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TITLE PREVENTION AND TREATMENT OF ELECTRIC SHOCK INJURIES

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MFR. *General.*

Approved

W. A. Mac Donald

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HAZELTINE SERVICE CORPORATION

Research Department

PREVENTION AND TREATMENT OF ELECTRIC SHOCK INJURIESSUMMARY

This report gives an account, by J. C. Wilson of our staff, of technical and procedural precautions to prevent accidents caused by electric shock; and also gives the substance of a lecture delivered at our laboratory by Dr. Henry W. Eisfelder describing the dangers of such shock and the administration of artificial respiration.

TECHNICAL AND ORGANIZATIONAL
ASPECTS OF HIGH-VOLTAGE DANGER

The purpose of this report is to notice certain technical effects connected with the contact of the human body with high-voltage sources. Certain questions of personnel discipline also arise and are briefly reviewed. Medical aspects are dealt with by Dr. Eisfelder in the second section of this report.

The following diagrams form a part of this report:

- Figure 1 - Equivalent Circuit of the Human Body
with Externally Applied Potential Difference
- " 2 - Equivalent Circuit of High-Voltage Source
- " 3 - Surge Trip Circuit for Local Precaution
with Extremely High Voltage
- " 4 - Bench Layout, Showing Danger Points.

There are three common high-voltage sources met with in laboratory work:

- (a) Direct-current or sixty-cycle alternating-current sources
- (b) High-frequency power oscillators
- (c) Tesla discharge exciters.

Of these, (a) may produce shock and burn, (b) may produce burn, and (c) in general cannot produce either shock or burn. Undoubtedly the greatest danger is to be expected in our laboratory work from high-voltage sixty-cycle sources (such as transformers), from rectifier-smoother circuits fed from these sources, or from charged capacitors forming part of the smoothing circuits. These devices are used principally in television work for supplying the gun potential for cathode-ray receiving tubes, and the electrical precautions taken should therefore in general be similar to those usual in connection with X-ray work.

Electrical Properties of the Body

In Figure 1 is shown an equivalent circuit for the human body, including the skin, when in normal condition. The two resistors, R , represent the resistance of the skin at entrance and exit points for current; the resistor r represents the internal resistance of the human body (tissues, blood, etc.). In normal conditions of humidity, the value of R is something of the order of a quarter of a megohm for light contacts over a small area, while that of r is very much lower: probably in the region of two to five thousand ohms.

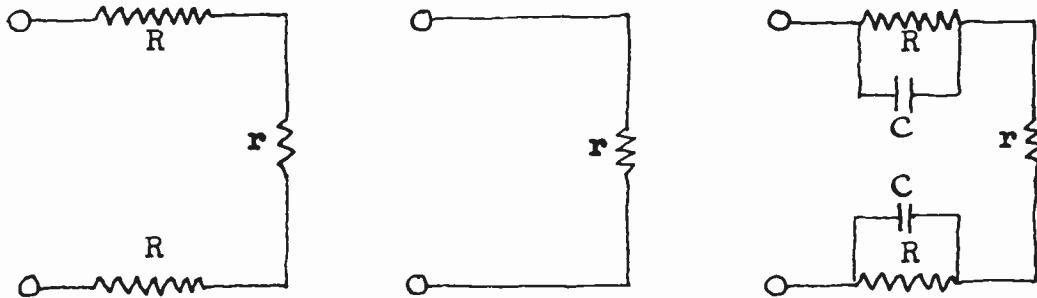


Figure 1

For summer conditions, however, and when the humidity is high, the skin resistance may fall considerably, taking a value of 50,000 ohms or less.

The malignant effect of contact with high voltage resides not in the production of potential drop across R , but in the flow of current through r . The skin resistance R is therefore of the nature of a valuable protection.

To keep the protective effect of the skin, it is important that it shall be dry. The result of immersing the hands in water (particularly in water containing some salt or acid in solution) is shown in the second diagram of Figure 1: the body-resistance r is practically the sole remaining circuit resistance and the high-voltage source can therefore force a correspondingly higher current through it.

The equivalent circuit for contact with high-frequency potentials is shown in the third diagram of Figure 1. When the area of contact of the h-f electrodes is substantial, the skin resistance is effectively shunted out by capacitances, C , across which the potential drop is small. The h-f energy is dissipated in r where it produces a rise of temperature. However, when contact is made over a restricted area, (such as by touching a wire, etc.), considerable energy may be dissipated at the skin and this disrupts the skin-tissue to form a painful, slowly healing burn which, if not attended to, may lead to more serious trouble.

Effect of Type of Source

In general it may be said that the voltage of the source alone is no criterion of its danger. Horses have been killed by voltages as low as 70 volts; men, on the other hand, coming in contact with a 20,000-volt supply have been little more than severely shaken.

What is important is the power-delivering capability of the source. Another way of looking at this is to inquire: "can the voltage of the source be maintained while the load formed by a human body is actually contacted across it".

Figure 2 shows an ordinary small mains transformer for high-voltage supply, together with its equivalent circuit as far as shock is concerned. Because it is not designed to deliver high power, but high voltage, it acts as a high-potential source E in series with a more or less large resistance R_0 . When a current I is drawn from it, the nominal voltage of the source is diminished by an amount IR_0 which in some cases may be large enough to drop the potential from 5000 volts to about 250 volts.

This suggests a precaution which can easily be taken in our experimental receiver equipment. Resistors of a megohm or so can be connected in series with the high-voltage leads so that accidental contact with terminals of the tube will be comparatively innocuous.

Examples of Shock with Various Sources

- (A) Source - 500-volt dry battery of heavy-duty type
Contact - Directly across the palms of the two hands
Duration- About 3-1/2 seconds
Effect - Very severe shock; fainting; small burns on the hands. Victim unable to work for two or three days.
- (B) Source - 600-volt 100-watt d-c generator
Contact - Wires grasped firmly in the hands
Duration- Less than five seconds
Effect - Very severe shock; extremely severe burns on the palms of both hands
- (C) Source - 6000-volt 3-kilowatt d-c generator with floating storage batteries
Contact - Palm of right hand, side of left ankle (through sock)
Duration- About ten seconds
Effect - Immediate loss of consciousness and death (probably instantaneous). Artificial respiration commenced within 15 seconds of first contact and continued five hours without success.
- (D) Source - 10,000-volt d-c supply from rectifier tubes
Contact - Across the fingers of the two hands
Duration- Less than one second
Effect - Shock; victim flung backwards, no after effects.

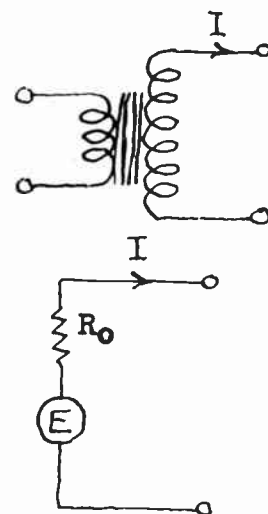


Figure 2

From these examples, which are all taken from the author's experience and comprise young healthy males of average age, about 27 years, it will be noted that the longer contact and the more powerful source, irrespective of voltage, produce the most harmful results.

In at least two cases, the victims were tired and not in an alert mental condition due to loss of sleep. It is therefore extremely unwise to use high-voltage apparatus when not feeling fit and fresh.

It is worth noting that certain low-voltage devices such as scanning circuits can generate peak voltages up to 3000 or 4000. The power involved, though small, may be sufficient to cause shock and local burns, but is unlikely to lead to unconsciousness or serious consequences.

Precautions with Extra-High Voltages

Figure 3 shows a surge trip circuit for use in circuits generating over 10,000 volts. A thyatron is connected in series with a relay across the high-voltage source with sufficient bias to inhibit discharge. A small inductance, L , in series with the supply develops a firing p.d. for the thyatron when there is a sudden increase of current drain on the source, such as might be produced by contact with the

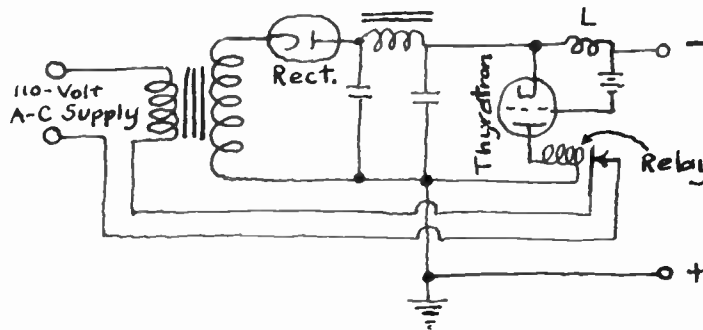


Figure 3

body. This trips the relay and breaks the primary circuit of the transformer, the apparatus remaining dead until reset.

Layout of Apparatus - a Common Danger

In the author's experience, more than eighty per cent of cases of shock have been due to contact across the hands or between one hand and the other wrist or arm. The reason for this is not hard to find in the type of layout of apparatus commonly employed in development work.

Figure 4 represents a typical instance. A chassis undergoing test, or on which experiments are being made, is located on the bench, with the mains supply plug inserted in a socket fastened to the back of the bench at A. In reaching over the bench to remove the plug (preparatory to making some alteration to the chassis), the engineer unconsciously places his left hand on the edge of the bench at C to steady himself and preserve balance. This type of reflex action cannot be entirely eliminated so long as the left hand is free. In doing this, it is possible that the left hand may come into contact with the metal of the chassis, which is generally earthed, or with earthed wire or tool on the bench.

Meanwhile, the arm which is stretched over the apparatus may come into contact with a high-voltage lead or terminal as shown at B. The circuit to earth is thus completed through the arms and chest.

Practically the only way of combating this kind of trouble is to make it a rigorous rule always to have one hand in a pocket when making any changes, switching, or adjustments in the neighborhood of apparatus having a high-voltage supply.

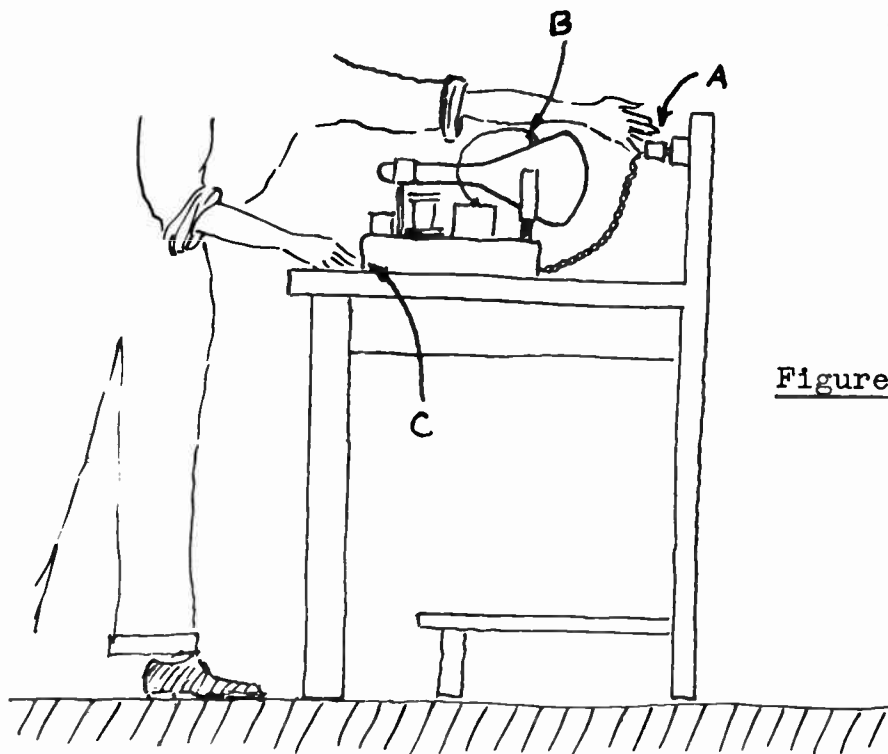


Figure 4

Precautions - Effective and Ineffective

The type of safety device normally incorporated in commercial equipment, (e.g. radio transmitters, X-ray machines, spark-plug testing equipment, electric signs and the like), which operates to disconnect the mains from the equipment when a cover is removed or a gate is opened, is usually worse than useless in experimental work. So many adjustments have to be made with the power on that invariably the automatic switch is short circuited temporarily by the engineer working on the equipment, which then instantly becomes a death-trap for others.

The most effective precautions are, in order of merit:

- (i) to render the engineering staff "shock-conscious"
- (ii) to have all apparatus built with an insulating hood over the mains transformer and rectifier
- (iii) to insert high resistors in all high-voltage tube leads.

Individual Responsibility

When dealing with equipment containing high voltages, do not work alone. It is prime requisite of safety to work in pairs, so that should an accident occur restorative measures can be taken promptly.

In case you have suddenly to deal with a case of shock, more particularly of unconsciousness induced by shock, do not go in search of help. Instantly disconnect the apparatus involved, and commence first-aid operations, meanwhile calling for assistance.

Usually, in the case of accidents of this kind the occurrence of the accident is nobody's fault and no blame attaches to anyone, but it is of the very first importance that in serious cases artificial respiration should be started instantly. For this reason, do not waste

time in explanations until the danger is past.

Summary

Current through the body is dangerous.

The greater part of the body impedance is located in the skin. This impedance is lowered by moisture. Never deal with high- or low-voltage equipment with wet hands, or immediately after operations such as photographic developing.

Do not deal with dangerous apparatus when alone, in the dark, or when tired.

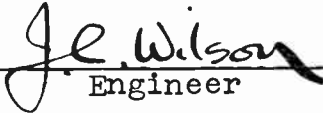
Have all high-voltage transformers and rectifiers enclosed and use high resistors in high-voltage leads wherever practicable.

All metal benches and tables for apparatus should be eliminated from television development work.

Keep one hand in a pocket when switching, plugging, or making any adjustment to high-voltage apparatus.

Take the proper measures instantly in case of shock to others. Attend to all electrical burns.

HAZELTINE SERVICE CORPORATION LABORATORY


Engineer

ELECTRICAL INJURIES:
THEIR AVOIDANCE AND TREATMENT

Electric shock may be induced either by currents of high voltage; by comparatively low voltage, as those used for domestic implements; or by lightning. We are concerned only with the first two groups. After reading the first section of this report, there will be no need of my attempting to go into the technical aspects of the problem, since they are already so well covered.

We are all well aware of cases of shock and burns which result from high voltages, yet the vast majority of serious electrical injuries come from currents of low voltage. The severity of an electrical burn depends upon whether the current is a.c. or d.c.; the voltage and amperage of the current; the character of the ground connection; duration of contact; and the extent of surface involved.

Electrical injuries may be classified as follows:

- (1) Shock, animation suspended and arrested respirations,
- (2) Electrical flashes or glare injuries to the eyes,
- (3) First-degree burns, with red dry skin as in sun-burn, followed early by blister formation and pain,
- (4) Second-degree burns where skin continuity is destroyed,
- (5) Third-degree burns where there is destruction en masse of the tissue, perhaps including muscle, nerve and bone.

In shock due to low voltage, such as used for our domestic household appliances, using 110 to 120 volts, the usual cause of accident is neglect to dry hands or other portions of the body properly. We all have read of cases where persons in a bath have been killed by reaching out to turn on a light, heater, fan or similar apparatus. A similar accident was recently reported where a woman answered the telephone and neglected to dry her hands. As she reached up to turn on a light she received a severe shock and had intense pains in her right shoulder. As she was unable to move her arm, her doctor ordered an X-ray. There was no history of a fall or other injury. The picture revealed a dislocation of the shoulder joint and complete avulsion of the greater tubercle. Attempts to reduce the dislocation resulted in fracture of the neck of the humerus. Open reduction through surgery was resorted to and it was found that the electric current had completely changed the character of the bone, which now was filled with thousands of tiny fissures. Similar effects have been noted in inorganic substances such as glass, porcelain, and metal. If, following an electrical injury, bone involvement is suspected, treat the bone with great care and immobilize it at once.

Both high- and low-tension currents have the same lethal effect, and death is not produced by amperage or voltage, but by a combination of several physiochemical and physiologic phenomena. Alternating currents are more dangerous than direct.

Where higher voltages are met with, such as those used here at the laboratory, the dangers have been brought out in the first section of this report. One point which cannot be stressed too often is the importance of dry skin when working around any electrical apparatus. Never touch any electrical fixture when your hands or other parts of your body are wet, especially when there are cuts or abrasions of the skin, and particularly where there is a ground current.

These higher voltages usually cause an immediate violent contraction of the muscles, and if the hand has grasped the wire, it cannot be released. Such unfortunates are said to be "frozen" as long as the current continues. Under no circumstances attempt to pull such a victim free or you may share his fate. Rush for the main switch if it is at hand, or otherwise disconnect all current first. Dry wood, dry rope or a dry coat may help in pulling a victim free, but the location of the switch should be known to everyone in the laboratory. Such a shock may, and usually does produce severe burns, and if the current is not shut off in time may even char the bones.

In severe cases of shock, leaving out burns and their treatment for the moment, we find the patient has become unconscious. Respirations have stopped completely but the heart continues to beat until asphyxia intervenes. A certain number of cases develop a ventricular fibrillation; that is, the electrical impulses which regulate the heart beat are thrown out of order so that the pacemaker is no longer in control, and instead of a normal of 70-80 beats per minute, we have 200-400. These cases, as a rule, end fatally.

Fortunately, in most cases, there is merely a prolonged apnea - stoppage of breathing. Artificial respiration by the prone or Schaefer method must be started at once and continued if necessary for 8 to 10 hours. Cases pronounced dead by all medical tests have suddenly been revived as late as eight hours after the accident. Injections of cardiac or respiratory stimulants are worthless and a waste of time in electrical shock.

After shock treatment has been started there is time to treat any burns. Let me suggest here that Carron oil has no place in modern medicine. Such preparations afford germs an excellent breeding ground. The best emergency treatment is a 5% solution of tannic acid sprayed on. If none is available, a thick paste of bicarbonate of soda is good and can be washed off at once when the doctor wants to apply tannic acid.

At the risk of telling you something that you all may be acquainted with, I would like to explain in detail the Prone Pressure Method of Artificial Respiration:

As soon as possible, feel with your fingers in the patient's mouth and throat and remove any foreign body (tobacco, false teeth, etc.). If the mouth is tight shut, pay no more attention to it until later. Do not stop to loosen patient's clothing, but immediately begin actual resuscitation. Every moment of delay is serious. Proceed as follows:

(1) Lay the patient on his belly, one arm extending directly overhead, the other arm bent at elbow and with the face turned outward and resting on hand or forearm so that the nose and mouth are free for breathing.

(2) Kneel, straddling the patient's thighs. Place the palms of the hands on the small of the back with fingers resting on the ribs, the little finger just touching the lowest rib, with the thumb and fingers in a natural position, and the tips of the fingers just out of sight.

(3) With arms held straight, swing forward slowly so that the weight of your body is gradually brought to bear upon the patient. The shoulder should be directly over the heel of the hand at the end of the forward swing. DO NOT BEND YOUR ELBOWS! This operation should take about two seconds.

(4) Now immediately swing backward so as to completely remove the pressure.

(5) After two seconds swing forward again. Thus repeat deliberately 12 to 15 times a minute the double movement of compression and release, a complete respiration in 4 or 5 seconds.

(6) Continue artificial respiration without interruption until natural breathing is restored, if necessary four hours or longer, or until a physician declares the patient is dead.

(7) As soon as artificial respiration has been started, and while it is being continued, an assistant should loosen any tight clothing about the patient's neck, chest or waist. KEEP THE PATIENT WARM. Do not give any liquids whatever by mouth until the patient is fully conscious.

(8) To avoid strain on the heart, when the patient revives, he should be kept lying down and should not be allowed to stand or sit up. If the doctor has not arrived by the time the patient has revived, he should be given some stimulant, such as one teaspoonful of aromatic spirits of ammonia in a small glass of water, or a hot drink of tea or coffee. Keep warm!

(9) Resuscitation should be carried on at the nearest possible point to where the patient received his injuries. He should not be moved from this point until he is breathing normally of his own volition and then moved only in a lying position.

(10) A brief return of natural respiration is not a certain indication for stopping the resuscitation. Not infrequently the patient, after a temporary recovery of respiration, stops breathing again. Watch, and if breathing stops, resume artificial respiration.

(11) In carrying out resuscitation it may be necessary to change the operator. This change must be made without losing the rhythm of respiration. By this procedure no confusion results at the time of change of operator and a regular rhythm is kept up.

GENERAL RULES

(1) Unconscious persons take cold very easily. Pneumonia is a very frequent complication. Keep warm by use of hot pads or hot water bottles, but remember an unconscious man cannot tell you when he is being burned.

(2) If necessary to move patient, keep him lying down and do not permit him to help himself.

(3) Never try to give an unconscious person a drink. It will choke him.

(4) Never stop artificial respirations in less than four hours if patient has not fully recovered, and if there has been any sign of recovery, continue at least eight hours.

(5) Start artificial respiration at once and have someone telephone for the Emergency Squad of the Police Department, and also the Gas Company Squad; then call a doctor.

(6) Do not put oil on burns.

So much for the victim! In conclusion, the following may be repeated:

NEVER TOUCH ELECTRICAL APPARATUS WITH WET HANDS, and if someone is "frozen", cut the circuit if at hand, or butt victim hard with the shoulder in the manner of a blocking back in football. If the

clothing is dry, it is fairly safe to pull on it, but never grasp him by the bare hand or arm. Safety switch or circuit breaker should be installed centrally in every room where work is done.

Henry W. Kiefelder, Jr.

