

Electrical Safety Guide	ESG-0040
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Title Effects Of Electrical Energy On Humans		Revision History: Rev 0 Date: 04-18-2006 Initial Issue Date: 04-18-2006
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Summary: This guide provides more detailed information on the effects of electrical energy on humans.		

1 Scope

This document provides more detailed information on the effects of electrical energy on humans.

2 Effects Of Electrical Energy On Humans

2.1 Electrical Shock

Most electrical systems establish a voltage reference point by connecting a portion of the system to an earth ground. Because these systems use conductors that have voltages with respect to ground, a shock hazard exists for workers who are in contact with the earth and are exposed to the conductors. If workers come in contact with an energized (ungrounded) conductor while they are in contact with the ground, they become part of the circuit and current passes through their bodies. Electricity following through the human body can shock, cause involuntary muscle reaction, paralyze muscles, burn tissues and organs, or kill. Typical effects of various electric currents are flowing through the body on the average 150-lb male and 115-lb female bodies are given in Table 6-1.

The effects of electric current on the human body depend on the following:

- Circuit characteristics (current, resistance, frequency, and voltage – 60 Hz (hertz) is the most dangerous frequency)
- Contact and internal resistance of the body
- The current's pathway through the body, determined by contact location and internal body chemistry
- Duration of contact

- Environmental conditions affecting the body’s contact resistance

The most damaging route of electricity is through the chest cavity or brain. Fatal ventricular fibrillation of the heart (stopping of rhythmic pumping action) can be initiated by a current flow of as little as several milliamperes (mA). Nearly instantaneous fatalities can result from either direct paralysis of the respiratory system, failure of the rhythmic pumping action of the heart, or immediate heart stoppage. Severe injuries, such as deep internal burns, can occur even if the current does not pass through vital organs or nerve centers.

Table 2-1 is based on limited experiments performed on human subjects in 1961. These figures are not completely reliable due to the unavailability of additional data and the inherent physiological differences between people. Electricity should be considered potentially lethal at lower levels than those cited.

Table 2-1 Quantitative Effects of Electric Current on Humans

Effects	Current, milliamperes					
	Direct Current		Alternating Current			
	150 lb	115 lb	60 Hz		10 kHz	
	150 lb	115 lb	150 lb	115 lb	150 lb	115 lb
Slight sensation of hand	1	0.6	0.4	0.3	7	5
Perception threshold	6.2	3.5	1.1	0.7	12	8
Shock – not painful and no loss of muscular control	9	6	1.8	1.2	17	11
Painful shock – muscular control lost by 0.5%	62	41	9	6	55	37
Painful shock – let-go threshold, media	76	51	16	10.5	75	50
Painful and severe shock – breathing difficult, muscular control lost by 99.5%	90	60	23	15	94	63
Possible ventricular fibrillation						
Three-second shocks	500	500	100	100		
Short shocks (where T is time in seconds)			A ^b	A ^b		
High-voltage surges	50 ^c	50 ^c	13.6 ^c	13.6 ^c		

Notes:

a. “Deleterious Effects of Electric Shock”, Charles F. Dalziel, p. 24, Presented at a meeting of experts on electrical accidents and related matters, sponsored by the International Labour Office, World Health Office and International Electrotechnical Commission, Geneva, Switzerland, October 23-31, 1961. See the study for definitions and details.

b.
$$A = \frac{165}{\sqrt{T}}$$

c. Energy in joules (watt-seconds)

2.2 Burns

Burns suffered in electrical accidents are of three basic types: electrical, arc, and thermal contact.

In electrical burns, tissue damage (whether skin deep or deeper) occurs because the body is unable to dissipate the heat from the current flow. Typically, electrical burns are slow to heal.

Arc burns are caused by electric arcs and are similar to heat burns from high-temperature sources. Temperatures generated by electric arcs can melt nearby material, vaporize metal in close vicinity, and burn flesh and ignite clothing at distances up to three meters (or 10 feet).

Thermal contact burns are those normally experienced from skin contact with the hot surfaces of overheated electric conductors (anything carrying electricity).

2.3 Delayed Effects

Damage to internal tissues may not be apparent immediately after contact with an electrical current. Delayed internal tissue swelling and irritation are possible. Prompt medical attention can help minimize these effects and avoid long-term injury or death.

2.4 Arc Flash

An arc-flash results from high currents arcing through air and the vaporized material such as copper or aluminum. These very high currents are initiated by contact between two energized points. This contact can be caused by improper work procedures while working on energized components. Arc temperatures can reach from 15,000 to 35,000 degrees, for comparison the temperature at the surface of the sun is about 10,800 degrees.

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, and type of clothing, have an effect on the degree of injury. Proper clothing, work distances and over-current protection can improve the chances of curable burns.

2.5 ARC - Blast Hazards

As compared to the arc flash, an arc-blast involves extremely high pressure and rapid pressure buildup. This pressure is a result of the rapidly expanding, superheated air in conjunction with the tremendous expansion of vaporized metals, such as copper. Not all occurrences of an arc flash result in an arc blast.

The high pressures generated by an ARC blast can knock workers off ladders, collapse lungs and rupture ear drums. Also, molten metal is expelled from the arc at speeds nearing 700 miles per hour.

3 References

NFPA 70E *Standard for Electrical Safety in the Workplace*, Annex K General Categories of Electrical Hazards

Deleterious Effects of Electric Shock, Charles F. Dalziel, International Labor Office, Meeting of Experts on Electrical Accidents and Related Matters, Geneva, 23-31 October 1961.