Electrical Impedance Hazards

FAST FACTS MAY 2018

OOC OSH Specialist using a circuit analyzer to measure impedance.

Impedance, in very simple terms, is resistance occurring in AC (as opposed to DC) electrical circuits. The degree of resistance is measured in units called ohms. The lower the impedance, the easier it is for electricity to flow through an object. If electricity can follow either a path with low impedance, such as a ground circuit, or high impedance, such as a person with dry hands, then the majority of the electricity will follow the path with low impedance. Impedance can occur in the hot wire portion, the neutral side, or in the ground conductor wiring portion of a three-wire circuit.

This publication focuses on the grounding conductor, located inside an electrical outlet, and the portion of the circuit between the outlet and the panel board or circuit breaker box.

GROUNDING CONDUCTORS

Grounding conductors should have very low impedance. Many electrical devices such as motors, ovens, and computers are designed so that if a fault (short) occurs and energizes something that is not meant to be energized, such as the frame of a computer monitor, an employee would not be shocked by touching the energized object. To prevent electrical shocks or electrocutions, electrical equipment designers install ground circuits in products to have an impedance of less than one ohm.

The grounding circuit (or "third wire" on electrical plugs) safely conducts the unwanted fault current to ground. Instead of shocking the person touching the energized object, most of the current follows the low resistance or impedance path to ground.

THE PATH OF LEAST RESISTANCE

The cliché about electricity following the path of least resistance is incorrect. Electricity will follow all paths back to the grounded source, but it will follow paths proportionally according to the conductivity of each path. When wall outlet ground circuits have very low impedance compared to a person in contact with an energized object, they can safely convey high current away from a faulty electrical device and trip the the ground fault circuit interrupter (GFCI) circuit breaker or fuse in most instances.

154 fatalities nationwide from exposure to electricity in the workplace

1,970 occupational injuries from exposure to electricity

Annual data in 2016. Source: Bureau of Labor Statistics

However, when impedance increases even slightly, the electrical current seeks paths to ground other than the path contained in the grounding circuit of a wall outlet, such as through a person in contact with an energized surface.

Different factors can influence whether an employee receives a serious shock when touching an energized device. Wet hands can lower a body's impedance. As a result, a person's body can become a better electrical conductor than a wall outlet ground circuit with higher impedance, and the person could receive an electrical shock. As the current going through a person's body increases, so does the potential for serious harm. Studies have shown that as few as 10 milliamps on a 115 volt system can cause an irregular heartbeat and could possibly stop a person's heart. (See chart below.)

CAUSES OF HAZARDOUS IMPEDANCE

On Capitol Hill, we have found that a poor contact between two electrical conductors is usually to blame for increased impedance. This occurs most often at the outlet itself or the panel-board connections. Sometimes the screw fastening the ground wire conductor in the receptacle needs to be tightened. Sometimes the outlet itself is broken or worn so much that it needs to be replaced. (See photo.) Sometimes the screw fastening the ground wire in the circuit breaker box needs to be tightened. In rare cases, the distance between the circuit breaker box and the outlet is too great and needs to be shortened by re-wiring the outlet to a closer box. Aluminum wiring, as opposed to copper wiring, can readily lead to impedance problems. Fortunately, aluminum wiring is no longer used in legislative branch buildings.

Effects of Electric Current in the Human Body

Current (Milliamperes)	Probable Effect on Human Body
1 mA	Perception level. Slight tingling sensation. Still dangerous under certain conditions.
5 mA	Slight shock felt; not painful but disturbing. Average individual can let go. However, strong involuntary reactions to shocks in this range may lead to injuries.
6 – 16 mA	Painful shock, begin to lose muscular control. Commonly referred to as the freezing current or "let-go" range.
17 – 99 mA	Extreme pain, respiratory arrest, severe muscular contractions. Individual cannot let go. Death is possible.
100 – 2000 mA	Ventricular fibrillation (uneven, uncoordinated pumping of the heart). Muscular contraction and nerve damage begin to occur. Death is likely.
> 2,000 mA	Cardiac arrest, internal organ damage, and severe burns. Death is probable.

Note: A common household circuit breaker may be rated at 15, 20, and 30A.
Sources: www.osha.gov/SLTC/etools/construction/electrical_incidents/mainpage.html#wet_conditions and www.ncbi.nlm.nih.gov/pmc/articles/PMC2763825/

OSHA'S ELECTRICAL REGULATIONS REQUIRE THAT CIRCUITS THAT COULD BE USED ON SENSITIVE ELECTRICAL EQUIPMENT, SUCH AS COMPUTERS, SHOULD HAVE AN EFFECTIVE GROUND WITH SUFFICIENTLY LOW IMPEDANCE. See 29 CFR 1910.304(b)(2)(ii); see also 29 CFR 1910.399.

ELECTRICAL SAFETY ENGINEERS HAVE CALCULATED THAT IMPEDANCE LEVELS IN GROUND CIRCUITS MUST REMAIN LESS THAN 1 OHM. COMMERCIAL TESTING EQUIPMENT IS AVAILABLE FOR MEASURING THE AMOUNT OF IMPEDANCE IN ELECTRICAL RECEPTACLES. INSPECTIONS IDENTIFY OUTLETS WITH GROUND IMPEDANCE LEVELS HIGHER THAN 1 OHM AS POTENTIAL SAFETY HAZARDS THAT NEED ATTENTION FROM A QUALIFIED ELECTRICAL TECHNICIAN.

Broken and burnt outlet