

Understanding and Managing Risk of Electric Shock

One of the most important roles of an electrical engineer in the mining industry is to make sure that electrical plant is not likely to cause electrical injury, either during normal operations or under fault conditions.

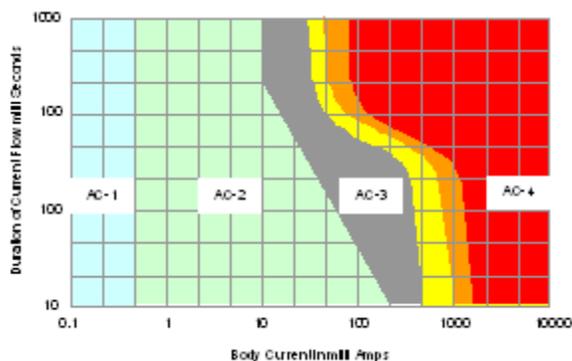
Injury can be due to electric shock, burns, arc blast, smoke inhalation and physical trauma from wayward operation of machinery.

In the mining industry, risk management practices are well established as a means of identifying hazards, assessing risk and identifying risk controls. The Risk Assessment is triggered at the design stage for new plant or activities, and for each subsequent stage of the life cycle. Risk Assessment is also triggered routinely during a review of operations, or by the availability of new information about risk, such as a safety alert.

To properly consider the risk of injury associated with electric shock, the physiological effects on the human body should be understood.

Effects can be immediate, or delayed. There might be obvious diagnostic signs of injury, or the injury might be internal or emotional. They can be affected by such factors as body mass, skin resistance, current path, age, duration and dampness.

There is a large variability in contributing factors and outcomes, but one thing is known. The Maximum Reasonable Consequence of contact with electricity above 50 Volts is **death of at least one person**. This is clearly demonstrated by Figure 14 in AS 60479.1



The probability of death from electric shock rises from possible, with duration greater than 2 seconds, in the grey zone (AC-3), to more than 50% probability in the red zone (AC-4).

For example the yellow region of the graph tells us that a current of 50 mA for 100 mS has a 5% probability of causing ventricular fibrillation.

A rule of thumb for determining current is to use 1000 Ohms for total body impedance. Current is Voltage divided by Impedance.

It can be seen that a Voltage of 50 V is sufficient to produce 50 mA of current through a person's chest. And from the curve, it only requires 100 mS to have fatal consequences.

There are many case examples of fatal welding accidents involving voltages of 85 Volts or less.

The number of fatal incidents involving electric shock in NSW is between 10 and 20 each year. There is many times this number of serious electrical injuries.

Unfortunately this fact has not always clearly emerged in risk assessment reports produced in the mining industry.

It is sometimes put forward that the Maximum Reasonable Consequence of electric shock is minor injury. This is based on a failure of logic that allows the likelihood to somehow enter the deliberations on the Maximum Reasonable Consequence.

It is through the application of engineered risk controls such as protection and earthing systems, that the **risk** (Probability AND Consequence) is managed to a level acceptable to the organisation.

When electrical risk controls are being considered, the possible effects need to be clearly understood. These can be divided into two broad categories:

- Immediate physiological effects, as detailed in **AS/NZS 60479**.ⁱ
- Delayed effects, as detailed by Morseⁱⁱ and Jenner.ⁱⁱⁱ

A complete knowledge of the potential effects of electric shock is also needed when preparing procedures for immediate care of the victim.

The following commonly observed effects are taken from Morse.

Immediate:

Exhaustion
Dizziness
Loss of Function along current path

Long Term:

Weakness/Dysfunction distal to injury path
Chronic pain
Headaches
Irritability
Depression
Chronic Exhaustion
Inability to function at a normal level
Inability to hold/maintain normal employment

It can be seen that a victim may present with minimal physical signs of injury, but may be far from ready to resume normal duties. This has even greater importance if the victim is an electricity worker, whose duties may include making judgements and decisions that affect the safety of himself, his workmates, and others in the workplace if the installation is compromised.

Electrical Engineering Risk Controls

A Mine Safety Management Plan should include plans for the control of the risk of electrical injury. These plans should have regard for the Maximum Reasonable Consequence of electric shock, control measures and victim management.

A properly engineered and maintained electrical installation will have multiple barriers to electric shock.

For prevention of direct contact with live conductors, Australian Standards describe insulation requirements, obstacles, minimum height of conductors, enclosures for electrical equipment and access restrictions.

For prevention of contact with faulty live apparatus, the standards describe earthing systems, electrical protection (including safety switches), double insulated apparatus and Safety Extra Low Voltage (SELV) systems.

The selection and combination of these barriers into an effective electrical engineering safety strategy is a matter for qualified electrical practitioners. The measures only remain effective if properly maintained and inspected, and used in combination with competent personnel and safe operating procedures.

ⁱ AS/NZS 60479.1:2002 Effects of current on human beings and livestock - General aspects

ⁱⁱ An Evaluation Protocol for Electric Shock Injury Supported by Minimal Diagnostic Evidence Presented at IEEE EMBS Morse San Diego, 1993

ⁱⁱⁱ Jensen, P (1987): "Electric Injury Causing Ventricular Arrhythmias" British Heart Journal Vol 57, No.3, pp 279-283