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1. Protection for Safety

Purpose

In any electrical installation there is an ever present risk of injury and/or damage from the physiological, thermal and magnetic effects of electric current and from mechanical movement associated with electrical devices and machines. This section introduces the methods required by the Wiring Rules to protect against these risks.

Objectives

At the completion of this section you should be able to:

• list the factors influencing the severity of an electric shock
• describe the effects of current flowing through a human body
• define the terms “touch voltage” and “touch current”
• explain the thermal effect of current and the hazards of overload current, fault current, arcing and poor electrical connections
• describe the effect of grouping cables
• list the precautions to be taken to protect electrical installations, structural and associated materials and persons from burns produced by heat in electrical equipment (thermal effect of current)
• explain how the fire (rating) integrity of a structure shall be maintained in relation to the electrical installation
• describe the hazards associated with mechanical movement associated with electric motors and the measures taken to mitigate the hazard
• define the terms “direct contact” and “indirect contact”
• provide examples of where and how a direct contact with live parts may occur in an electrical installation
• provide examples of where and how an indirect contact with conductive parts may occur in an electrical installation
• list the methods of protection against direct contact in an electrical installation
• describe the methods of protection against indirect contact in an electrical installation.
1. Introduction

Learning Activities

To help you learn the material in this section there are blank spaces for you to write the appropriate information from the references given.

The Wiring Rules AS/NZS 3000 set out the standards for electrical installations to function safely. As an introduction to this section, complete the following statements by referring to Section 1 of the Wiring Rules.

(a) The title of Section 1 of the Wiring Rules is:

(b) The Scope of the Wiring Rules, as outlined by Clause ________________, sets out the minimum requirements for the design, construction and testing of electrical installations. The requirements of the Wiring Rules are intended to protect:

(c) The principal application of the Wiring Rules, as outlined by Clause ________________, relates to electrical installations in:

(d) The two major types of risk in an electrical installation described by AS/NZS 3000, under Protection against dangers and damage ________________, are
2. Factors of Electric Shock

The effects of electricity on the human body are complex and to a certain extent are not completely understood. However, the effects on lung and heart function of some measurable factors are known. These factors are:

- whether the current is d.c. or a.c.
- the amount of current flow
- the duration of current flow, and
- the current path through the body.

More complex are the physiological effects, such as:

- interference to the nervous system and motor functions
- chemical effects/reactions on the human body; and
- thermal effects on the human body.

All of the above affect the results of an electric shock in causing temporary or permanent damage to the fundamental health of a person. Further information on the effects of electricity on the human body can be found in the IEC Report number 479 written by Professor G. Beigelmeier.

Touch Voltage / Touch Current

When a person experiences an electric shock they are first exposed to a ‘touch voltage’ that results in a ‘touch current’.

(a) “Touch Voltage” is defined by AS/NZS 3000 in Clause ______________ as:

(b) “Touch Current” is defined by AS/NZS 3000 in Clause ______________ as:

Current Paths Through the Human Body

(c) Typical impedance values for various current paths through the human body are given below. Using these values and a touch voltage of 230 V, calculate the touch current for the each pathway.

- Hand to Hand: 1000 ohms
- Hand to Foot: 1000 ohms
- Hand to Both Feet: 750 ohms
- Hand to Seat: 500 ohms
- Both Hands to Seat: 250 ohms
Pathway Calculation Touch current

Hand to hand \( I = \frac{V}{Z} = \frac{230}{1000} \) 230 mA

Hand to foot

Hand to both feet

Hand to seat

Both hands to seat

**Amount of Current**

As can be seen from the calculated touch current, relatively small amounts of current will flow through the human body in the event of electric shock. These values of current may be fatal!

**Duration of Current Flow**

The duration of current through the human body, along with the value of current will determine the severity of the electric shock.

**Time in Contact with Current**

Figure 1.2 is a current - duration diagram showing 4 danger zones, each zone having a different influence and damaging effect on the human body.

*Figure 1.2 - Diagram supplied courtesy of Clipsal*
Physiological Effects Table provided courtesy of Clipsal

<table>
<thead>
<tr>
<th>Zone</th>
<th>Physiological Effects</th>
<th>Likelihood of muscular contractions and difficulty in breathing.</th>
<th>Possibility of cardiac arrest increasing with value of current and time.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Usually no reaction.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Usually no harmful physiological effects.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Usually no organic damage.</td>
<td>Likelihood of muscular contractions and difficulty in breathing.</td>
<td>Possibility of cardiac arrest increasing with value of current and time.</td>
</tr>
<tr>
<td>4</td>
<td>Including the effects of zone 3.</td>
<td>c1 probability of ventricular fibrillation increased to 5%.</td>
<td>c2 probability of ventricular fibrillation increased to 50%.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>c3 probability of ventricular fibrillation increased to above 50%.</td>
<td>Further increases in time and/or current are likely to cause arrest and burns.</td>
</tr>
</tbody>
</table>

(d) Consider various durations for a touch current of 200 mA. What would be the likely physiological effect for each of the durations given in the following table?

<table>
<thead>
<tr>
<th>Current Duration</th>
<th>Zone</th>
<th>Physiological Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 mS</td>
<td>2</td>
<td>Usually no harmful physiological effect</td>
</tr>
<tr>
<td>100 mS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>500 mS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1000 mS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2000 mS</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(e) Curve b is the division between zone 2 and 3. For a touch current of 20 mA, how long would it take for the body to cross the division and enter zone 3 and what would be the impedance of the body when the touch voltage is 230 V?

\[
\text{Time} = \text{______________ ms} \\
\text{Impedance} = \text{______________ ohms}
\]
3. Hazards from Thermal Effects of Current

A major effect of electric current is to produce heat in the conductor through which it flows. The quantity of heat produced is given by the equation:

\[ H = I^2Rt \]

Where: 
- \( H \) is the heat energy produced in joules.
- \( I \) is the current flowing through the conductor in amperes.
- \( R \) is the resistance of the current path in ohms.
- \( t \) is the duration of current flow in seconds.

(a) You will note from the equation that the heat produced is proportional to the current squared. What heat will result if the current in a circuit is doubled?

Overload and Fault Current

(b) AS/NZS 3000 defines ‘fault current’ as ____________________________

Clause ____________ and ‘overload current’ as ____________________________

Clause ________________.

(c) The Wiring Rules clause ‘Protection against earth fault currents’, Clause number ____________ requires that conductors or any other parts required to carry a fault current shall be capable of:

__________________________

(d) The Wiring Rules allows for one of two methods to be used for ‘protection against overcurrent’. The two permissible methods are:

- ________________
- ________________

AS/NZS 3000 Clause: ____________

(e) Requirements for protection against overcurrent are set out in Section ____________ of the Wiring Rules.
*Heat Sources*

**Protection Against Thermal Effects in Normal Service** - AS/NZS 3000 Clause: 

Protection against the risk of ignition of flammable material in normal service may be provided by:

- 
- 

Further information on the thermal effects associated with the installation of electrical equipment is given in Clause: 

**Electrical Equipment Requiring Protection Against Thermal Effects** - AS/NZS 3000 Clause: 

Heat is developed during the normal operation of electrical equipment. In order to maintain the operating temperature below the rated specified limits, then shall be provided.

When the surface temperature of electrical equipment reaches a temperature that may cause a fire hazard to adjacent materials, the electrical equipment will be:

- 
- 
- 

Name two items of electrical equipment that would be considered to be a high temperature source:

- 
- 

*Installation and Connection of Cables*

**Loosening of Connections** - AS/NZS 3000 Clause: 

During normal service, an electrical connection must not loosen due to vibration, alteration of materials or: 

- 
- 