Government of **Western Australia**
North Metropolitan **TAFE**

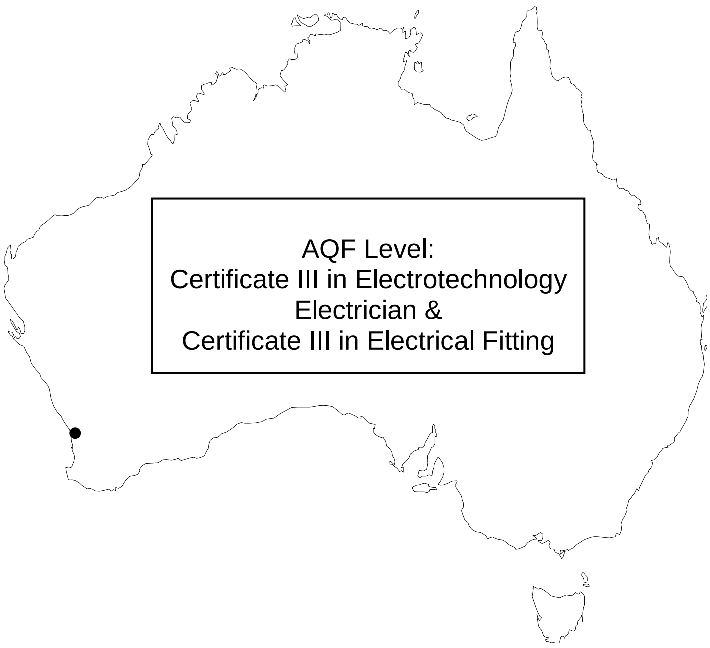
UEE 11 Training Package Support Material
(Non-Endorsed Component)

Based on:
National Electrotechnology Industry Standards

Resource Book

UEENEEG108A

Trouble-shoot and Repair Faults in Low Voltage Electrical Apparatus and Circuits



AQF Level:
Certificate III in Electrotechnology Electrician &
Certificate III in Electrical Fitting

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North Metropolitan TAFE

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UEENEEG108A Trouble-shoot and repair faults in low voltage electrical apparatus and circuits

C O N T E N T S

Work Completed:

Section	**Topic**	Completed
1	Legislative Requirements	
2	Earthing Conductor Resistance Tests	
2	Insulation Resistance Tests	
2	Polarity and connection Tests	
2	Installation Inspection and Testing 1 (Project 1)	
2	Installation Inspection and Testing 2 (Project 2)	
2	Installation Inspection and Testing 3 (Project 3)	
3	Fault Finding in Electric Hot Water Systems	
3	Fault Finding in Electric Hot Water Systems (Project 1)	
3	Fault Finding in Electric Hot Water Systems (Project 2)	
4	Florescent Lighting	
4	Troubleshooting 18watt fluro with fault switches	
5	Troubleshooting single and three phase induction motors	
5	Troubleshooting 3 phase induction motors (Project 1)	
5	Troubleshooting split phase motors (Project 2)	

References

- AS/NZS 3000 (Current edition) – Wiring Rule (Standards Australia)
- AS/NZS 3017 (Current edition) – Electrical Installations – Testing and Inspection
- H B 301 – 2001 Electrical Installations: Designing to the Wiring Rules
- AS/NZS 3008.1.1 (Current edition) – Electrical Installations- Selection of Cables
- WA Electrical Requirements (Current edition)
- Electrical Wiring Practice (7th ed.) Pethebridge, K. & Neeson, I.

UEENEEG108A Trouble-shoot and repair faults in low voltage electrical apparatus and circuits

Competency Standard Units

Prerequisite Units
Granting competency in this unit shall be made only after competency in the following units have been confirmed.

UEENEEE101A	Apply Occupational Health and Safety regulations, codes and practices in the workplace
UEENEEE102A	Fabricate, dismantle, assemble of electrotechnology components
UEENEEE104A	Solve problems in d.c circuits
UEENEEE105A	Fix and secure electrotechnology equipment
UEENEEE107A	Use drawings, diagrams, schedules, standards, codes and specifications
UEENEEG006A	Solve problems in single and three phase low voltage machines
UEENEEG033A	Solve problems in single and three phase electrical apparatus and circuits
UEENEEG063A	Arrange circuits, control and protection for general electrical installations
UEENEEG101A	Solve problems in electromagnetic devices and related circuits
UEENEEG102A	Solve problems in low voltage a.c. circuit
UEENEEG106A	Terminate cables, cords and accessories for low voltage circuits

ELEMENT		PERFORMANCE CRITERIA	
1	Prepare to trouble-shoot and rectify faults.	1.1	The extent and nature of the electrical installation is determined from job specifications.
		1.2	Safety and other regulatory requirements to which the electrical installation shall comply area are identified, obtained and understood.
		1.3	OHS procedures for a given work area are identified, obtained and understood.
		1.4	OHS risk control measures and procedures in preparation for the work are followed.
		1.5	The likely extent of work to be undertaken is envisaged from fault/breakdown reports and/or discussions with appropriate person(s).
		1.6	Advice is sought from the work supervisor to ensure the work is coordinated effectively with others.
2	Trouble-shoot and repair faults.	2.1	OHS risk control measures and procedures for carrying out the work are followed.
		2.2	The need to test or measure live is determined in strict accordance with OHS requirements and when necessary conducted within established safety procedures.

ELEMENT		PERFORMANCE CRITERIA	
		2.3	Circuits/machines/plant are checked as being isolated where necessary in strict accordance OHS requirements and procedures.
		2.4	Safety hazards resulting from the fault or breakdown are documented and risk control measures devised and implemented in consultation with appropriate personnel.
		2.5	Trouble-shooting is approached methodically drawing on knowledge of electrical circuits and apparatus using measured and calculated values of circuit/apparatus parameters.
		2.6	Circuit/apparatus components are dismantled where necessary and parts stored to protect them against loss or damage.
		2.7	Faulty circuits/components are rechecked and their fault status and acquired.
		2.8	Materials/replacement parts required to rectify faults are sourced and obtained in accordance with established procedures.
		2.9	Effectiveness of the repair is tested in accordance with established procedures.
		2.10	Apparatus is reassembled, finally tested and prepared for return to service.
		2.11	Unexpected situations are dealt with safely and with the approval of an authorised person.
		2.12	Trouble-shooting and repair activities are carried out without damage to apparatus, circuits, the surrounding environment or services and using sustainable energy practices.
3	Completion and report trouble-shoot and repair activities.	3.1	OHS work completion risk control measures and procedures are followed.
		3.2	Work area is cleaned and made safe in accordance with established procedures.
		3.3	Written justification is made for repairs to apparatus.
		3.4	Work completion is documented and an appropriate person or persons notified in accordance with established procedures.

Required Skills and Knowledge

KS01-EG108A	Electrical circuit and equipment faults and fault finding techniques
Evidence shall show an understanding of electrical circuit and equipment faults and fault finding techniques to an extent indicated by the following aspects:	
T1	**Troubleshooting concepts encompassing:**
•	need to understand the correct operation of a circuit or equipment, switching and control circuit arrangements.
•	common faults with circuits and equipment including operator faults, incorrect connections, open-circuits, short-circuits, device faults (mechanical), supply faults.
•	typical faults symptoms and their causes: operation of circuit protective device, appliance does not operate, single phase motor does not develop enough torque to drive the load, three phase motor does not develop enough torque to drive the load, motor overload trips
•	factors to consider in clarifying the nature of a fault: initial fault report, confirmation of symptoms of the fault, comparison of symptoms with normal operation
•	effect to cause reasoning — assumptions of possible causes
•	methods for testing assumptions: visual inspection, component isolation, test equipment, sectional testing, split-half tests
•	repairing the fault and the steps needed to ensure fault doesn't re-occur
•	dealing with intermittent faults (typical causes of intermittent faults are vibration, shock, changes in temperature and electromagnetic interference).
•	final testing and re commissioning
T2	**Troubleshooting water heater and appliance circuits/equipment encompassing:**
•	circuit diagrams of common single phase and three phase hot water systems
•	single phase and three phase element resistance values (determined from measurement and calculation from power and voltage ratings)
•	testing single and three phase elements for correct insulation resistance and continuity
•	element replacement techniques
•	operation of thermostats, thermal cut-outs and pressure relief valves, flow switches and checking sacrificial anodes
•	locating faults in common single and three phase hot water systems
•	repairing faulty water heating systems
T3	**Troubleshooting electrical appliance circuits/equipment encompassing:**
•	circuit diagrams of common single phase and three phase appliances
•	methods to determine the cause of an RCD operation
•	identification of appliances that is causing an RCD to trip
•	testing single and three phase appliances for correct insulation resistance and continuity
•	operation of appliances controls
•	locating faults in common single and three phase appliances
•	repairing faulty appliances
T4	**Troubleshooting lighting circuits encompassing:**
•	circuit and wiring diagrams of common lighting circuits including single light controlled by a single switch, multiple lights controlled by a single switch, two and three way switching using the loop at the light method and the loop at the switch method.
•	causes of wiring faults from supplied symptoms and circuit and/or wiring diagrams
•	causes of faults in ELV lighting devices, include transformer (iron core or electronic), voltage drop, heat, over-voltage, poor connections, incompatible dimmers
•	diagrams of a basic fluorescent light circuit including lamp, ballast and starter
•	locating faults in fluorescent light circuits
•	operation of a range of lighting control including passive infra-red (PIR), dimmers, photo electric or day-light switches and time clocks
•	locating faults in lighting control circuits
T5	**Troubleshooting single phase motor and control circuits encompassing:**
•	circuit diagrams of split phase, capacitor start, capacitor start capacitor run, universal and shaded pole single phase motors
•	causes of single phase motor faults from supplied symptoms and circuit diagrams
•	causes of electrical faults in single phase motors, include open and partially open circuit winding, short and partially short circuit winding, open circuit rotor, burnt out winding, coil shorted to frame.
•	reasons for a thermal overload trip and how often they are to be reset before investigating a cause
•	internal mechanical faults and their consequences, include bearings, fans, bent shaft, locked rotor, blocked air vents, centrifugal switches, environmental factors

- faults on driven loads and couplings and their consequences, include slipping belts, poorly aligned coupling (shims), vibration, loads bearing failing, load stalling.
- locating faults in single phase motors and their controls

T6 Troubleshooting three phase induction motor encompassing:

- circuit diagrams of three phase induction motors
- causes of three phase motor faults from supplied symptoms and circuit diagrams
- causes of electrical faults in three phase motors, include open and partially open circuit phase winding, short and partially short circuit phase winding, open circuit rotor, burnt out phase winding, coil shorted to frame.
- reasons for a thermal overload trip and how often they are to be reset before investigating a cause
- internal mechanical faults and their consequences, include bearings, fans, bent shaft, locked rotor, blocked air vents, environmental factors.
- faults on driven loads and couplings and their consequences, include slipping belts, poorly aligned coupling (shims), vibration, loads bearing failing, load stalling.
- locating faults in three phase induction motors and their controls

T7 Troubleshooting electrical installations encompassing:

- circuit diagrams, wiring diagrams, cable schedules and specifications of electrical installations
- causes of electrical installation faults from supplied symptoms and circuit diagrams include open and partially open circuit wiring, short and partially short circuit wiring, low insulation resistance, incorrect polarity, transposition of conductors, RCD tripping.
- locating faults in electrical installations
- repairing faulty electrical installation circuits components and wiring.

G108A Work Performance Tasks:

UEENEEG108A – Trouble-shoot and repair faults in low voltage electrical apparatus and circuits

1. Performance requirements:

1a. Related to the following elements:

1. Prepare to trouble-shoot and rectify faults.
2. Trouble-shoot and repair faults.
3. Completion and report trouble-shoot and repair activities.

1b. For each element demonstrate performance:

- across a representative body of performance criteria,
- on at least 2 occasions,
- autonomously and to requirements,
- within the timeframes typically expected of the discipline, work function and industrial environment.

2. Representative range includes the following:
All listed tasks related to performance across a representative range of contexts from the prescribed items below:

The minimum number of items on which skill is to be demonstrated Group No			Item List
A.	At least four of the following:	**Equipment and associated circuits**	
			• Switchboards • Protective devices • Lighting • Heating • Socket outlets • Control devices
B.	At least three of the following:	**Machines and associated control circuits**	
			• Single phase motors • Single phase motor controls • Three phase motors • Three phase motor controls • Synchronous machines • DC machines • DC machines controls • Transformers and auxiliary components

Workplace Rules:

Rule 1	Follow the instructions
Rule 2	Tolerate ambiguity
Rule 3	Meet your obligations

Note: This information and current details of critical aspects for each competency standard unit (CSU) in this qualification can be found at the Australian Training Standards website www.training.gov.au.

UEENEEG108A Trouble-shoot and repair faults in low voltage electrical apparatus and circuits

Learning and Assessment Plan

Name of Lecturer: ____________________

Contact Details: ____________________

Delivery Mode/s: ☐ Face to Face ☐ On-Line ☐ Blended Delivery ☐ Other

Using:

- AS/NZS 3000 (Current edition) – Wiring Rule (Standards Australia)
- H B 301 – 2001 Electrical Installations: Designing to the Wiring Rules
- AS/NZS 3008.1.1 (Current edition) – Electrical Installations- Selection of Cables
- WA Electrical Requirements (Current edition)
- Electrical Wiring Practice (7th ed.) Pethebridge, K. & Neeson, I.

Session	Nominal Duration	Program of Work (Topics to be covered)	Primary Reference
1	4 hours	Introduction to UEENEEG108A Recognition of Prior Learning Section 1 Regulations	Resource Book
2	12 hours	Installation Testing and Fault-finding	Resource Book
3	4 hours	Hot Water Systems Fault-finding	Resource Book
4	4 hours	Lighting Systems Fault-finding	Resource Book
5	8 hours	Trouble-shooting Single & Three Phase Motors	Resource Book
6	2 hours	**Written Assessment**	RSAK – KS01 – EG108A
7	2 hours	**Observed Practical Assessment**	UEENEEG108A Elements

I acknowledge that I have received and read this Delivery and Assessment Plan Student Name: ____________ Signature: ____________ Date: ________		
Lecturer Name	Lecturer Signature	Date

Assessment Strategy

Conditions of Assessment:

Normally learning and assessment will take place in an integrated classroom/ laboratory environment.

It is essential to work through the worksheets and activities in this workbook and follow the guidance of your lecturer. The worksheets and practical activities will provide the required skills and knowledge outlined in this Unit and assist you in achieving competency.

Assessment Methods:

Written Assessment – based on the Require Skills and Knowledge (RSAK). You must achieve a mark of 75% or more in this assessment.

Observed Practical Assessment – based on the Elements and Performance Criteria of this Competency Unit UEENEEG108A. You must achieve a mark of 100% in this assessment.

On-Job-Training:

It is expected that the off-job component of this competency unit will be complemented by appropriate on-job development involving exposure to re-occurring workplace events and supervised experiences. (See Work Performance Tasks.) You are required to log your on-the-job training in your 'Q-Tracker account.

Sufficiency of Evidence:

In all instances competency is to be attributed on evidence sufficient to show that a person has the necessary skills required for the scope of work. These include:

- Task skills - performing individual tasks
- Task management skills - managing a number of different tasks
- Contingency management skills - responding to irregularities and breakdowns in routines
- Job/role environment skills - dealing with the responsibilities and expectations of the work environment including working with others.

Evidence must demonstrate that an individual can perform competently across the specified range of activities and has the required skills and knowledge underpinning the competency.

LABORATORY SAFETY INSTRUCTIONS

Students working in Laboratories at this campus do so, on condition that they agree to abide by the following safety instructions. Failure to observe the safety instructions may result in immediate suspension.

1. No circuit is to be plugged in or switched on without specific permission of the lecturer in charge of the class. A circuit must be switched off and tested for zero volts before any connection leads are removed. The DANGER TAG PROCEDURE must be used at all times.

2. Do not leave any circuit switched on any longer than necessary for testing. Do not walk away and leave the circuit switched on.

3. Report any broken, damaged or unserviceable equipment to your lecturer.

4. All of your wiring must be disconnected at the end of each practical class or as each project is completed.

5. Make all connections in a safe manner with an appropriate connecting device. Unshielded 4 mm banana plugs are not to be used for wiring.

6. Switch off, remove the plug from the socket and attach your danger tag to the plug top before working on the project. It is not sufficient to simply turn the supply switch off.

7. When disconnecting your wiring from a connection made under a screw, undo the screw- do not cut the wires off.

8. Observe the correct colour code for all wiring projects.

9. Check your circuit for short circuits with your multimeter before asking your lecturer to switch on. Check the checker before and after EACH check.

10. Skylarking is not permitted at any time.

11. Proper clothing and footwear must be worn at all times when you attend this campus. Thongs, sandals and singles alone are not permitted. **Safety boots or safety shoes must be worn in workshops, laboratories and installation skills areas**.

12. Where a project sheet is issued for a practical project, complete each step in the Procedure before moving on to the next step.

13. Draw all diagrams in pencil so that they can be easily changed or corrected. Mark off each connection on your circuit or wiring diagram as it is made.

14. Check the function and range before taking a reading with a multimeter.

15. Make sure that it is YOUR plug before you insert it into a socket outlet.

16. Always switch a multimeter OFF or to the highest possible AC volts range when you have finished using it.

Student's Signature ___________________________ Date: __________________

WORKSHOP SAFETY INSTRUCTIONS

Students working in workshops and installation skills areas at this college do so on condition that they agree to abide by the following safety instructions. Failure to observe the safety instructions may result in immediate suspension.

1. Personally owned eye protection must be worn AT ALL TIMES. Other safety equipment including hearing protection must be worn when applicable to a particular task.

2. Loose clothing must not be worn when working on fixed or portable machines. Hairnets must be worn where applicable. Clothing must cover the upper arms and body.

3. Enclosed footwear must be worn at all times on this campus. Thongs or sandals are not permitted. **Safety boots or safety shoes must be worn in workshop and installation skills areas**.

4. Tools and safety equipment are issued from the tool store on request. It is your responsibility to ask for the correct item (Size, Type and Tool). Check to see that you have been given the correct item before using it. If in doubt ask your LECTURER, not the storeperson.

5. Report any broken, damaged or unserviceable equipment to your Lecturer. Do not use damaged tools or machines.

6. Clean down the machines immediately after use. All tools must be cleaned before returning them to the store.

7. Skylarking is not permitted at any time.

8. Always use protective vice jaws when cutting off material in a bench vice.

9. Accidents resulting in cuts, abrasions or other personal injury must be reported to your Lecturer immediately - no matter how minor they may seem. A first-aid kit is available in the tool store.

10. Never leave a machine unattended when it is running. Do not allow yourself to be distracted when operating a machine.

11. Read all safety signs and notices and follow the instructions.

12. Do not use a fixed or portable machine unless you have been instructed in its proper use.

13. Read all risk assessment documentation provided (JSAs) and conduct a relevant risk assessment process before performing any task.

Student's Signature _________________________ Date: _________________

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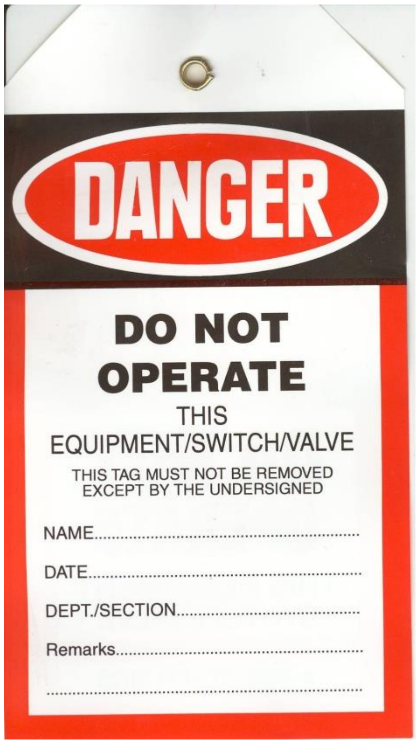
Danger Tag Procedure

Use of Danger Tags



If you have a practical task to do and there is a possibility that you could be injured if someone turns on the electricity, then you **MUST** fasten a red danger tag to the machine main isolation switch, circuit-breaker or the equipment plug top.

Each danger tag you use must clearly show; your name, your section (class) and the date.

Nobody must operate the danger tagged switch or control point until the job is made safe and the danger tag has been removed.

Your lecturer will check your task before you are allowed to remove your danger tag.

Only the person, who is named on the tag and attached the tag, is allowed to remove it.

Points to Watch

Make absolutely sure the switch/circuit-breaker/plug top is the correct one to tag. If you have any doubts, ask your lecturer.

Make sure that you have switched the isolator to **OFF** position before you attach your danger tag.

Fasten the danger tag securely.

The purpose of using Danger Tags is to prevent electrical accidents from happening.

Failure to follow Danger Tag Procedures when working on practical activities and practical assessments will result in a '**Not yet competent'** comment recorded for this Unit of Competency – UEENEEG108A

Student's Signature ___________________________ Date: ___________________

Legislation Requirements

Task:

To describe the requirements to ensure that all circuits and electrical equipment are safe in accordance with legislation and regulations.

In order to be able to correctly test circuits and electrical equipment, you must know the regulatory and legislative requirements which apply to the particular installation, and the extent of your responsibility in meeting those requirements.

To Pass:

You must correctly answer the questions on the Work Sheets provided and achieve a mark of 75% or more in the written assessment.

Equipment

Nil

References

* AS/NZS 3000:2018 - Wiring Rules. Standards Australia
* WA Electrical Requirements (2014)
* Electricity (Licensing) Regulations 1991
* AS/NZS 3017(current edition) Electrical Installations - Testing guidelines
* Electrical Wiring Practice (7th Ed) - Volume 1, Pethebridge & Neeson

Legislation Requirements

Suggested Self-Study Guide

1. Study the following sections in the recommended references:

   Electricity (Licensing) Regulations 1991

   Part 1 Preliminary (Definitions)
   Clause 19 Electrical work prohibited useless authorised
   Clause 50 Duty to effectively supervise electrical work
   Clause 50A Licence holder not to cause or permit unsafe wiring or equipment to be connected to electrical installation

   Wiring Rules

   Section 1 Scope, Application and Fundamental Principles

   Electrical Wiring Practice - Volume 1

   Section 3.1 Electrical Licensing

   Section 3.2 Standards

   WA Electrical Requirements - 2015

   Section 1 Introduction

   Section 9 Special Requirements for Installations in WA

2. Read the Summary and answer the questions provided on the Work Sheet. Use a separate answer sheet or sheets for the Work Sheet. Refer to other relevant texts if you feel it is necessary.

3. Submit your answers to the Work Sheet to your Lecturer for discussion and assessment.

Legislation Requirements

Legislation and Standards

1. All electrical installations including circuits and electrical equipment, must comply with relevant legislative requirements to ensure that they safe to connect to the supply for two main reasons:

   a. To prevent electrocution.

   b. To prevent unwanted fire or damage resulting from overheating.

2. The process of ensuring that an installation complies with relevant requirements involves two often inter-related activities:

   a. Checking the installation to ensure that it complies with all relevant regulations and requirements, by visually inspecting all parts of the installation.

   b. Testing the relevant components, circuits and electrical equipment in the installation with suitable measuring instruments to ensure that they are within the limits specified in relevant regulations and standards. See Wiring Rules Section 8 - Verification.

3. The person responsible for ensuring that the installation meets all relevant requirements is the licensed electrical worker who performs the electrical work. Electrical installing work is defined in the WA Electricity (Licensing) Regulations - 1991, Part 1 as:

   "·... the work of assembling and fixing in place, altering or adding to any electrical installation or maintaining, enhancing, repairing, removing, or, connecting to fixed wiring, any electrical equipment."

4. Electrical work, as defined in the Electricity (Licensing) Regulations, relates to equipment which is supplied or intended to be supplied at a nominal pressure of 50 volts a.c. or 115 volts d.c.

5. Although Electricity (Licensing) Regulations, Regulation 19(2) specifies certain types of electrical work which may be performed under certain conditions without an electrical worker's licence, none of the exceptions apply to permanent electrical installation work over 50 volts a.c. and 115 volts d.c. in domestic or non-domestic buildings.

6. The Electricity (Licensing) Regulations, Regulation 49(1) specifies that all electrical work must be carried out in accordance with the requirements of the Wiring Rules, the WA Electrical Requirements and several specified

standards (as amended from time to time).
If a person carries out electrical work without an unrestricted electrical mechanic's licence, or if he or she is found to have performed sub-standard electrical installation work, he or she is liable to prosecution under the Electricity (Licensing) Regulations. Electrical permit holders and apprentices are not permitted to test an installation unless they are under the supervision of a fully licenced electrical mechanic, nor are they permitted to sign any documents certifying that an installation is safe to connect to the supply.

7. Although the Wiring Rules contains all the relevant requirements for checking and testing installation work, and Section 8 - Verification, guidelines for the testing of installations is the subject of another Australian Standard AS/NZS 3017 Electrical installations - Testing guidelines. AS/NZS 3017 contains explanatory pictorial representations of typical testing processes in the following aspects of a complete MEN installation:

   a. earth resistance.

   b. insulation resistance.

   c. polarity.

   d. incorrect circuit connections.

Testing Processes

8. When a completed installation has been visually inspected to ensure that all cables and equipment have been installed and terminated correctly, and the installation complies with all relevant requirements of the Wiring Rules, WA Electrical Requirements and other standards, several specific tests must be carried out with measuring instruments. In order to correctly perform the tests, you must know:

   a. The precise purpose of a specific type of test,

   b. What you are testing for,

   c. What you need to test with,

   d. What results you could expect for this test,

   e. What results you actually obtained.

   f. Whether the indicated results are permissible or not permissible.

9. In general terms the electrical tests required are:

   a. Earth continuity tests. Are all earthing conductors continuous, and does the circuit conform to the requirements of Table 5.l of the Wiring Rules?

   b. Earth resistance test. Is the resistance of the main earthing conductor within the permissible limit of 0.5Ω. Do all protective earth conductors meet the requirements of AS/NZS 3000 - Table 8.2?

c. Insulation resistance test. Is the insulation resistance between all live conductors and earth within the permissible limits?

d. Short circuit test. Are there any short circuits in the installation?

e. Polarity test. Ensure that no shock hazard arises from incorrect connection of active, neutral and earthing conductors.
Are all socket outlets polarised correctly?

f. Switch polarity test. Are all switches in active conductors?

g. Neutral polarity test. Are all neutrals connected to the correct neutral link?

h. Circuit continuity test. Are all circuits electrically continuous?

i. Earth/Neutral separation test. Is the earthing system connected to the neutrals at the MEN point only?

j. Functional operation test. Should the installed equipment function as intended?

10. Typical detailed procedures for conducting tests are described later in this unit. Descriptions of tests are based on a simplified single phase domestic installation which meets all of the regulatory and legislative requirements for such an installation in WA.

11. The simplified installation (see attached diagram) contains one sample of each of the types of final sub-circuit circuit typically found in a domestic installation:

a. A lighting circuit (two-way).

b. A protected power circuit for single phase socket outlets.

c. A protected circuit for lighting.

d. A fixed wired electrical appliance (oven).

e. A storage type hot water system with metallic water pipes.

12. You need to ensure that you are completely familiar with the components shown on the diagram before proceeding to the next section. In an actual installation there could be several of each type of final sub-circuit, and more points on each. There could also be other types of final sub-circuit such as 15 amp socket outlets, motors, air-conditioners, cooking ranges and so on. There could also be a different mix of circuits on the RCDs - such as one light and one power circuit on each RCD.

Clause 2.6.2.4 (a) of the Wiring Rules specifies that where there is more than one RCD and more than one lighting circuit installed, the lighting circuits shall be distributed between RCDs.

Clause 2.6.2.4 (b) of the Wiring Rules specifies that where there is more than one final sub-circuit in a residential installation, a minimum of two RCD's shall be installed.
The installation should be designed so that some lighting and some socket-outlet (power) circuits are protected by one RCD, and the remainder by the other RCD. These arrangements are intended to minimize the impact of the operation of a single RCD.

Other Standards

13. Although the typical testing procedures in this unit focus on domestic installations, the general principles apply to all installations and equipment testing. However, there are many other types of installations and electrical equipment which have special requirements (see Electricity (Licensing) Regulations 1991, Clause 49). Appendix A of the Wiring Rules contains information relating to other Australian Standards for particular situations and installations.

14. Use the information contained in Appendix A of AS/NZS 3000 to determine the name of the following standards/documents:

    a. AS/NZS 3100 Approval and test specifications – General requirements for electrical equipment.

    b. AS/NZS 3001 Electrical Installations – Transportable structures and vehicles including their sire supplies.

    c. AS/NZS 3002 Electrical Installations – Shows and carnivals.

    d. AS/NZS 3003 Electrical Installations – Patient areas

    e. AS/NZS 3004 Electrical Installations – Marinas and boats.

    g. AS/NZS 3012 Electrical Installations – Construction and demolitions sites

    h. AS/NZS 3760 In service safety inspection and testing of electrical equipment.

    i. AS/CA S009 Installation requirements for customer cabling (Telecommunications wiring rules)

15. It is the responsibility of the licensed electrical worker to be familiar with the requirements of the relevant standard(s) when carrying out associated electrical work or testing.

Legislative Requirements

1. Name the two main publications which specify the requirements for testing of domestic and non-domestic electrical installations in WA.
2. Who is responsible for testing a completed installation to ensure that it complies with all legislative requirements and is safe to connect to the electrical supply?
3. List the four types of electrical tests which must be completed before a single or three phase electrical appliance can be regarded as safe to connect to the electrical supply.
4. Which Australian Standard contains specific guidelines and diagrams describing typical procedures for testing a completed electrical installation?
5. What type of electrical installation is the subject of Standard AS/NZ 3001?
6. Name the publication which specifies the requirements for in-service safety inspection and testing of electrical equipment.

Notes

Installation Circuit Testing and Fault Finding

Task

To test installation circuits with measuring instruments and ensure that they complies with all relevant regulatory and legislative requirements.

You must be able to test an installation for all aspects of operation and safety so that it is safe to connect to the supply.

To Pass:

1. You must correctly answer the questions on the Work Sheets provided and achieve a mark of 75% or more in a competency written assessment.

2. You must satisfactorily complete the set laboratory projects.

3. You must achieve 100% in the practical competency assessment.

Equipment

Nil

References

* AS/NZS 3000 (current edition) Wiring Rules. Standards Australia.
* WA Electrical Requirements (2014) WA Office of Energy
* AS/NZS 3017 (current edition) Electrical Installations - Testing guidelines
* Checking and Testing Electrical Installation Work, WA Office of Energy
* Safety Guidelines for Electrical Workers, WA Office of Energy
* Electrical Wiring Practice (7th Ed) - Volume 1, Pethebridge & Neeson

Installation Circuit Testing and Fault Finding

Suggested Self-Study Guide

1. Study the following sections in the recommended references:

AS/NZS3000 Wiring Rules

Clause 1.8 Verification (Inspection and Testing)
Section 8 Verification

AS/NZS 3017(current edition) Electrical Installations - Testing guidelines

Electrical Wiring Practice - Volume 1

Chapter 9 Testing techniques and compliance verification

WA Electrical Requirements 2014

Section 3.2 Earthing System
Section 9.2 Consumers Mains
Section 9.5 Protection of PV Array DC Cables
Section 9.6 Equipotential Bonding in Shower Recesses and Bathrooms

Checking and Testing Electrical Installation Work, WA Office of Energy

2. Read the Summaries and answer the questions provided on the Work Sheet(s). Use a separate answer sheet or sheets for each Work Sheet. Refer to other relevant texts if you feel it is necessary.

3. Submit your answers to the Work Sheets to your Lecturer for discussion and assessment.

Earth Resistance Tests

1. The purpose of earth resistance tests is to ensure that the resistance of earthing conductors, including the main earth conductor, protective earthing conductors and bonding conductors, is low enough to allow sufficient current to flow to cause the circuit protection device to automatically operate and isolate the electrical supply if a short circuit occurs between a live part and earth.

Requirements

2. The resistance of protective earthing conductors shall be low enough to cause overcurrent protection devices to operate (see AS/NZS 3000: 2018 Table 8.2 *Maximum values of resistance of final subcircuits)*.

3. The resistance of the main earthing conductor and equipotential bonding conductors must not exceed 0.5 ohms.

Considerations

4. Main earthing conductor and bonding conductor resistance tests require an ohmmeter or multimeter capable of accurately reading values around 0.5 ohms. Although typical inexpensive analogue multimeters have an ohms times 1 range, reading 0.5 ohms at the extreme right-hand end of the scale does not provide the required degree of accuracy for measuring earth resistance. Digital multimeters with a low ohms range or insulation testers with a low ohms range setting are usually suitable, but care must be taken to ensure that the instrument is set to the correct scale.

5. Testing the resistance of protective conductors of final sub-circuits requires the electrical worker to first check the current rating and the type of the protective device of the circuit to be tested. This information is needed to select the maximum value of resistance (*Re*) from Table 8.2 of the Wiring Rules.

One long roving lead is required on the measuring instrument so that it can reach each earthed point on the circuit when measuring the continuity of an earthing conductor. The length of the longest circuit must be less than the value specified in Table B1 of the Wiring Rules.

6. When checking the continuity of earthing conductors it is essential to temporarily disconnect any other earthing conductors or equipotential bonding conductors which are in parallel with the one under test.

7. In installations which have an electric hot water system with metallic water pipes, the water pipes would typically be connected to the general mass of earth because they are installed underground. An equipotential bonding conductor is required between the main earthing conductor and the metallic water pipe (see AS/NZS 3000 Clause 5.6.2.2), and an earthing conductor is required from the main earthing conductor to the hot water system.

Since this arrangement constitutes a parallel path, the earthing conductor at the hot water system must be temporarily disconnected while the resistance of the main earthing conductor is measured.

8. In some MEN installations the circuit earths are connected to the main earthing conductor (or neutral bonding conductor) by means of a soldered tee joint (see AS/NZS 3000 Clause 3.7.2.7). In other installations the main earthing conductor, the neutral bonding conductor and all circuit earths are terminated at an earth link or earth bar, and the MEN connection is made by connecting the earth link/bar to the main neutral link.

Reconnecting after testing

9. It is essential to ensure that all circuits or components which were disconnected during the testing process are reconnected correctly after the tests have been completed. Ensure that the MEN connection is re-instated.

Typical Earthing Conductor Testing Procedures

10. Main Earthing Conductor. A typical procedure for testing the resistance of a main earthing conductor is described below (based on AS/NZS3017:2007).
Refer to Diagram 1 - some of the processes described below are referenced with a letter in the text, with a corresponding letter in a circle on the diagram.

a. Ensure that the consumer's mains are not connected to the supply and test for zero volts.

b. Disconnect the water pipe equipotential bonding conductor and the water heater earthing conductor (if applicable) (A) and (B).

c. Disconnect the main earthing conductor from the neutral link (C).

d. Select an appropriate low-reading ohmmeter or multimeter with one lead long enough to reach the earthing electrode. Zero the instrument or note the resistance of the leads.

e. Connect one lead of the measuring instrument to the disconnected main earth conductor and the other to the earthing electrode. Note the reading. Subtract the resistance of the leads from the total resistance to obtain the resistance of the main earthing conductor. The resistance of the main earthing conductor must not exceed 0.5 ohms.

f. Re-connect the main earthing conductor.

11. Protective Earthing Conductors. When the main earthing conductor has been tested, all other circuit protective earths and equipotential bonding conductors must be checked for continuity. A typical procedure is as follows. Refer to Diagram 2.

a. Ensure that the consumer's mains are not connected to the supply and test for zero volts.

b. Disconnect the water pipe equipotential bonding conductor and the water heater protective earthing conductor (if applicable) (A) and (B).

c. Disconnect the neutral conductor from the neutral link for the portion of the installation under test (C).

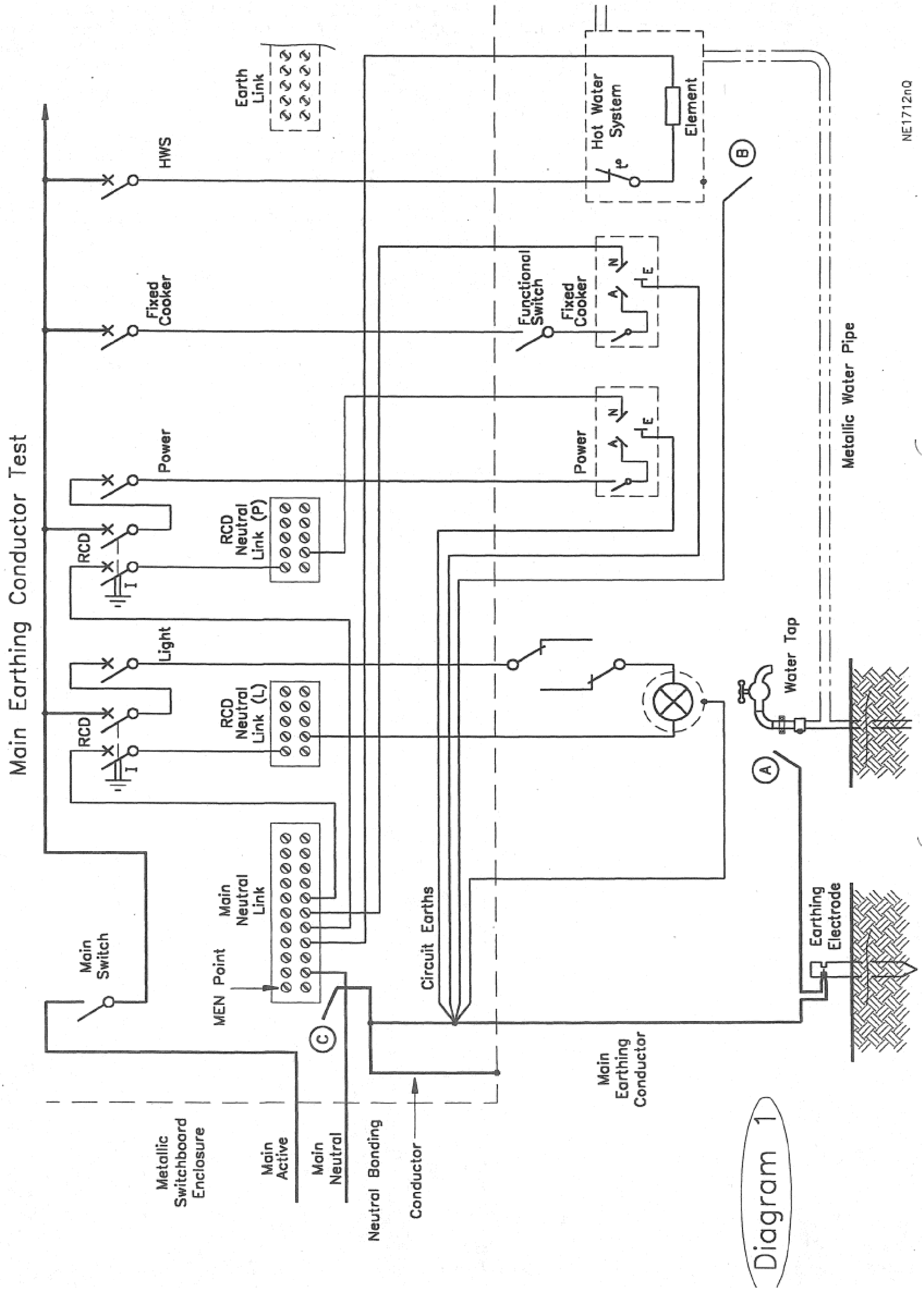
d. Select an appropriate low-reading ohmmeter or multimeter with one lead long enough to reach the most remote earth on equipment required to be earthed.

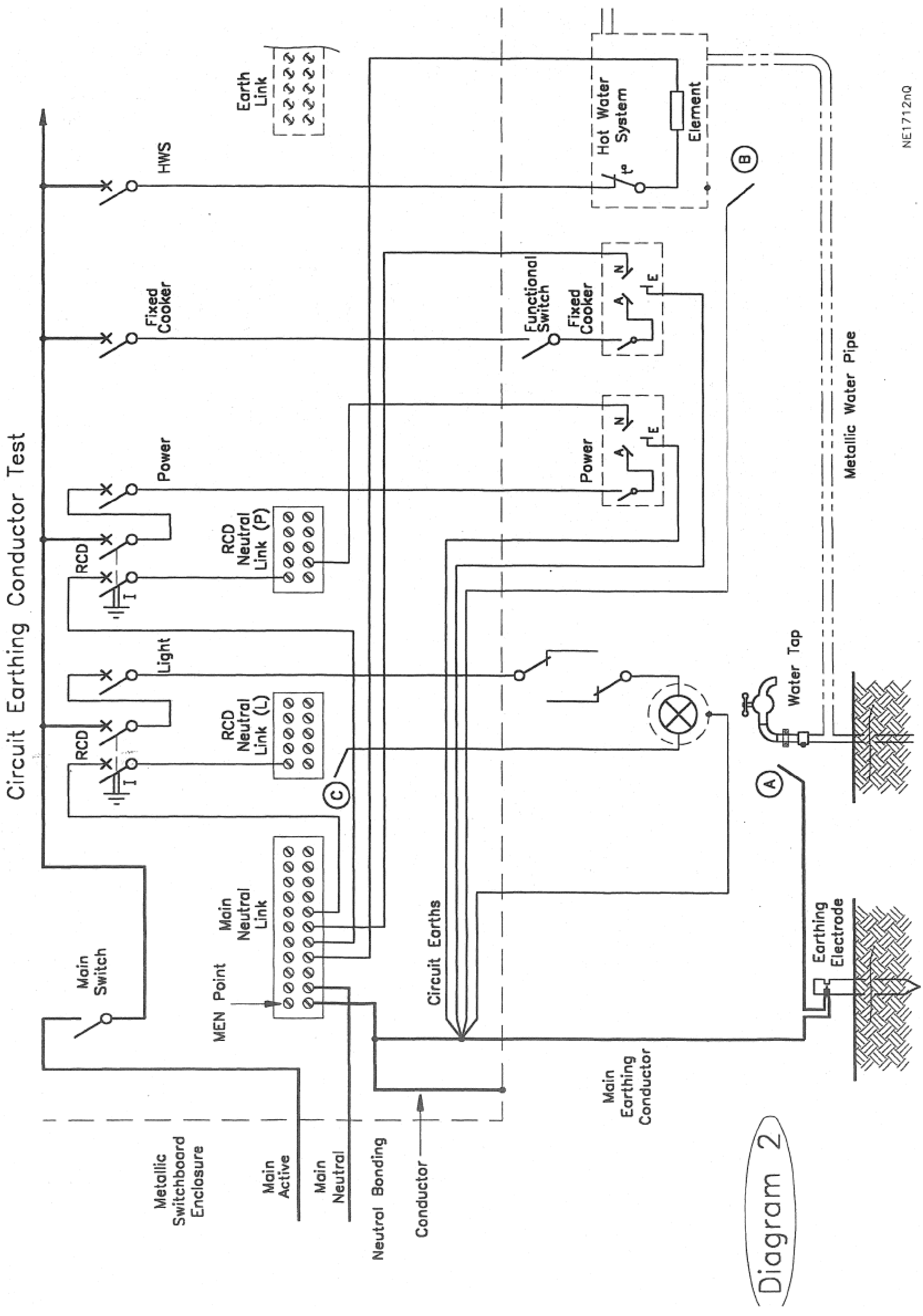
e. Connect one lead of the measuring instrument to the earthing conductor at the neutral link and the other to the protective earth for each item of equipment required to be earthed (in turn). Note the reading in each case to confirm continuity. Check your readings against the maximum values of resistance in Table 8.2 of the Wiring Rules.

f. Test the water heater protective earthing conductor for continuity.

g. Connect the multimeter test leads to the ends of each disconnected equipotential conductor and ensure that the conductors are continuous.

h. Re-connect all disconnected conductors.


Main Earthing Conductor Test
Main Switch
MEN Point
Main Neutral Link
RCD
I
RCD Neutral Link (L)
Light
RCD Neutral Link (P)
Power
Fixed Cooker
HWS
Earth Link
Circuit Earths
Functional Switch
A
N
E
Hot Water System
Element
B
A
C
Water Tap
Metallic Water Pipe
Earthing Electrode
Main Earthing Conductor
Metallic Switchboard Enclosure
Main Active
Main Neutral
Neutral Bonding Conductor
NE1712nQ
Diagram 1



Circuit Earthing Conductor Test
Main Switch
HWS
Fixed Cooker
Power
RCD
Light
RCD
Earth Link
RCD Neutral Link (P)
RCD Neutral Link (L)
Main Neutral Link
MEN Point
Circuit Earths
Hot Water System
Element
Functional Switch
Fixed Cooker
Power
A
N
E
B
C
A
Water Tap
Metallic Water Pipe
Earthing Electrode
Main Earthing Conductor
Metallic Switchboard Enclosure
Main Active
Main Neutral
Neutral Bonding Conductor
NE1712nQ
Diagram 2

Earthing Conductor Resistance Tests

1. What is the maximum permissible resistance from the earthing electrode to the point where the main earthing conductor is connected to the neutral bar?

2. Why is it essential to disconnect the equipotential bonding conductor to the metallic water system when checking the continuity of the protective earthing conductor to the electric hot water heater?

3. According to Table 8.2, what is the maximum permissible resistance of the protective earthing conductor of a circuit protected by a 20 amp ‘C’ type circuit breaker?

4. What is the maximum permissible length of a $4mm^2$ V75 TPS twin and earth cable protected by a 25 amp ‘C’ type circuit breaker?

Insulation Resistance Tests

1. The purpose of insulation resistance tests is to ensure that the resistance of the insulation live parts and earth, is sufficient to prevent any significant leakage current from any live part to earth when the supply voltage is applied. If the insulation resistance is too low it could result in a person coming in contact with a live part (electric shock hazard), fire hazards from short circuits and equipment damage.

Requirements

2. Clause 8.3.6.1 of the Wiring Rules requires that the insulation resistance between any live parts and earth is adequate to ensure that the integrity of the insulation is maintained.

3. For low voltage wiring, the insulation resistance between all live conductors connected together and earth must be not less than 1 megohm when measured by applying 500 volts d.c. (See AS/NZS 3000 Clause 8.3.6.2).

An exception is made in the case of appliances incorporating a sheathed heating element, in which case, the insulation resistance between live parts and the earthing terminal of the appliance must be not less than 0.01 MΩ (10 000 ohms).

Considerations

4. The value of insulation resistance to earth may be obtained with appliances disconnected.

5. Measuring insulation resistance to earth with a typical multimeter is not satisfactory because the measuring voltage is not high enough.
A special high voltage insulation tester set on the correct range must be used. One common brand name for a high voltage insulation tester is 'Megger', but several other brands are available.

6. It is essential to check to see that the instrument is set to the correct range, because some types of tester have a setting for measuring insulation resistance and another for testing low resistance circuits.

7. Insulation resistance tests must only be carried out on circuits which are de-energised and isolated from the supply.

8. Some electronic components (such as electronic switching and control devices) are sensitive to high voltages and can be damaged by high voltage insulation testers if adequate precautions are not taken.

9. All circuit conductors in an installation must be tested for insulation resistance to earth, so multiple switching circuits such as two-way, three-way and master-on circuits must be tested in all possible switch positions. The load side of magnetic relay or contactor circuits must also be tested.

10. Do not test between actives and neutrals with a high voltage insulation tester because many circuits incorporate electronic devices (dimmers, downlight drivers etc.) and the test voltage of the insulation tester may destroy the device.

11. If an insulation resistance is found to be below the required value, it is necessary to re-test the resistance of the earthing conductors after the insulation fault has been corrected.

Reconnecting after testing

12. It is essential to ensure that all circuits or components which were disconnected during the testing process are re-connected correctly after the tests have been completed. Ensure that the MEN connection is re-instated.

Typical Insulation Resistance Testing Procedure

13. A typical procedure for testing insulation resistance with the supply disconnected is described below (based on the requirements of AS 3017:2007). Refer to Diagram 3:

a. Ensure that the supply is not connected to the installation and test for zero volts.

b. Disconnect the MEN connection and appliances connected to the fixed wiring.

c. Ensure that all switches in the installation under test are switched on so that all switch wires are included in the test (A).

d. Temporarily connect the consumers mains active and neutral tails together (B).

e. Turn the main switch(s) on (the power is off) (C).

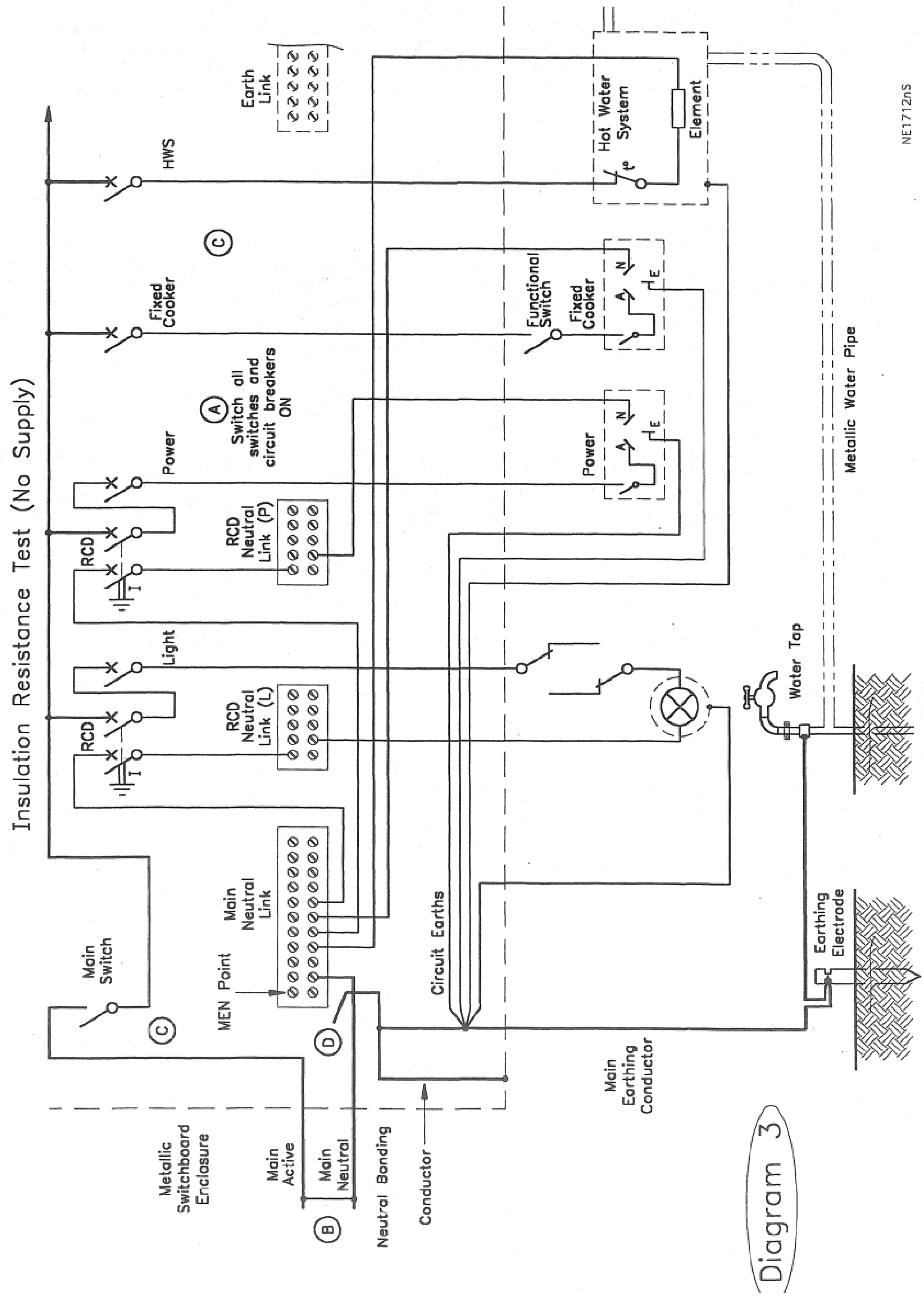
f. Ensure that all circuit fuses are in and circuit breakers on (A).

g. Disconnect the MEN connection from the neutral link (D).

h. Set the 500 volt high voltage insulation tester to the megohms (MΩ) scale.

i. Connect one lead of the insulation tester to the main earthing conductor and the other lead to the joined active and neutral tails.Test the insulation resistance and ensure that it is not less than 1 megohm. Operate all multi-way switches during this test.

j. Remove the temporary connection between the consumers mains active and neutral tails, reconnect the MEN connection to the neutral link and reconnect any relevant appliances.



Insulation Resistance Test (No Supply)
Main Switch
MEN Point
Main Neutral Link
RCD
Light
RCD Neutral Link (L)
Power
RCD Neutral Link (P)
A Switch all switches and circuit breakers ON
Fixed Cooker
C
HWS
Earth Link
Circuit Earths
D
Metallic Switchboard Enclosure
Main Active
Main Neutral
B
Neutral Bonding
Conductor
Main Earthing Conductor
Functional Switch
Fixed Cooker
Power
A
N
E
Hot Water System
Element
t°
Water Tap
Earthing Electrode
Metallic Water Pipe
NE1712nS
Diagram 3

Insulation Resistance Tests

1. What is the minimum permissible insulation resistance to earth in a single phase 240 volt installation which does not include an appliance with a heating element?

2. At what voltage must the insulation resistance to earth in a three phase 415 volt installation be measured?

3. Why is a typical multimeter unsuitable for measuring the insulation resistance to earth in a 240 volt single phase installation?

4. What is the minimum permissible insulation resistance to earth in a single phase 240 volt installation which includes an appliance which incorporates a heating element?

5. What additional action must be taken when measuring the insulation resistance to earth in circuits involving multiple switching such as two-way, three-way and master-on circuits?

6. What is the common trade name for one brand of high voltage insulation tester?

7. What electrical test must always be carried out before a high voltage insulation test is connected to an existing circuit?

Polarity and Connection Tests

1. The purpose of polarity tests is to ensure that no electric shock hazard arises from the incorrect connection of active and neutral conductors in lampholders, luminaires, socket outlets and permanently connected equipment. Incorrect circuit connection tests are necessary to ensure that final subcircuit earthing conductors do not carry current and there are no short circuits.

Requirements

2. Clause 2.3.7.2 and 8.3.7(c) of the Wiring Rules requires that single pole switches be connected so that they operate in the active conductor of the circuit in which they are connected.

3. Clause 2.3.2.1.1(ii) of the Wiring Rules requires that multi-pole switches or circuit breakers operate in such a way that a neutral is not disconnected before the associated active conductor, and an active is not connected before the associated neutral.

4. Clause 4.4.5 of the Wiring Rules requires that socket outlets designed to accommodate flat pins be connected so that when viewed from the front of the outlet, the order of connection is earth, active, neutral in a clockwise direction.

Considerations

5. If the active and neutral conductors of the consumers mains are transposed the installation earthing system would be energised, so the main neutral must be connected to the main neutral link at the main switchboard.

6. If an appliance switch was incorrectly connected so that it switched the neutral instead of the active, internal parts of the appliance can be alive although the appliance is switched off. If a switch in a lighting circuit was connected in a neutral, lampholder or luminaire terminals would be alive although the lamp is not operating.

7. In an MEN system all neutrals must be connected to the correct neutral link. In general, the only point at which an earth should be connected to the neutral is the main earthing conductor (or neutral bonding conductor) at the main neutral link on the main switchboard.

8. No. neutral conductors are permitted to be connected to an earth link.

9. The neutral from one circuit must not be connected to the neutral of another circuit at any point other than at the neutral link.

10. All components in an installation must operate as intended, and there must be no short circuits. The resistance of equipment must be consistent with the value expected.

11. In multi-way lighting circuits all switches must be operated during the tests to ensure that all associated conductors are tested.

12. Final subcircuit earthing conductors do not carry current.

Reconnecting After Testing

13. It is essential to ensure that all circuits or components which were disconnected during the testing process are re-connected correctly after the tests have been completed.

Typical Polarity Testing Procedures

14. Typical procedures for polarity testing with the supply disconnected are described below (based on the requirements of AS 3017:2007):

15. Polarity Testing of Consumers Mains

a. Ensure that the supply is not connected to the installation and test for zero volts.

b. Turn the main switch off.

c. Set the multimeter to a low ohms range and zero the instrument.

d. Connect one lead of the multimeter to the main neutral tail and the other to the neutral link. The meter reading must be close to zero ohms.

e. Connect one lead of the multimeter to the main active tail and the other to the supply side of the main switch. The meter reading must be close to zero ohms.

16. Polarity Testing of Single Pole Switches

a. Ensure that the supply is not connected to the installation.

b. Identify the correct circuit breaker for the circuit to be tested and switch it off. Connect one ohmmeter lead to the load side of the protective device.

c. Connect the other lead of the ohmmeter to each side of the relevant switch in turn.Ensure that the resistance is 0Ω at both switch terminals with the switch on and infinity at the load terminal with the switch off.

d. Repeat the test procedure for each single pole switch.

17. Polarity and Connection Testing of Lighting Points (resistor method) See Diagram 4.

a. Ensure that the supply is not connected to the installation.

b. Identify the correct circuit breaker for the circuit to be tested and switch it off (A).

c. Remove the lamp from the lighting point under test (B).

d. Disconnect the neutral conductor from the main neutral link for the circuit under test (C).

e. Connect one lead of a 10 Ω resistor to the load side of the circuit breaker for the circuit and the other lead to the main neutral link (D).

f. Connect one lead of a 5 Ω resistor to the disconnected neutral conductor and the other lead to the main neutral link (E).

Polarity Test (RCD switched on)

g. Connect one ohmmeter lead to the earth point of the lampholder or luminaire under test and the other lead to each terminal of the lampholder or luminaire in turn, with the lighting RCD on.

h. Ensure that with the control switch on, the resistance is approximately 5 ohms at the neutral terminal and 10 Ω at the active terminal.

i. Ensure that with the control switch off, the resistance is approximately 5 Ω at the neutral terminal and infinity at the active terminal.

Connection Test

j. Disconnect the ohmmeter lead from the earth point and connect it to the one terminal of the lampholder or luminaire under test.

k. Connect the other ohmmeter lead to the other terminal of the lampholder or luminaire under test.

l. Ensure that with the control switch on, the resistance is approximately 15 ohms, and with the switch off it is infinity.

m. Repeat the test procedure for each lampholder.

n. Remove the test equipment and re-connect the circuit conductors.

18. Polarity and Connection Testing of Socket Outlets (resistor method) See Diagram 5.

a. Ensure that the supply is not connected to the installation.

b. Identify the correct circuit breaker for the circuit to be tested and switch it off (A).

c. Ensure that no appliances are connected to the socket outlet under test.

d. Disconnect the neutral conductor from the main neutral link for the circuit under test (B).

e. Connect one lead of a 10 Ω resistor to the load side of the circuit breaker for the circuit and the other lead to the main neutral link (C).

f. Connect one lead of a 5 Ω resistor to the disconnected neutral conductor and the other lead to the main neutral link (D).

Polarity Test (With Power RCD On)

g. Connect one ohmmeter lead to the earth contact of the socket-outlet under test and the other lead to the active terminal.

h. Ensure that with the control switch on, the resistance is approximately 10 ohms, and with the switch off it is infinity.

i. Remove the ohmmeter lead from the active contact and connect it to the neutral contact. Ensure that the resistance is approximately 5 ohms.

Connection Test

j. Disconnect the ohmmeter lead from the earth contact of the socket-outlet and connect it the active contact.

k. Ensure that with the control switch on, the resistance is approximately 15 Ω, and with the switch off it is infinity.

l. Repeat the test procedure for each outlet.

m. Remove the test equipment and re-connect the circuit conductors.

19. Polarity and Connection Testing of Equipment

a. Ensure that the supply is not connected to the installation and the MEN earth connection is made at the main neutral link.

b. Identify the correct circuit breaker for the equipment to be tested (e.g. hot water system) and switch it off.

c. Set the ohmmeter to zero ohms with the test leads connected together.

d. Connect one ohmmeter lead to the active terminal of the equipment and the other to the neutral and ensure that the resistance is consistent with the load (e.g. a 240 volt 3.6 kW element should have a resistance of about 16 ohms).

e. Disconnect the ohmmeter test lead from the neutral terminal and connect it to earth on the equipment.The resistance should be consistent with the connected load.

f. Disconnect the ohmmeter test lead from the active terminal and connect it to the neutral terminal on the equipment. Ensure that it is zero ohms.

g. Remove the MEN earth connection from the main neutral link.

h. Connect one ohmmeter lead to the active terminal of the equipment and the other to the earth on the equipment. Ensure that the resistance is infinity.

i. Remove the ohmmeter lead from the active terminal of the equipment and connect it to the neutral terminal on the equipment. Ensure ·that the resistance is infinity.

j Repeat the test procedure for each item of equipment.

k. Remove the test equipment and re-connect the circuit conductors.

Polarity and Connection Test – Lighting Points (No Supply)

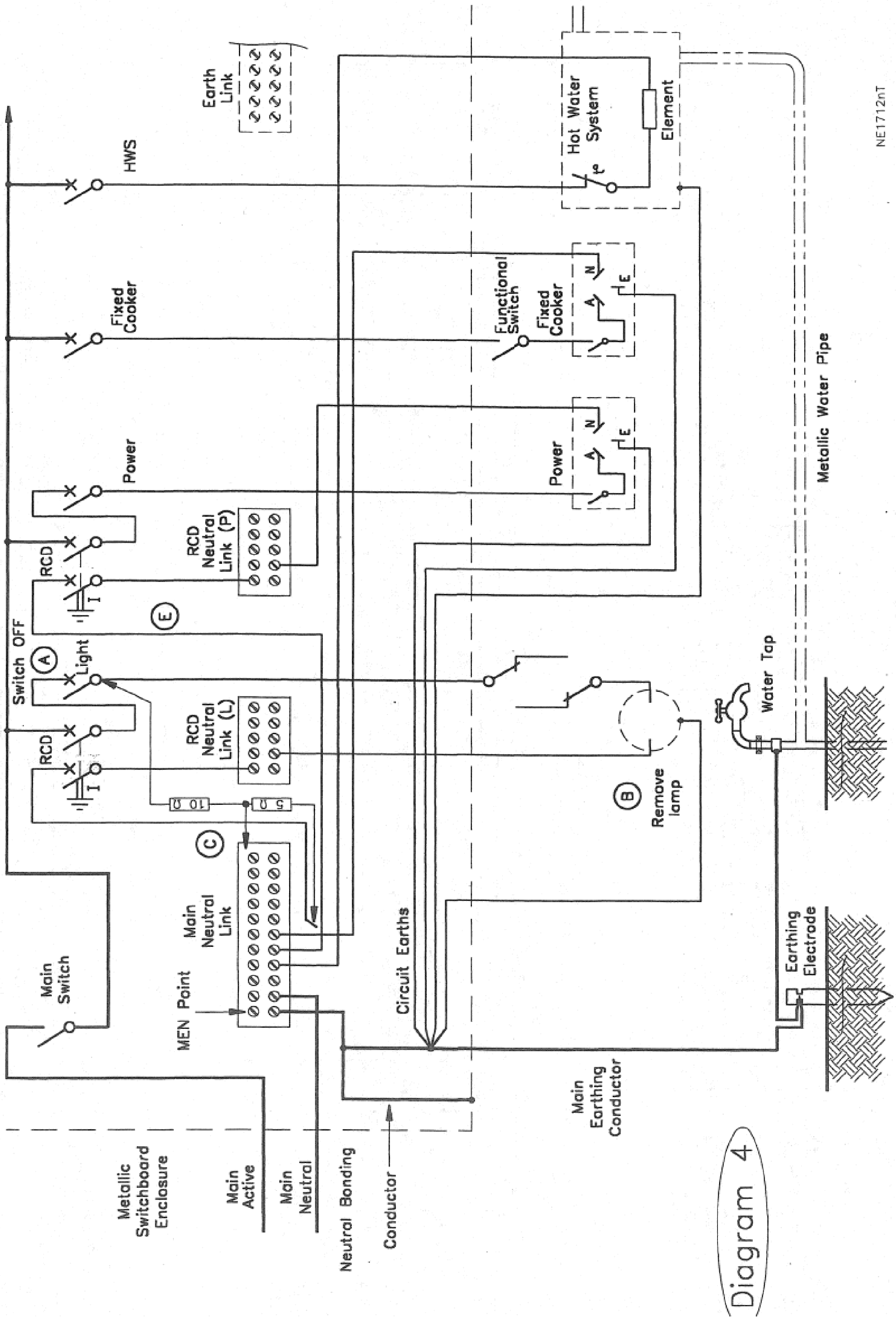


Diagram 4

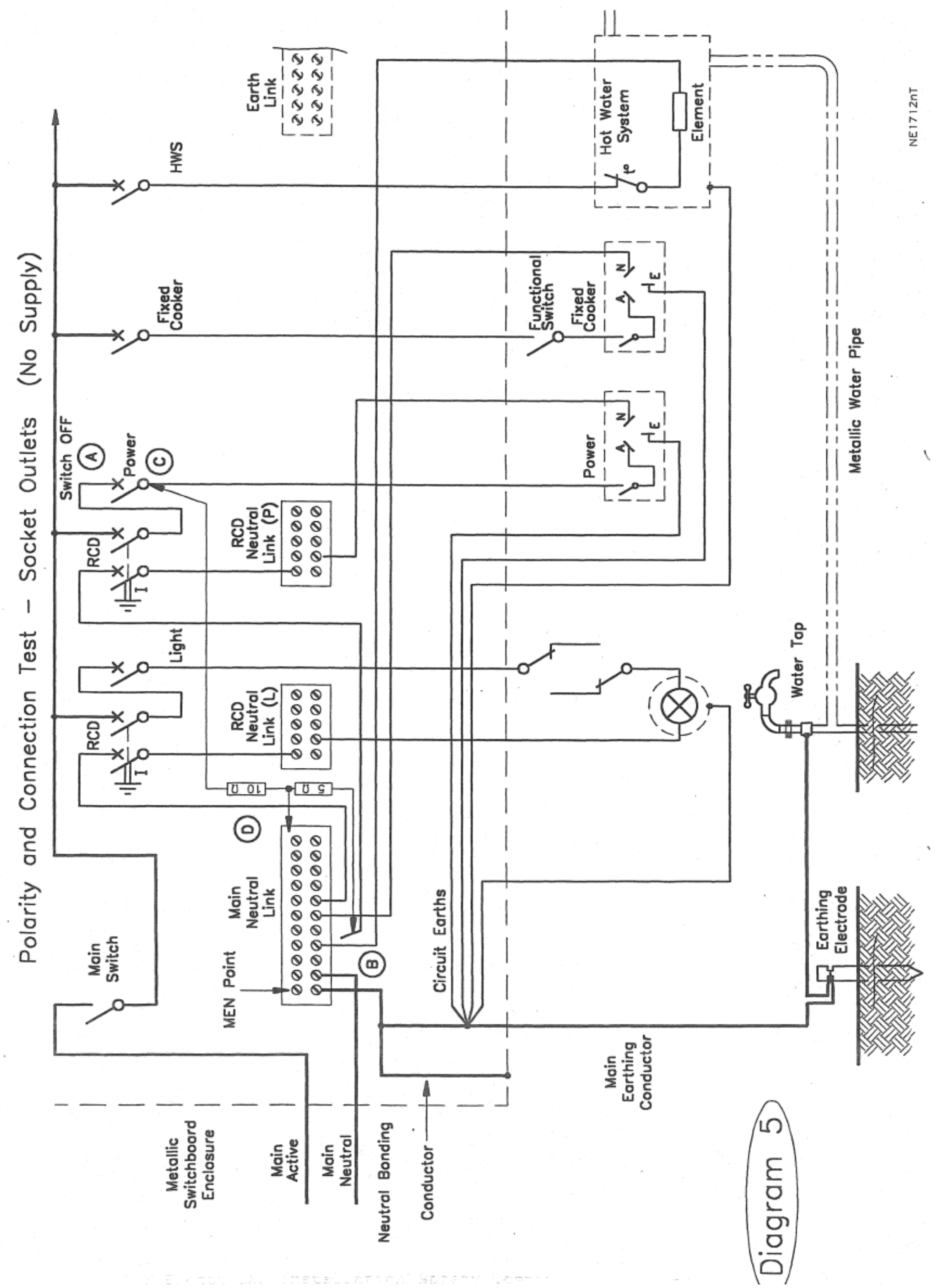

Polarity and Connection Test – Socket Outlets (No Supply)
Main Switch
Metallic Switchboard Enclosure
Main Active
Main Neutral
Neutral Bonding Conductor
MEN Point
Main Neutral Link
B
D
10 Ω
5 Ω
RCD
I
Light
RCD Neutral Link (L)
RCD
I
RCD Neutral Link (P)
Switch OFF
A
Power
C
Fixed Cooker
HWS
Earth Link
Circuit Earths
Main Earthing Conductor
Power
A
N
E
Functional Switch
Fixed Cooker
A
N
E
Hot Water System
t°
Element
Water Tap
Earthing Electrode
Metallic Water Pipe
NE1712nT

Diagram 5

Polarity and Connection Tests

1. How must a single phase 10 amp socket outlet be polarised? Give the AS/NZS 3000 Clause number.

2. Is it permissible to connect a single pole switch in a neutral conductor? Give the AS/NZS 3000 Clause number.

3. Is it permissible to connect a neutral from one final subcircuit to the neutral of another final subcircuit at a roof junction?

4. What fault would be indicated if a resistance of zero ohms was obtained between the active and neutral tails in an installation without a supply connected?

5. Is it permissible to connect a circuit neutral to an earth link?

6. What resistance would be expected when measuring the resistance of the heating element of a 240 volt 4.8 kW hot water system?

7. List the order in which installation tests should be carried out in a typical new single domestic installation before the supply is connected.

Installation Inspection and Testing 1

Objective

To inspect and test an electrical installation using measuring instruments to ensure that it satisfies all electrical safety regulatory requirements.

Equipment

Simulated electrical installation (no supply connected).

High voltage installation tester.

Multimeter with a low ohms range.

Hand tools as required.

Other test equipment as required.

AS/NZS 3000:2018, AS/NZS 3017:2007

Procedure

1. Examine the simulated electrical installation provided and note the equipment installed therein.
2. Inspect and test the installation for all aspects of safety with appropriate measuring instruments and/or special equipment.
3. Complete the following Installation Verification Results Sheet for your installation.
4. Submit your work to your Lecturer for comment and assessment.

Installation Verification	Satisfactory	Not Yet Satisfactory	Lecturer: Date:

Test Board Identification ____________________________________

Visual Inspection

Item	Comments & Details	Good	Bad
General			
Consumer's Mains			
Switchboard			
Wiring Systems			
Electrical Equipment			
Earthing			

Continuity & Resistance of the Earthing System

Circuit	Conductor Size	Rating Circuit Breaker	Measured Value	Maximum Value
Main Earth		Not Applicable		

Insulation Resistance

Test	Measured Value	Minimum Permissible Value
Consumer Mains Active to Mains Neutral		
Consumer Mains Active/Neutral to Earth		
All Circuits Active/Neutral to Earth		

Polarity & Correct Circuit Connections -

Circuit	Polarity		Connections	
	Correct	Incorrect	Correct	Incorrect
Power-1				
Power-2				
Lighting-1				
Lighting-2				
Hot Water System				

Earth Fault-Loop Impedance

Power Not Available

Circuit	Conductor Size		Rating Circuit Breaker	Measured Value R_{phe}	Maximum Permissible Value R_{phe}
	Active	Earth			
Power-1					
Power-2					

Fault	Corrective Action

Installation Inspection and Testing 2

Objective

To inspect and test an electrical installation using measuring instruments to ensure that it satisfies all electrical safety regulatory requirements.

Equipment

Simulated electrical installation (no supply connected).

High voltage installation tester.

Multimeter with a low ohms range.

Hand tools as required.

Other test equipment as required.

AS/NZS 3000:2018, AS/NZS 3017:2007

Procedure

1. Examine the simulated electrical installation provided and note the equipment installed therein.
2. Inspect and test the installation for all aspects of safety with appropriate measuring instruments and/or special equipment.
3. Complete the following Installation Verification Results Sheet for your installation.
4. Submit your work to your Lecturer for comment and assessment.

Installation Verification	Satisfactory	Not Yet Satisfactory	Lecturer: Date:

Test Board Identification ____________________________________

Visual Inspection

Item	Comments & Details	Good	Bad
General			
Consumer’s Mains			
Switchboard			
Wiring Systems			
Electrical Equipment			
Earthing			

Continuity & Resistance of the Earthing System

Circuit	Conductor Size	Rating Circuit Breaker	Measured Value	Maximum Value
Main Earth		Not Applicable		

Insulation Resistance

Test	Measured Value	Minimum Permissible Value
Consumer Mains Active to Mains Neutral		
Consumer Mains Active/Neutral to Earth		
All Circuits Active/Neutral to Earth		

Polarity & Correct Circuit Connections -

Circuit	Polarity		Connections	
	Correct	Incorrect	Correct	Incorrect
Power-1				
Power-2				
Lighting-1				
Lighting-2				
Hot Water System				

Earth Fault-Loop Impedance

Power Not Available

Circuit	Conductor Size		Rating Circuit Breaker	Measured Value R_{phe}	Maximum Permissible Value R_{phe}
	Active	Earth			
Power-1					
Power-2					

Fault	Corrective Action

Installation Inspection and Testing 3

Objective

To inspect and test an electrical installation using measuring instruments to ensure that it satisfies all electrical safety regulatory requirements.

Equipment

Simulated electrical installation (no supply connected).

High voltage installation tester.

Multimeter with a low ohms range.

Hand tools as required.

Other test equipment as required.

AS/NZS 3000:2018, AS/NZS 3017:2007

Procedure

1. Examine the simulated electrical installation provided and note the equipment installed therein.

2. Inspect and test the installation for all aspects of safety with appropriate measuring instruments and/or special equipment.

3. Complete the following Installation Verification Results Sheet for your installation.

4. Submit your work to your Lecturer for comment and assessment.

Installation Verification	Satisfactory	Not Yet Satisfactory	Lecturer: Date:

Test Board Identification ____________________________________

Visual Inspection

Item	Comments & Details	Good	Bad
General			
Consumer's Mains			
Switchboard			
Wiring Systems			
Electrical Equipment			
Earthing			

Continuity & Resistance of the Earthing System

Circuit	Conductor Size	Rating Circuit Breaker	Measured Value	Maximum Value
Main Earth		Not Applicable		

Insulation Resistance

Test	Measured Value	Minimum Permissible Value
Consumer Mains Active to Mains Neutral		
Consumer Mains Active/Neutral to Earth		
All Circuits Active/Neutral to Earth		

Polarity & Correct Circuit Connections -

Circuit	Polarity		Connections	
	Correct	Incorrect	Correct	Incorrect
Power-1				
Power-2				
Lighting-1				
Lighting-2				
Hot Water System				

Earth Fault-Loop Impedance

Power Not Available

Circuit	Conductor Size		Rating Circuit Breaker	Measured Value R_{phe}	Maximum Permissible Value R_{phe}
	Active	Earth			
Power-1					
Power-2					

Fault	Corrective Action

Fault finding in Electric Hot-Water Systems

Task

Describe the types of faults likely to occur in electric hot-water heating equipment, and describe the tests necessary to diagnose those faults.

Why

Electrical hot-water systems are widely used in the electrical industry. A knowledge of different types of faults, and the testing procedures required to find them, will enable you to diagnose and locate faults in electrical heating equipment in the workplace.

To Pass:

1. You must correctly answer the questions on the Work Sheets provided and achieve a mark of 75% or more in a written assessment.
2. You must satisfactorily complete the set laboratory tasks.
3. You must achieve 100% in a practical competency assessment.

Equipment:

Demonstration water heaters, elements, over-temperature cutouts, thermostats and simmerstats.

References:

* Electrical Wiring Practice (7th ed.) Volume 2, Pethebridge, K and Neeson, I

Fault finding in Electric Hot-Water Systems

Suggested Self-Study Guide

1. Study the following sections in the recommended references:

Electrical Wiring Practice (7th ed.) – Volume 1

Chapter 9 – Testing Techniques and compliance verification

9.5 Fault finding and performance testing

Electrical Wiring Practice (7th ed.) – Volume 2

Chapter 6 – Appliances: Electric heating and motors

2. Read the Summary and practise answering the questions provided on the Work Sheet. Refer to other relevant texts if you feel it is necessary.

3. Answer the questions given on the Work Sheet. Use a separate answer sheet or sheets for each Work Sheet. Note that you are required to answer ALL questions correctly, although not necessarily at the same time.

4. Complete the laboratory projects in this Section.

5. Submit your answers to the Work Sheets and your completed practical project sheets to your Lecturer for discussion and assessment.

Fault finding in Electric Hot-Water Systems

1. Faults in electric hot-water systems may fall into four main categories:

   a) Supply faults
   b) Short circuits
   c) Opencircuits
   d) Insulation faults.

Although there is a huge range of possible faults involved in hot water appliances, we will consider a small number of the most common types.

Supply Faults

2. Should the supply authority system fail, the heating device will either not heat at all, or heat will be greatly reduced. A common fault is a loss of one phase, known as single phasing. This will reduce the output of a three phase hot water heater by 50%, which will be the same result if one of the elements open circuits.

3. Use a multimeter to check that all three phases are present. If so then isolate the heating appliance from the supply and check ·for equal resistances between element terminals on the heater.

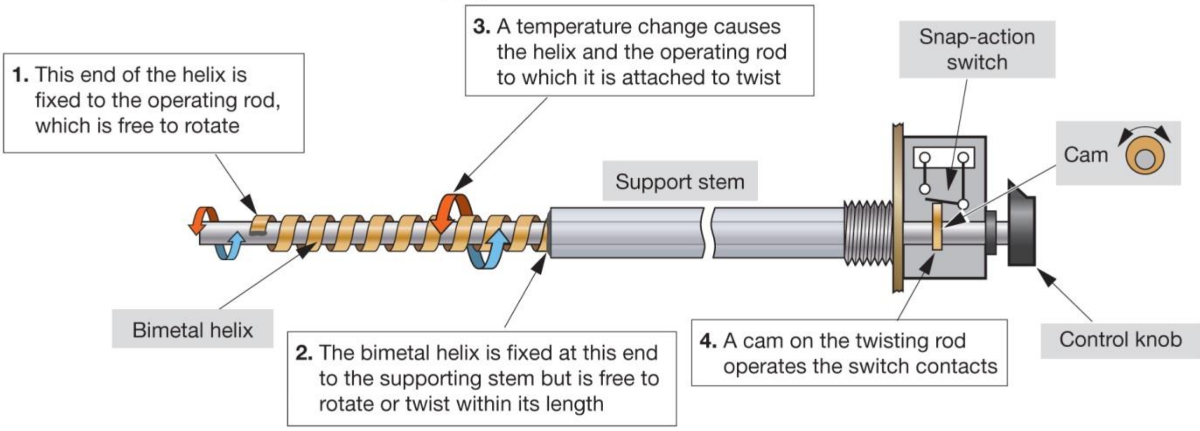
Element Faults

4. Element failure generally occurs as either an open circuit in the resistance path, or as a breakdown of insulation to earth. The latter is especially so with MIMS type elements, as the compressed mineral powder insulation absorbs moisture from the atmosphere. This problem occurs if the seals at the ends of the element leak, or the outer sheath of the element pits or cracks.

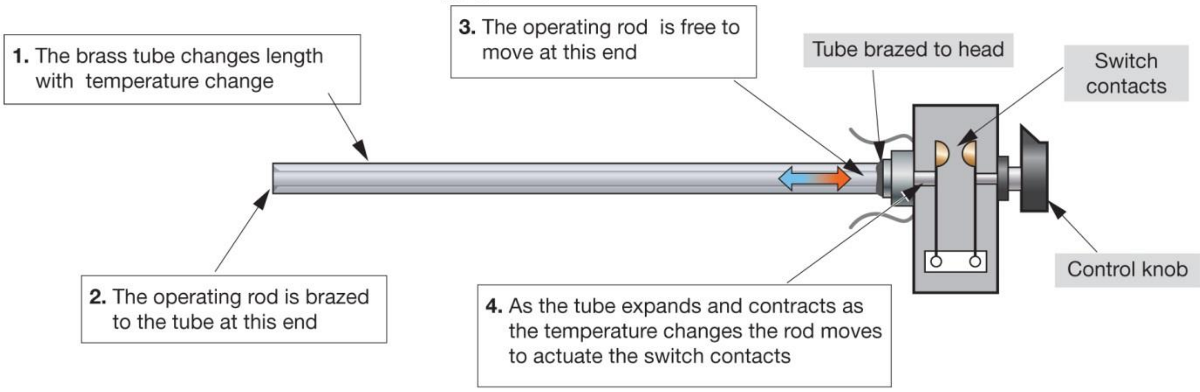
Control Device Faults

Thermostats.

5. Bi-metal helix and Expanding tube thermostats fail because of burnt terminals or contacts, or because of mechanical failure of components in the switch mechanism.



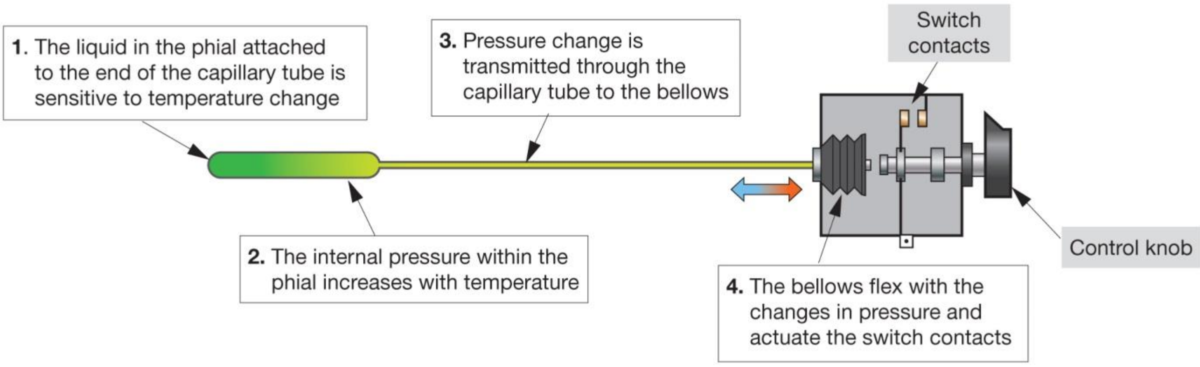
Bimetal Helix Thermostat



Expanding tube Thermostat

6. Capillary type thermostats fail because of burnt terminals or contacts, or because of loss of the liquid stored in the phial (bulb). This occurs because of cracks or pinholes in the capillary tube or bulb. The capillary type thermostat are not commonly used in hot water heaters. You are more likely to see this type of thermostat in electric ovens.

The advantage of this type is that the sensor (phial) and the control head may be some distance apart, as in an electric oven.



Capillary Tube Thermostat

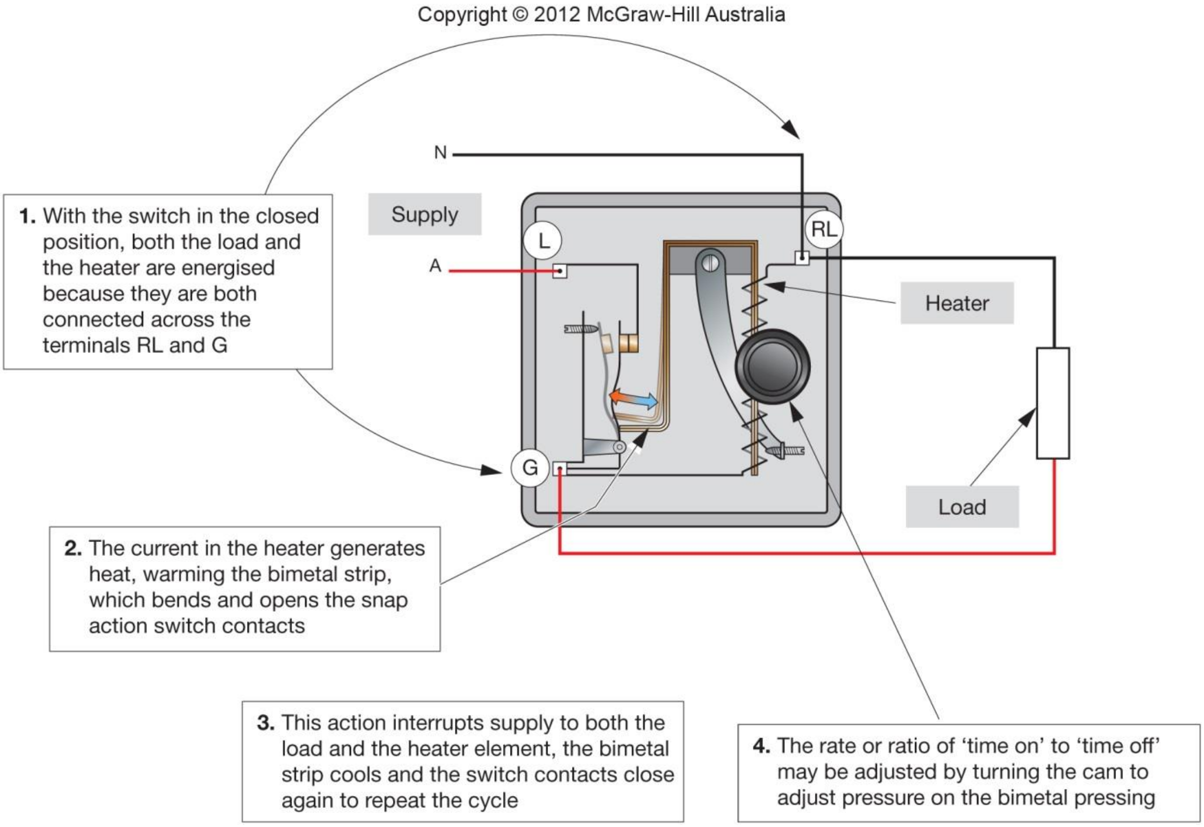
7. Bimetallic disc type thermostats incorporating over temperature cutouts (OTC) are used extensively in electric storage hot-water heaters and solar hot-water systems with electric booster elements. These devices are secured directly to the hot-water tank to monitor the water temperature.

Bimetallic Disc Type Thermostat ©NMTAFE 2014

A seasonal fault of solar hot-water systems at the beginning of winter is the electric booster will not produce hot water. Check that the over temperature cutout has not operated during the summer because of excessive tank temperatures. Manually resetting the OTC button on the thermostat should rectify the problem.

Simmerstats

8. Simmerstats are often used to control the temperature in hot water urns. Common simmerstat faults are burnt terminals or contacts, mechanical failure of the switch mechanism, or an open circuit of the internal heater element. This last problem results in the simmerstat switch remaining on continuously.

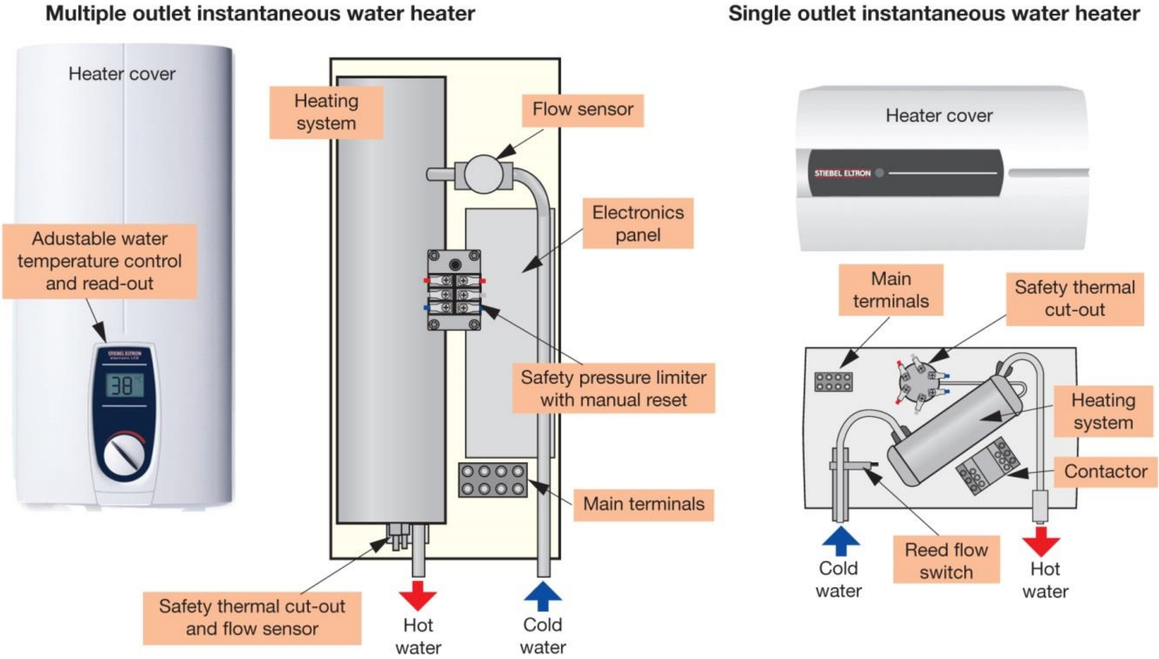


Simmerstat control for a 'tea' Urn

Flow Switches

9. In instantaneous hot water heaters, the elements are enclosed within a small copper container of about one litre capacity. When the water is flowing through the unit the elements are switched on to quickly heat the water. An automatic flow switch is used to control the electrical supply to the elements. Instantaneous hot water used in WA are usually rated at 415 volts three phase, at between 12 and 18 amps per phase. Single phase units are available, but are only used for kitchen sinks or hand basins. Single phase units have a maximum power rating of 3 kW. Three phase units can have a power rating up to 13 kW.

The heating elements in instantaneous water heaters are enclosed within a small copper tank, making it essential to have water flowing through the heater when the elements are energised. The automatic controls require a minimum mains water flow rate to activate the switching that connects the heater elements to the supply. The units shown are relatively small and are intended for installation at point of use, such as a bathroom, reducing installation cost. The maximum delivery temperature is 50°C without the need for a tempering valve. Units for kitchen and laundry use have a delivery temperature of 60°C.



Examples of Three phase and Single phase Instantaneous Hot Water Heaters

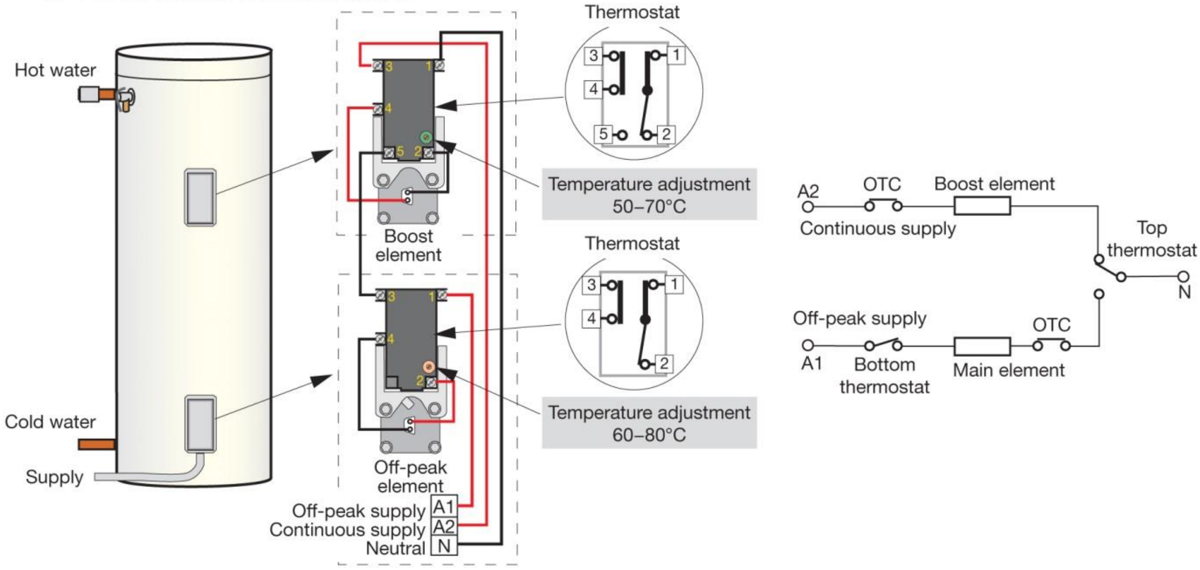
Over Temperature Protection

10. There is always a risk with Hot water systems that the thermostat may not disconnect the supply to the elements when the water temperature has reached the preset level. All electric hot water heaters must be equipped with an over temperature cut-out (OTC). The OTC will open circuit the element circuit if the water temperature in the tank exceeds 95°C. This is to prevent the water boiling in the enclosed tank and possibly causing an explosion.

Shown here is a typical mains pressure storage water heater fitted with an off-peak main element and booster element, each being controlled by a Robertshaw thermostat. The two heater elements are wired for non-simultaneous operation with the top thermostat being set 10°C lower than the bottom thermostat. The over-temperature cut-out (OTC) that forms part of the thermostat assembly is to prevent the water exceeding 95°C in the event of thermostat failure.

A bimetal disc on the underside of the thermostat detects the changes in temperature to switch the elements on or off within a differential of 4 to 12°C.

The OTC is also operated by a bimetal disc but must be manually reset if the heater cuts out due to over-temperature, the cause of which should be investigated and rectified before it is reset.



Main Pressure Storage HWS with booster element and OTC protection

Water Heater Valves

11. Mains pressure hot water heaters are equipped with valves that are designed to operate when the water pressure or water temperature in the tank exceeds preset values. If these safety valves become faulty, this may cause the stored hot water in the system to drop in temperature or a more costly problem, the heater is using more electrical energy than necessary. Main pressure storage hot water systems, either electric, gas or solar, are installed with a temperature and pressure relief valve, a cold water relief valve and a non-return valve. Electricians need to understand the operation of these safety devices because if they become faulty the symptom can present itself as an electrical problem of limited hot water and excessive power bills.

12. Temperature and Pressure Relief (T&PR) Valves. It is a mandatory requirement that all main pressure hot water systems are fitted with a T&PR valve. The valve is fitted into an inlet near the hot water outlet at the top of the tank. It is designed to vent the tank if preset values of temperature and /or pressure are exceeded.

Temperature and pressure relief (T&PR) valve © NMTAFE 2014

The relief valve should be manually operated to ensure that it releases water through the outlet pipe at least twice per year. A typical relief valve on systems above 160 litre capacity is set to operate if water pressure exceeds 1000 – 1400 kPa.

13. Cold Water Relief Valves. All water heaters installed in Western Australia must have a cold water expansion valve to comply with local plumbing regulations. Cold water relief valves are installed in the inlet water supply to the heater after the non-return valve. These valves can drip water when the tank is being heated. This is normal operation because water expands as it is heated. This water discharge should not be excessive and should only happen when the water temperature in the tank is close to approximately 60°C and the element is in operation. If the cold water relief valve is discharging water constantly, this could cause the element to operating for extended periods of time and increasing power bills.
Cold water relief valves have a pre-set pressure release of 850 – 1200 kPa and must be a lower pressure setting than the T&PR valve installed at the top of the heater tank.

Cold water stop-cock incorporating a non-return valve © NMTAFE 2014

14. Non-Return Valves. All water supply authorities require the fitting of a non-return valve in the cold water supply to main pressure hot water systems. The non-return valve prevents hot water from the tank flowing back into the cold water system. If a non-return valve is not installed or is faulty, hot water can flow back into the cold water system as the pressure in the tank will increase because of heating process or if the water mains pressure drops.

Sacrificial Anodes

15. All types of storage water heater require a **sacrificial anode** to limit corrosion of the metal components (steel tank) due to electrolytic action. These anodes must be checked for corrosion or replaced at regular intervals – typically every two to three years or as per HWS manufacturer's requirements.

Electrical Testing

16. Electrical faults fall into four categories of; Supply faults, open circuit faults, short circuit faults and insulation breakdown faults. Using multimeters and insulation testers, and analyzing your test results, electrical faults can be identified and hopefully rectified quickly.

Insulation Testing

17. A 500 volt Insulation Resistance Tester or Megger is required to test for insulation breakdown to earth. AS/NZS 3000:2018 requires the MINIMUM value to be 0.01 megohms (Clause 8.3.6.2 (b) i) for sheathed heating elements. However this is an extremely low value, and good practise suggests a reading of 1 megohm is usually desirable.

Continuity Test

18. An Ohmmeter or multimeter is used to check for correct readings of elements, wiring or switch contacts. Element resistance will vary according to the wattage rating, but an approximate value for test comparison can be calculated by:

$$R = \frac{V^2}{P}$$

19. The actual value measured will depend on whether the appliance is connected star or delta, star being the most common. The important point is that all three readings obtained should be the same.

Visual

20. Since many of the faults in heating appliances are started or made worse by the heat, a careful visual check will often reveal distortion or discoloration of insulation near terminals, or of the terminal connections themselves. This may even be apparent when a fault has not yet really shown up.

Fault finding in Electric Hot-Water Systems

1. List three categories of faults which occur in water heaters and their circuits.
2. You are called out to repair a three phase instantaneous hot water service in which the water is only luke warm. What is the first thing you would check?
3. List the two most common faults which occur in water heating elements.
4. What type of conductor insulation is used in most elements for hot water systems?
5. What is likely fault if the booster element of a solar hot water system fails to produce hot water when it is switched on at the beginning of winter?
6. What readings should you expect to get when measuring the resistance of a 3.6 kW element in a single phase 240 volt hot water system?
7. What is the minimum permissible insulation resistance in an appliance which incorporates a sheathed heating element?
8. What is the purpose of the T&PR valve?

Fault finding in Electric Hot-Water Systems

Objective

To test Hot-water systems for faults.

Equipment

Sample of simulated Hot water systems
Circuit diagrams for the appliance
Multimeter with low ohms range
High voltage Insulation tester (megger)

Procedure

1. Examine the appliance and its circuit diagram.
2. Discuss the operation of the Hot water system with your Lecturer.
3. Test the appliance for correct operation and identify any faults. Check your circuit for short circuits, open circuits and Earth faults with appropriate test meters.
4. Enter your results on to tables.
5. Have your results checked by your Lecturer.
6. Return all the equipment used in this Laboratory Project to its proper place

Trouble-shooting Hot-water Systems	Satisfactory	Not Yet Satisfactory	Lecturer: Date:

Hot Water System Inspection Report 1

Owner:	**Date of Inspection:**
HWS type:	**Inspected by:**
Line Voltage:	**Phases:**
Frequency:	**Line Current :**
Element Rating:	**Thermostat type:**

HWS - Test Results

Test	Instrument	Test Result	Work Required
Visual Inspection			
Short circuits			
Open circuits			
Earth continuity resistance			
Resistance of element			
D.C. resistance of element			
Insulation Resistance of element			
Describe the fault(s) you have found and how you would rectify the fault(s)			

Hot Water System Inspection Report 2

Owner:	**Date of Inspection:**
HWS type:	**Inspected by:**
Line Voltage:	**Phases:**
Frequency:	**Line Current :**
Element Rating:	**Thermostat type:**

HWS - Test Results

Test	Instrument	Test Result	Work Required
Visual Inspection			
Short circuits			
Open circuits			
Earth continuity resistance			
Resistance of element			
D.C. resistance of element			
Insulation Resistance of element			
Describe the fault(s) you have found and how you would rectify the fault(s)			

Fault finding in Lightings

Task

Describe the types of faults likely to occur in lighting circuits, and describe the tests necessary to diagnose those faults.

Why

A major component of the electrical industry is the installation and the maintaining of lighting systems and their associated circuitry. A knowledge of the different types of faults, and the testing procedures required to find them, will enable you to diagnose and locate faults in lighting equipment in the workplace.

To Pass:

1. You must correctly answer the questions on the Work Sheets provided and achieve a mark of 75% or more in a written assessment.
2. You must satisfactorily complete the set laboratory tasks.
3. You must achieve 100% in a practical competency assessment.

Equipment:

Sample of illuminating lamps and their associated control equipment.

References:

- AS/NZS 3000 (current edition) Wiring Rules. Standards Australia.
- Electrical Wiring Practice (7th ed.) – Volume 1, Petherbridge, K and Neeson, I
- Electrical Wiring Practice (7th ed.) Volume 2, Pethebridge, K and Neeson, I

Fault finding in Lighting

Suggested Self-Study Guide

1. Study the following sections in the recommended references:

AS/NZS3000 Wiring Rules

Section 4.5 Lighting Equipment and Accessories

Electrical Wiring Practice (7th ed.) – Volume 1

Chapter 7 – Testing Techniques and compliance verification

9.5 Fault finding and performance testing

Electrical Wiring Practice (7th ed.) – Volume 2

Chapter 7 – Lighting Applications

2. Read the Summary and practise answering the questions provided on the Work Sheet. Refer to other relevant texts if you feel it is necessary.

3. Answer the questions given on the Work Sheet. Use a separate answer sheet or sheets for each Work Sheet. Note that you are required to answer ALL questions correctly, although not necessarily at the same time.

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5. Submit your answers to the Work Sheets and your completed practical project sheets to your Lecturer for discussion and assessment.

Trouble-shooting Lighting Circuits

Fluorescent Lighting

Fluorescent Lamps

1. The fluorescent lamp uses an electric discharge in mercury vapour at very low pressure to produce ultra violet radiation.

   This radiation is converted to visible light by a fluorescent powder phosphor coating on the lamp wall.

2. Lamp Construction. A fluorescent lamp consists of a straight or bent glass tube coated on the inside with a phosphor powder and provided with caps at each end.

   See Figure 1. The pins maintain the contact between the lamp-holder and the cathodes inside the tube.

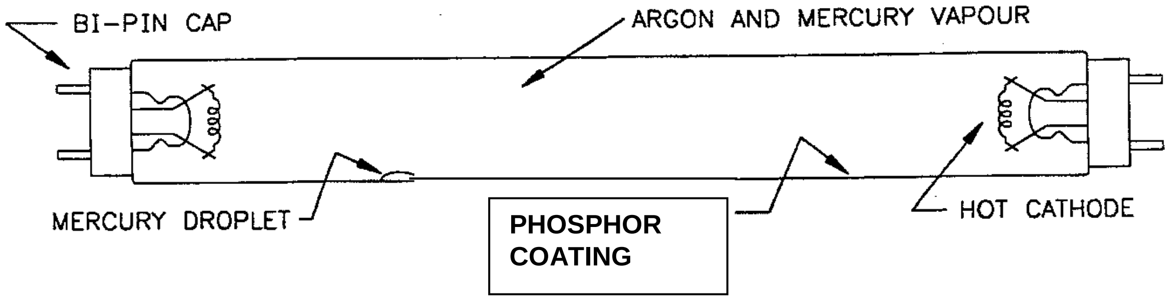


Figure 1 - General construction of a standard fluorescent tube.

3. The inert gas argon is added to the mercury vapour to assist starting since the vapour pressure of the mercury is very low.

4. The types of phosphors used determine the colour appearance, and to some extent the efficacy of a lamp and may be divided into two groups:·

   a. One which gives the highest attainable efficacy.

   b. Where efficacy is sacrificed to give better colour rendering.

5. Cathodes Cathode construction varies slightly between different manufacturers, but as they are of the 'hot type' all are made of tungsten and are normally in the form of a coiled coil.

6. By braiding together very thin strands of tungsten wire to form the coiled cathode, a much greater emission of electrons is obtained. Coating the cathode with an emissive material is a further aid in achieving effective electron emission.

7. Cathode shields are often used to trap evaporation from the cathode during life, which, helps to prevent black marks forming at the end of the tube and to reduce flicker.

8. Fluorescent lamps are usually referred to by their power rating in watts, or their nominal length in millimetres.

Typical sizes of standard 240 volt straight fluorescent lamps are:

18 watt	600 mm	(Older lamps are 20 watts)
36 watt	1200 mm	(Older lamps are 40 watts)
58 watt	1500 mm	(Older lamps are 65 watts)

Auxiliary Control Equipment

9. The conventional fluorescent lamp on a.c. requires the following control equipment.

a. **Ballast or choke** A fluorescent tube ballast is an inductive coil wound on a laminated core, encapsulated in pitch or polyester to reduce hum, and enclosed in a metal box. The main purpose of the ballast is to limit the discharge current once the tube has struck. In most cases they also provide an inductive kick to aid striking.
The reactance of ballasts vary to suit a particular tubes rating, e.g. 18 w, 36 w etc.

b. **Starter Switch** The function of the starter switch is to accurately time the pre-heating of the lamps cathodes until the proper starting conditions are reached with a minimum loss of electron emissive materials from the filament.

10. Thermal glow type starters are the most common starter in use today. It is plugged into a holder mounted in, or near to, the lamp unit and is usually contained in a plastic case which also houses a small radio interference capacitor.

A typical glow type starter is shown in Figure 2.

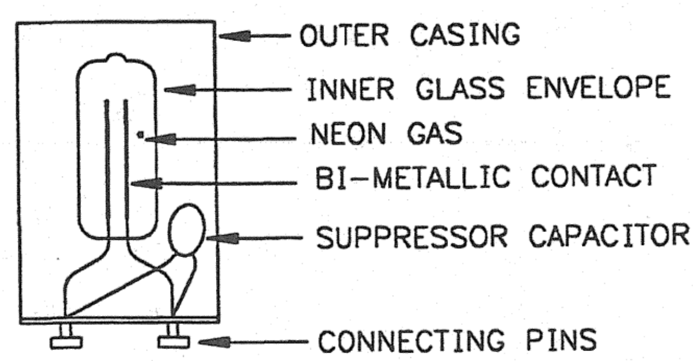


Figure 2 - A typical glow type fluorescent starter.

11. **Starter Operation** When sufficient voltage is applied to the connecting pins an electrical discharge occurs between the normally open contacts through the neon gas (starter glows).
The heat developed from the discharge will cause the bi-metallic contact to bend and close.
With the contacts closed the arc is extinguished and with the source of heat removed the bi-metallic contact cools and returns to the normally open position.

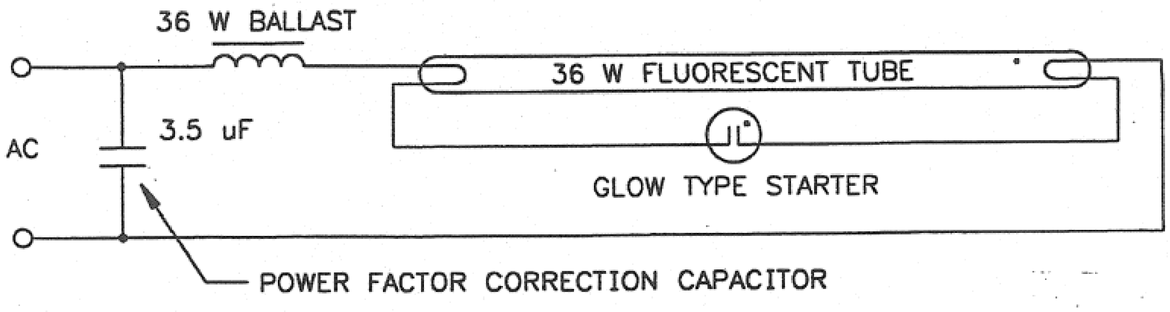
12. Several types of thermal glow type starters are available with ratings to suit a particular lamp size.
Care should be taken to match the starter with the lamp in accordance with manufacturer's instructions.

13. Alternative methods of starting are being developed one such method is a solid state starter suitable for lamps up to 18 w.
With this type of the characteristic blinking of a fluorescent tube when starting is eliminated.

14. Most 240 volt fluorescent lamps require a ballast to provide the high starting voltage and limit the running current.
Since the ballast results in the circuit having a lagging power factor a power factor correction capacitor must be included in the circuit to correct the power factor to more than 0.8 lagging.
A typical power factor correction capacitor for a 36 watt fluorescent unit has a capacitance of about 3.5 microfarads.

Typical Fluorescent Lighting Circuit

15. A typical circuit for a single 36 watt fluorescent lamp is shown in Figure 3.



16. **Operation of a Fluorescent Lamp Circuit**

When the circuit is energised:

a. A small initial current flows via the ballast, cathodes and the neon discharge in the starter switch (a glow appears in the starter).

b. The starter contacts close causing a larger current to flow via the ballast closed starter switch contacts and the cathodes.

   The cathodes heat up reaching an electron emissive state.

c. When sufficient time has elapsed the starter contacts cool and open. An inductive kick (high induced voltage) is produced by the ballast, which is sufficient to strike the tube, and electrons flow through the length of the tube between the cathodes.

d. At this stage the ballast will limit the flow of current in the lamp. The starter, which is in parallel with the lamp will not restrike as the reduced operating voltage across the lamp is insufficient to cause a further glow discharge in the starter.

e. The starter contacts remain open while the lamp is operating if the tube is in good condition.

   When the lamp is at the end of its life or in adverse conditions the starting cycle will be continuously repeated.

17. The efficacy of fluorescent lamps varies from 50-90 lumens per watt according to the colour capabilities of the lamp (see table of tube applications).
A life rating of 7500 hours is normal for tubes that are not frequently switched on (once in three hours).

18. Frequent starting of fluorescent tubes will release more electron emissive material from the cathodes than when they are operating continuously, until a point is reached where the voltage available to induce striking of the lamp is no longer sufficient.

19. A typical 240 volt 36 watt fluorescent unit draws a current of about 0.25 amps with a power factor correct on capacitor fitted.
If the power factor correction is disconnected the line current increases to about 0.5 amps with no significant change to the light output or the power consumed.

If the power factor capacitor is faulty it should be replaced with another of the same type - a 240 volt fluorescent unit must not be operated without a capacitor because of the high line current.

20. **Table of Tube Applications**

The following table shows applications for some of the 240 volt fluorescent tubes available.
The colour and efficacies quoted are approximate as various lamp manufacturers differ in their colour names.
For a complete guide to fluorescent lamp types consult a manufacturer's catalogue.

Typical Colour Name	Efficacy	Colour Rendering	Effect	Application
Daylight	80 lm/w	Fair	Cool	General
White	75 lm/w	Fair	Intermediate	High Output/ white light
Warm white	90 lm/w	Fair	Warm	Where warm atmosphere is required
Natural	55 lm/w	Fair	Intermediate	General lighting display
Warm white delux	50 lm/w	Fair	Warm	Similar to incandescent lighting
Special daylight	44 lm/w	Fair	Cool	Suitable for colour matching

21. Fluorescent lamps are widely accepted in commercial, industrial and domestic installations due to their high luminous efficacy, long life, low surface brightness and adaptability for various lighting arrangements.
    Although an incandescent lamp installation is initially less expensive than an equivalent fluorescent lamp, it consumes approximately three times as much electricity.

22. A compact type of 240 volt fluorescent lamp is available as a direct replacement for a GLS incandescent lamp (without any additional control equipment).
    A 15 watt compact fluorescent lamp gives about the same light output as a 75 W incandescent lamp with a life expectancy about 8 times greater.
    Although the initial cost is greater, the overall energy use is significantly less with these types of lamp.

    Typical sizes range from 9 watts to about 25 watts.

Typical Fluorescent Lamp Circuits

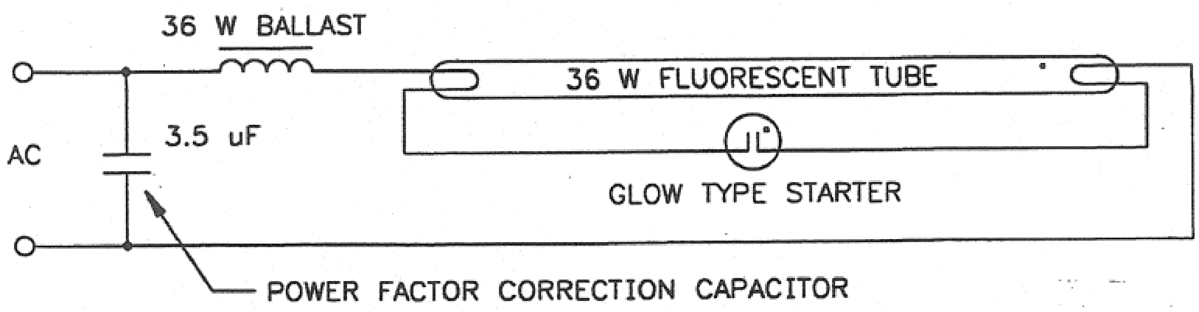
23. Single 36 W Switch Start

Comments:

Conventional glow switch starter 36 w or universal.

Ballast and tube must match.

Power factor correction capacitor required.



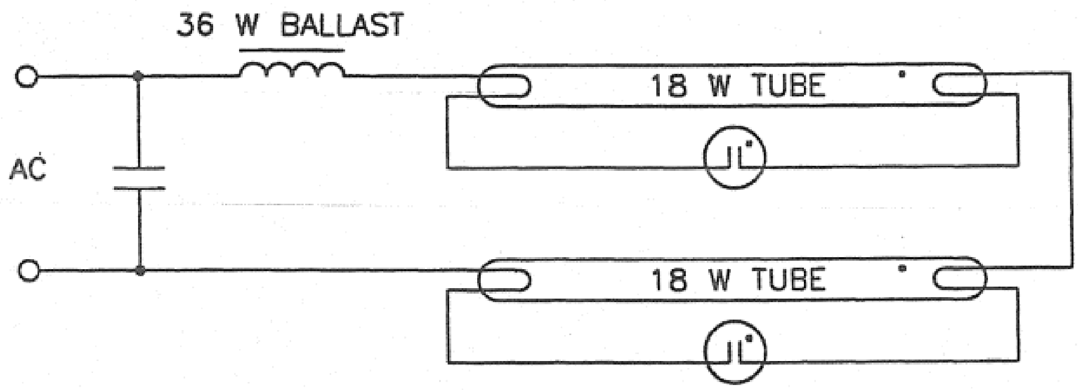
24. Twin 18 W Switch Start using single 36 w ballast

Comments:

Conventional 18w glow starters. Do not use universal or 40 w. (lamps will not start)

Lamps in series 2 x 18 W equivalent to 1 x 36w 36/40 W ballast required.

Power factor correction capacitor required (usually 3.5 μF).



Instant Start Circuits

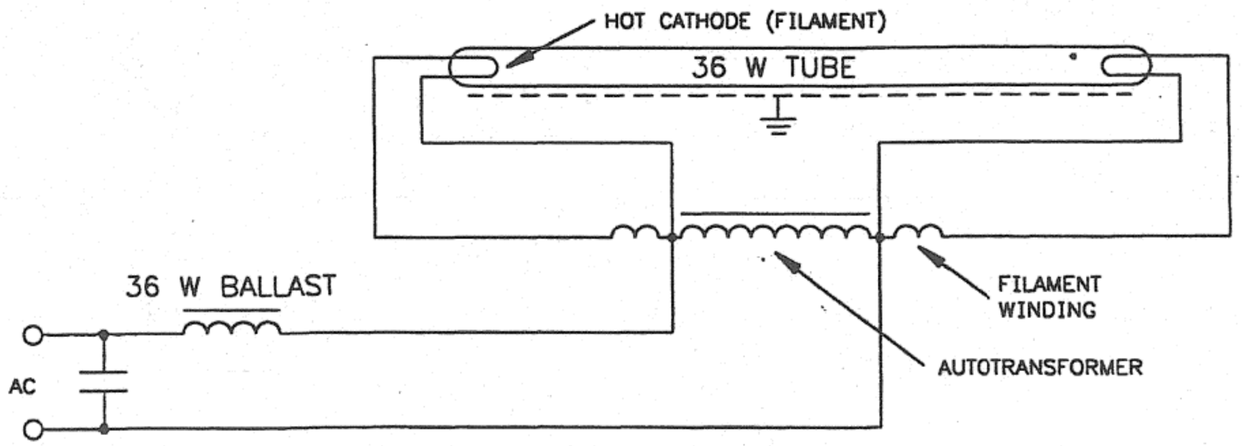
25. An instant start or quick start circuit is one in which the lamp lights after a very short delay without flickering.
Their circuits do not generally use a starting switch.

26. Switchless starting The voltage required for fluorescent tubes is partially dependant on the electrical resistance of the lamp's glass surface and is a minimum when the resistance is either high or low.
Lamps used in switchless circuits are of low resistance type.

27. Low resistance lamps are obtained by running a metallic strip down the side of the lamp that must be connected to earth to provide a high potential gradient between one cathode and earth to assist ionisation and starting.

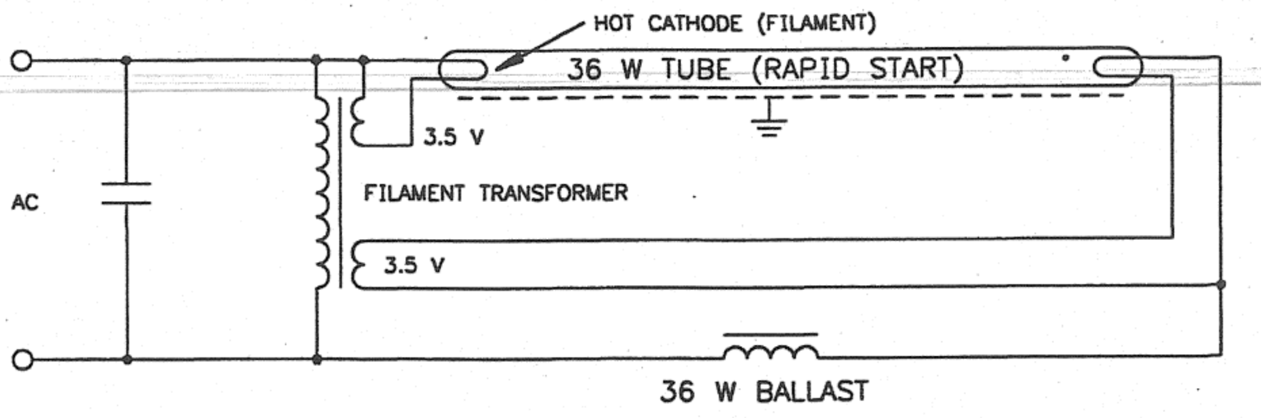
A normal tube used in a metallic fitting which is earthed will often perform the same function.

28. Quick start Transformer Circuit



29. The filaments are pre-heated by the filament winding. The voltage is stepped up through the auto-transformer for starting. An earthed starting aid is required.
Lamps listed as quick start must be used (high resistance cathodes and earthed metal strip).

30 Rapid Start



The filaments are pre-heated from tapping on the filament transformer.
An earthed starting aid is required. Lamps listed as rapid start (RS) must be used (low resistance cathodes and silicon coated tube).

Lamps in Service

31. Although the life rating of fluorescent lamps is typically 7500 hours they are subject to ageing.
After 3000 hours running time a depreciation of luminous flux of 15-20% can be expected.
Where a high luminous output is required it is advisable to change the lamps before they fail. A lamp usually fails when all of the emissive material has been removed from one or both cathodes.

32. Blackening at the tube ends normally indicate the lamp is at the end of its useful life, premature blackening can also be caused by high or low voltage, faulty starting, frequent switching and loose contacts

33. Most circuits which have direct heating for the cathodes can be dimmed using a special circuit which incorporates a typical electronic lamp dimmer. See Electrical Wiring Practice Volume 2 Chapter 7, Figure 7.10d on dimmable DALI electronic ballasts.

Faults in Fluorescent lighting Circuits

34. The same electrical faults of short circuits, open circuits and earth faults are found in fluorescent lighting systems. The internal components of a luminaire can be check with an ohm meter when it is isolated from the supply as the tube and the ballast are in series. The ballast should have a DC resistance of between 30 and 50 ohms. A short circuit in the ballast will cause the fluorescent tube to burn out on energisation. The tube cathodes can also be checked with an ohm meter for continuity.
The glow type starter needs to be changed out each time the fluorescent tube is changed. If the starter is faulty, it will affect the performance of the tube.

Warning! Older fluorescent fittings were equipped with metal can type capacitors for power factor correction. If there is a leakage of oily fluid from the capacitor, you should not touch it as it could be Polychlorinated Biphenyl (PCB) which is highly toxic and possibly carcinogenic. Specialist training is required to remove PCB dialectic capacitors

35. Exercise. Locate a circuit diagram for a fluorescent lamp unit which incorporates an electronic dimmer (use manufacturers' information or a relevant text).

Draw the circuit in the space below:

Fluorescent Lighting

1. What type of cathodes are used in a standard '36 watt' fluorescent lamp?
2. What are the standard nominal lengths of each of the following fluorescent lamps: 18/20 watt, 36/40 watt and 65/80 watt?
3. What type of device is used to limit the operating line current in a 240 volt fluorescent lamp circuit?
4. What effect does it have on the operation of a 240 volt 36 watt fluorescent lamp if the power factor correction capacitor has been disconnected?
5. What resistance would be measured between the contacts of a glow type fluorescent starter when it is not connected in a circuit?
6. What special item of control equipment is required if a fluorescent lamp is to be controlled from an electronic light dimmer?
7. A fluorescent lamp has black rings at each end of the tube and it blinks on and off when operating. What is the most likely cause?
8. What is the special characteristic of 'instant start' type fluorescent lamps?
9. The ends of a fluorescent lamp glow brightly when it is switched on but the lamp does not strike. What is the most likely cause?
10. Draw the circuit of a typical single 36 (40} watt fluorescent lamp.
11. Draw the circuit of a typical twin 18 (20) watt luminaire supplied from a single 36 (40) watt ballast.
12. What are two functions of the ballast in a 36 watt fluorescent unit?
13. State two causes of premature blackening of the ends of a fluorescent tube.
14. Are fluorescent lamps suitable for installations in which they would be frequently switched on and off?
15. What is the practical cure for a fluorescent lamp which continually blinks on and off after it has been in service for about three years?
16. With regard to conventional fluorescent lamp circuits, what item of auxiliary control equipment, other than a ballast or starter switch, is needed to satisfy Supply Authority requirements?
17. Which type of fluorescent circuit is suitable for use over rotating machinery?

Trouble-shooting - 18watt Fluorescent with fault switches.

1. Draw and label a diagram of a single fluoro circuit in the space below.

2. Connect circuit to your diagram and have it checked by your lecturer.
3. **OH&S safety precautions and Danger Tag Procedure must be followed.**
4. Complete the table below.

SWITCH No.	SYMPTOM	FAULT	CORRECTIVE MEASURE
1			
2			
3			
4			
5			

5. In your own words explain each symptom and fault with the help of your diagram, and explain your corrective measure
6. Have your answers checked by your lecturer.

Trouble-shooting Fluorescents	Satisfactory	Not Yet Satisfactory	Lecturer: Date:

Trouble-shooting: Single and three phase induction motors

1. Part of every routine major service of an electric motor should be to test it for electrical faults and visually inspect it for mechanical faults. The electrical tests require you to use relevant test equipment and correctly interpret the results. Some of the tests can only be conducted with the motor dismantled.

2. For the purposes of this unit it is assumed that the motor has been operating satisfactorily at some time in the past (more extensive testing would be required if the motor had just been rewound).

3. As with most electrical machines, the three general types of electrical faults are:

a. Earth faults (low insulation resistance to earth or frame).

b. Short circuits (between phases, coils or turns).

c. Open circuits.

Earth Faults

4. An earth fault is said to exist of any part of the insulated stator winding is in electrical contact with the frame or any metal part of the motor. An inter-winding fault is a low insulation resistance between phases.

5. An earth fault or inter-winding fault can take the form a 'dead short' (a low resistance electrical contact between the winding and the frame or earth), or a higher resistance contact between live parts and earth caused by a partial breakdown of the insulation between components.

6. The insulation resistance to earth must be measured with a high voltage insulation resistance tester (e.g. a Megger). The test voltage for 415 volt machines must be 500 volts (Direct current), or 1000 volts (d.c.) if the working voltage to earth exceeds 250 volts. The resistance so measured must be no less than 1 megohm.

7. Low voltage testing devices such as multimeters, battery test lamps and ohmmeters will detect a 'dead short' to earth, but their operating voltage may not be high enough to detect a fault which only occurs at higher voltages, so they are not suitable for reliably testing for earth faults or inter-winding faults.

8. Before you attempt to test a motor for insulation resistance you must make sure that the motor is isolated from the supply and you must test for zero volts at the motor terminals with a suitable testing device (test before you touch). You should also make sure that you do not touch the metallic portion of the insulation tester test probes during an insulation test because you may receive an electric shock from the test instrument.

9. Before you conduct an insulation resistance test you should check the test instrument to ensure that it is on the correct range – megohms (MΩ). Some instruments have an ohms range as well as a megohms range and you may get incorrect results if it is set to the wrong range.

Three Terminal Motors

10. If a three phase motor is internally connected in either star or delta it is only necessary to measure the insulation resistance to earth from one of the line terminals of the motor to any metal part of the motor which is electrically connected to the stator core or any other part which may be in contact with the stator winding.

Testing from one line terminal to the metallic frame of the motor is usually sufficient as shown in Figure 1.

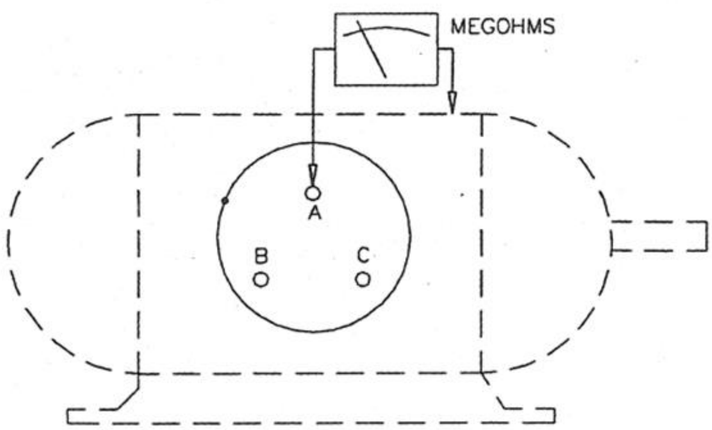


Figure 1 - Insulation test on a three terminal three phase motor

Six Terminal Motors

11. If the motor has six line terminals and it is connected in either star or delta it is only necessary to test for insulation resistance between one of the terminals and the motor frame. If the star or delta links have been removed it is necessary to test between EACH phase winding and the motor frame (i.e. three separate tests are required) as shown in Figure 2.

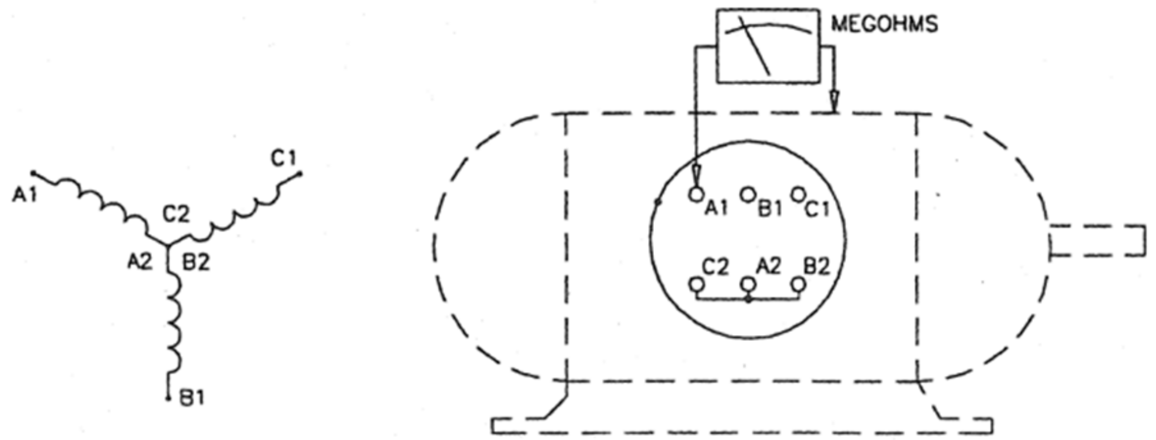


Figure 2 - Insulation test on a six terminal three phase motor

Effects of Moisture

12. If the insulation resistance to earth or between phase windings is slightly less than 1 MΩ it could be due to the presence of moisture in the stator winding. In such cases you should clean the motor and dry it out by placing it in a ventilated drying oven at about 90 degrees for several hours, then re-check it.

13. Although it is legal to put a motor into service if it has an insulation resistance of 1 MΩ it is poor workmanship to do so because if moisture is present the insulation resistance could soon fall below the permissible limit. Ideally the insulation resistance should be greater than 200 MΩ, but in practice a reading of > 5 MΩ can usually be regarded as satisfactory. Large motors usually tend to have a lower insulation resistance than small motors.

14. If a motor has an insulation resistance below 1 MΩ and the reading does not improve after cleaning and drying, it will usually be necessary for the motor to be rewound before it is returned to service because earth faults are almost impossible to locate and correct.

Rotors

15. Squirrel cage rotors do not have any insulation between the rotor winding and the rotor core, so it is not necessary to test them for insulation resistance. Rotors out of wound rotor motors have an insulated star connected winding, so the winding should be tested for insulation resistance as in three terminal three phase motors - by testing from one of the slip-rings to the rotor core or the shaft.

Electronic Equipment

16. Some motors may have sensitive temperature sensing devices such as thermistors embedded in in the windings. Thermistors and their associated circuits are usually sensitive to excess voltages so you need to make sure that you do not connect the insulation tester to these devices.

Short Circuits

17. A short circuit is said to exist when any part of the stator winding is in unintended electrical contact with any other part. Short circuits can occur between the coils of different phases, coils of the same phase, or turns within a single coil.

They are usually the result of breakdown of the insulation in the winding or on connecting leads due to mechanical damage, rubbing together of poorly secured windings, or the ingress of conductive dust or other foreign materials.

18. Internal short circuits can form closed loops inside the stator winding. These loops behave like the secondary of a transformer; circulating currents can result in reduced motor performance and overheating of parts of the winding.

19. Each of the three sets of coils in a standard three phase stator winding should have the same d.c. resistance, so any reasonably accurate resistance measuring instrument such as a multimeter or ohmmeter can be used to compare the resistances of the windings.

20. If the resistances are not almost identical it could indicate a short circuit, but some variation is possible in a sound stator winding due to slight differences in the number of turns on each coil. If a wide variation is found (greater than about 4-5%), it would be reasonable to assume that there is a short circuit, but if the three readings are the same it does not indicate positively that there is not a short circuit.

21. A more reliable instrument for testing for short circuits in stator windings is an internal growler (or Prufrex), but the rotor must be removed from the stator. The internal growler is positioned so that it straddles each stator slot in turn. If the neon indicator lights up, it indicates a short circuit in the coil in that slot.

22. If there are any parallel connections in a stator winding the internal growler will indicate short circuits in the relevant slots, so it is necessary to disconnect any parallel connections before beginning the test. A delta connection is a parallel connection, so the delta connection must be disconnected before testing the stator.

Open Circuits

23. The test for open circuits (or winding continuity) in the stator winding can usually be carried out without dismantling the motor. The open circuit test is a matter of measuring the resistance between each of the line terminals with a low reading multimeter and interpreting the results.

24. You should always draw a diagram of the terminal arrangement and show the resistance readings as you measure them - this helps to ensure accurate interpretation of the results.

25. **Six Terminal Motor** If the motor terminal block has six terminals the coils for each phase would usually be connected in one of two ways - as shown in Figure 3. If the motor is connected in star or delta at the terminal block the links should be removed. A reading of greater than 200MΩ between any pair of coil terminals would indicate an open circuit.

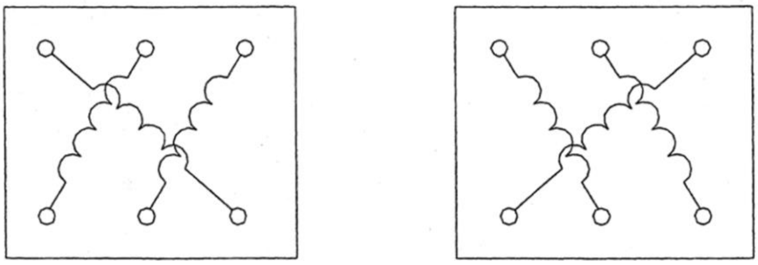
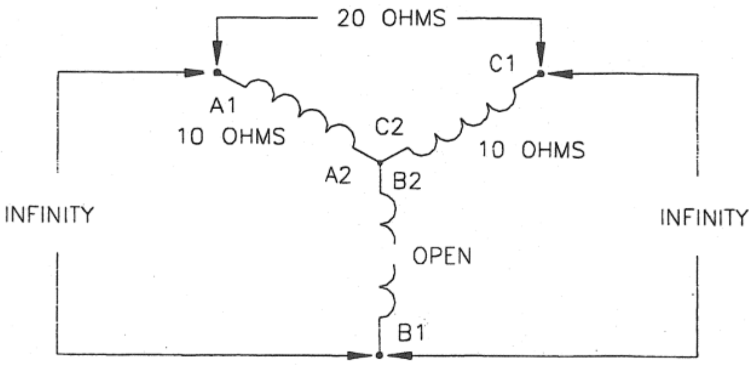


Figure 3 - Six terminal Motor terminal blocks.

26. **Three Terminal Motor - Star Connected** If there is an open circuit in one of the phases of a star connected motor the resistance reading should be infinity between two pairs of terminals, and the resistance measured between the remaining two terminals should indicate the resistance of two phase windings in series - as shown in Figure 4.

Figure 4 - Motor star



Three terminal terminal block - connected.

27. **Three Terminal Motor - Delta Connected** If there is an open circuit in one of the phases of a delta connected motor the resistance reading should be low between two pairs of terminals, and the resistance measured between the remaining two terminals should indicate the resistance of two phase windings in series (double the resistance between the other pairs) –as shown in Figure 5.

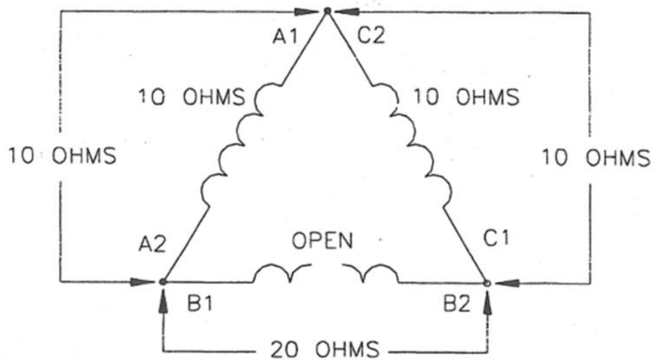


Figure 5 - Three terminal Motor terminal block - delta connected.

28. If a resistance of infinity is indicated between more than one pair of terminals it indicates that there is more than one open circuit - in which case it may not be necessary to conduct further resistance tests because it would only take one open circuit to render the motor unserviceable. If you locate an open circuit you should check the visible leads and terminations before you declare the fault to be an open circuit in the winding.

Squirrel Cage Rotors

29. The construction of a squirrel cage rotor is such that earth faults and short circuits do not occur, but it is possible for the rotor bars to crack or for open circuits to develop where the rotor bars join the end rings, particularly when copper rotor bars are brazed to the end rings.

30. Relatively small squirrel cage rotors can be checked for open circuits using an external growler - the same as the type used for testing small armatures. Safely connect a suitable a.c. ammeter in series with the growler coil and place the rotor on the growler - as shown in Figure 6. Energise the growler and rotate the rotor by hand - if there is a variation in the reading as the rotor is rotated it indicates that there is an open circuit in the rotor winding.

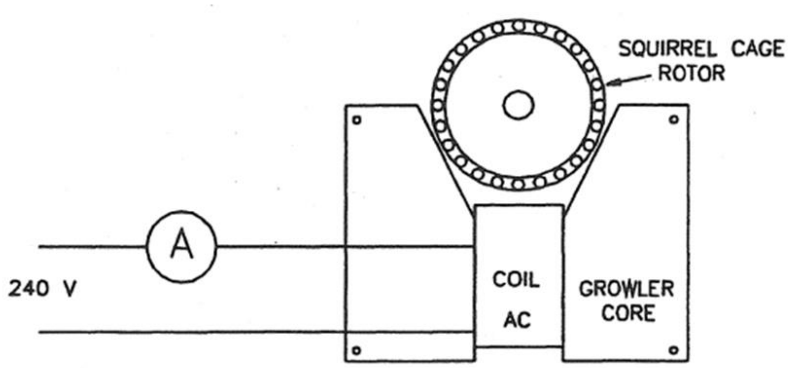


Figure 6 - Testing a small rotor for open circuits.

Wound Rotor Motors

31. Since wound rotor motors have the same type of stator winding as squirrel cage motors, the procedures for testing them is the same as for squirrel cage motors. The insulated rotor winding is usually star connected, so the procedure for testing the rotor is the same as for testing a star connected stator winding.

Operational Check

32. If all bench checks and tests indicate that the motor is serviceable, and there are no visible signs of any mechanical faults, the motor should be test-run on no load. The current in each of the phases should be same, and the value should be less than the value given on the motor nameplate. There should not be any unusual noise or excessive vibration. The no-load speed should be up to about 5 rev/min below the synchronous speed (i.e. higher than the full load speed given on the nameplate).

33. Before you attempt to energise the motor you should ensure that the motor is adequately fastened down, so that the inertia of the rotor does not cause the motor to move when energised.

Single Phase Motor Testing

34. The same types of faults which occur in three phase motors also occur in single phase motors. These common electrical faults are; short circuits, open circuits and insulation resistance faults. In split phase type motors which incorporate a switching mechanism to disconnect the starting winding, the contacts on the switch can weld together causing the start winding to overheat and burn out.

35. Before you connect a motor to the supply you need to accurately identify the ends of the electrical components. The most suitable instrument to use is a multimeter set to the ohms x 1 range. The connections at the terminal block should be disconnected during the test to avoid any unwanted parallel connections.

36. The start or auxiliary winding is usually the one with the highest d.c. resistance - typically 10-12 ohms for a 180 watt split phase motor. The resistance will be less for a larger motor or for a capacitor type motor. If the resistance of a winding is zero ohms it indicates a short circuit. A resistance of infinity indicates an open circuit.

37. The run winding usually has a resistance of about 8-10 ohms for a 180 watt split phase motor, or less for a larger motor.

38. The resistance of the normally closed centrifugal switch should be zero ohms when measured with a multimeter.

39. The capacitor can usually be tested or identified by noting that the multimeter resistance reading goes up-scale on a high ohms range, then slowly moves down scale to the infinity position (as the battery in the multimeter charges the capacitor). If the multimeter indicates around zero ohms it indicates that the capacitor is short circuited. If it indicates infinity ohms without moving, it indicates that the capacitor is open circuited.

40. If a split phase motor is tested for winding resistance with all connections correctly made, the resistance reading should be the equivalent resistance of the run winding and the start winding connected in parallel. If a capacitor type motor is tested the resistance reading would be the resistance of the run winding alone, because the capacitors would be virtually equivalent to an open circuit.

41. In split phase type motors the start winding usually has a higher resistance than the run winding, but this is not always the case, particularly in capacitor start motors. To avoid permanent damage to the motor resulting from incorrectly connecting the run winding in series with the centrifugal switch you should always run a newly connected motor for a few seconds on no load and check the line current. It should be LESS than the value shown on the nameplate. If it is not, you could have the start winding connected direct across the supply.

42. Short circuits between turns in a winding can be detected with an internal growler the motor must be dismantled for this test, and any parallel connections must be disconnected.

43. The insulation resistance between windings and from each winding to earth (or frame) must be measured with a 500 volt high voltage insulation tester (a Megger). The minimum permissible insulation resistance is 1 Megohm, but most single phase motors should have an insulation resistance greater than 200 Megohms.

Trouble-shooting: Single and three phase induction motors

1. What are the three general types of fault which can occur in a three phase motor stator winding? What test instrument should be used to detect each type of fault?
2. What precaution should be taken before testing a delta connected three phase stator for short circuits with an internal growler?
3. What test instrument is usually used to test a small three phase star connected wound rotor motor rotor for short circuits?
4. What instrument can be used to detect an open circuit in a three phase wound rotor motor rotor?
5. What device should be used to check a wound rotor motor STATOR for short circuits?
6. Each of the phase windings in a particular three terminal three phase STAR connected motor has a designed resistance of 6 ohms. What resistance reading will be obtained between each pair of line terminals if the A phase winding is open circuited?
7. Each of the phase windings in a particular three terminal three phase DELTA connected motor has a designed resistance of 9 ohms. What resistance reading will be obtained between each pair of line terminals if the A phase winding is open circuited?
8. Each of the phase windings in a particular three terminal three phase STAR connected motor has a designed resistance of 5 ohms. What resistance reading should be obtained between each pair of line terminals?
9. Each of the phase windings in a particular three terminal three phase DELTA connected motor has a designed resistance of 12 ohms. What resistance reading will be obtained between each pair of line terminals?
10. Each of the phase windings in a particular three terminal three phase DELTA connected motor has a designed resistance of 6 ohms. What resistance reading will be obtained between each pair of line terminals if the B phase winding has short circuited turns which reduce its resistance to 4 ohms?
11. How can a single phase split phase stator winding be distinguished from a 3 phase winding of about the same power rating?
12. How many windings does a single speed capacitor start motor have and what are they usually called?
13. What component do most single phase split phase induction motors have that three phase squirrel cage induction motors do not have?
14. Is the resistance of the start winding higher or lower than the resistance of the run winding in a typical split phase type motor?
15. What is the likely outcome if the switching mechanism was open circuited when a typical split phase motor attempted to start?

Notes

Trouble-shooting: Three phase induction motors

Objective

To test a typical 415 volt three phase induction (SCI) motors for serviceability.

Equipment

Three phase single speed squirrel cage induction motor up to about 3 kW.

Three phase wound rotor motor up to about 3 kW.

High voltage insulation resistance tester.

Internal growler

Multimeter.

Inspection Report Sheet.

Suitable parts tray.

Hand tools as required.

Felt tip marking pen.

Procedure

1. Make sure that the motor is not connected to the supply.
2. Examine the three phase induction motor provided and record all nameplate details on the Inspection Report.
3. Carefully remove the rotor from the stator and place all the small components in the parts tray.
4. Visually inspect all motor components and carry out the electrical tests required to complete the Inspection Report. You are not required to correct any faults.
5. Submit your Inspection Report to your Lecturer for comment and assessment. Note that it is not necessary to complete all details in the Final Test Results on the Inspection Report if the motor tested is unserviceable.
6. Repeat the inspection procedure on the other motor (or parts thereof) supplied.
7. Return all of the equipment to its proper place.

Trouble-shooting **Three Phase Motors**	Satisfactory	Not Yet Satisfactory	Lecturer: Date:

Inspection Report 1

Owner:	**Date:**
Motor type:	**Inspected by:**
Line Voltage:	**Phases:**
Frequency:	**Full Load Speed:**
Line Current (full load):	**Connection:**
Insulation Class:	**Manufacturer:**
Mounting Position:	**Serial Number:**

Stator - Test Results

Test	Instrument	Test Result	Work Required
Visual Inspection			
Short circuits			
Open circuits			
Earth faults			
Inter-winding			
D.C. resistance			
Terminals			
Connection leads			
Microtherms			
Thermistors			

Rotor

Test	Instrument	Test Result	Work Required
Visual Inspection			
Open circuits			

Mechanical Inspection

Component	Good Condition	Poor Condition	Work Required
Carcase			
Drive shaft			
Keyway			
Drive Pulley			
End shields			
Rotor			
Bearings			
Bearing housing			
Lubrication			
Internal fan			
Mounting feet			
Terminal box			
Airways			
Cowling			
External fan			
Other			

Final Testing Results

Insulation resistance to earth		MΩ	@ Volts d.c.
Inter-winding resistance		MΩ	@ Volts d.c.
Winding resistance	$U_1 – U_2$	$V_1 – V_2$	$W_1 – W_2$
Line Current	A Phase	B Phase	C Phase
Speed (no load)			
Noise			
Other observations			

Inspection Report 2

Owner:	**Date:**
Motor type:	**Inspected by:**
Line Voltage:	**Phases:**
Frequency:	**Full Load Speed:**
Line Current (full load):	**Connection:**
Insulation Class:	**Manufacturer:**
Mounting Position:	**Serial Number:**

Stator - Test Results

Test	Instrument	Test Result	Work Required
Visual Inspection			
Short circuits			
Open circuits			
Earth faults			
Inter-winding			
D.C. resistance			
Terminals			
Connection leads			
Microtherms			
Thermistors			

Rotor

Test	Instrument	Test Result	Work Required
Visual Inspection			
Open circuits			

Mechanical Inspection

Component	Good Condition	Poor Condition	Work Required
Carcase			
Drive shaft			
Keyway			
Drive Pulley			
End shields			
Rotor			
Bearings			
Bearing housing			
Lubrication			
Internal fan			
Mounting feet			
Terminal box			
Airways			
Cowling			
External fan			
Other			

Final Testing Results

Insulation resistance to earth		MΩ	@ Volts d.c.
Inter-winding resistance		MΩ	@ Volts d.c.
Winding resistance	$U_1 - U_2$	$V_1 - V_2$	$W_1 - W_2$
Line Current	A Phase	B Phase	C Phase
Speed (no load)			
Noise			
Other observations			

Trouble-shooting: Split Phase Motors

Objective

To trouble-shoot a typical single speed single phase split phase induction motor.

Equipment

Typical split-phase single phase motor up to about 0.5 kW.
Suitable parts tray.
Hand tools as required.
High voltage insulation tester.
Multimeter.
Felt tip marking pen.

Procedure

Note: Minor variations to this procedure may be necessary for different types of motor.

1. Make sure that the motor is not connected to the supply.

2. Examine the motor provided and record all nameplate details.
Record the general type of construction of the motor, and the intended mounting position (e.g. foot mounted or flange mounted).

Nameplate Details

Type of Construction --------------- Mounting Position -----------------

3. Mark the position of both end shields in relation to the stator carcass using a felt pen. Use one line for the drive end and two lines for the non-drive end. Note that in industry it is common to mark the position of the end shields with small centre punch marks.

4. Plan the job - decide on the general sequence in which the motor should be dismantled. If the bearings are of the ball or roller type with bolted bearing caps, the earing caps should be removed first, otherwise the end shield retaining bolts should be removed first. All parts must be placed in a parts tray.

5. Carefully loosen both end shields and remove the end shield which does not house the centrifugal switch.

6. Withdraw the squirrel cage rotor, taking care not to allow it to touch the stator winding at any time (if you are not careful you could damage the stator winding with the rotor or the shaft). Support the end shield housing the centrifugal switch so that no strain is placed on the connecting wires.

7. Examine the parts of the motor and answer the following questions:

a. What metal are the end shields made from?

b. What type of fasteners are used to secure the end shields to the stator carcass (e.g. bolts, through bolts, socket-head screws)?

c. What type of bearing is used on the drive end of the motor?

d. What type of bearing is used on the non-drive end of the motor?

e. What is the identification number on the drive-end bearing (ball or roller type)?

f. What is the identification number on the non-drive-end bearing (if any)?

g. What type of material is the stator core made from?

h. What type of material is the rotor core made from?

i. What type of material is the rotor winding made from?

j. How many slots are there in the stator?

k. How many separate windings are there in the stator? What are they called and what is the resistance of each?

l. What material is the terminal block made from?

m. How many terminals are there on the terminal block and how are they marked?

n. How many screws (or bolts) are used to retain the drive end bearing cap (if any)?

o. What size is the conduit entry to the terminal box (if any)?

p. Where is the main cooling fan located?

q. Are the rotor bars parallel to the rotor shaft?

r. Note and record the specifications and ratings of the starting capacitor.

s. Are the centrifugal switch contacts normally open or normally closed?

8. Measure and record the insulation resistance of the stator winding.

9. Re-assemble the motor, taking care not to damage any components or force them into position.

11. Have your answers and results checked by your Lecturer.

12. Return all of the equipment to its proper place.

Questions

1. Use the power and voltage ratings of the motor to calculate the expected line current using Ohm's Law. Explain why the calculated current is much higher than the current shown on the nameplate.

2. What is the d.c. resistance of the following components:

a. The run winding.

b. The start winding.

c. The centrifugal switch.

3. What is the minimum permissible insulation resistance for a split phase start motor which is to be operated on a normal 240 volt single phase 50 Hz supply?

Trouble-shooting Split Phase Motors	Satisfactory	Not Yet Satisfactory	Lecturer: Date: