrolyte solutions (such as sweat) are more effective than water in lowering skin resistance.

Those facts are taken into account when designing and using cardiac monitors and defibrillators. Some pre-packaged electrodes have an abrasive area that can be rubbed on the skin before the electrode is applied. The electrode has a relatively large (one square centimeter) surface area, which is covered by an electrolyte-containing electrode jelly.

Defibrillator paddles (a defibrillator is shown in Fig. 4) are used to deliver strong shocks that change the heart rhythm (For more about defibrillators and what they do, see the August 1984 issue of **Radio-Electronics**). The paddle surface area is roughly 50 square centimeters. Medical personnel are taught to apply about 20 pounds of force on each paddle when defibrillating (trying to apply more pressure than that causes some people to lose their balance).

Electrolyte-containing electrode jelly or saline-soaked pads are used to a make uniform electrical connection between each paddle and the skin. Saline pads have the advantage of not leaving a slippery surface that makes chest compressions (CPR) difficult. The jelly may also coat the chest between the electrodes, giving an unwanted current path. Alcohol-soaked pads are not used because they might ignite. If no conductive medium is placed between the paddles and the chest wall, a spark and burns may occur. Even so, chest-wall burns sometimes occur even when proper defibrillation techniques and equipment are used.

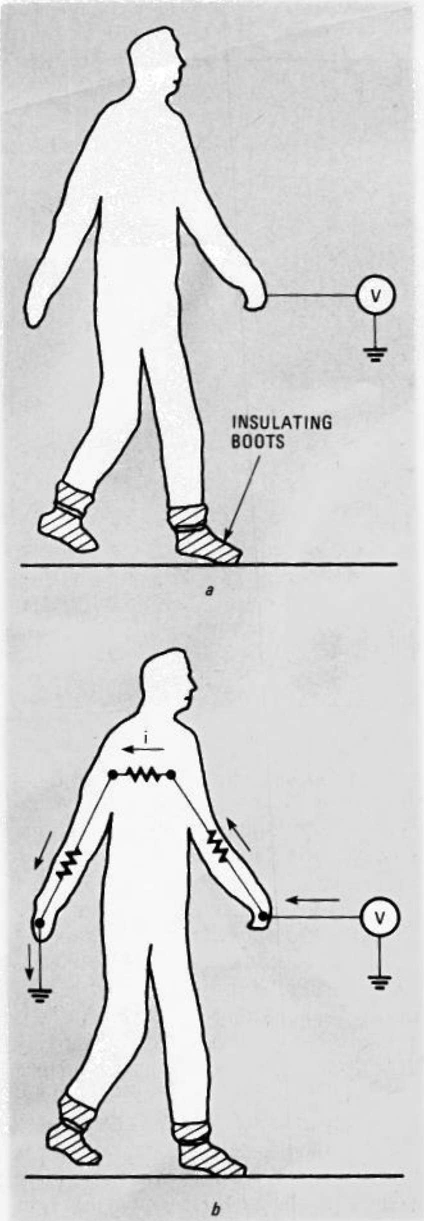


FIG. 2—MERELY TOUCHING a voltage source is not sufficient to cause shock. But when a person comes in contact with two voltage sources of different levels (such as 120 volts and ground), a circuit is completed and current flows.

The effects of electrical shock

As you might expect with current flowing through a resistance, electrical shock causes the heating of tissues. Electrical shock heats body tissues in several ways. A high voltage can give flash burns due to arcing of current through the air to the body. The arcing may even cause your clothing to catch on fire. In either case you end up with a burn.

More commonly, heat is caused by the flow of current through the resistance of bodily tissues. Burns of tissues by electrical current itself often give painless round or oval gray areas with surrounding redness.

The heat delivered to each area of tissue depends on the current flowing in that area and the resistance at that point. In some applications, such as defibrillation, a certain amount of current must be delivered. A large paddle area spreads the current over a surface area sufficiently large that skin burns are usually avoided (though, as noted above, not always).

With uncontrolled shock, burns can be significant. Temperatures up to 3000 degrees Centigrade may be generated. Much of the tissue damage with electrical burns is often under the skin. As such, many major electrical burns look deceptively minor at first. Deep injury to muscle and blood vessels is much more common than with other types of burns (such as those due to hot water and fires).

In addition to burns, electrical shock can have many other effects. Let's look at some of them next.

Contact with alternating (but not direct) current can cause a sustained contraction of muscles. That can prevent the victim from releasing the source of voltage, causing the damage to the body to be much more severe.

Electrical shock can cause death within minutes by stopping breathing or the beating of the heart. Breathing can be stopped by current passing through the respiratory centers of the brain. Electrical current passing through the heart itself can disrupt the heart's normal beating pattern. With severe shocks, such as those caused by lightning, the heart's electrical activity may cease altogether.

In cases where heart activity has been disrupted by an electrical shock, CPR should be performed to keep the brain from dying. When CPR has been performed, there have been reports of victims recovering after even hours of no spontaneous heart or respiratory activity.

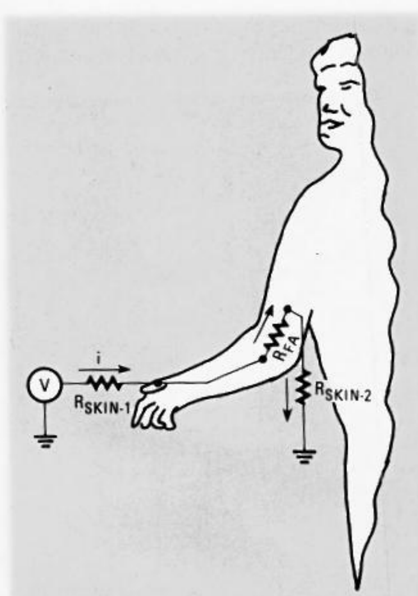


FIG. 3—WHEN A SHOCK is received between the hand and the elbow, resistance is offered by the skin at both the hand and the elbow, as well as by the arm itself.

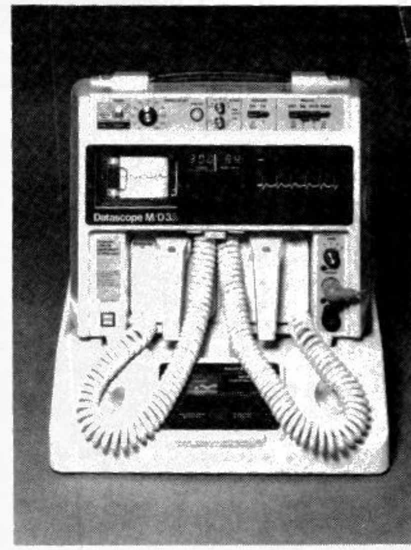


FIG. 4—A DEFIBRILLATOR uses electrical shock to restore a heartbeat to normal.

The nervous system can be directly affected by electrical shock. Paralysis, amnesia, and other conditions all can result from nerve damage.

Kidney damage can occur if an electric current passes through that organ. Kidney damage can also occur if that organ is blocked by large amounts of a chemical (called mycoglobin) that is released from muscle cells that are damaged by the passage of an electrical current.

Finally, large and small blood vessels may bleed or develop clots after electrical shock. That can lead to deeper and more extensive tissue damage than is apparent on initial inspection.

Lightning

Lightning produces all of the above effects, and more. A person hit directly by lightning will, in all likelihood, be killed immediately. People who have been "hit by lightning" and have survived, are those who were fortunate enough to be victims only of a near miss. They were merely close enough to the lightning to receive severe electrical shocks.

If lightning hits a tree (or other object in the ground), a voltage gradient leading from the tree will exist along the ground. A cow standing facing the tree will receive more voltage between its legs than a cow standing with its side to the tree. People lying on the ground may develop burns on areas of the skin that were in contact with the ground. If the burns are not severe, they may resemble light red, fine paintings—small burns may resemble stick figures, while larger ones may look like evergreen bushes with thousands of needles on their branches. In addition to the burns, there may also be transient paralysis or transient loss of vision or hearing.

Serious effects of a lightning "strike" can include severe burns and cardiac arrest.

continued on page 92

ELECTRIC SHOCK

continued from page 58

Microshock

Microshock is electrical shock caused by very small amounts of current. As is shown in Table 1, currents of less than 1 milliampere are usually of no consequence. If a shock is delivered directly to the heart, however, even 20 microamperes of current can be dangerous. Current can be delivered directly to the heart through a pacemaker wire. Wires for use with external (temporary) pacemakers

TABLE 1—EFFECTS OF A 60 Hz ELECTRIC SHOCK

Current held one second	Effect (current applied to skin, unless otherwise noted)
20 µA	Ventricular fibrillation if applied directly to the heart
1 mA	Sensation
5 mA	Maximum harmless current
1–10 mA	Mild to moderate pain
10–20 mA	May cause muscular contractions, preventing release from shock source
30 mA	Breathing may stop
75–300 mA	Ventricular fibrillation may occur
5 A	Burns tissues

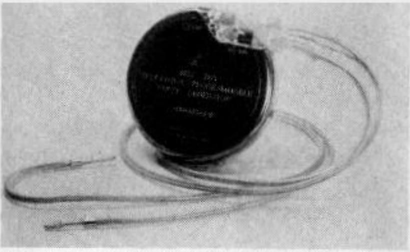


FIG. 5—IF A PACEMAKER'S LEADS accidentally contact a voltage source, it is easy to deliver a dangerous voltage (greater than 20 mA) to the heart.

come out of the body through the chest wall or through veins that lead to an arm, the neck, or elsewhere (see Fig. 5). If such a wire were touched by a person who was holding onto a light switch, electric bed frame, television set, or other appliance, many microamperes could be conducted to the pacemaker wire.

Many appliances will supply a good fraction of a milliampere to someone who is grounded. To see that for yourself, connect an ammeter between the metal parts of an appliance and ground. (Start on a high range to protect the meter.) Unless there is a very good third wire ground, significant currents will be measured.

Why electrical shock occurs

It is easy to receive an electrical shock. All that is required is to come into contact with two different voltages. Electrical shock can occur in a variety of settings. Electronics technicians and hobbyists can be exposed to many situations in which shock can occur. Capacitors and CRT's, for instance, store large voltages for days or longer. Tools held in the hand may conduct electric currents from objects touched. High voltages may arc across space to cause shocks.

Even if you are someone who doesn't do much electronics work or experimenting, there are many "opportunities" around the house to receive a shock. Damaged line cords, defective appliances, or accidents, such as dropping an AC-powered radio into a full bathtub, can quickly teach anyone about the dangers of electrical shocks. **R-E**

SHOCK!

a danger for all who work in electronics—don't take it lightly

by Carl Everson

The Scale of Shock	
CURRENT IN MILLIAMPERES (APPROXIMATE)	SENSATION OR EFFECT EXPERIENCED BY THE HUMAN BODY
1 OR LESS	LITTLE OR NO SENSATION
5	PAINFUL SHOCK
10 TO 15	MUSCLE CONTRACTION SUFFICIENT TO CAUSE 'FREEZING' TO THE SOURCE
30	BREATHING BECOMES DIFFICULT — POSSIBLE LOSS OF CONSCIOUSNESS
70	BREATHING COMPLETELY CEASES — VENTRICULAR TACHYCARDIA
100 TO 200	VENTRICULAR FIBRILLATION
OVER 200	'CLAMPING' OF THE MUSCLES

It seems ironic that one of the most common and constant companions of our daily life, electricity, is one of the most dangerous products of modern technology. It is with us in our homes, offices, factories, cars and even our boats. Power lines criss-cross the countryside from one ocean to the other. Children fly kites into overhead lines and underground lines lie waiting to be dug up by some unsuspecting individual. People still stick screwdrivers into outlet receptacles and fingers into light sockets with total abandon, and the number of tattered extension cords ending in multiple taps which a serviceman encounters in his daily rounds testify to the complete disregard which we have for this monster. It is common knowledge that an electrical shock can be lethal but surprisingly few people know how or why. Knowing what actually happens is the first step in taking the proper precautions to prevent accidents or rendering assistance when it is needed.

The Body

Electricity may eventually prove to the basis of life itself. Nerve pulses are electrical in nature and can be measured with sensitive amplifiers and electrodes placed on certain areas of the body. True, the voltages are measured in microvolts but they are there, nevertheless, and the resulting waveforms have meaning for the trained diagnostician. The electrocardiogram, or waveform of the heart, is especially interesting in that it performs in the manner of a rotating vector. Nerve pulses from the brain stimulate a sensitive node in the right auricle which determines the beat rate. The electrical activity then spreads to the left auricle and thence to the ventricles. A disruption of this sequence can throw the heart 'out of sync' or into ventricular fibrillation, a haphazard, erratic beating which renders the organ useless and generally causes death because vital body organs cease to be supplied with fresh blood.

Normal breathing is controlled by an electrical pulse from the medulla oblongata section of the brain which travels through a complex nerve system to the breathing muscles. An alien current can easily disrupt and paralyze this system resulting in asphyxiation and death.

The minute voltage pulses of the nerve fibres are the essence of life itself but, like many good things, an excess can be devastating and it is this excess with which we are concerned when we consider electric shock. A hundred volts between a finger and thumb can be uncomfortable to say the least but between a hand and foot can easily prove fatal.

Resistance and 32 Volt Fatalities

We have been talking in terms of voltage, as we invariably do, but actually *it is the current that does the damage*. It is the amount and duration of electric current through the human body which determines the severity of the shock. Uncontrolled currents which flow during an electrical shock swamp out the nerve pulses going to different parts of the body. Particularly dangerous are those currents which enter or pass through the heart and respiratory centers. Thus the path which the current takes through the body is also a key factor in death by electrical shock.

It is true that current is a function of voltage, that is, the higher the voltage, the greater the current. But current is also inversely proportional to resistance, so that the higher the resistance of the conducting medium, the lower the current. The resistance of the human body is not a constant but varies quite widely. Because of this, no one voltage can be tagged as safe or another one as dangerous. People have survived contact with several thousand volts but have also been killed by less than fifty. In fact, there are cases on record of deaths caused by 32-volt farm lighting systems.

Body resistance is of two orders: internal and external. Internal, or flesh, resistance is in the neighbourhood of 500 ohms from a hand to a foot with shorter paths more or less reduced accordingly. External, or skin, resistance varies greatly from approximately 1000 ohms per square cm. of contact for wet skin to more than 500,000 ohms per square cm. for dry skin. The result depends on the area of contact with the body. Thus a person taking a bath presents little more than 500 ohms resistance to the electrical current if he touches a 'hot' or faulty appliance or fixture. A simple application of Ohm's Law, $I = \frac{E}{R}$, using the standard supply of 110 volts for this situation gives us $I = \frac{110}{500} = .22$ amperes, or more than 200 milliamperes which, as we shall point out, would result in almost certain death. The resistance of the body decreases rapidly with continued contact as the skin chars and burns so that immediate removal of the source is imperative before the climbing current reaches a more dangerous value.

The Damage

Damage to the human body by electricity can occur in several ways, the most dangerous of which is interference with the nervous system and especially with the functioning of the heart and respiratory systems. Currents of approximately 50 to 100 milliamperes produce ventricular tachycardia, a rapid beating of the heart at reduced efficiency. At currents of roughly 100 to 200 ma., ventricular fibrillation, a weak, random beating occurs and results in almost certain death.

At currents greater than 200 ma., the chances of survival, surprisingly, may be better because there is a 'clamping' or sudden violent contraction of the muscles, including the heart muscles, which prevents the death-dealing ventricular fibrillation. The heart muscles may resume normal action if the victim is released within a few minutes. This sudden muscle contraction may also aid in 'throwing' the victim away from the power source. Although he may sustain secondary injuries if he happens to hit something in his flight, this could easily be a means of saving his life.

We have been talking in terms of hundreds of milliamperes of current but profound effects occur at much lower values. While one milliampere may produce little or no sensation, a current of 5 ma. will produce a painful shock and 10 to 15 ma. will produce muscle contraction sufficient to cause 'freezing' to the source. If the path is through the

continued on p. 55

IS THERE ONE OF THESE ▼ NEAR YOUR WORKBENCH?

CUT OUT HERE

RESCUE BREATHING (MOUTH-TO-MOUTH)

THE CANADIAN RED CROSS SOCIETY

Start immediately: The sooner you start, the greater the chance of success.

Open airway by lifting neck with one hand and tilting the head back with the other hand.	**Pinch nostrils to prevent air leakage. Maintain open airway by keeping the neck elevated.**	**Seal your mouth tightly around the victim's mouth and blow in. The victim's chest should rise.**	**Remove mouth. Release nostrils. Listen for air escaping from lungs. Watch for chest to fall.**

CUT OUT HERE

CUT OUT HERE

REPEAT LAST THREE STEPS TWELVE TO FIFTEEN TIMES PER MINUTE.

IF AIR PASSAGES ARE NOT OPEN: Check neck and head positions, CLEAR mouth and throat of foreign substances.

For infants and children, cover entire mouth and nose with your mouth. Use small puffs of air about 20 times per minute.

USE RESCUE BREATHING when persons have stopped breathing as a result of: DROWNING, CHOKING, ELECTRIC SHOCK, HEART ATTACK, SUFFOCATION and GAS POISONING.

Don't give up. Send someone for a doctor. Continue until medical help arrives or breathing is restored.

CUT OUT HERE

Shock *(cont'd from p. 39)*

chest area, the muscles of the diaphragm could contract sufficiently to cause the victim to die of asphyxia even though the heart and respiratory centers are not directly affected. For women, this effect occurs at a current value of about 1/3 less than that quoted which is for men. A secondary effect with 'freeze-on' is that, as the current continues to flow, the skin blisters and chars, resulting in increased current and further complications. At about 30 ma., breathing becomes difficult with possible loss of consciousness and at about 70 ma., breathing ceases completely. While these values are only approximate and vary widely from person to person, they give a rough idea of the different phases of electrical shock and illustrate the small amount of current which can be lethal.

The seriousness of an electrical shock is dependent to a certain extent upon the path of the current through the body. A small current from hand to elbow may only produce a painful shock but the same current from hand to hand or hand to foot could more easily prove fatal. The practice of keeping one hand in your pocket when working around high voltage cannot be overrated or stressed too much, nor can working on an insulated floor such as dry wood.

Another factor to be considered is the frequency of the current. Alternating current appears to be several times more dangerous than direct current. With A.C., muscle contractions are more severe and sweating is stimulated thus lowering the skin resistance and leading to increased current. The standard power line frequency of 60 Hz. is, unfortunately, in the most dangerous range.

What to Do

Anyone working with or near electrical equipment should be familiar with rescue techniques. The first step, of course, is to break the connection between the power source and the victim. If this can be done by simply moving a switch, so much the better, but otherwise the victim must be removed from the source without endangering yourself. Most conducting wires can be safely cut with a *wooden*-handled axe unless they are of an extremely high voltage type. The victim can also be dragged with reasonable safety by grasping only his *dry* clothes. He can also be pushed off the power source with a dry stick or board. Your own safety, while doing this, can be increased by standing on some insulating material such as dry boards, a pile of dry newspapers, or other non-conducting objects. As soon as you can safely touch the victim, artificial respiration should be applied. Details of the mouth-to-mouth method are on page 39. Cut it out and keep it handy.

It is imperative that artificial respiration be applied *immediately*. If you are alone, *don't take time to go for help*, speed is essential! A few seconds here may well mean the difference between life and death for the victim and any delay at all greatly reduces the chance of his recovery. According to one survey of some 600 cases, over 70% of those receiving artificial respiration within three minutes recovered. One more minute delay reduced this to 58% and another minute made death almost certain. While most of those who recover do so within 20 minutes, it has been known to take as long as eight hours to revive a victim. During this time there could be no discernible pulse and a stiffening condition similar to rigor mortis. These should not be taken as evidence of death until so pronounced by a physician.

We would do well, then, to keep these four facts in mind:

(1) Voltage is not a reliable indicator of danger but even a small current is dangerous and lethal.

(2) Alternating current, particularly 60 Hz., is more dangerous than direct current.

(3) Skin resistance decreases, and thus current increases, with dampness, area of contact, and continued exposure to current.

(4) The victim must be freed from the power source as quickly as possible and artificial respiration applied immediately and continued until he recovers or a physician pronounces death.

As the foregoing shows, any assistance must be provided by someone else: there is nothing the victim can do for himself. At the risk of sounding corny we must say that prevention is the best medicine. Keep a healthy respect for all power sources. ■