



Standard for Electrical Installations

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Document Number: D16/116468

File: 47662E

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1 INTRODUCTION

1.1 Background

Shoalhaven Water is embarking on a program of upgrade projects for their water and wastewater assets. The organisation has a strategic view to establish consistency for the delivery of electrical installations through the development of a suite of electrical standard specifications so that future electrical works can be designed and constructed to derive the benefits of harmonisation including.

- Increased safety in operations and maintenance due to consistency of design and construction practices;
- Cost savings due to:
 - reduced training needs for a less variable range of design practices, equipment and spares holdings;
 - potential reduction in construction costs that are attributed to ‘bespoke’ design;
- More efficient project and contract management of service providers/contractors through less variability in contract technical specifications.

1.2 Scope and Purpose

This electrical specification sets out the minimum guidelines for the design and construction of low voltage electrical works. As the majority of Council’s installations are supplied at low voltage, specifications for high voltage infrastructure will be provided separately to this document.

It is intended to provide consistency in electrical design and installation requirements and through the harmonisation, allow Shoalhaven Water to fulfil its health, safety and environmental obligations in the delivery and implementation of their electrical works.

This document is not intended to be prescriptive to the extent that it restricts design choices by the electrical designer. However, any alternative design decisions shall require the prior approval of Council. Where there is a conflict between this document and statutory requirements, the later takes precedence.

1.3 Definitions and Abbreviations

Abbreviation	Definition
ASP	Accredited Service Provider
DB	Distribution Board
EE	Endeavour Energy
EMC	Electromagnetic Compatibility
MCC	Motor Control Centre
MSB	Main Switchboard
PLC	Programmable Logic Controller
RTU	Remote Terminal Unit
SCA	Switchgear and controlgear assembly
SCC	Shoalhaven City Council

1.4 Terminology

The following terms are used interchangeably in this Document:

- Shoalhaven Water and Council
- Principal and Principal’s Authorised Representative

2 STANDARDS, CODES AND REGULATIONS

2.1 List of Standards, codes and regulations

All electrical work performed and electrical equipment supplied under this Contract shall comply in every respect with the relevant by-laws, regulations, Standards and Codes of the following:

- Shoalhaven City Council;
- Australian/New Zealand Standards;
- Endeavour Energy;
- Service and Installation Rules of New South Wales;
- Environment Protection Authority;
- Australian Communications and Media Authority;
- Building Code of Australia;
- WorkCover Authority of New South Wales; and
- Any other authority having jurisdiction over this particular installation.

Where no Australian Standard or Code exists, those of the British Standards Institution, including the latest amendments, shall apply.

Proof of compliance with a Standard or specified tests may be required. Where requested, such proof shall comprise a test certificate from an independent Testing Authority.

Where a Standard Specification requires reference to another Standard Specification and that Standard has been amended, replaced or superseded or withdrawn, the reference shall be taken to apply to the replacement of that Standard. If necessary, the Standards Association of Australia shall be consulted for a determination of the appropriate replacement Standard.

2.2 Precedence and Contradictions

Where conflict arises between the reference standards and this specification, the precedence shall be as follows:

- AS/NZS 3000 Wiring Rules;
- Endeavour Energy Supply Authority Standards;
- NSW Service and Installation Rules; and
- This Specification.

2.3 Accredited Service Provider Works

Where Levels 3, 2, or 1 works are required under the scope of the Contract to which this Specification is applied, the Contractor shall be, or shall engage as a sub-Contractor, a Level 3, 2, or 1 ASP (as applicable to the works) registered with the Department of Fair Trading and approved by the relevant Supply Authority.

The ASP's works shall be in accordance with the relevant Supply Authority's certified drawings and to the relevant supply authority's standards.

3 OPERATING AND DESIGN CONDITIONS

3.1 Environmental Conditions

3.1.1 General

All equipment and materials shall be designed and constructed for service under the atmospheric and site conditions prevalent in the catchment areas of Shoalhaven City Council.

3.1.2 Equipment Ratings

Equipment shall be rated for continuous operation within the range of ambient conditions as follows, unless otherwise specified:

- Temperature: 0°C to 40°C (indoor)
0°C to 50°C (outdoor)
- Relative Humidity: 10% to 95%

3.1.3 Equipment Protection

Equipment protection considerations fall under two categories:

Ingress Protection (IP) as defined in AS 60529 for protection of the equipment from different forms of environmental conditions; and

Equipment Protection Level (EPL) as defined in AS 60079 for determining and selecting devices for their suitability to be installed in specific zones of hazardous areas.

All equipment shall be selected to suit the IP or EPL classification for their use.

3.2 Electrical Supply

3.2.1 General

Endeavour Energy is the Supply Authority in Council's catchment area.

The majority of Council's electrical infrastructure is supplied at low voltage. Where ASP works are required, suitable parties shall be engaged to perform these works (refer Clause 2.3)

3.2.2 Fault Levels

The electrical designer shall be responsible for determining the fault levels to be applied to the design of the electrical supply to Council's assets (pump stations, treatment plants, depots and other buildings or installations), and for coordinating and liaising with the Supply Authority in determining the fault levels.

Typically, the expected fault level at Council's standard pump stations is 30kA, while main switchgear and controlgear assemblies in installations such as treatment plants are designed to withstand 50kA for 1 second.

3.2.3 Power Factor Correction

The electrical systems for Council's plants shall be designed to ensure that the power factor for the whole installation meets or better 0.95 lagging during plant normal operations.

The design of the power factor correction equipment shall comply with the requirements of the Supply Authority and shall be considered in a holistic context as follows:

- Automatic adjusting versus load-based or fixed compensation capacitor banks to suit the particular application with regard to operability, maintainability and value; and
- The total network environment of the plant with regard to implications of harmonics-producing drives, harmonics emissions and catering for potential changes in plant loading due to plant upgrades or re-configuration.

3.2.4 Management of harmonics issues

Electrical installations for Council's plants shall be designed to ensure that any distorting or fluctuating loads do not result in harmonics emissions and voltage regulation issues that are unacceptable to both internal plant and Supply Authority networks.

Electrical installations shall therefore comply with, but not limited to the following:

- AS/NZS 61000 Parts 3.2, 3.4 and 3.12 pertaining to limits for harmonic current emissions;
- AS/NZS 61000 Parts 3.3 and 3.5 pertaining to limitation of voltage fluctuations and flicker;
- AS/NZS 61000 Parts 3.6 and 3.7 pertaining to assessment of emission limits for the connection of distorting and fluctuating loads to MV, HV and EHV power systems;
- Agreed limits with Endeavour Energy (as applicable to the project);
- Agreed acceptance criteria/process with Endeavour Energy (as applicable to the project) for the harmonics mitigation solutions; and
- Agreed approach and assessment process with Shoalhaven Water to consider and take into account pre-existing power quality conditions at the site in question.

If required, all harmonics mitigation solutions, outcomes of electromagnetic compatibility (EMC) considerations and filtering equipment shall be designed and installed to comply with the foregoing standards and formally agreed limits and/or approach.

3.3 General Design Philosophy

3.3.1 General

The design of electrical infrastructure in all Council plants or assets shall duly consider the purpose, safe operation and required level of reliability for the plant. The design process shall incorporate key principles of risk assessment, safety-in-design, failure mode analysis, and availability and reliability concepts.

3.3.2 Standby Power

Use of standby power shall be considered on a case by case basis, in consultation with the plant process designers and Council, and based on the design principles described in the preceding clause.

3.3.3 Drive Isolation

Council's philosophy for drive isolation is to isolate each drive at its main circuit breaker/isolator at the source of its power supply, that is, at the Motor Control Centre (MCC), to Council's electrical isolation procedures. Visual indicator lights shall be provided to indicate status of all phases.

3.3.4 Emergency Stops

Drive emergency stops must, as a minimum, comply with the requirements of AS4024 and current Health, Safety and Environment statutory requirements.

A risk assessment shall be undertaken during the design process with operations and maintenance input from Council so that elimination of risks is properly considered.

Emergency stops must be only used for their intended purpose which is to stop the relevant drive upon an abnormal or emergency situation and must not be used for the purpose of electrically isolating drives for maintenance purposes.

3.3.5 Hazardous Areas

Where hazardous areas (including confined spaces) cannot be avoided in the process design for the plants, the electrical installations shall be suitable for the respective classification of hazardous areas.

3.4 Materials and Workmanship

All materials used in the equipment supplied under this Contract shall be new and suitable for the service required.

All electrical insulating materials shall be of high dielectric strength and shall comply with the requirements as specified in the relevant Standards.

Equipment models shall be current unless otherwise specified and/or approved by Council.

The whole of the electrical installation carried out under this Contract shall be carried out in a professional workmanlike manner, in accordance with the best industry practice.

3.5 Preferred and Nominated Equipment Suppliers

The term “preferred” as applied in this Specification implies that the “family” or brand of products is known or familiar to Council but does not necessarily mean restrictions to selection of other brands.

The term “nominated” as applied in this Specification implies that where possible, the “family” or brand of products should be selected to ensure proper harmonisation and interfacing with key equipment already installed in the plant.

Alternative brands and models of nominated equipment shall be subject to Council’s approval. Where such alternative brands and models are offered and accepted by Council, the Contractor will be required to warrant the substituted brand and model, and may be required to alter standard design drawings.

The following two tables list nominated and preferred equipment suppliers respectively for the electrical, instrumentation and control equipment.

Table 1 Nominated Equipment Suppliers

Equipment	Brand	Notes
SCADA Software	Schneider Electric ClearSCADA	
Programmable Logic Controller	Omron	
Remote Telemetry Unit	Schneider Electric SCADAPack	
Data Radios	Schneider Electric Trio Q Series Digital	Other radios may be used for different applications. Refer to the Principal for specific requirements on a case by case basis.

Emergency/Exit Lights	Bardic with Sentinel auto test	
Spitfire Emergency Lights	Bardic with Sentinel auto test	
Security/access control system	Concept	

Table 2 Preferred Equipment Suppliers

Equipment	Brand	Notes
Variable Speed Drives	Danfoss	Principal to approve Supplier
Pressure gauge	Bourdon	
pH monitoring	Prominent	
ORP monitoring	Royce	
DO monitoring	Hach	Principal to approve Supplier
Residual chlorine monitoring	Prominent	
Chlorine gas monitoring	Siemens	
Touch screens	Omron	
Radar level sensors	Vega	Principal to approve Supplier

4 BUILDINGS

4.1 General Requirements

This section of the Electrical Specification must be read in conjunction with the scope and civil works requirements of the project at hand.

In providing the electrical works for the project in which such works will be installed in electrical switchrooms, the Contractor must coordinate and liaise with the Principal and other service providers as applicable to:

- consider any access constraints to the site to ensure that major items such as SCA's and MCC's can be delivered and installed in the final location;
- ensure civil and other building requirements for SCA's, MCC's and other major electrical equipment have been duly considered and included in the building/room design including but not limited to door head heights, cable penetrations, underfloor access, drainage of pits, etc; and
- ensure the design and installation of electrical building services will be properly incorporated by the party providing the civil/building works.

This section is therefore in two sub-sections, with the purpose of each sub-section described as follows:

1. Concept for electrical switchroom design that will typically fall under a civil works/building scope – to serve as reference information for the electrical services provider in considering placement of SCAs and cable entries; and
2. Building services requirements (egress, safety, emergency lighting, fire detection, building security) – these are performance and standard specifications for the electrical works for the building.

4.2 Electrical Switchrooms

4.2.1 Infinite Access Floor

Electrical switchrooms in Council's plants and facilities will typically have underfloor access. Where such floors are constructed (by others) to comprise a modular panel arrangement with an under-structure:

- The under-structure shall be connected by the electrical contractor to the site electrical earth;
- The installation of the floor panels must be coordinated with the installation of the SCA frames as SCA's must not be directly on the infinite access floor.

Cables in underfloor space shall be run on hot-dipped galvanised cable ladders.

4.2.2 Drainage of Electrical Switchrooms

The electrical switchroom sub-floor will be designed to slope toward a drainage sump or the site sewer. The drainage system will be fitted with an isolation valve to prevent ingress of sewer gases into the sub-floor area.

4.3 Building Services

4.3.1 Lighting

General Requirements

All light fittings for buildings shall be procured from a reputable supplier and manufactured in accordance with AS/NZS 60598.1 and AS 3100.

Luminaires shall be complete with new lamps and diffusers as specified and all new accessories required for the proper functioning of the fittings.

All luminaires shall be complete with facility for earthing. All luminaire accessories such as fuses, ballasts, capacitors etc. shall be positioned so that they are readily accessible.

Photometric data, copies of Statutory Approvals and Supply Authority letters shall be supplied to the Principal's Authorised Representative if requested.

The metal work of luminaires exposed to dust, water or weather shall be protected against corrosion.

All fittings shall be fitted with capacitors to give a power factor of 0.9 lagging minimum. Capacitors shall comply with AS/NZS 61048 and be connected in shunt across the AC supply.

All fittings shall incorporate electronic ballasts (class EE1-A2).

Where luminaires are mounted on a fire rated ceiling or fire rated walls, the integrity of the ceiling or wall shall be maintained.

Installation of Luminaires

All screws, battens, roses, noggins, trims, packing, etc necessary for the proper fixing of luminaires, shall be provided as part of the works, whether individually specified or not. Packing pieces of approved material shall be fitted where required to level the luminaires and to prevent distortion.

Where a building member does not exist in the position required, supply and install a suitable fixing.

Proprietary mounting brackets shall be used to mount luminaires to ensure the integrity of the IP rating is maintained.

Where painted surfaces are damaged, they shall be made good by the Contractor. Such repairs shall be of the same standard as the original paintwork.

Lamps

Fluorescent lamps shall use bi-pin connection, triphosphor with a colour temperature of 4000 K and a colour rendering of 84 or greater except where otherwise noted. Fluorescent lamps shall be equal to Philips or Osram, unless otherwise noted.

Light Switches

The light switch flush plate or panel shall be mounted at a height of 1300 mm to centre line.

The light switch mechanism shall have a minimum 20 amp rating, quick make and break type except in small rooms with less than 4 fittings, where 15 Amp rating to be used. The light switch mechanism

shall be suitable for fluorescent and discharge lamp switching. Double pole light switches where required shall be capable of switching the active load through both poles.

Description of Lighting Operation and Controls

Lighting shall be controlled by the following methods as appropriate to suit the function of the plant areas:

- Manual switching;
- Time adjustment through the SCADA system; and/or
- Photo-electric switching

Photo Electric Switch

A photo electric switch shall be used for control of external lighting with the following features:

1. Light sensitive controller (P.E. Cell) to turn switch on and/or off at dusk and/or daybreak respectively and incorporating a time delay circuit, so that it is not affected by sudden or brief change in light level caused by intermittent cloud cover, reflections, vehicular lights or lightning.
2. IP56 impact resistant housing, with non-corroding and non-conductive cover, suitable for permanent fixing direct on a wall (not plug in type).
3. Rating 230-250 Volts, 50 Hz, 8 Amps, suitable for AC 3 type load.
4. Operating temp range:- 10°C to +50°C.
5. Final position to be determined on site.

Mixed Circuits

Mixed circuits of light and power will NOT be permitted.

4.3.2 Emergency and Exit Signs

General

The emergency lights and exit sign light fittings shall be complete with self-contained battery/inverter units, dual rate charger and shall comply with AS 2293 Parts 1 and 2. Electronic components to be rated for 105°C operation.

All emergency and exit fittings shall be appropriately labelled and a log book provided to the Principal's Authorised Representative.

All emergency and exit lights shall be wired from a local distribution board with an emergency lighting testing circuit as required by AS 2293.

Product data

Submit manufacturer's data for each type of luminaire and exit sign including tables indicating the maximum luminaire spacing for a given mounting height.

Single-Point System Luminaires

General:

Visual indicator lights: Provide a red indicator, readily visible when the luminaire is in its operating location, which indicates that the battery is being charged.

Inverter system: Provide protection of the inverter system against damage in the event of failure, removal or replacement of the lamp, while in normal operation.

Local test switches: Provide a momentary action test switch, accessible from below the ceiling, on each luminaire to temporarily disconnect the mains supply and connect the battery to the lamp.

Emergency Lighting Common Test Facility:

Provide a common test switch on the local distribution board which disconnects main supply to the emergency luminaires and exit signs for 90 minutes as per AS2293 to test for discharge performance. After testing, this switch must automatically revert to normal operating mode.

Batteries:

Type: Lead-acid or nickel-cadmium batteries capable of operating each lamp at its rated output continuously at least 2 hours during acceptance tests and 1.5 hours during subsequent tests.

Battery life: At least 3 years when operating under normal conditions at an ambient temperature of 25°C and subjected to charging and discharging at 6 monthly intervals.

Marking: Indelibly mark each battery with its date of manufacture.

Power Supply to Single-Point Systems:

Provide an unswitched active supply to each luminaire and exit sign, originating from the test switch control panel.

Marking and Labelling:

Label each luminaire with a unique identifying number and record the number and luminaire location in a schedule included in the emergency evacuation lighting operation and maintenance manual. The label must be permanently fixed, indelible and readable at a distance of 1 m.

Testing and Commissioning

Carry out tests, including out-of-hours tests, to demonstrate the emergency and evacuation system's performance. Include the following:

- Test components for correct function and operation.
- Demonstrate illumination performance on site, to at least the level stated in the manufacturer's performance specification for that device.
- Test operation of battery discharge test and control test switch functions, including discharge and restoration.
- Demonstrate system functions under mains fail condition.
- Demonstrate operation of the battery and charger including a full discharge/recharge over the designated time.

Mains Supply

Before commissioning, ensure mains supply has been continuously connected for at least 24 hours.

Commissioning

Verify the correct operation of luminaires and exit signs for a continuous period of at least 2 hours. Then restore normal supply and verify the operation of the indicator lights on each luminaire.

Maintenance

Subject to the contractual conditions and duration of the contract, the Contractor shall be required to carry out the required 6-monthly maintenance procedures before works completion.

4.3.3 General Power and Socket Outlets

Connections to Equipment

Where items of equipment are noted to be connected via a plug, allow for the supply and connection of a suitable plug top and flexible cord on equipment.

For permanent connections, provide an isolating switch adjacent to the equipment as per AS3000.

All permanent connected equipment shall be wired through an isolating switch. The isolating switch shall typically be provided with 2m of the equipment at a minimum of 1m above the finished floor level unless otherwise indicated or apparent from the location of the power unit. Sufficient cable shall be provided to allow un-fixed equipment to be moved for cleaning purposes.

Isolating switches shall be of approved type and rating to meet the requirements of the location and function. Isolating switches, except where otherwise indicated, shall be of the impact resistant all insulated moulded type.

Socket Outlets

Fitting and accessories for socket outlets shall be of approved manufacture and rating and shall be selected to meet the requirements of the location and functions. All socket outlets shall have the earth pin located at 6 o'clock position and shall be polarised as in the wiring rules. Socket outlets, unless otherwise specified, shall have a 10 amp capacity rating..

Socket outlets shall be selected with an IP rating to suit the installation location.

Three Phase Socket Outlets

For three phase socket outlets provide a five round pin arrangement with the earth pin at the 6 o'clock position, the neutral pin in the centre, and the red, white and blue phases in a clockwise sequence when viewed from the front of the socket.

Three phase socket outlets shall comprise an approved, industrial heavy duty, surface mounted combination switch socket IP56 assembly of impact resistant plastic, with flap lid and complete with five pin plug top and screw ring for holding plug top in position.

4.3.4 Fire Detection and Alarm

General

This section of the specification sets out the requirements for the provision of an automatic Fire Detection and Alarm System (FDAS) for the facility where such a system is required.

A fire detection and alarm system (FDAS) shall be provided in accordance with the Building Code of Australia (BCA) to suit the building classification. Building types shall include but be limited to the following:

- Administration/office/amenities buildings;
- Chlorination building, blower rooms and chemical dosing buildings;
- Substation and switchroom buildings;
- Standalone pump station buildings and/or switchrooms;
- Other ancillary buildings within treatment plants.

In the case of a treatment plant or similar major facility, the FDAS shall be distributed to a variety of building types/ancillary structures with a main Fire Indicator Panel (FIP) usually located at the main administration building.

The Fire Detection and Alarm System shall comply with the relevant requirements of AS 1670 'Automatic Fire Alarm Installations' and AS 4428.1 'Automatic Fire Detection, Warning, Control and Intercom Systems – Control and Indicating Equipment - Part 1: Fire'.

System Requirements - General

The automatic fire detection and alarm installation shall be carried out in accordance with the Building Code of Australia, AS 1670, and with the requirements of the Fire and Accident Underwriter's Association.

Generally the complete fire alarm system shall incorporate the following:

- Point type smoke and thermal (as applicable) detectors throughout the area in accordance with AS 1670.1;
- Manual call points;
- Alarm signalling and indicating devices;
- Early warning speakers;
- Early warning visual indicators;
- Monitoring of fire protection systems and equipment in accordance with AS2118, AS2419 and AS1841 as applicable;
- Interface to the building security and access control system;
- Interface to the fire alarm and security system monitoring service provider; and
- Interface to associated services switchboard as applicable and in accordance with AS1668.

Fire Detection and Alarm System Components

Fire Indicator Panel(s)

A new fully addressable Fire Indicator Panel (FIP) shall be provided for the facility.

An interface between the FIP and the building access control system shall be provided to release door strikes etc during an alarm situation.

A Certificate of Compliance with Australian Standards shall be supplied for the modified panel.

Detectors – General

Detectors shall be of the addressable type and be fully compatible with the FIP.

An indicating light shall be built into each detector to show that the detector has operated. It shall be orientated for ease of viewing of the indicator light from the normal access area of the room. The indicator light shall also pulse to indicate the device has been polled by the FIP.

If a detector incorporates electrical contacts, these contacts shall operate with a wiping action and shall be adequately protected from dust, insects or other foreign matter that may hinder the operation of the detector.

Detectors having raised an alarm shall reset on return to normal conditions.

Each detector shall be surface-mounted on a round recessed junction box. The detector shall incorporate white circular flush plates to cover the edges of the junction box.

A Certificate of Compliance with Australian Standards shall be supplied.

Smoke Detectors

Smoke detectors shall be an approved photo-optical or ionisation type. In all cases, detectors shall comply with the requirements of AS 1603.2 'Automatic Fire Detection and Alarm Systems Part 2 Point Type Smoke Detectors'. The sensitivity levels shall comply with the requirements of the Insurance Council of Australia.

Every smoke detector shall be permanently marked with its sensitivity level.

Heat Detectors

Heat detectors (if required) shall be of an approved temperature compensating type. In all cases detectors shall comply with the requirements of AS 1603.1 'Automatic Fire Detection and Alarm Systems Part 1 Heat Detectors'. Detector shall be effective in operation both in the case of slow and rapid rates of temperature rise. The temperature limits of operation shall comply with the requirements of the Insurance Council of Australia. Generally, Type A thermal detectors shall be used throughout unless otherwise indicated.

Every thermal detector shall be permanently marked with the maximum temperature to which it can be raised before it operates an alarm when tested with a temperature rise at the rate of 2°C per minute.

Concealed Detectors

Where detectors are mounted in concealed locations (i.e. In duct, ceiling space, lockable switchboard cupboard) a separate indicator lamp with bezel for each detector, shall be mounted in a visible location as near as possible to the detector on the external face of the duct, underside of ceiling or external to the lockable cupboard.

This indicator shall be illuminated when the related detector has operated.

A permanent engraved traffolyte label shall be mounted adjacent to each separate indicator and be clearly worded "Concealed Fire Detector" in minimum 6 mm high read letters on a white background.

Manual Call Points

Fire detection system manual call points shall be coloured red and shall comply with AS 1603.5. Manual call points shall be located at the FIP.

Speakers

Speakers shall be capable of handling a minimum of 5 watts RMS continuous rating at specified frequency range. The frequency response shall be 300 Hz to 20 kHz \pm 6dB. Sound pressure level shall be 91 dB (A)/Watt at 1 m from the speaker. Multitap impedance matching transformer shall be suitable for 70/100V line and shall incorporate integral terminals with maximum insertion loss of 1 dB. Tappings shall be nominal – 6dB to + 6dB.

Speaker tapings shall be set to provide even sound pressure throughout the area.

Visual Indication Devices

Visual alarm devices shall be zenon discharge type. A visual indication device shall be outside above the main entrance to the building containing the amenities room and laboratory.

Installation of Devices

When determining the final positioning detectors, attention shall be given to the effect of air currents that could render the detector either ineffective or prone to false alarms.

Detectors shall not be mounted within 500 mm of light fittings. Detectors shall be installed and located to facilitate access for maintenance.

Spacing of detectors shall be in accordance with AS 1670.1 and the Building Code of Australia.

Wiring – Specific Requirements Detection and Alarm System

All fire alarm wiring shall be segregated from other wiring installations and be distinct from all other wiring systems in accordance with AS 3000.

All fire alarm wiring shall be stranded copper and have a minimum cross-sectional area of 1 mm².

All fire alarm wiring shall have a red outer sheath. Each conductor shall be permanently colour marked throughout its length to ensure easy identification at each termination.

RADOX or FIRETUF type cable shall be used for the dedicated power supplies and fire alarm wiring.

Where it is necessary for the Contractor to install cable tray, this shall be of medium duty galvanised type secured on U channel and drop rods and shall be minimum 2 hour fire rated. The cable tray shall be run in an unobtrusive manner in locations that do not affect the operation of equipment within the station, typically around the perimeter of rooms.

Fire alarm cables shall be routed together in common cable runs wherever possible.

The wiring system shall be in compliance with the relevant sections of AS 1670.

'As Installed' Drawings

The Contractor shall supply two copies of updated 'As Installed' drawings enclosed in a rigid plastic wallet and place the drawings inside the FIP at the completion of the installation and prior to commencement of commissioning tests. This is in addition to the requirement for the general 'As-Installed' drawings.

Fire Brigade Test Instructions shall also be included where applicable.

The drawings shall be durable ink prints and shall contain fully scaled plans of locations and types of detectors, external cabling and all specified fire equipment. The detectors shall be numbered as to their alarm group number as well as a separate number of each detector in the group e.g. 8.09 (ninth detector in alarm group 8).

The Contractor shall provide two copies of an updated maintenance manual with detailed drawings of the Fire Indicator Board and Fire Alarm Panel, fire detector layouts for the complete installation and external pipe locations. The manual shall set out the procedure to be followed for all tests as outlined in AS 1670.

The drawings shall be 'As-Installed' drawings showing final detector locations, final circuit groups, end of line resistors and circuit diagrams of the board, panel and external equipment.

Commissioning

The Contractor shall provide:

- a completed Commissioning Test Report in accordance with Appendix E of AS 1670; and
- a completed Installer's Statement in accordance with Appendix F of AS 1670.

Log Book

A revised hardbound log book shall be included in the FIP prior to the commissioning tests. The book shall contain a minimum of 100 off 150 mm x 100 mm pages.

4.3.5 Security and Access Control System

General

Security/access control systems shall consist of:

- System master controller;
- Access controller module;
- Main automatic gate controller (where applicable)
- Security CCTV system with IP cameras and networked video recorder (where applicable)
- Motion sensors; and
- Numeric keypads.

Functionality

The security/access control system shall provide the following functionality:

- Fully programmable time clock operations;
- Monitor reed switches on external doors and alarm locally if reed switches change state after pre-programmed times;
- Programmable keycode access from the local keypads throughout the building;
- Automatic pre-programmable timer control for afterhours access; and
- The electronic door strikes will unlock after a pre-programmed time.

4.3.6 Building Evacuation Siren System

At Council's plants, administration buildings may require a building evacuation siren system to facilitate the safe and efficient evacuation of personnel from the site should an emergency arise.

The building evacuation siren system shall typically comprise the following components:

- Pull/push switch located internally adjacent to main entry door
- Siren mounted on building roof
- Strobe lights mounted on building fascia
- The system shall operate as follows:
 - Pull front entry switch to activate siren and strobe lights.
 - Push front entry switch to deactivate siren and strobe lights.

The building evacuation system shall be connected to the telemetry system so that such evacuation incidents can be alerted on the telemetry master station.

5 DIESEL GENERATOR

5.1 General

This section describes the requirements for a permanent emergency generator installed in a generator room, in cases where standby power is required to be provided by a diesel generator.

In providing the electrical design for the standby generator, the Contractor must coordinate and liaise with the Principal and other service providers as applicable to:

- consider any access constraints to the site to ensure that the generator can be delivered and installed in the final location; and
- ensure civil and other building requirements for the generator room have been duly considered and included in the building/room design including but not limited to building services, generator exhaust outlets, exhaust lines and drainage.

5.2 Generator Operating Philosophy

The generator shall operate during periods when the mains supply from the Supply Authority is not available.

Upon mains power failure, the automatic transfer switch shall send a start signal to the generator following a pre-programmed delay. The automatic transfer switch shall then open the mains supply circuit breaker and close the generator supply breaker. The mains supply and the generator circuit breakers shall be interlocked so that both circuit breakers cannot be on at the same time. Upon resumption of mains power the automatic transfer switch shall, following a delay, disconnect the generator supply and reinstate the main supply.

5.3 Components

5.3.1 General

Standards

Alternators: To AS 1359 Parts 0, 2, 3, 10, 30, 31, 40, 41, 101, 102.1, 102.2, 107, 109 and 114

Engines: To AS 4594 Parts 0, 1, 5 and 6.

Electrical output

415 V, 3 phase, 4 wire, 50 Hz, star connected with neutral terminal.

5.3.2 Alternators

Voltage Waveform

Sinusoidal, with total wave form deviation not exceeding 10%.

Excitation

Provide permanent magnetic excitation to ensure a reliable source of excitation power for optimum motor starting and short circuit performance.

Overspeed withstand

A speed of 1.2 x unit rated speed for both alternator and engine.

Alternator underspeed withstand

Normal operation at net continuous rated output at a speed of 0.95 x unit rated speed, without overheating.

Sustained short-circuit withstand

At least 2.5 x full load steady state short-circuit current, for at least 5 s.

Number of poles

4.

Cooling method classification

Class IC 01, to AS 1359.106.

Insulation classification

Class 180, to AS 2768

Anti-condensation heaters

General: Provide at least 1 anti-condensation heater within the winding enclosure.

Rating: Rate heaters to maintain the windings and insulation at least 60C above ambient temperature when the alternator is at rest and one heater is in service.

Location: Locate the heater at the end of alternator winding in a position which allows heat transfer to the winding insulation by convection, without exceeding maximum allowable insulation temperature. Do not fix heaters to windings.

Terminations: Connect heater to separate identified terminals within a separate accessories terminal box which is connected to a permanent supply.

Connection diagram: Provide a connection diagram for the heaters. Locate within the terminal box.

Winding thermistors

General: Provide thermistors to alternator stator windings.

Standard: To AS 60947.8.

Thermistor type: Positive temperature coefficient.

Thermistor temperatures:

- Engine shutdown: 160°C.
- Winding temperature high pre-alarm: 140°C.

Terminal boxes

Construction: Provide metal terminal boxes. Size to allow the current transformers, power and control cables and cable lugs to be neatly installed and terminated with necessary clearances between live parts and the box, and without placing undue strain on termination points.

Supply cable terminal box: Provide removable lid and side covers.

Terminals: Provide star connected windings. Bring both ends of each winding out to separate terminals. Establish a neutral terminal.

Sealing: Provide neoprene or bonded cork gaskets between terminal boxes and their frames and covers.

5.3.3 Engines

General

Sizing: When sizing the engine, take into account the nature of connected loads including auxiliaries, harmonics and transient operation

The engine shall incorporate water jacket heaters.

Bearings: Provide front and rear main bearings, so that crankshaft alignment is not affected by dismantling of the alternator.

Governing

General: Provide electronic controlled governors, which enable engine to operate continuously at 1480 r/min from no-load to the maximum rated electrical load connected to the alternator. Provide filters, which ensure that harmonics or switching spikes generated by the load do not interfere with the operation of the governor, overspeed or underspeed cut out devices.

Governing accuracy: Class A1, to AS 4594.4.

Governor adjustments: Provide adjustment settings for

- Speed droop;
- Stability;
- Maximum speed;
- Acceleration rate; and
- Load gain.

5.3.4 Operation

General

Provide automatic and manual modes to start and shut down generating sets in the selected sequence.

Manual sequence control

Provide controls to manually shutdown generating set. Include emergency stop, meters, selector switches, and status indicating lights.

Automatic start control

Provide for the following:

- Upon receipt of a "start" signal, for generating set to start automatically, come on-line and connect to the load; and

- Connection of alternator for sequential control of load sharing/shedding.

Automatic engine shutdown

Provide for generating set to run to suit the load demand until receipt of the mains "restored" signal. At this point the automatic sequenced engine shut-down signal must be activated after an adjustable time delay of (nominally) 0 - 30 min.

Engine shutdown

Provide a shutdown control system which disconnects the alternators, and shuts down engines upon the occurrence of fault conditions such that

Engines cannot be restarted before safety devices have been manually reset and system alarm sensors have returned to the normal state;

The over-speed shutdown acts directly to disconnect the fuel supply independent of the governor; and

The shutdown control system may be reset by the operation of one reset switch, after safety devices have been manually reset.

Emergency and fault shutdown

Provide for the following conditions to register as audible and visible alarms at the generator control panel and to cause the generating set main circuit breaker to open immediately and the generating set to immediately shutdown:

Emergency stop push-button: Pressed.

Generating set: Over voltage.

Generating set protection: Activated.

Generating set: Over current.

Engine: Over-speed.

Engine oil pressure: Low.

Jacket water temperature: High.

5.4 Control Panel

5.4.1 General

Provide control panel complete with graphic user interface (GUI), switchgear and controlgear assemblies, which accommodate equipment operating the generating set at all load steps.

5.4.2 Engine local control board

For the generating set, provide the following:

- Key operated local engine start/stop control at the control panel;
- Controls for auto/off/manual/load test;
- Emergency manual shutdown;

- Digital Multifunction meter with following outputs: Speed, kW, frequency, current, kVAr, power factor, and hours run;
- Indicator showing generating set under local control;
- Oil pressure indicator;
- Coolant temperature indicator;
- Undervoltage protection: Adjustable down to 90% rated voltage with time delay 0-10 s;
- Under frequency protection with two stages.
 - First stage: Adjustable 47-50 Hz with time delay 0-10 s.
 - Second stage: Adjustable down to 40 Hz and with instantaneous trip;
- Automatic voltage regulator consisting of the following:
- Switch to select manual or automatic voltage control.
- Solid-state type automatic voltage regulator;
- Under and overvoltage sensing;
- Power transducers; and
- Over and underspeed sensors.
- Voltage-free contacts for connections to the plant SCADA for monitoring the following status and alarm signals:
 - Fault;
 - Running;
 - Failed to start;
 - Low fuel;
 - Fuel tank leakage;
 - Low oil pressure;
 - Battery volts low; and
 - Battery charger failed

5.4.3 Control Modes

Auto mode

- Generating set to start automatically on sensing power failure at the phase failure relay in the Main Switchboard (MSB).
- After a programmable period of time has elapsed the automatic changeover switches at the MSB shall automatically switch to generator supply.
- On sensing the return of Supply Authority power for a set period of time the automatic changeover switches at the MSB shall switch back to Supply Authority power.
- The Generator shall continue to run in cool-down mode for a programmable period.
- Pressing any Emergency STOP button on the generator assembly will immediately stop the Generating set.

Manual Test mode

Generating set shall be able to be started/stopped from SCADA HMI interface (GUI).

When started in Manual Test Mode the generator will run up to speed before the automatic changeover switches at the MSB automatically switch the live load to generator power.

At completion of manual testing the automatic changeover switches at the MSB will switch back to Supply Authority power.

The generating set will continue to run in cool-down mode for a programmable period prior to shutdown.

Pressing the emergency STOP button will immediately stop the Generating set.

Load Test Mode

Generating set can be Start / Stop from key switch at the Control panel.

Control Panel Software

The generator system control panel shall incorporate all software and hardware necessary for generator system control and shall log all system parameters such as faults, test times, power failures, generator load etc.

5.5 Batteries and Charges

5.5.1 General

Provide separate batteries and charger systems for

- Engine start; and
- Control and alarm functions.

5.5.2 Standards

Engine start batteries

To AS 2149.

Battery chargers

To AS 4044.

Control and alarm batteries

To AS 3731.1, AS 3731.2, AS 4029.2 or AS 4029.3.

5.5.3 Control and alarm batteries

Location

Segregate battery and charger equipment from generator control equipment.

Capacity

Sufficient to supply full generating set control, monitoring and alarm functions for a period of 48 hours, and then operate circuit breaker and all load transfer devices for 10 consecutive open-trip-close cycles with mains supply off and at minimum ambient temperature of 0° Celsius.

5.5.4 Charges – control and alarm batteries

Provide the following local audible and visual alarms together with facilities for extending them via a common alarm output to a remote location:

- Mains off;
- Over voltage;
- Over current;
- Low battery voltage; and

- Insufficient charge rate.

5.6 Starting

5.6.1 Electric Starting

General

Provide starter motors, batteries and chargers, and associated control equipment to automatically start the engine.

Wiring

Wire starter motors so that starter motor solenoid contacts are on the active side and field windings are at earth potential when the motor is de-energised. Provide an interlock, connected directly to the engine, to prevent the starter motor operating when the engine is running.

Starting interlock

Provide a starting lock out system, which prevents further starting attempts after 3 successive unsuccessful attempts.

5.6.2 Starting Batteries

Location

Locate in proprietary battery holders attached to the generating set, or on purpose-built stands enclosed within the generator canopy and constructed corrosion resistant material. Isolate batteries from vibration.

Covers

Provide a high-impact resistant transparent cover for each battery.

Capacity

Sufficient to crank the engine for 3 successive attempted starts repeated at 5-min intervals.

Isolator

Provide a lockable isolator to prevent accidental starting.

5.6.3 Starting batteries charges

Mains power

Connect chargers to the generating set auxiliary supply so that mains power is maintained when the generator system is in operation.

Alarm outputs

Provide the following local audible and visual alarms together with facilities for extending them via a common alarm output to a remote location:

- Mains off;
- Over voltage;
- Over current;
- Low battery voltage; and

- Insufficient charge rate.

5.7 Engine Cooling

Provide a cooling system consisting of radiators, fans and pumps.

5.8 Engine Air Intake

Provide dry type air intake filters of sufficient capacity to permit continuous engine operation for 200 hours before filter servicing becomes necessary.

5.9 Exhaust System

5.9.1 General

Provide exhaust piping from the engine complete with silencers, piping, ductwork, supports and expansion devices.

Exhaust piping

Grade 321 Stainless steel.

Diameter

Match engine exhaust manifold connection.

Connections

Provide flanged connections to silencers and pipe interconnections.

Vibration isolation

Provide a stainless steel flexible connection to the engine.

5.9.2 Installation

The generator exhaust shall be installed through the roof of the generator room. The exhaust outlet shall be located so that it is a minimum of 6m away from any existing mechanical air intakes or operable windows.

5.9.3 Weatherproofing

Provide weatherproof flashing, sleeves and acoustic seals where the exhaust system penetrates the roof or external walls.

5.9.4 Exhaust drainage

Grade the exhaust line away from the engine to drainage pockets, or connect to a suitable drainage outlet.

5.9.5 Lagging

General

Lag internal exhaust piping and ductwork with calcium silicate insulation sheathed with zinc-coated steel sheet.

Lagging thickness

Minimum 55 mm.

5.10 Generator Fuel System

The generating set shall incorporate an integral fuel tank capable of running the set at full load for a minimum of 24 hours.

5.11 Installation

5.11.1 Mounting

Mount the engine and alternator units on a common structural steel frame to support the generating set assembly and the engine local control board.

5.11.2 Plinths

Provide reinforced concrete plinths for floor mounted equipment, sized to suit equipment footprints.

5.11.3 Resilient mounts

Provide at least 6 resilient mounting blocks between the frame and the plinth.

5.11.4 Coupling

Directly couple the engine and generator shafts with a self-aligning type coupling, capable of transmitting the engine maximum output torque under operating conditions, including starting and overload.

5.11.5 Signs

Warning: Provide the following on each side of each generating set:

- "WARNING: This set may start at any time without notice."; and
- Lettering: 50 mm high, red on white background.

5.11.6 Drip trays

General

Provide removable drip trays under those parts of the assembly where fuel or lubricant leakage may occur. Provide overflow outlet pipes taken to a point where a receptacle can be fitted under the pipe outlet.

Capacity

At least 1.5 times the oil capacity of the engine sump.

5.11.7 Emergency stop Push-Buttons

Provide 2 push-buttons located one on each side of the set.

Type

40 mm diameter red, palm operated type mounted in a metal wall box fixed to a free standing "U" channel pedestal. Wire to disconnect the generator and immediately shut down the engine when the controls are in the automatic or manual mode.

5.11.8 Fuel Connections

Fuel piping and associated auxiliary equipment:

To AS 1940.

Stop valves

Provide stop valves on the inlet to, and outlets from, the daily service tank.

5.12 Labelling and Marking

5.12.1 Rating Plates

Temperature-rise limits

If temperature-rise limits are achieved by de-rating an oversized generator, state the de-rated value.

Alternator mass

State alternator mass.

Thermistor detector identification and warning plates

Thermistors: Provide details of thermistor type classification and reference temperature.

Warning: Provide a warning engraved in 4 mm high lettering as follows:

- "WARNING - Do not apply more than 2.5 V across the protection thermistor devices".

Anti-condensation heater identification and warning

Locate next to heater terminals. State the number, voltage and power rating of the heaters, and the following separate warning engraved in red letters on a white background:

- "WARNING - Anti-condensation heater. Circuit is live when the set is off".

Auxiliary wiring

Provide ferrules to wiring ends identifying each conductor.

Engine direction of rotation

General: If driving shafts or associated rotating parts are accessible, clearly and permanently mark the direction of rotation on an adjacent fixed surface.

Rotation identification: Provide a label within the supply cable terminal box identifying the relationship between the direction of rotation and the marking of terminals.

Charger enclosure markings

General: Provide enclosure with:

- Main nameplate engraved in 10 mm high lettering;
- Minor nameplates engraved in 4 mm high lettering to interior and exterior components;
- Manufacturer's rating plates; and
- Markings to AS 4044.

Plate material: Stainless steel.

5.13 Generator Room

5.13.1 Generator Exhaust

The generator exhaust shall be installed through the roof of the generator room as described under "Exhaust System".

5.13.2 Signs

Fit the following signs to maintenance doors:

- "Wear hearing conservation protection", to AS 1319; and
- "WARNING: This machine may start at any time without notice", in red lettering on white background.

5.14 Inspections and Testing

5.14.1 Inspection

Notice

Give sufficient notice so that inspections may be made of the complete generating set and associated systems at the manufacturer's or supplier's factory before delivery to the site.

5.14.2 Pre-Completion Tests

Production Tests

Generating sets: Carry out acceptance tests to AS 4594.0.

Alternators: Carry out performance tests to AS 60034.1.

5.14.3 Completion Tests

Acceptance Tests Generally

General: For the generating set carry out the following:

- Check tightness of connections and securing devices;
- Verify correctness of operation of protection devices and systems including sensor settings. Simulate actual conditions as far as possible, in order to test responses to faults imposed;
- Functional checks to AS 4594.1 Table 7 List C, items C1 to C5 inclusive;
- Cold start with the engine having been at rest for the previous 24 hours, timed from receipt of mains failure signal to acceptance of full rated load in 3 load steps to within the limits of output voltage and frequency;
- Continuous operational trial consisting of:
 - 4 hours at 100% rated power.
 - 1 hour at 110% rated power.
 - 30 min at 75% rated power.
 - 30 min at 50% rated power;
- Record fuel consumption for each step of the continuous trial;
- Sample engine oil from engine sump before and after tests; and
- Continuous operational trial: During the trial, measure the following at maximum intervals of 30 minutes:
 - Generator kW and kVAr output.
 - Generator output voltage.
 - Generator output current.
 - Generator output frequency.
 - Power factor.
 - Oil pressure and water temperature.
 - Electrical power requirements of continuously running electric motor driven ancillaries.

- Each battery charger current and voltage readings.
- Noise level.

Temporary Test Loads

Provide test loads including power and control wiring, ancillary equipment and test instruments to achieve the kW, kVAR and necessary load steps.

Final Tests

Submit reports from manufacturers or suppliers verifying the performance of safety and control functions of each system.

5.15 Warranty Period, Maintenance and Service

The supply of the diesel generator package shall cover warranty, maintenance and services of the generator. Typically, the requirements pertaining to these services shall be as follows:

1. **Warranty:** A minimum warranty period of 24 months from completion.
2. **Service:** Provide three-monthly service for the first 12 months after completion and provide corrective maintenance, rectify faults and replace faulty materials and equipment identified during the service.
3. **Call out:** Respond to call outs for breakdowns or other faults requiring corrective maintenance. Attend on site within 24 hours of notification. Rectify faults and replace faulty materials and equipment.

5.16 Training

The supply of the diesel generator shall include the provision of a customised training package for maintenance staff designed to provide specific knowledge on all system functions and capabilities.

5.17 Dummy Load Bank

Subject to approval by the Principal, a permanent, fan cooled, resistive dummy load may be provided where practical, connected to the generator set control panel and rated for 24 hour continuous operation. The dummy load resistors and fans(s) shall be enclosed in a segregated, ventilated and vermin-proof enclosure rated IP56. The dummy load bank shall ventilate to the outside of the building.

The dummy load bank shall be rated for continuous operation and to provide sufficient load for the diesel engine so that it can operate continuously with only the dummy load without causing damage to the engine.

Resistor banks shall be 415V, 3 phase, delta connected, stainless steel finned, sheathed element type. Interconnect resistors using nickel-plated copper links supported on stand-off insulators. A permanent automatic switching arrangement for connecting and disconnecting the banks of resistors to suit the external load on the generator set shall be installed to maintain sufficient load for continuous operation of the engine. The system shall also provide a minimum load for use during the shut down cycle of the generator set.

Fan(s) shall run on 5 minutes after load disconnection.

5.18 Documentation

5.18.1 Product Data

Submit product data for test, manual and auto modes, including the following:

- Technical description and specifications of the generating set, including output curves for base load and stand-by conditions, alternator and engine data, automatic voltage regulator, synchronising and load sharing modules and auxiliaries;
- Transient and sub-transient reactance of the alternator;
- Voltage regulation grade;
- Generating set efficiency at 50%, 75% and 100% load;
- Measurements for performance of acoustic enclosures and silencers; and
- Evidence that the engine type has previously passed cold starting tests at the minimum ambient site temperature.

5.18.2 Shop drawings

Submit shop drawings indicating the following:

- Maximum mass and overall dimensions of each separable assembly;
- Access clearances for operational maintenance and dismantling;
- Electrical single line diagram, and general arrangement for the complete system;
- Control diagrams;
- Alarms and shutdown annunciator text engraving schedule; and
- Details of foundations and anti-vibration mountings.

6 SWITCHGEAR AND CONTROLGEAR ASSEMBLY (SCA) AND MOTOR CONTROL CENTRES (MCCs)

6.1 Design Criteria

Table 3 Treatment Plant SCAs

Design Element	Description
Construction	Free standing floor mounting front access
Method of connection to incoming supply	Bottom Entry
Method of connection to outgoing submains	Top or Bottom Entry (Outdoor SCA – bottom entry only)
Form of Separation	Form 3b in accordance with the latest revision of AS 3439.1 Annex ZF
Type Test Requirement	PTTA for temperature rise
Compliance with	in accordance with the latest revision of AS 3439.1 and this specification
Ventilation	Natural only
Earthing system	MEN
Limiting Dimensions	Consider any building access limitations for installation of the switchboard.
Degree of protection of switchboard cabinet	IP54 indoor, minimum IP56 outdoor
Supply	400V, 3 phase, 4 wire 50 Hz alternating current
Maximum prospective fault Level	As applicable Peak Factor shall be minimum 2.2
Main Busbar Rating	As applicable
Diversity factor for load circuits:	One
Doors	Dust proof, smoke sealed zinc coated sheet steel, doors must be hinged and allow 135° swing through an arc. Doors shall require tools to be opened (thumb screws are not acceptable).
Door Hinges	Stainless steel pintle pin type hinges
Door Locks	Turnbuckle
Gland Plates	Aluminium - 6mm minimum thickness

Table 4 Pump Station Outdoor Kiosk SCAs

Design Element	Description
Construction	Free standing “kiosk”-type, front access, with appropriate sun-hood
Method of connection to incoming supply	Bottom Entry
Method of connection to outgoing submains	Bottom Entry
Form of Separation	Form 3b in accordance with the latest revision of AS

	3439.1 Annex ZF
Type Test Requirement	PTTA for temperature rise
Compliance with	in accordance with the latest revision of AS 3439.1 and this specification
Ventilation	Natural only
Earthing system	MEN
Limiting Dimensions	Consider any safety, building access, site or environmental limitations for installation of the switchboard.
Degree of protection of switchboard cabinet	IP56 minimum, higher rating may be required subject to specific site and environmental conditions
Supply	400V, 3 phase, 4 wire 50 Hz alternating current
Maximum prospective fault Level	As applicable Peak Factor shall be minimum 2.2
Main Busbar Rating	As applicable
Diversity factor for load circuits:	One
Doors	doors must be hinged and allow 135° swing through an arc. Doors shall require tools to be opened (thumb screws are not acceptable).
Escutcheon (if applicable)	Dust proof, smoke sealed 2.0 mm zinc coated sheet steel
Door Hinges	Stainless steel pintle pin type hinges
Door Locks	Padlockable Swing Handle
Gland Plates	Aluminium - 6mm minimum thickness

6.2 Layout

Equipment shall be positioned to provide safe and easy access for operation and maintenance. Consideration shall be given to the functional relationship between items of equipment in the layout of the assembly.

6.3 Supply Authority's Equipment

The Contractor shall undertake liaison with the Supply Authority with regard to the installation and coordination with their upstream protection and control equipment.

6.4 Earthing

The main earth bar and the earth bar or cable connecting metal parts of the SCA, such as the frames of the air break circuit breakers, fuse switches etc to the main earth bar, shall have a cross sectional area such that when the maximum earth fault current is carried for the specified time, the temperature rise shall not cause any damage.

Earthing of components via mounting fixings is not acceptable.

All metal cases of instruments, relays, selector switches, etc, either mounted on hinged doors or front covers, shall be connected by an unbroken insulated earth wire of minimum size 2.5 mm² to the main earth bar. The earthing connections shall be arranged so that removal of one component shall not affect continuity of the earthing conductor associated with any other component.

6.5 Discrimination

Total and full discrimination shall be achievable between incoming supply main switch(es) and all outgoing circuit breakers on the main switchboard. Trip curves for all breakers, displayed in a manner as to demonstrate that full discrimination has been achieved shall be provided. These trip curves shall be submitted with workshop drawings for acceptance.

6.6 Temperature Rise

The temperature rise limits shall apply for an ambient temperature of 40°C after the switchboard has been operating at full load for a minimum period of 48 hours. The temperature rise limits shall comply with Table 2 - Temperature Rise Limits in accordance with the latest revision of AS/NZS 3439.1 and shall be such that:

1. All equipment operating temperatures shall be according to manufacturers' stated values taking into consideration the temperature in the assembly;
2. The above temperature rise limit shall be applicable to all built in components of the assembly as defined in Table 2 in accordance with the latest revision of AS AS/NZS 3439.1;
3. A temperature rise of 70°C shall apply to all insulated outgoing and incoming terminals for PVC cables with all the external conductors connected, and in service; (i.e. connected and operating at continuous duty full load); and
4. The outgoing cabling includes fire rated cables which can operate at a temperature exceeding the abovementioned 70°C temperature rise for PVC cables. The outgoing functional units busbars with such fire rated cables shall include adequate naturally ventilated copper bus heat sinks (etc) in the cable zone adjacent to the outgoing functional units, to prevent the temperature exceeding a 70°C rise at the point where the busbars of the outgoing functional units penetrate into the cable zone and within the functional units.

No part of any switchboard, or piece of equipment installed in a switchboard, shall reach a temperature which will be detrimental to itself or any part of the switchboard and/or cause it to operate incorrectly due to excessive temperature conditions. For example, this applies to tripping of circuit breakers below their trip setting, operation of electronic/microprocessor based components outside temperature limits stated by the relevant equipment manufacturer, etc.

6.7 Anti-Condensation Heaters

Anti-condensation heaters shall be installed to maintain the internal surface temperature above the dew point temperature.

The selection of the anti-condensation heater shall be determined by the amount of temperature that a switchboard will naturally dissipate when there is a temperature difference between the internal part of the switchboard and the environment.

6.8 Cabinet Construction

The SCA shall be minimum 2 mm thick zinc-coated sheet steel for indoor installations, and minimum 1.6 mm thick grade 316 stainless steel or 2 mm thick marine grade aluminium for outdoor installations, except where specified otherwise, with all joints continuously welded. The following additional construction requirements apply:

1. The cabinet shall include trim, door, lock, hinges, circuit schedule, switchgear and all wiring;

2. The cabinet shall be of the totally enclosed, metal-clad type using folded sections and/or angle iron bracing where necessary for stiffeners and all joints welded with continuous seam welds. Grind all welds flush;
3. Thoroughly rub down after fabrication and coat with etching type, rust-inhibiting primer and then carefully fill and paint as detailed in this Specification;
4. Finished surfaces shall show no weld marks or other imperfections. Rectify any damages to finished surfaces caused in the factory, during transportation and installation;
5. Doors to all sub distribution boards shall be fitted using chrome plated pintle pin type hinges which allow the door to swing through a minimum arc of 135 degrees. Access to the wiring and removal of escutcheon plates shall be made possible without removing doors from the cabinet;
6. Stiffen doors and escutcheon plates in an approved manner to prevent distortion and fit with approved chrome plated handles with locks;
7. Use three point latching bars of appropriate cross sections and provide adequate guides to prevent bars from distortion when latching or unlatching;
8. The escutcheon panels shall be removable and shall have “D” type chromed lifting handles mounted on each side of panel;
9. All escutcheon panels fixing hardware shall be minimum M6 studs chromed acorn (dome) nuts;
10. All escutcheon panels, access panels, doors, etc., shall be provided with returned edges and neoprene or soft rubber sealing strips to give a degree of protection to IP54 for indoor switchboards and minimum IP56 for outdoor switchboards. Foam plastic strips will not be permitted;
11. The sealing strip shall be mounted and glued into a channel section, which has been formed by the return edge and an angle section spot welded to the panel or door, etc;
12. The SCA shall be arranged for front connection of wiring. Provision shall be made for neat fitting dead front escutcheon plates over all circuit breakers and fuses to conceal all wiring;
13. Wiring reticulated to door mounted equipment shall be bunched and looped into the cubicle on the hinged side of the doors with adequate slack to allow the door to swing through a minimum arc of 135 degrees;
14. All ferrous nuts, bolts, washers, etc., used inside the switchboard shall be chrome plated steel;
15. All nuts and fixing screws visible from the outside of the cubicle shall be chrome plated. The only fixing screws visible on the outside of the cubicles shall be those used for securing escutcheon panels and labels;
16. The main switchboard shall be provided with removable undrilled non-magnetic gland plates for cables entry/exit. These cables shall be fitted with cable glands to maintain the IP rating of the switchboard;
17. Doors shall be dust proof, smoke sealed, hinged and latched to switchboard fixed casing;
18. Escutcheons shall be hinged or removable and independent from switchboard door;
19. Care shall be exercised to avoid contact between metals of widely dissimilar electrode potential to minimise possible electrolytic corrosion arising there from. In particular, copper or brass shall not be placed where it can be contacted with aluminium;
20. The main switchboard shall be floor mounted on a full perimeter hot dipped galvanised steel channel base. The minimum dimensions of the channel base shall be 75 mm high, 40 mm wide, and 6 mm thick; and
21. The colours of the switchboards shall comply with AS2700. They shall be:
 - Indoor switchboards: X15 orange;

- Weatherproof switchboards: G54 Mist Green;
- Removable equipment panels (e.g. backing panels, mounting panels): N14 white.

6.9 Type Test Certificates

6.9.1 Switchboard Manufacturer

The switchboard manufacturer shall be the responsible for the issue of type test certificates for the switchboard.

6.9.2 Type Tests Proof of Performance

All switchboards shall be partially type tested assemblies as defined in accordance with the latest revision of AS/NZS 3439.1.

Prior to final switchboard manufacture, the Contractor shall submit a clearly marked up set of drawings of each type of switchboard design, which has been assembled from relevant type tested assemblies and obtain approval from the Principal's Authorised Representative.

Each drawing shall bear cross reference to the relevant Type Test Certificate and Report.

6.10 Switchboard Components

6.10.1 Busbars Size and Ratings

Busbars sizes in relation to ratings shall be in accordance with the latest revision of AS/NZS 3000 assuming the switchboard is of magnetic material, located indoors in a well ventilated room. The sizing of cross section of conductors inside each switchboard shall be the responsibility of the Contractor, who shall guarantee their ratings. Busbars shall be de-rated for the density of conductors and for temperature within the enclosure.

The busbar system shall be capable of withstanding thermal and magnetic stresses imposed by the designated fault level for a duration of one second. Certificates of compliance with the test requirements in accordance with the latest revision of AS/NZS 3439.1 from an independent authority shall be provided by the Contractor.

All busbars shall be rectangular in section with round edges consisting of hard drawn high conductivity copper.

6.10.2 Busbar Supports

Busbar joints and supports shall be made using minimum M10 plated steel precision bolts in accordance with the latest revision of AS 1110.1 with minimum strength grade of 8:8. One plated steel full flat washer on each side of the joint and one plated steel full nut torque tightened to the manufacturer's recommendation.

The busbar and terminals shall be insulated with a flame retardant material. All busbar connection and extension ends shall be pre-drilled for installation of future switchgear and extensions.

6.10.3 Insulation

Busbars shall be encapsulated with heavy duty coloured PVC and marked in their phase colours.

Busbars joints shall be sleeved with heat shrink PVC and marked in their phase colours.

All insulating material shall withstand maximum busbar temperature without any deterioration.

6.10.4 Earthing

- The multiple earthed neutral (MEN) system shall be used and all related requirements in accordance with the latest revision of AS/NZS 3000 shall be observed. An earth cable shall be bonded to every individual item of electrical equipment so that the earthing is electrically continuous;
- The connection of the earth electrical installation earthing system to the general mass earth shall be achieved by means of an earth electrode. The resistance to earth is required to be in accordance with the latest revision of AS/NZS 3000 and MEN must meet the earth fault-loop impedance requirements specified in accordance with the latest revision of AS 3017;
- Earth electrodes materials and dimensions shall be selected to withstand corrosion and have adequate mechanical strength and be installed in accordance with the latest revision of AS/NZS 3000;
- Earth wires shall be enclosed with their respective circuit runs throughout their length;
- All exposed metal in electrical equipment shall be solidly earthed to the incoming main earth conductor in accordance with the latest revision of AS/NZS 3000;
- The frame of each component shall be earthed within the cubicle;
- Earthing of equipment shall be arranged so that the removal of one item of equipment shall not interfere with the earth continuity of other equipment;
- Hinged doors and other movable equipment shall be earthed by a flexible conductor;
- A rectangular copper earth bar rated to handle the determined fault current shall be provided at the bottom of the cabling zone of the switchboard;
- The earth bar shall run the full length of each switchboard and provision for extension of the earth bar shall be made at each end when additional cubicles are added; and
- The metal frames of switchboard cubicles and equipment (e.g. Air break circuit breakers, etc.) shall be effectively bonded to the earth busbar. To achieve a good metal to metal contact, painted surfaces shall be stripped and provide corrosion resistant coating just prior to bolting to the earth busbar.

6.10.5 Neutral Bars

The number of neutral links shall correspond to the total number of circuit breaker (CB) chassis poles and main neutral link. The neutral conductor of each submain or final subcircuit shall be connected into the neutral link that corresponds to the circuit breaker and earth link terminal number.

6.10.6 Earthing Bars

The number of earth links shall correspond to the total number of CB chassis poles and the main neutral link. The earth conductor of each submain or final subcircuit shall be connected into the earth link that corresponds to the circuit breaker and neutral link terminal number.

6.10.7 Terminals

Terminals shall be designed for the connected cables and also be suitable for cables at least two sizes larger. All terminals suitable for up to 70 mm² cable shall be of the same manufacture and type and shall be suitable for mounting on standard 32 mm rail. Terminals shall be manufactured from polyamide.

Terminals for cables above 70 mm² shall be stud connected and screw mounted to the switchboard (They shall not be rail mounted).

Terminal blocks shall be mounted horizontally, not less than 250 mm from the floor. The terminal rail length shall be made long enough to provide capacity for future terminals. Spare terminal rail capacity for each rail shall be minimum 20% or 3 terminal blocks, whichever is the greater.

Control terminals must be suitable for 4 mm² connectors (e.g. SAK4 series).

6.10.8 Switchboard Conductors

- All conductors shall be annealed high conductivity copper conductors, in accordance with the latest revision of AS/NZS 1125.
- PVC and PVC/PVC cables shall be type V-75, manufactured in accordance with AS 1125. Conductors smaller than 2.5 mm² for power circuits or 1.5 mm² for lighting or control circuits shall not be used. Single strand cables shall not be used.
- All conductors throughout the installation shall be coloured for ease of identification in accordance with AS 3191. Colours used shall be red, white and blue for phase wiring, black for neutral, green/yellow for earth wires and grey for control wires.
- Before drawing in the conductors, the enclosures need to be fully erected for inspection and testing. Inert powders of the French chalk type shall be used to assist cable insertion. Twisted, kinked, knotted or crossed over cables shall not be permitted in any enclosure. Allow adequate slack at all terminals, junction boxes and accessories to facilitate servicing.
- Circuits shall be balanced over the three phases.
- Control cables shall be multicore PVC insulated and sheathed 0.6/1 kV underground type with stranded copper conductors having a cross sectional area of not less than 1.5 mm². Each conductor shall be numbered in accordance with the latest revision of AS/NZS 5000.1.
- Instrument signal cables shall be insulated and sheathed electronic instrument type with stranded copper conductors having a cross-sectional area of not less than 0.5 mm². Each pair of conductors shall be twisted to reduce inductively coupled magnetic noise and each cable shall have individually and overall screened pairs to reduce capacity coupled static noise. Sheath colour shall be black. Earthing of the screen shall be at the control panel only and shall be achieved by connecting the screen to the instrument earth busbar.
- All cables throughout the installation shall be correctly segregated in accordance with the requirements for segregation of different voltage levels set out in AS/NZS 3000.

6.10.9 Main Switch

Main switches shall be interlocked with switchboard escutcheon/door to prevent opening in the “ON” position.

Adequate labelling shall be provided to notify any person of the interlock between the escutcheons and main switch.

6.10.10 Meters and Metering Equipment

Meters

All indicating meters cases shall comply with AS 60529 to at least IP54.

Unless otherwise indicated, meters may be quadrant type with 96 square bezel.

Accuracy class for all meters shall be 1.5 unless otherwise specified.

Where indicated, ammeters, and hour meters, shall be provided.

Current Transformers

For both measurement and protection, only CT's of encapsulated design will be acceptable, except for any CT that is an integral part of any unit e.g. thermal overload relay, such CT's may be acceptable pending on a suitable design for the whole unit.

Current transformers shall comply with the latest revision of AS 60044.1. Consideration must be given to the correct choice of ratios, burden and saturation factor.

All secondary windings shall be brought out to a current transformer terminal box and wired to separate terminals.

Current transformers shall be securely clamped to prevent movement under all fault conditions.

The nominal secondary current rating of all measurement current transformers shall be 5 Amps.

Measurement current transformers shall be capable of supplying twice the connected load burden or 10 VA, whichever is greater.

Measurement current transformers supplying panel meters shall have an accuracy class of at least 2.0M.

Provide test links for connection of calibration instruments and meters and for shorting of current transformer secondaries. Current transformer test links shall be rail-mounted and clip on type, featuring built in test and disconnect facilities.

Current transformers must be of the epoxy encapsulated type.

CTs shall be mounted so that they may be removed or replaced with a minimum disturbance to the remainder of the equipment. CT labels shall be easily readable. Label inscription shall be a minimum of 4mm black letters on a white background and shall be located so that labels can be read without removing CT's in accordance with the relevant Australian Standards.

Indicating Instruments

All indicating instruments cases shall be dustproof and comply with AS 60529 to at least IP56.

Indicating instruments and meters shall be adequately protected against normal vibrations encountered in service such that accuracy is not impaired.

Normal operation of the plant shall where possible correspond to a reading of approximately 75% full scale deflection of the instrument.

Indicating instruments shall be flush-mounted on all panels. Black narrow bezels are preferred.

Zero adjustment shall be provided that is readily accessible from the front of the panel.

Analogue Meters

Normal load conditions shall be highlighted on the meter face by a red line.

Accuracy class for all meters shall be 1.0 unless otherwise specified.

Meter scales shall be black on a white background.

Digital Power Monitors

The digital power analyser monitors shall provide the following information locally and shall include facility to be connected via the SCADA system via 4 to 20 mA signal, serial or industrial Ethernet interface, where applicable (the latter being preferred):

- Voltage: phase to phase, phase to neutral;
- Current: three phases and neutral currents;
- Power: active reactive and apparent power;
- Energy: cumulative kWh;
- Frequency; and
- Power factor.

Character height shall not be less than 15 mm and clearly visible from 1000 mm under normal lighting conditions.

Displays shall be suitably scaled such that under normal operation conditions the least significant digit shall be clearly legible.

Users' digital display of indicated measurements shall be in recognised engineering units.

6.10.11 Selector Switches

Selector switches shall be flush mounted with a tear drop type handle.

The switches shall be rotary-cam type.

Ammeter and voltmeter switches shall be provided for the meters in the incoming supply compartment of the SCA.

Switches shall be supplied with a complete escutcheon plate engraved by the manufacturer.

6.10.12 Phase Failure Relay

The phase failure relay shall monitor each phase of the incoming supply for undervoltage and shall provide an open contact output upon any of the phases going outside the preset range. The relay output shall have a programmable delay of between 0.1 and 10 seconds. The relay shall be rated at 415 V, 20 A.

6.10.13 Fuses

High rupturing capacity fuses, in accordance with the latest revision of AS 60269.1, shall be installed where indicated.

Spare fuses shall be provided to 10% of the number of each of the different fuses used in this installation, or four, whichever is the greater, to be located in a supplied spare parts cabinet.

6.10.14 Circuit Breakers

Moulded Case Circuit Breakers

All moulded case circuit breakers shall be designed for horizontal or vertical mounting without any adverse effect on electrical performance. In particular, the breaker shall be suitably de-rated to allow for temperature rise in its switchboard enclosure.

Current ratings shall be rated for enclosed operation and prospective fault level.

The operating mechanism shall be of the quick-make, quick-break, trip-free type and shall provide a positive break indication.

The breakers shall be operated by a toggle which shall clearly indicate the three positions "ON", "OFF" and "TRIPPED".

Each moulded case circuit breaker shall be provided with an integral thermal-magnetic trip unit, unless otherwise specified. Solid state protection units shall be provided where shown on the drawings.

Each solid state protection unit, where required, shall have long and short time protection and time delays adjustable to achieve discrimination with downstream protective devices, including those supplied by others. Details of the protective devices supplied by others shall be determined by the Contractor.

Provide integral protective relays which trip in the event of relay operation and for manually resetting. Provide operation indicators with a set of changeover voltage free alarm contacts, for connection to an alarm circuit.

Miniature moulded case circuit breakers shall be in accordance with the latest revision of AS/NZS 3111.

Large frame moulded case circuit breakers shall be in accordance with the latest revision of AS 60947.2 and AS 2184.

Two and three phase circuit breakers shall be of the multipole type with a common tripping device.

All circuit breakers must be continuous current.

6.10.15 Residual Current Devices (RCD)

Residual current operated circuit breakers shall be in accordance with the latest revision of AS/NZS 61009.1 - 'Residual current operated circuit-breakers with integral overcurrent protection for household or similar uses (RCBOs) – General Rules'. The following general requirements apply:

Integral overcurrent type: Incorporate earth leakage in circuit breaker protection operation;

Residual current classification: Type II; and

Maximum tripping current: 30 mA.

6.10.16 Contactors

Control contactors shall be of the electromagnetically operated air break type.

Contactors shall be in accordance with the latest revision of AS 60947.4.1 - Low-voltage switchgear and controlgear - Contactors and motor-starters - Electromechanical contactors and motor-starters.

Unless otherwise indicated, the following features shall also be incorporated as a minimum:

Mechanical life: 10 million operations;

Contact life: 1 million operations at AC 3 rating;

Three phase contactors: 415 V, at AC 3 rating;

One N/O spare auxiliary contact and one N/C spare auxiliary contact;

Terminal markings to EN 50 012;

Coil: Pick up and hold in characteristic down to at least 80% rated minimum voltage;

Contactors up to 15kW rating must be DIN rail mounted; and

Contactors must be of the moulded block type construction and rated at 150% greater than the full Load.

6.10.17 Indicator Lights

All indicator lights shall be LED type.

Standard

Indicator lights shall be in accordance with the latest revision of AS 60947.5.1 - Low-voltage switchgear and controlgear - Control circuit devices and switching elements - Electromechanical control circuit devices.

Degree of protection

LED Indicator lights shall have an ingress protection rating of IP54.

LED indicators Technical Requirements

The following technical specifications apply:

- Power Supply shall be 12 or 24 V as necessary;
- Housed in corrosion-resistant bezel;
- Nominal 5 mm diameter;
- Press-to-test;
- Compartments/subsections with < 5 indicating lights: Provide each indicating light with a fitted integral press-to-test lamp actuator; and
- Compartments/subsections with > 5 indicating lights: Provide a common press-to-test lamp push-button.

Colours of Indicator Lights

- | | |
|-----------------------------|--------|
| • Stopped (or valve closed) | Grey |
| • Running (or valve open) | Green |
| • Fault | Red |
| • Unavailable | Yellow |

6.10.18 Pushbuttons

Push Buttons shall be of the oil tight type with minimum rated operational current of 4 A, 240 V AC. Size classification shall be uniformly D30 or D22.

Each pushbutton shall be provided with a legend plate indicating its function. All reset buttons are to be on the same panel as the control switches.

6.10.19 Emergency Stop Pushbuttons

In the case of latched 'STOP' or 'EMERGENCY STOP' push buttons, instructions for releasing the latch shall be included either on the legend plate or on the face of the button.

Push buttons and emergency stop buttons where located outdoors, shall be contained within a corrosion proof metal housing having an IP56 classification to AS 60529.

6.10.20 Automatic Transfer Switch

The automatic transfer switch arrangement shall comprise air circuit breakers on the mains and generator supplies, and a microprocessor based controller.

The ATS controller shall be complete with auxiliaries control plate.

The ATS shall monitor all phases of the mains power and activate the diesel generator when the mains voltage or frequency reaches an unacceptable level.

Automatic controls shall signal the generator set to start upon a signal from the normal source sensors. A time delay before load transfer from normal to emergency source, adjustable from 0 to 120 seconds shall be provided.

Controls shall signal the generator set to stop after a time delay upon return of the normal source. A time delay before load transfer from emergency to normal source, adjustable from 0 to 30 minutes shall be provided.

Power for the transfer shall be from the source to which the load is being transferred.

A set of terminals shall be provided to allow connection to the plant SCADA system to monitor which supply is selected (e.g. mains or back-up generator).

6.11 Infra-Red Scanning

During the commissioning stage of the project all busbars, switchgear, connections and any other equipment within each switchboard shall be checked with an infra-red scanner and the temperatures recorded. All temperatures shall be recorded in degrees Celsius on an appropriate diagram of the switchboard.

The Principal will require infra-red scanning to be carried out 6 and 11 months after works completion.

Any defects shall be submitted to the Principal's Authorised Representative in an evaluation report outlining the procedure of rectification.

All scanning shall be carried out in the presence of and under the supervision of the Principal's Authorised Representative.

Any sections of the switchboard that produce abnormal temperature readings shall be disassembled, checked, reassembled and then tested by the Contractor at no variation in price.

6.12 Switchboard Labelling

6.12.1 General

Indoor switchboard labels shall be engraved Traffolyte type and shall be screw fixed to switchboard escutcheon. Switchboard labelling shall include as a minimum the following information:

- Switchboard unique identifier (number);
- Configuration and size of the switchboard's supply mains or sub-mains;
- Supply switchboard or substation identification number;
- Supply circuit breaker or fuse identifier and capacity/protection settings;
- Fault level of switchboard in kA;
- IP Rating;
- Form of separation;
- Year of Manufacture;
- Manufacturer; and
- Model (Serial No.)

All labels shall be minimum 4 mm black letters on a white background and be in accordance with the latest revision of AS/NZS 3000. In addition, the labelling of terminals shall be visible from the front of the switchboard with wiring installed.

6.12.2 Manufacture Name/ Designation

The new switchboard Identification number (plant number) and switchboard naming protocol shall be obtained from the Principal's Authorised Representative prior to fabrication.

6.12.3 Pole Numbering

Each circuit breaker pole space shall be numbered from top left to bottom left consecutively on each side of chassis, down vertically, commencing from number one. Each side of the chassis shall not be alternately numbered.

6.12.4 Duplication

No two circuits on any switchboard shall carry the same numerical identifier.

Prefixes to denote power or light circuits shall not be used.

6.12.5 Schedules

Circuit schedules shall be produced in MS Excel® format and an electronic copy shall be submitted to the Principal's Authorised Representative. Handwritten amendments of the schedules are not allowed.

Circuit schedules shall be laminated and placed in an A4 sized holder fixed to the switchboard panel.

6.13 Transient Protection System

6.13.1 General

Lightning and surge protection equipment shall be installed at the main switchboard and at other locations as determined by the specific design. Such equipment shall provide protection against surges and transients induced in power and control circuits by lightning or electrical switching or transients.

The Surge Diverters shall provide protection against transients caused by lightning, power network switching, standby generator switching, capacitor switching and load switching.

The surge diverters shall protect low voltage switchgear and control equipment.

The surge diverter shall be connected between each Main Switchboard active/neutral busbar and the MEN earth link.

The units shall utilise Metal Oxide Varistors individually fused or protected by an appropriately rated circuit breaker and shall incorporate a voltage free normally closed contact, providing an individual phase segment failure alarm to the external monitoring system. The surge diverter unit shall also have a local digital display, visible without removal of escutcheon indicating a percentage activation per phase and an integral alarm to indicate required maintenance.

6.13.2 Approval

Data sheets for the proposed Surge Diverters shall be submitted for approval prior to installation.

6.13.3 Surge Diverter Performance

- Lines protected 3 phases to earth at MEN point
- Operating voltage 230 V, 50 Hz
- Maximum line voltage 275 V, 50 Hz
- Protection modes Transverse and common mode
- Impulse rating:
 - Single pulse 200 kA
 - 5 pulses 40 kA
 - 10 pulses 25 kA
- Residual voltage level:
 - Category C, 10 kA 8/20 microseconds < 1000 V
 - Category D, 70 kA 8/20 microseconds < 1500 V
- MOV failure indication Individual LED
- MOV failure alarm Changeover contacts, 24 V DC, 1 A

6.14 Motor starter circuits

Motor starter circuits shall be to typical industry standards, and shall interface with the plant PLC/RTU system via the following typical signals:

- Thermal overload (digital input);
- Running (digital input);
- Available (digital input);
- Fault (digital input);
- Run request (digital output);
- Softstarter fault (digital input) – for softstarters only;
- Drive fault (digital input) – for VSDs only;
- Speed (analogue input) – for VSDs only; and
- Speed setpoint (analogue output) – for VSDs only.

Fault signals shall be wired for fail safe operation.

The final design of motor starter circuits shall be confirmed in consultation with the Principal.

7 POWER FACTOR CORRECTION

7.1 General

Power factor correction equipment (if required) including all capacitor banks and controllers shall to be installed in a separate enclosure to the SCA.

Cabling between the SCA and the power factor correction unit shall be installed in accordance with AS 3000.

7.2 System Requirements

The power factor correction equipment shall meet the following parameters:

Rated Voltage	400 V
Maximum Voltage	520 V
Rated Frequency	50 Hz
Rated short circuit current	As applicable
Capacitor bank rating	As applicable
Capacitor steps	As applicable, typically at 50k VAr, 25K VAr, 12.5 kVAr

The power factor correction system shall be designed to correct the power factor of the plant in accordance with Supply Authority requirements, that is, better than 0.95 lagging and not more than 1.

7.3 Configuration

The power factor correction equipment shall generally be comprised of modular capacitor steps complete with protection and switching devices.

7.4 Capacitors

The capacitor units shall consist of three single phase units connected in delta to form a three phase capacitor. The three phase capacitors shall have the following characteristics:

Table 5 Three Phase Capacitors Characteristics

Item	Description
Double insulation	Capacitors shall be double insulated and have no earthing requirements
Self-extinguishing polyurethane resin casting	Non-corrosive and suitable for indoor installation
Capacitor coils coated under vacuum	Internal electric protection for each coil with overpressure disconnecting device
Terminals	Brass and non-overlapping terminals
Monobloc	Connections between terminals shall be welded and coated with resin
Self-healing metallised polypropylene film	To maintain capacitor coil operation in case of dielectric breakdown
Dry type (no oil)	No oil to minimise risk of leakage or fire
Discharge resistors	Rated to reduce capacitor voltage to less than 50 volts within one minute of disconnection



The capacitor units shall comply with the requirements of AS 1013 Shunt Capacitors for Connection to Power Frequency Systems.

The capacitor units shall be fitted with suitably rated discharge resistors. These discharge resistors shall be capable of reducing the capacitor terminal voltage below 50V within one minute of disconnection.

Capacitors shall be type-tested with type test certificates provided.

The capacitors shall be designed and installed to continuously withstand 130% of the nominal capacitor current in accordance with AS 3000.

7.5 Harmonic Performance

The power factor correction equipment shall be suitable for use on the existing power supply system for all operating conditions and shall comply with the relevant part of the AS 61000.3.x suite of standards.

Reactors or equivalent equipment shall be provided where required to protect the power factor correction equipment from harmonic currents which may arise on the existing power supply system under all possible operating conditions.

7.6 Harmonic Reactors

Harmonic reactors shall be 7% of the capacitors impedance so as to avoid or minimise resonance under all operating conditions. The rating of the reactors shall not be less than 1.25 times the rated capacitor current and shall be designed to carry 1.5 times the rated capacitor current without saturating.

Reactors shall be air cooled with copper conductors and class F insulation. Reactors shall be rigidly constructed and mounted in an approved manner to minimise noise.

7.7 Controller

The capacitor switching system shall provide automatic and manual control of the switching of the individual capacitor units so as to maintain the required power factor.

The power factor controller shall be microprocessor based and shall have the following features:

- Automatic self-adjustment to any capacitor step value;
- Digital indication of power factor;
- No-volt release to automatically disconnect all capacitors in the event of power failure;
- TTL interface;
- Plug in terminal connection;
- Indication of number of switching operations per step;
- Indication of capacitor size;
- Visual display of target power factor alarm; and
- Visual display of harmonic overload alarm.

8 VARIABLE SPEED DRIVES

8.1 Standards

IEC 61000	Electromagnetic compatibility (EMC)
AS 60529	Degrees of Protection Provided by Enclosures (IP Code)
AS 60947.4.2	Low-voltage switchgear and control gear: Contactors and motor starters - AC semiconductor motor controllers and starters

8.2 Design

8.2.1 General

Variable speed drives shall be selected to match the pump motor operation, and have a continuous maximum rating of not less than the full output rating of the connected motor while operating under ambient conditions

The variable frequency controller shall be of the variable voltage variable frequency converter fed type suitable for operating a standard squirrel-cage induction motor direct coupled to the driven equipment.

The controller shall be a fully microprocessor based solid state electronic type unit with all set-up and operating parameters entered/displayed via an integral keypad and digital display console.

8.2.2 Enclosure

Each controller and associated equipment shall be housed in a switchgear and controlgear assembly constructed to the applicable requirements of Section 6. For indoor applications, VSDs weighing over 11 kilograms are not to be housed in a separate SCA assembly. Where VSDs weighing less than 11 kilograms can be mounted in a separate SCA assembly without hampering maintenance, the SCA assembly may be installed on the wall or floor-mounted to suit.

The maximum size of any VVVF enclosure penetration shall be designed to limit RFI radiation.

Ventilation of the enclosure shall be provided to ensure components do not overheat. Switchroom ambient conditions shall be taken into consideration in selecting the VSD with respect to cooling features of the VSD. A high quality, replaceable air filter element shall be fitted to the enclosure air intake. If a cooling fan is required, a quiet running centrifugal type shall be used.

8.2.3 Performance

Power Factor

Not less than 0.95 at all speeds and loads.

Motor Noise

The design and operation of the controller is to be such that internal switching frequency of the controller does not result in the output of additional audible noise beyond that which is experienced in a 50 Hz fixed speed application. The PWM carrier frequency shall be adjustable in order to minimise available motor noise. Adjustment in the range 2 to 14 kHz is required.

If necessary, harmonic filtering equipment shall be included.

Radio Frequency Interference

Controllers shall not cause interference external to the controller that would exceed the limits set down in AS CISPR 11. The controllers shall include integral RFI filters to meet these requirements.

Provide test certificates demonstrating compliance with these requirements.

Speed Control

The controller shall allow the associated motor speed to be continuously varied over a speed ratio of at least 25:1. Operation over this range must be stable and regulation within $\pm 2\%$ not withstanding variations in temperature, supply voltage or other external or internal variables. Acceleration and deceleration is to be adjustable to at least 0 to 50 seconds to ensure smooth ramping of speed and avoid tripping of protection circuits.

Efficiency

The total VSD efficiency including converter, inverter, harmonic filter, capacitors and auxiliaries shall be a minimum of 96% at full load and full speed.

Diagnostics

The controller shall have a full suite of diagnostic software tools to facilitate commissioning and fault finding.

8.3 Operation

The controller design shall incorporate an integral line contactor to start and stop the drive power circuits. When the drive is started it shall uniformly ramp the motor speed to the setting of the speed control device/signal. The rate of acceleration shall be an adjustable parameter.

8.4 Harmonic Distortion

In general, the maximum AC harmonic distortion, including voltage notching caused by the controller shall not exceed the limits set down in AS 61000.3.6, however, the design of variable speed drives must be coordinated with the assessment of harmonic emissions for the power system of the whole site.

Electromagnetic interference emitted by the equipment shall be within the limits specified in AS 61800.3.

If filters are used, the filters shall be integral to the VSD and designed to prevent any harmonic resonance in the operating speed range.

8.5 Controls

Control equipment and indications shall be provided to allow for remote and local control of the controllers/connected equipment.

24 V DC shall be used for the control voltage and separate from the power circuit supply.

The following control equipment and indications are to be provided for speed control of the controller:

- Auto/Off/Manual control selection;
- Manual speed control potentiometer or adjustment (keypad entry, etc.);

- Digital speed indicator to show motor speed from 0 to 100%; and
- Auto speed control input from an external 4 to 20 mA DC signal when auto control is selected.

Where integral control 'status' contacts are used in externally supplied circuits, the fault capacity shall be higher than that of the circuit protection device in that circuit or provide additional protection if necessary within the VVVF controller.

8.6 Protection

Protection features shall, as a minimum, include:

- Motor overload;
- Over-temperature protection;
- Instantaneous overcurrent and overvoltage trip;
- Instantaneous earth fault;
- Undervoltage and loss of power;
- Input and output loss of phase;
- Thermistor protection; and
- Motor stall protection.

Protection equipment shall be arranged to trip the controller when operated and to prevent restarting of the controller until manually reset. Where reset push-buttons external to the VSD control panel are warranted in the design, they shall be mounted on the front of the enclosure.

Each type of fault shall be individually indicated on the front of the enclosure containing the controller and associated equipment. Fault indications shall remain active after the controller has been stopped and or tripped due to the fault condition.

8.7 Motor Cabling

All cabling between VVVF controller and the motor shall be installed in screened type power cable to the manufacturer's recommendations. Steel wire armoured cable is not acceptable. The VSD system shall be designed such that the motor insulation system is not compromised thermally due to dV/dt stresses.

8.8 Testing

Perform on-site testing once all controllers are installed and operating to verify compliance with harmonic distortion and radio frequency interference requirements specified. Test certification shall be provided to demonstrate stated VSD efficiencies.

9 SOFT STARTERS

Where soft starters are required to limit the motor current at starting whilst providing sufficient torque for smooth acceleration, they shall incorporate the following features:

- separate current limit and voltage ramp adjustment;
- microprocessor based;
- six solid state switches, one pair per phase;
- breakaway torque adjustment;
- extended stop time;
- transient protection;
- ramp time adjustment;
- radio frequency interference suppression unit;
- LED diagnostic indication and status panel for mounting on the motor starter doors;
- system protection, such as overload , short circuit and motor stall protection; and
- bypass contactor.

10 CABLES

10.1 General

All conductors shall be annealed high conductivity copper in accordance with AS 1125.

Power and control conductors shall not be incorporated in the same cable unless specified or approved.

Single strand conductors shall not be used. The minimum conductor sizes shall be:

Internal Control Cubicle Wiring	1.5 mm ²
Instrumentation Cabling (including ELV PLC I/O Cabling)	0.5 mm ²
Control Cabling	1.5 mm ²
Power Cabling (230 VAC)	2.5 mm ²
Power Cabling (24 VDC)	1.5 mm ²
Lighting Cabling	1.5 mm ²

Power cables shall be sized according to the following considerations:

1. Current rating in accordance with AS 3008.1.
2. Short circuit rating in accordance with AS 3008.1.
3. Motor supply cables shall produce a maximum voltage drop of 20% on starting at the motor terminals.
4. Feeder cables shall give a maximum voltage drop of 5% at the busbars when the largest load or motor is started with all other loads running.
5. Steady state voltage drop shall not exceed 5% under any circumstances.

Instrumentation cabling shall be designed to ensure that adequate voltage is present at the instrument/equipment terminations to allow correct operation and within the tolerances of the instrument/equipment as specified by the manufacturer.

10.2 Size and Rating of equipment

All mains, submains, and final sub-circuit cables shall be sized according to the loads of selected equipment. Circuit breaker ratings and settings shall ensure all cables are protected under fault conditions.

10.3 Wire Identification

Cable cores shall be numbered and coloured as follows:

WIRE IDENTIFICATION CODE

Function	Colour
400 V AC	Red, White and Blue
230 V AC (Controlled from within	Active - Red



WIRE IDENTIFICATION CODE

Function	Colour
panel)	Neutral - Black
230 V AC (Not controlled from within panel)	Active - Orange Neutral - Black
ELV AC	Active - Brown/Red stripe Neutral - Brown/White stripe
DC, all voltages	(+) ve - Blue/Red stripe (-) ve - Blue/White stripe
Earths	Green/Yellow stripe
Telemetry/SCADA	Violet
Field instrument cabling	White/Black twisted pairs

10.4 PVC Insulated Cables

Cables shall be PVC insulated to V75 specification.

All cables, excepting panel wiring, shall be double insulated.

Control cables shall have white core insulation bearing black core numbers and a green with yellow stripe insulated earth.

Twisted pair instrumentation cables shall be screened with each pair numbered.

10.5 Cross Linked Polyethylene Cables (XLPE)

XLPE cables for voltages up to 0.6/1 kV shall comply with AS 5000.

10.6 Instrumentation and Control Cables

Instrumentation and control cables shall be multicore PVC insulated and sheathed 0.6/1 kV underground type with stranded copper conductors having a cross sectional area of no less than 1.5 mm². Each conductor shall be numbered at intervals not exceeding 100 m. Numbering shall be in accordance with wiring diagrams at each terminal.

Instrument signal cables shall be insulated and sheathed electronic instrument type (such as Dekoron®) with stranded copper conductors having a cross sectional area of not less than 0.5 mm². Each pair of conductors shall be twisted to reduce inductively coupled magnetic noise and each cable shall have individually and overall screened pairs to reduce capacity coupled static noise. Sheath colour shall be black. Earthing of the screen shall be at the control panel only and shall be achieved by connection to the instrument earth busbar.

10.7 Cables for Hazardous Areas

Cables for explosive atmosphere applications (“Exd”) shall be suitably rated and steel wire armoured.

10.8 Optical Fibre Cables

Where optical fibre cabling is required, it shall satisfy the following requirements as a minimum:

- Optical fibre cabling shall be installed in a minimum 50mm diameter conduit.
- Optical fibre shall be multi-core as determined by the specific design, single mode, non-armoured, loose tube type suitable for underground installations and routing. Data sheets in respect of optical fibre shall be submitted to the Principal’s Authorised Person for approval.
- Ethernet-fibre media converters shall be fully compatible with the optical fibre supplied.
- For optical fibre cables terminated into a fibre optic break out tray, a minimum of 15m of cable shall be stored/coiled in the nearest adjacent pit. A minimum of 3m of cable for splicing shall be provided.
- Optical fibres cables shall be continuous and have no breaks/terminations other than at the beginning and end of the run where the fibre terminates to a fibre optic break out tray at the respective enclosures. Splicing/joining of optical fibre cabling/cores along a route is prohibited.
- Care shall be taken during installation of optical fibre. The cable shall not be subjected to high pulling tensions or stresses. Any equipment used to pull cables shall be fitted with tension monitor and an automatic shutdown device calibrated to operate when the pre-set maximum pulling tension, as identified in the cable manufacturer’s data sheets, is reached.
- Cables shall not be bent beyond the maximum bending radii as detailed in the manufacturer’s cable data sheets.
- All installation works shall be coordinated with adjacent works to ensure cables are installed without damage or are not affected in any way by adjacent works activity.
- All optical fibre cabling and installations shall be tested in accordance with AS/NZS ISO/IEC14763.3:2012 Telecommunications installations – Implementation and operation of customer premises cabling Part 3: Testing of optical fibre cabling (ISO/IEC 14763.3:2011 MOD).
- The Contractor shall submit to the Principal’s Authorised Person detailed testing documentation outlining tests performed and results obtained.

11 UNINTERRUPTIBLE POWER SUPPLY (UPS)

11.1 General

UPS shall be a three phase input and output, 400 volts, 4 wire, true on-line uninterruptible power system rated as applicable to the specific requirements of the installation. The UPS shall convert its AC input into filtered DC voltage to charge the system battery and supply power to the inverter section. The inverter shall produce regulated and filtered AC power which, under normal operation, supplies the critical load via an electronic bypass switch.

The UPS shall be designed to operate with sealed lead acid maintenance free batteries.

In addition, the system shall contain a static bypass switch to connect the critical load to an alternate power source in the event of a UPS internal failure and in the case of overloads or short circuits. This bypass shall be rated for continuous duty at 150% of rating and 200% for 1 minute.

The UPS shall have the ability to be placed into a “master-slave” configuration on site without disruption to the critical load.

The UPS shall comply with the current version of the AS 62040 series of standards.

11.2 Component Ratings

The system shall be designed in such a way that all electronic components operate at no more than 80% of their absolute ratings. All other electrical components shall be appropriately rated as per the standards and industry best practice.

11.3 System Components

11.3.1 General

The proposed equipment shall contain the following basic components and subassemblies:

- Input circuit breaker or fuse switch, with an appropriate rating;
- Digital control of rectifier/charger of sufficient rating to support the operation of the inverter at full load and recharge the battery in the specified time;
- IGBT technology and instantaneous control of the inverter;
- Digital control of static transfer switch; and
- Maintenance bypass switch gear which can supply power to the critical load while isolating internal UPS components from the input power and the load.

11.3.2 Rectifier/Battery Charger

The rectifier shall be 6 or 12 pulse design configuration and be digitally controlled. Rectifiers shall be protected by a circuit breaker.

11.3.3 Automatic Charge Control

The rectifier/charger shall be optionally capable of automatically providing discharge time dependent boost charge over an adjustable period suitable for lead acid and NiCd batteries. Current limiting shall be provided. The rectifier shall be capable of reduced current limiting for operation with a standby engine generator.

11.3.4 Inverter and Output Transformer/Filter

The inverter section shall be a pulse width modulated design. The power semiconductors in the inverters shall be silicon, bi-polar transistors or Insulated Gate Bipolar Transistors (IGBT). Inverters shall be fuse protected and incorporate transistor desaturation protection.

The output frequency shall remain synchronised to the input frequency, over an adjustable time during load and line transients.

The inverter logic shall provide current limit protection for the inverter. The protection shall be sufficient to allow a direct short to be applied to the output without damage to any components within the inverter.

11.3.5 Battery

The UPS shall operate with a battery bank made up of maintenance-free; sealed lead acid battery. Batteries can be internal or housed in a steel cabinet of similar dimensions to the UPS.

Adequate ventilation shall be provided such that any gases that could potentially be released from failing batteries do not reach toxic/dangerous levels. Ventilation requirements shall comply with the relevant clauses of AS 62040.1.1.

The design of batteries shall be a minimum of 5 years.

11.3.6 Static Transfer Switch

The static transfer switch shall be an electronic switch employing 6 silicon-controlled rectifiers (SCRs) to connect the bypass source to the load, under conditions of inverter overload or failure. The static switch shall be digitally controlled. On removal of overloads the switch shall reconnect the load to the inverter output automatically. Manual reconnect may be selected if required.

11.4 Performance

The following describes the minimum electrical performance of an on-line reverse transfer UPS system:

Table 6 UPS Characteristics

Characteristics	
Voltage Tolerance	400 VAC 3 Phase ± 10%
Frequency Tolerance	50 Hz ± 5%
Power Factor	Greater than 0.8 at full load & input voltage.
Walk In	2 seconds programmable from 0 - 100% load.
Current Inrush	The input current shall not exceed 125% of full load output current.
Protection	Fuses and/or circuit breakers
Rectifier/Charger	
Type	6 or 12 pulse phase Controlled S.C.R.
Input Tolerance	400 VAC 3 Phase ± 10%
Rated Input Power with Charged Battery	As applicable
Input Power Factor	Greater than 0.80 lag
Rated Output Voltage	250 VDC
Float Voltage Adjustment	± 15%

Voltage Ripple	1% RMS
Battery Specifications:	
Battery backup time	As applicable to the specific requirements of the project
Protection	Low voltage automatic inverter
Inverter Data:	
Inverter Type	Transistorised or Insulated Gate Bipolar Transistor (IGBT), pulse width modulated, and transformer isolated
Output Current - Full Load @ 0.8pf	As applicable
Efficiency -	Greater than 92%
Load Power Factor	At nominal load 0.7 lead - 0.8 lag At reduced load 0.5 lead to 0.5 lag
Voltage Regulation	Static balanced load $\pm 1\%$ Static 100% unbalanced $\pm 1\%$ load Dynamic 50% load step $\pm 4\%$ Dynamic 100% load step $\pm 5\%$
Voltage Transient Recovery Time (to $\pm 2\%$)	Less than 50 ms.
Short Circuit Current	150%
Nominal Frequency	50Hz
Overload Capacity	Inverter: 125% 10 minutes 150 % 1 minutes Static Bypass: 2000% 20 ms 200% 1 minutes 150% continually

11.5 Cabinets

All UPS equipment supplied under this specification shall be housed in cabinets and enclosures to IP20 degree of protection for installation indoors. The enclosure shall have doors or removable panels which allow free access to all components for service and replacement. Doors shall be equipped with a special access key. Cabinets which house forced air cooled components shall be designed to permit air to enter at floor level and exit at the top rear. Bottom entry shall be provided for AC Input, AC output and battery power cables.

11.6 Materials

Any metal parts which are subject to corrosion shall be plated, painted or otherwise treated to prevent corrosion and other effects of ageing. All materials used in the equipment shall meet the requirements for flammability and dielectric properties as set forth in the applicable Australian and International Standards.

11.7 Component Marking

All components shall be clearly and permanently marked with appropriate part number or reference designators so that there will be no confusion as to proper identification during operation or service.

11.8 Access and Serviceability

All sections of the supplied equipment shall be designed and constructed to allow for easy access and service for all components. Once installed, minimum access to the sides and rear of the equipment shall only be required to perform routine service. The equipment shall be constructed in a modular manner which allows for quick replacement of components and assemblies. Diagnostic alarms and LED's shall provide for rapid diagnosis and repairs by suitably trained service personnel.

11.9 Cooling

Forced air cooling shall be employed. In the event of fan failure, the UPS shall continue to function normally. An over temperature warning shall be provided. Should temperature continue to rise, an over temperature shut down circuit shall shut off the UPS and the load shall transfer to the bypass source if available.

11.10 Labelling and Indications

The UPS shall have a mimic diagram, in a block diagram form, with integrated LED's which allow a quick check of the UPS status.

As a minimum requirement the LED's shall indicate:

- Mains present;
- Rectifier status;
- Battery switch status;
- Battery discharging;
- Static bypass status;
- Maintenance bypass switch status;
- Inverter status;
- Load fed by inverter status;
- Load fed by static bypass;
- Load is supplied;
- Battery test;
- Emergency power off status;
- Static switch;
- Battery indicator;
- Load percentage; and
- Common alarm.

11.11 Alarms

The following alarm conditions shall be communicated externally by means of voltage free relay contacts.

- AC Mains OK;
- Load fed by AC Mains; and
- Load fed by Inverter.

12 FIELD EQUIPMENT AND INSTRUMENTS

12.1 Local Control Stations

The term local control station (LCS) in this section shall be taken to include all associated works including mounts/foundations, base, stands, sunhoods, equipment and enclosures installed outdoors. The LCS may be a minor distribution board for distribution of power to a small number of local equipment, in which case such an application will be of Form 1 construction in accordance with AS3439.1

LCS shall be constructed of 2 mm marine grade aluminium or 1.6 mm grade 316 stainless steel with sunhood and supported on a marine grade aluminium channel post and base with cover plates. The LCS equipment enclosure shall be sufficiently deep for at least two contact blocks to be used or have available a replaceable lid which will enable the use of two contact blocks per operator. Terminal strips shall be provided for all cabling other than motor sub-circuits. A safety strap shall be installed to support open front cover if not supported by hinges.

LCS shall not be used for the looping or marshalling of cables.

A sample LCS (equipment enclosure only) shall be submitted for approval to the Principal's Authorised Representative prior to mass fabrication. This sample shall be of the type to be provided under this Contract and include typical equipment, terminals, ferrules, internal wiring and glanded external wiring with cable protection.

12.2 Junction Boxes

Junction boxes shall be used for the marshalling and looping of all field cabling and shall be constructed of 2 mm marine grade aluminium or 1.6 mm grade 316 stainless steel, as applicable to the particular environment in which the junction boxes will be installed. Junctions shall be effected through terminal strips within the junction box. The terminal strips shall be provided with 25% spare terminals in addition to that provided for initial requirements.

Separate junction boxes shall be provided for each different drive or equipment system.

12.3 Instrument Enclosures

All instrument units, terminals, power supplies etc, shall be mounted in Grade 316 stainless steel enclosures to a minimum protection rating of IP 66 (AS 60739).

Enclosures shall be tapped at the base to accept cable entry via cable glands.

For instruments and instrumentation enclosures mounted outdoors, provide additional protection from rain and sun by installing rain hoods and sun shields constructed from minimum 1.6 mm fully welded stainless steel. Mounting of instrumentation is to be such that the orientation is to be "south-facing" unless otherwise approved.

Provide hot dip galvanised steel mounting posts for instruments as required and constructed of 150 mm x 75 mm x 8 mm steel channels or approved equivalent. A reinforced concrete 1m² hardstand area shall be provided in front of the instrument enclosure.

12.4 Instrumentation

12.4.1 Environment

Instrumentation shall operate reliably over an ambient temperature range of -5°C to 50°C and between 5% to 95% relative humidity (non-condensing).

12.4.2 Instrumentation Generally

Instrument accuracy shall be to within $\pm 0.5\%$ of span. For primary instruments accuracy is the comparison between the analogue output signal and the actual measured variable. For secondary instruments, accuracy is the comparison between the analog input signal and the output signal (display, trace, etc).

Microprocessor based instrumentation is preferred over analogue electronics type.

Range shall be as required and generally selected such that the normal working maximum to be measured is approximately 80% of the range unless otherwise approved. Scales for indicators and outputs shall be as required.

Indication shall be directly in SI engineering units. Graduation shall be sufficient to allow reading to the accuracy of the measurement of the indicated variable. Multiplying factors, except those used in unit designations such as millimetre, are not acceptable. Instruments to be provided with indicators are to be mounted with the readout mounted at a location accessible by the operator without the need to use access ladders or open access covers. If necessary, additional indicators are to be provided to meet this requirement if the instrument is mounted in a location not accessible to the operator.

Instruments shall be suitable for continuous unattended operation. Instruments shall maintain rated accuracy with a minimum of maintenance or need for calibration and adjustment. Span/zero adjustment shall be by entry of parameters into microprocessor electronics via a keypad or similar.

Analog signal outputs shall be live zero, isolated 4 to 20 mA DC suitable for input to a load of at least 600 ohms at 24 V DC. The signal shall be linear with respect to measured variable. Digital (on/off) signal outputs shall be volt free changeover contacts rated for at least 1 A at 240 V AC.

Instruments shall where possible be of the "two wire" type deriving electrical power from the loop 24 VDC supply.

Instruments shall be unaffected by electromagnetic fields of a strength up to 10 volts per metre over a frequency range of 10 kHz to 1000 MHz. In any case, the operation of a 10 watt hand held radio within a distance of one metre is to have no effect on the operation of the instrumentation or any signal from the instrumentation for the entire route of any connected cabling.

Instruments shall not generate a level of electromagnetic interference that exceeds the limits defined in AS/NZS CISPR 11.

Sensors shall be provided with sufficient cable length for final mounting positions.

12.4.3 Materials Generally

Materials used shall be suitable for use in the required environment (e.g. a raw sewage environment) and resistant against corrosion and UV light.

12.4.4 Instrument Pipework

All instrument pipework and valves shall be stainless steel.

12.4.5 Calibration

All instrumentation shall be correctly calibrated for the intended application. A calibration certificate shall be provided for each instrument including all test results to demonstrate satisfactory measurement of the variable over the required range to the accuracy specified.

12.4.6 Instrument Tags

All primary measuring elements, transmitters and signal converters shall be tagged in accordance with an approved numbering system.

Instrument tags shall be stamped aluminium or stainless steel disks secured to the instrument via a stainless steel cable tie.

12.4.7 Mounting

Mount all primary elements, transmitters and signal converters that do not mount directly in or on pipework or tapings in the instrument cubicle. Final location, arrangement and mounting of all instrumentation and associated equipment shall be to the Principal's approval.

All equipment shall be mounted in accordance with the manufacturer's recommendations.

12.4.8 Analogue and Switched Control Signals

Where instruments interface with analogue 'field' instruments as either inputs or outputs the analogue transmission signal level shall be 4 20 mA live zero DC current. The analogue signal level within the SCA may be any standard live (+ or -) zero DC voltage or current to suit the instruments offered. Outputs shall be capable of accommodating a range of load impedance consistent with reasonable flexibility of instrumentation at the receiving end.

Any switched instrumentation control signals to or from field devices shall employ clean voltage free contacts.

Maximum attention will be given to the termination of signal wire screens and earthing wires to and from field mounted devices to avoid multiple ground loops

12.4.9 Instrument Relays

Relays used in the control cubicles for instrumentation circuits shall be miniature hermetically sealed plug in types with coils continuously rated at the nominated instrumentation circuit voltage. Coil operating currents shall not exceed 200 milliamperes. Contacts providing inputs to the RTU equipment shall reliably switch 24 V to 5 mA.

Silicon semiconductor diodes of adequate voltage and current rating shall be connected across these relay coils to prevent damage to transistor or integrated circuit output stages.

12.4.10 Wiring

Wiring within instrument cubicles shall be neatly arranged and wherever practicable groups of wire shall be contained in capped plastic ducting. Elsewhere groups of wire shall be strapped together with nylon, or other strong plastic ties or spiral binding to form neat wire bundles. The use of adhesive tape to contain or secure wire groups will not be accepted. Electrical wiring methods shall be in accordance with the requirements of AS 3000.

All instrument wiring shall be colour coded to standard colours.

12.4.11 Lightning and Surge Protection

Lightning and surge protection units shall be provided for field mounted analogue instruments.

12.4.12 Power Supply Units

Supply voltage

The power supply shall be suitable for connection to a 230 V +/- 10%, 50 Hz +/- 2% single phase supply.

Standards compliance

The power supplies shall comply with relevant standards for electromagnetic emissions, immunity and electrical safety.

Isolation

The power supply shall be fed from a 230/24 V isolation transformer with interwinding earth screen.

Rating

The power supply rating shall be a minimum of 125% of the connected load.

Ripple Voltage

The maximum ripple voltage at the output shall not exceed 20 mV p/p.

Overload protection

The power supply shall be fully protected against overloads. The design shall incorporate linear fold back limiting, thermal protection and short circuit protection. The power supply shall be capable of withstanding an indefinite overload or an indefinite output short circuit. Removal of the overload or short circuit shall result in the immediate correct functioning of the power supply.

Output overvoltage protection

The unit shall incorporate overvoltage protection to disconnect the power supply from the load if the power supply output voltage exceeds 26 V. This function shall be self-resetting.

Power Supply Fail Relay

Incorporate a dry changeover relay contact to indicate that the power supply voltage is within acceptable limits. If the output is over 26 V the relay shall de-energize. The relay shall not re-energize until the power supply falls below 25 V. If the power supply voltage falls below 22 V the relay shall de-energize. The relay shall not re-energize until the power supply exceeds 23 V.

LED Indication

The unit shall have separate LED's to indicate 'Power Supply OK', 'Supply Low' and 'Supply High'.

Discharge capacitor

Provide a discharge capacitor in the output circuit, to trip the 24 V distribution circuit breaker on a faulty circuit.

Terminals

The power supply shall have separate terminals for connection of the load and relay contacts including an extra negative output terminal for earthing such that only one wire need be placed in each terminal. All terminals shall incorporate wire protection clamps and accommodate up to 2.5 mm² cable.

Surge protection

Surge reduction filters shall be provided as necessary to protect all instrument power supplies against input over-voltage and mains borne sags, surges and impulses originating from lightning, switching operations or other causes. Common and normal mode noise rejection, and isolation characteristics of the supplies shall be adequate to allow for reliable operation. Voltage and frequency regulation shall be provided as necessary. Surge reduction filters shall be placed at both ends of the instrument power cable.

The surge reduction filter shall be rated at 250 VAC, 40 kA on a single shot 8/20 μ s impulse and shall be capable of continuous supply of 10 A. The maximum let-through voltage of the device shall be 500 V. A surge diversion failure indicator shall be provided which shall be clearly visible on the switchboard front panel without the need to open doors.

12.4.13 Electromagnetic Flowmeters

General

Electromagnetic flowmeters shall be of the self-zeroing pulsed DC field design with remotely mounted signal converters. Flowmeters shall be suitable for use in empty pipes without the need to de-activate the flowmeter. The Principal prefers that all magnetic flow meters be of the same brand and manufacturer.

Meter tube

Meter tubes shall be of short form pattern with an internal abrasion. Corrosion resistant neoprene lining suitable for wastewater service shall also be provided for wastewater applications. All external surfaces shall be protected against corrosion through either the use of suitable materials of construction or through the use of a suitable corrosion resistant surface finish.

Meter tube flange drillings shall be to AS4087, Class 16. The flowmeter shall be rated to suit the required test and working pressures.

Enclosure of electrical components and devices attached to the metering tube shall be rated IP 68 (submersible to 5 meters and suitable for buried service). Cable entries shall be via suitable cable glands consistent with enclosure class.

An earth ring constructed of 316 SS shall be provided, including associated connections, earthing straps and gaskets as necessary.

Electrodes shall be manufactured from 316 Stainless Steel and be suitable for submerged operation. Electrodes shall be removable and arranged to minimise both corrosion and coating.

Signal converter

The signal derived from the meter tube shall be converted to an isolated 4-20 mA DC output current linear with flow via a signal converter.

The converter shall be microprocessor based and have an integral LCD backlit display of two (2) lines. The upper line on the display shall show the instantaneous flowrate and the second line shall display a re-settable totaliser.

The instantaneous flowrate indicator shall have selectable engineering units.

The converter shall have a passive scale pulse output with an adjustable pulse rate and pulse width.

The converter shall have configurable maximum and/or minimum process flow alarm contacts.

The configuration of the converter shall be achieved through access keys on the front panel and be menu driven. The menu system shall be self-explanatory so that no programming knowledge is required to configure the converter.

Totaliser values and configuration must be maintained in the event of power failure.

Surge protection for the 230 V 50 Hz supply, 4-20 mA signal and pulse outputs shall be supplied and be housed in the one enclosure and must be compatible with the flow converter. The flow converter and surge protection unit must be located together.

Connection

Meter tubes shall be sized dimensionally as close as possible to the pipe size whilst maintaining velocity ranges that will provide accuracy in operation for the meter tube and signal converter.

If the meter tubes are slightly smaller in dimension than the pipe ID, then protection flanges shall be fitted to the inlet side of the flow meter to protect the liner edge from erosion.

Meter tubes shall have interconnection and power cables terminated in the terminal box before delivery to site.

Testing

The complete flowmeter comprising meter tube, signal converter and connecting cable shall be tested in a flow test rig to verify that calibration is correct and within overall accuracy tolerance. Calibration of the analog output is to be checked at 0%, 10%, 50%, 75% and 100% of span.

Calibration testing shall be performed at a suitably equipped NATA certified hydraulic laboratory and a certificate provided.

12.4.14 Turbidity Transmitter

Turbidity sensors shall be true nephelometric instruments based on the scattering of a beam of light by particulate matters in the liquid sample. Both scattered and transmitted light is to be measured allowing compensation for lamp output variation. The lamp shall be operated below rated voltage to prolong life, and supplied by a regulated source to minimise effects of power supply variations.

Sampling flow shall be arranged to allow calibration without interruption to the flow. A "de-bubbling" device shall be provided to effectively remove air bubbles prior to the turbidimeter.

An integral turbidity indicator shall be included. Measurement ranges shall be switch selectable.

A permanent turbidity reference standard shall be provided to assist in calibration. A "dry" type standard is preferred over chemical preparation type standards.

The transmitter shall have a 4-20 mA output. The 4-20 mA output for the system shall be wired to the auto control PLC analogue input card.

12.4.15 pH Transmitter

pH systems shall have the following features:

- Jet cleaning systems using compressed air (where available) to clean the pH sensors;
- 4-20 mA output for pH. The 4-20 mA output for the system shall be wired to the plant PLC; and
- Relay outputs wired to the plant PLC.

Provide two spare electrodes for each sensor.

It shall be part of the scope of the instrument supply to have the instrument supplier representative on site to set up, test and commission the pH systems during the site testing period.

12.4.16 ORP Monitoring System

ORP systems shall have the following features:

- Jet cleaning systems using compressed air to clean the ORP sensors;
- 4-20 mA output for ORP. The 4-20 mA output for the system shall be wired to the plant PLC; and
- Relay inputs and outputs wired to the plant PLC.

Provide two spare electrodes for each sensor.

It shall be part of the scope of the instrument supply to have a Royce representative on site to set up, test and commission the ORP systems during the site testing period.

12.4.17 Dissolved Oxygen Analyser

Dissolved Oxygen analysers shall have the following features:

- Incorporate a self-cleaning head system; and
- Have a 4-20 mA output. The 4-20 mA output for the system shall be wired to the auto control PLC analogue input card.

Provide two spare electrodes for each sensor.

12.4.18 Residual Chlorine Analyser

Residual Chlorine analysers shall have a 4-20 mA output. The 4-20 mA output for the system shall be wired to the plant PLC.

12.4.19 Flow Measurement

Rotameter (Variable Area Flowmeter)

Each rotameter shall be of the tapered tube and float type, of straight through construction, with flanged or threaded end connections as required.

The flowmeters shall have tempered glass tubes, stainless steel end fittings and stainless steel floats. The flow meters shall incorporate a metering tube that can be removed and cleaned without removing the meter body from the line.

The flow meters shall be selected to suit the range for each individual application and shall be accurate to $\pm 2\%$ of full scale over a minimum turndown ratio of 10:1. The flow meters shall be fitted with a direct reading scale, nominally 250 mm long and scaled in litres/second as appropriate for the flow ranges of each application.

Where switching is required, a magnetically activated switch arrangement providing a voltage free contact shall be provided for 2 wire connection.

Rotameter (Purgemeter)

The flowmeters required for monitoring purge air flow shall include an integral inlet needle valve to allow adjustment of the flow of air.

Each rotameter shall be of the tapered tube and float type, of straight through construction with screwed end connections.

All materials shall be suitable for the application.

The flowmeters shall be selected to suit the range for each individual application and shall be accurate to $\pm 2\%$ of full scale over a minimum turndown rates of 10:1. The flow meter shall be fitted with a direct reading scale, nominally 70 mm long and scaled in litre/second or as appropriate for the flow ranges of each application.

Open Channel Flow Meter (Ultrasonic Level Sensing Type)

Ultrasonic open channel flow instruments shall have the specifications similar to the ultrasonic level instruments. Ultrasonic flow instruments shall provide the following features:

- Separate LCD digital displays with 4 digits of flow in L/s and totalised flow in kL;
- Microprocessor based;
- Capable of providing a 4-20 mA analogue output proportional to flow;
- Provided with a pulsed contact for volume set at 1 pulse/kL;
- Provided with a fault safe relay, a sampling relay, at least 2 output relays and LED status;
- $\pm 0.2\%$ maximum linearity error at 25°C; and

It shall be part of the scope of the instrument supply to obtain the flume HQ curve and calibrate the flow meter to suit.

Orifice Plate / Differential Pressure Transmitter Mass Flowmeter

The differential pressure transmitter shall be loop powered and shall provide a 4-20 mA output signal proportional to the calculated flow rate.

The static pressure range and maximum working pressure of the pressure transmitter shall be as specified or as otherwise suitable for the application. Positive over-range protection shall be provided.

The transmitter shall include independently adjustable zero and span adjustment and adjustable internal signal damping. A digital display shall be included at the transmitter.

The differential pressure transmitter shall be supplied with a three valve manifold.

12.4.20 Level Measurement

Level Transmitters (Ultrasonic Type)

Provision shall be made at the transmitter for independently adjustable span and zero adjustment and adjustable internal damping. The transmitter shall incorporate a digital indicator. Accuracy shall not be less than $\pm 0.25\%$ of maximum range or 6mm, whichever is the greater.

Level Transmitters (Hydrostatic Type)

Level transmitters shall be of the capacitance sensing type for continuous measurement of the water level within tanks, storages or pump wells. The capacitance change shall be directly proportional to the depth of wastewater/reclaimed water above the capacitance sensor probe. Probe cabling shall incorporate a breather tube.

The probe assembly is to terminate within the supplier proprietary termination box and provide for transmission of signal to an opto-isolator and capacitance level indicator.

The 4-20 mA output signal shall be displayed as percentage full on a panel mounted level indicator and then wired to the plant PLC.

Each sensor shall to be installed in a PVC stilling tube.

Level Sensing Relays and Probes

Level sensing relays and probes shall have differential action with sensors operating at extra low voltage AC. Sensor shall be either stainless steel rods or cable supported single or multipoint sensors. Sensor mounting brackets shall be 316 stainless steel and where cable supported sensors are used the cable shall be clamped between two plates in position. The sensing relay shall have adjustable sensitivity with a latched output between top and bottom sensors.

Minimum contact rating shall be 5 Ampere 240 V AC-11.

Level Switches (Float Type I)

Each level switch shall be of the encapsulated immersible switch type for water and wastewater applications. Each shall be supplied complete with a sufficient length of heavy duty flexible cable to provide a generous allowance for adjustment of the operating level.

All wetted materials shall be inherently non corrosive material and entirely suitable for the application.

Level Switches (Float Type II)

Each level switch shall be of the float-activated bulkhead mounting type.

Float, stem and other wetted materials shall be constructed from inherently non corrosive material and entirely suitable for the application.

Each level switch shall be provided with a voltage free, changeover contact.

Level Switches (Float Type III)

Each level switch shall be of the encapsulated, immersible mechanical switch type. Each shall be supplied complete with a sufficient length of heavy duty flexible cable to provide a generous allowance for adjustment of the operating level.

All wetted materials shall be inherently non corrosive material and entirely suitable for the application.

Level Switches (Paddle Type)

Level switches for sensing level of non-liquid bulk materials shall be of the motor driven rotating paddle type. The detection of material is achieved by a rotating paddle with the control signal changing when material impedes rotation of the paddle.

Shafts and paddles shall be constructed from materials which are corrosion resistant to the material being sensed.

The number and size of paddle vanes shall be selected as appropriate for the density of materials sensed.

The paddle switch sensing unit shall include controls to ensure that when material impedes the rotation of the paddle that all moving parts are stationary and no wear takes place.

Each paddle switch shall satisfy enclosure class IP65 or better and shall be provided with a voltage free, changeover contact output.

12.4.21 Temperature Measurement

RTDs

Unless otherwise specified resistance thermometers shall be utilised for temperature measurement.

Each resistance thermometer shall include a 3-wire platinum resistance temperature detector complying with IEC 60751 ($R_0 = 100 \Omega$). The sensing element shall be sealed in a ceramic former and enclosed in a stainless steel sheath. Sensing currents of up to 10 mA shall not have a significant effect on accuracy.

Each thermometer shall include a suitable connector head, with enclosure class equivalent to IP65 allowing cable entry via a compression type cable gland.

Thermowells shall be provided for installation of the resistance thermometers. Thermowell material shall be 316 stainless steel. Inside diameter of the thermowells shall be sized to match the thermometer so as to permit easy removal whilst providing close contact for maximum heat transfer and fast accurate temperature measurement.

Installation of the resistance thermometers, including wiring to the associated resistance to current converter, shall comply with BS 1041 Part 3. A "3 wire" circuit shall be used between each thermometer and the associated converter. The converter shall be located in the thermometer connector head.

Resistance to current converters shall be of the "two wire" type deriving electrical power from the loop 24 VDC supply. Converters shall include continuously variable span and zero. The output shall be a 4-20 mA DC signal linear with respect to temperature.

Accuracy shall be $\pm 0.5\%$ of span or better.

Thermocouples

Where specified or as otherwise required for the temperature range, thermocouple type sensors shall be utilised for temperature measurement.

Each thermocouple shall include a Type J or Type K, to suit temperature range, single element, ungrounded temperature detector. The sensing element shall be sealed in a ceramic former and enclosed in a stainless steel sheath.

Each thermometer shall include a suitable connector head, with enclosure class equivalent to IP65 allowing cable entry via a compression type cable gland.

Thermowells shall be provided for installation of the thermocouples. Thermowell material shall be 316 stainless steel. Inside diameter of the thermowell shall be sized to match the thermocouple so as to permit ready removal whilst providing close contact for maximum heat transfer and fast accurate temperature measurement.

Thermocouples and signal converters shall be interconnected with wire that will maintain the specified accuracy of the temperature measurement. The converter shall be located in the thermocouple connector head.

Signal converters shall be of the "two wire" type deriving electrical power from the loop 24 VDC power supply. The output shall be a 4-20 mA DC signal linear with respect to temperature. Converters shall include continuously variable span and zero.

The converter shall include automation reference junction compensation and thermocouple burnout protection.

Accuracy shall be $\pm 0.5\%$ of span or better.

12.4.22 Pressure Measurement

Pressure Transmitters

Each electronic pressure transmitter shall use a differential pressure cell arrangement. The pressure transmitter shall be loop powered and shall provide a 4-20mA output signal proportional to the measured differential pressure.

The range and maximum working pressure of the pressure transmitter shall be as specified or as otherwise suitable for the application. Positive over-range protection shall be provided.

The transmitter shall include independently adjustable zero and span adjustment and adjustable internal signal damping.

Process connections shall be subject to detailed design. However, typical valve manifold arrangements shall be as follows:

Two valve manifolds shall be supplied with each gauge pressure transmitter;

Three valve manifolds shall be supplied with each differential pressure transmitter.

Diaphragm seals shall be considered in installations where the instrument comes into contact with process water that could foul, block, damage or corrode the instrument.

Pressure Switches

Pressure switches shall be a force balance spring activated adjustable differential action type fitted with a switching single pole changeover contact rated 5 Amp, 240 Volt, AC-11.

Minimum Switching Differential: 5% of span

Indoor Enclosure Protection Rating: IP 56

Outdoor Enclosure Protection Rating: IP 66

Rating: 10 A, AC11

Sensing Element: Stainless Steel

The adjustable set point range shall be such that the noted setpoint falls between 30 and 70% of the adjustable range. The switch shall be of the automatic reset type.

Pressure Gauges (Bourdon)

All pressure gauges unless otherwise specified shall be of the Bourdon type, and shall be fitted with a gauge isolating cock.

Pressure gauges shall have a concentric dial of 80 mm diameter unless otherwise specified and shall be calibrated in kPa with a range as specified. Where specified, or as required, pressure gauges shall be oil-filled and fitted with isolating diaphragm to ensure the process material does not foul the gauge.

Snubbers shall be fitted to pressure gauges subject to pulsations.

Where pipework is subject to mechanical vibration, pressure gauges shall be mounted adjacent to the pipework and connected to the pipework tapping via pipework.

Where specified or as otherwise required where gauges are subject to a process medium of high temperature that would affect operation, a siphon shall be provided to isolate the medium from direct contact with the gauge.

Pressure gauges shall be accurate to $\pm 1\%$ of full scale.

12.4.23 Flow Switches

Flow switches shall be non-indicating, snap-acting type with internal adjustable range setting and differential adjustment. They shall have a degree of protection of IP56 with screwed conduit entry.

Electrical switch shall comprise a single pole changeover contact rated 5 amp, 240 V, AC-2.

13 INSTALLATION

13.1 Reticulation

13.1.1 Setting out of runs

General

Cables shall be carefully installed to ensure that insulation is not damaged nor is likely to be damaged in service. Cables shall either be contained in conduit or cable ducting or alternatively secured to perforated cable tray. Power cables and signal cables shall not be run in the same conduit or duct or on the same cable tray. Such separation shall also apply to ducting and conduits on desks and on walls. Cables shall be run as one continuous length with no joints unless otherwise approved.

Minimum Requirements

The following are minimum guidelines when setting out cable runs:

- All cables and conduits must be installed neatly;
- Cables and conduits shall be installed parallel to walls, doors, building members and installed square wherever possible;
- Chasing of walls, floors and ceilings shall only be done with approval;
- Conduits in chases shall be firmly fixed and concealed, with adequate cover to prevent cracking and provision for expansion and movement by approved methods;
- Conduits shall be located within or behind cavities, skirting, fixtures or bulkheads in preference to chasing;
- Cables and conduits in roof spaces must be installed in consideration of being co-located with roof insulation and sarking and de-rated as necessary;
- Cable runs under computer floors shall be installed on hot-dipped galvanised cable trays; and
- Cables must always be installed such that they can be disconnected and replaced.

13.1.2 Underground reticulation

Trenching - General

Trenching refers to all works associated with providing trenches for underground reticulation including excavation, backfilling, reinstatement as well as ancillary works such as drainage, shoring, bracing and other necessary temporary works during construction of the trenches.

All trenches, unless otherwise directed by the Principal, shall be excavated in ground to an even surface.

The line of the trench must be kept perfectly straight and parallel to the planned alignment. The bottom must be kept level across the trench and the sides as near the vertical as is practicable. Any cavities in the bottom of the trench must be filled with selected sand, properly compacted to the proper grade.

Shoring shall be erected as necessary to effectively prevent the sides of the trench from running or falling into the excavation and to keep trenches free from water during all cable laying operations.

Where trenches are to be excavated across roads, the road pavement material shall be kept separate from other excavated material to allow for same being easily replaced after backfilling. If this is not achieved, provide the same consolidated depth of pavement material of the same quality as previously existed, compacted to the same density as surrounding material.

Provide all precautions necessary for the protection from injury of all existing drain pipes, electric and telephone conduits and other existing works and services wherever met with, or which are adjacent to the work, and to avoid damaging such drains, conduits or service connections or any fittings attached thereto.

Maintenance of Trenches Before Cabling Laying

Trenches shall be kept clean and maintained in good order and condition between the time of excavation and laying prior to cable laying. This maintenance includes all measures to divert any water interfering with the progress of the works, keeping the trenches and excavations free from water while the works are in progress, and preventing any injury to the works by water due to floods or other causes.

Proper and approved pumping equipment shall be used for keeping the trenches and excavations free from water while the works are in progress.

Trench construction

After the excavation has been completed and approved, the trench shall be cleared of all sharp objects and a foundation layer of bedding sand shall be placed. Prior to backfilling, draw wires shall be re-installed in the ducts and the ends sealed with a non-setting mastic compound. Any caps or draw wires in spare ducts, which may have been disturbed, shall be reinstated.

Backfilling of the trench shall only commence after witnessing and approval of the trench installation by the Principal.

Backfilling

A layer of sand shall be laid over the cables with a minimum cover of 100 mm. The minimum depth of sand including bedding shall be 100 mm.

General backfill may comprise the excavated soil or imported soil or sand provided that any material in the soil will pass through a 50 mm screen or subject to the Principal's approval.

Backfilling is required to refill the full width of trench above the level specified for sand surround, back to natural surface level. Marker tape shall be incorporated during backfilling. In addition, cable protection slabs shall be used where required.

The compaction of the backfilling shall be to a density not less than the density of the existing adjacent material and to the entire satisfaction of the Principal's Authorised Representative. Backfilling shall be carefully placed in layers not exceeding 150 mm well watered if necessary, then tamped and compacted with mechanical rammers.

In existing paved areas the surface shall be reinstated to the original level and finish to the satisfaction of the Principal's Authorised Representative.

Excess spoil from the trench excavation not required for backfill in the trench shall be removed from site.

Cable Protection and Marker Tape

Mechanical protection shall be installed over direct buried cables for their entire route as required by AS 3000.

Mechanic protection shall be of approved proprietary manufacture consisting of either:

- Polymeric cable protection covers manufactured from orange coloured material. Painting of the covers is not acceptable; and
- Precast bricks or precast concrete. Concrete covers cast on site or in situ are not acceptable.

Orange Polyethylene marker tapes of 150 mm width shall be laid in the trench directly over all underground cables at a depth of 150 mm. The tape shall be marked with the warning:

"CAUTION - ELECTRICITY"

or similar, in black letters which shall not fade.

Cable Markers

Underground cable route concrete markers shall be installed above all underground cable joints, at every change of direction of underground cable and on straight runs at least every 30 metres.

Markers shall consist of a concrete block 400 mm square 100 mm deep with an engraved brass label attached. The marker shall identify the cable and indicate its direction of lay as indicated on the drawings. Labels shall be fixed to the concrete block with screw fixings (not rawl plugs) and epoxy adhesive.

Markers in unpaved areas shall be installed with 20 mm projecting above the surface. Markers in paved areas shall be flush with the surface.

Inspection of Trenches

All trenches shall be left ready for inspection by the Principal's Authorised Representative at the following stages of the work:

After laying the conduits, but before any backfilling or laying of marker tape; and

After laying marker tape.

13.1.3 Pits and Conduits

Pits

Construction: Pits, lids and the method of installation shall be suitable for the trafficable class duty anticipated in the area in which they are installed. Pits in roads shall be provided with "gatic" type covers suitable for the trafficable duty. Pits over 1000 mm in height shall be provided with iron step-ladders for safe access.

Marking: Lids to electrical pits shall be marked 'Electrical'. Lids for communications pits shall be marked 'Communications'.

Size: The cable pits shall be:

- Adequately sized accommodate the number of conduit entries.
- Allow the installation of cables without infringing on the minimum bending radius of cables, either during installation or when complete. In particular the minimum length of cable pits shall not be less than 4 times the minimum bending radius of the largest cable.

- Of minimum dimensions 600 L x 600 W x 900 D, if not conflicting with the preceding criteria or indicated otherwise

Installation: Conduit entries into pits shall have bell mouthed ends. Pits in paved surfaces shall be installed at grade with the surrounding surface. Pits outside paved surfaces shall be installed 30mm above the surrounding surface and the surrounding ground graded up to the pit for a distance of 1 metre.

Drainage: Cable pits shall be drained with a 100 mm drain fitted with a non-return valve to a stormwater pit or where not practicable to a rubble soakage pit. The last pit prior to entry into the switchroom shall be built lower than the switchroom floor and drained to prevent water ingress into the switchroom via the pit and conduit system.

Conduits

General: All conduit types shall be selected to comply with the requirements of AS3000 and the Wiring System (WS) classification system of AS3013. All PVC conduits installed underground shall be installed in a similar manner as that outlined for a Category B system AS 3000. No wires shall be installed until all conduits are in place.

No conduit less than 20 mm shall be installed for any part of the installation.

All conduits shall have a minimum spare space capacity of 25% for future additions except where otherwise specified. A minimum of 25% spare conduits shall be provided for runs between external pits and between external pits and switch panels/switchrooms.

Installation: Conduits shall be installed in such a manner to allow easy draw-in and replacement of cables; draw-in boxes shall be used where necessary to enable draw in of long runs of cables and shall not exceed spacing of 20 m. A draw wire shall be installed in each conduit. The draw wire shall be tagged as such. A 1.5 mm² zinc plated or galvanised steel draw wire shall be provided in all empty conduits. Material used to lubricate cables whilst drawing in to conduit shall be dry, non-conductive, non-abrasive and non-hygroscopic.

Wherever inaccessible or concealed conduits change direction, the conduit shall be set with as large a radius as practicable. Field bends shall have a minimum bending radius of six times the enclosure diameter. Kinked or squashed enclosures are not acceptable.

Single conduit runs shall have their ends bushed via nylon bushings wherever cables exit onto neighbouring cable trays or to enclosures.

All screw or fastenings used for fixing conduit saddles shall be plated or galvanised.

During installation, the ends of conduits shall be temporarily plugged to prevent the ingress of dirt.

All runs to floor mounted equipment shall be laid in the floor slabs. Where overhead connections are approved, drops shall be neatly and adequately supported.

Conduit types: Conduits shall be of the type indicated in the following areas:

Table 7 Conduit Types

Method of Installation	Type
Buried in situ concrete	Rigid PVC
Buried in precast concrete	Screwed steel
Exposed to weather	Clipsal HFT or approved equivalent
Surface run in plant rooms etc	Galvanised screwed steel
Subject to mechanical damage	Galvanised screwed steel
Chased into rendered brickwork	Rigid PVC
Underground	Heavy duty UPVC

Rigid PVC Conduits: Rigid PVC Conduit and fittings shall be of high impact strength heavy gauge complying with AS 2053. All fittings and accessories shall be secured with an approved solvent cementing compound. Screwed joints shall not be permitted.

Rigid PVC conduit shall be installed so as to enable cables to be 'drawn-in' after erection and junction boxes are to be provided for this purpose. Inspection type fittings are not permitted as draw-in points.

Flexible Conduits: Unless otherwise indicated, flexible PVC (to AS 2053) or plastic covered flexible steel conduit (to AS 2052) shall be used for final connections to indoor lighting and small power. The length of flexible conduit shall be kept to the minimum necessary to make the connection and accommodate plant movement.

The flexible conduits shall be complete with oil tight, water proof end fittings. Where cables are required to enter an enclosure via cable glands, the flexible conduit end fittings shall be attached via a bracket secured to the device or nearby structure at a short distance from the cable gland. Coupling adaptors shall be of the plated steel or brass type.

The flexible conduit type shall be suitable for the WS rating of the wiring system, hazardous area classification and the ambient conditions, such as sunlight, temperature, chemicals etc.

Steel Conduits: Steel conduits shall be heavy duty galvanised steel in accordance with AS 1074 and be of minimum 20 mm diameter.

Galvanised steel conduits shall be complete with all accessories such as junction boxes, bends, unions, locknuts, bushes, saddles, etc. Fittings shall comprise screwed elbows, tees, bends and draw-in boxes.

All galvanised steel conduit accessories such as junction boxes, bends, etc installed in the hazardous locations as defined by AS 2430 and shown on the drawings, shall be of the weatherproof and flameproof inspection type complying with AS 1826.

Surface Conduit Installation: Conduit run on the surface and exposed to view shall be run parallel to walls, doors and structural members. The conduits shall be symmetrically set and evenly spaced with sufficient saddles to eliminate sagging.

All elbows, tees, draw in boxes and other fittings shall be of the inspection type and shall be securely fixed individually.

Conduit shall be installed so as to avoid all mechanical duct systems and other pipe systems and services and shall in all cases be at least 75 mm from heating pipes and at least 500 mm from boilers or furnaces.

Conduits - Cast in Concrete: Where conduits are cast in-situ into concrete they shall be installed only with approval by the Principal.

Where slabs and walls have a layer of reinforcement adjacent to each surface, the conduit shall be installed in the neutral plane between the two layers of reinforcement in such a manner that the reinforcement is not displaced in any way. Deep or extension conduit boxes shall be used as necessary.

Conduit run between the reinforcement and the surface of the slab will not be permitted.

Where slabs or walls have only one layer of reinforcement placed centrally in the slab, the conduit shall be placed as nearly as possible to the centre of the slab without displacing the reinforcement.

13.1.4 Open, Unlined Drainage Channel Crossings

Where cables cross open, unlined drainage channels the cables shall be covered with a 75 mm thick continuously poured concrete slab which overlaps the sides of the cables by a minimum of 150 mm on both sides. The concrete slab shall be located 200 mm below finished ground level. An additional layer of marker tape shall be provided directly on top of the concrete.

13.1.5 Communications services

A minimum spacing of 150 mm shall be maintained between power and communications conduits when these are run in parallel.

A minimum spacing of 300 mm shall be maintained between power and communications conduits when these are run underground, with the communications conduits above the electrical conduits.

Separate communications conduits shall be installed between communications pits with a minimum of 25% spare conduits.

Conduits for communications services shall terminate onto floor or wall mounted boxes.

13.2 Penetrations, Fixings, Cutting and Making Good

13.2.1 Penetrations

Cable penetrations through walls, floors, ceilings and the like must be sealed after cable installation.

Penetrations through damp courses are not allowed. Where penetrations are required for pipes entering a building at ground level, the pipes shall be run under the waterproof membrane and shall penetrate the waterproof membrane vertically at suitable locations.

13.2.2 Cutting and Making Good

All cutting and making good required for the installation of work must only be undertaken by written approval. No welding to or drilling of structural members of the building will be permitted without approval.

13.2.3 Brackets and Fixing

All necessary brackets for mounting of wiring systems, etc, shall be provided by the Contractor. In general brackets shall be fabricated from hot-dipped galvanised mild steel for indoor areas and

marine grade aluminium or stainless steel for outdoor/wet areas. The sections or plates shall be of adequate size and thickness.

Fixings shall be by means of bolts, nuts and washers (hot-dipped galvanised mild steel for indoor and stainless steel for outdoor/wet areas). Fixings into brickwork or concrete shall be by means of expansion bolts excepting that plastic plugs with stainless steel screws or locking pins may be used for securing conduit saddles. All holes for fixings shall be neatly drilled to the correct size and depth. Explosive powered fixings shall not be used.

Fixings to structural steel shall be in the form of the clamping to webs, rails, etc. Drilling or welding of structural steel members will not be permitted.

13.3 Earthing

Earthing shall be designed in accordance with AS/NZS 3000.

Earth system resistance values and fault loop impedance values at the worst points shall not exceed the values stipulated in the applicable sections of AS/NZS 3000.

Earth electrodes for the earthing system shall be copper plated or copper clad steel. Bare earth conductors shall not be used as earth electrodes.

13.4 Installation of Switchboards

Floor mounted switchboards shall be fixed to the floor with M12 hot dipped galvanised bolts. Where computer floors are modular-panel infinite access flooring, switchboards shall not be installed directly onto these infinite access floors.

Wall mounted switchboards shall be securely mounted with a suitable number of fixings.

Externally mounted switchboards shall not have top entry cables.

Switchboards shall be fitted with aluminium cable entry plates with spare plates for future expansion.

13.5 Cabling and Wiring Methods

13.5.1 Cabling in General

Cables shall be handled with care. When laying or snaking the cable no twists or kinks shall be allowed to occur. Throughout the installation twisted, kinked, knotted or crossed over cables shall not be permitted in any enclosure. Cable runs shall present a neat and workmanlike appearance.

Any damage occurring to a cable (including the serving) shall be reported to the Principal's Authorised Representative before work on the particular cable proceeds.

Adequate slack shall be provided at all terminations, wiring boxes and accessories to facilitate servicing and re-termination of cores.

Cables shall not be bent to a radius of less than that recommended by the manufacturer.

Cables shall be adequately supported along their entire length. Supports shall be provided as close as possible to the point of termination.

A non ferrous label of approved material shall be permanently strapped to each end of every power and control cable, before and after points where its route cannot easily be followed and at such other

points as the Principal's Authorised Representative may require. The label shall be clearly and legibly marked indicating the cable number.

Unless otherwise approved by the Principal's Authorised Representative, single core cables forming part of a three phase system shall be clamped together in trefoil, each trefoil clamp containing one conductor from each phase. For high current parallel circuits the trefoil arrangements shall be such that impedance equalisation and minimum reactive loss is achieved.

The mechanical strength of cable clamps shall be adequate to restrain the forces generated by fault currents.

Cables shall not be run in a manner resulting in hysteresis and eddy currents being circulated in surrounding metal work or any steelwork forming part of the cleat.

Unused terminals in equipment shall not be used as connection terminals for looping control and power cables. Junction boxes, connection boxes, switchboards etc shall not be used as marshalling areas for cabling to other equipment.

All cable entries to equipment to be terminated shall be by cable glands. Wire armoured cables shall have their armour wires neatly terminated in glands designed for that purpose.

Any winch used to pull cables shall have automatic limitation of pull exerted. The pull shall not exceed that specified by the manufacturer for the cable and conditions applying. If winch ropes are used, they shall be attached to the cable armouring with steel mesh sleeves.

Cables shall be installed in continuous lengths without joints except where approved. In no circumstances shall cable terminations or connections be made inside cable ducting.

When not installed on racks or trays, cables shall be installed in conduit saddled to concrete masonry or steelwork or clipped by cable clamps to fixed Unistrut channels where approved by the Principal. Channels shall be of sufficient width to accommodate the cables in the run plus an allowance of 25% for future cabling.

All cables shall be supported at a maximum interval of 1000 mm or at lesser intervals, to prevent undue sagging. Cables in sloping and vertical runs shall be evenly supported at no greater than 600 mm intervals.

Apply cable ties at even spacings, trimmed and same hand orientation.

Any damage to civil works or steel, including paintwork, resulting from electrical installation works shall be 'made good' by the electrical Contractor.

Structural steelwork shall not be drilled, welded or cut to facilitate cable installation without the written approval of the Principal's Authorised Representative.

Ensure SCADA and ELV cabling systems are segregated from power cables in accordance with the Australian Standards.

13.5.2 Cable Trays and Ladders

Cable ladder and tray shall be of adequate width to accommodate the cables specified plus a 50% allowance for future cabling.

Where cable is run within ducting, allow 50% spare space for future cabling. The easy removal of a single wire or cable shall be considered to be the limiting criterion.

Ducting installed outdoors shall be provided with drain holes.

Power cables laid in racks or trays shall be in a single layer and shall be permitted to touch.

All tray bends, both horizontal and vertical shall have a minimum radius of 450 mm for power and control cables unless otherwise noted.

Cable ladder and tray shall have a maximum rung spacing of 300 mm and be supported on fabricated mild steel brackets welded or bolted to building structures. They shall be supported at intervals not exceeding the manufacturer's recommendations. Cables shall be fixed to sloping and vertical runs of cable ladder and tray by saddles, clamps or nylon cable ties.

Ducts, cable trays and ladders shall be bolted together by fish plates or other approved means. Bolts shall not protrude into the rack section which may damage cables during installation.

Cable trays, ducts and ladders shall be welded hot dipped galvanised steel or PVC. For outdoor installations, hot dipped galvanised steel must be used.

Expansion joints shall be utilised between independent structures or where any straight section of duct, tray, etc exceeds manufacturer's recommendations. Continuous earth continuity must be maintained across such joints by means of an earth strap for steel cable trays.

Where it is necessary to cut or weld steel cable ladder racks, the exposed metal shall be painted with a zinc rich paint approved by the Principal's Authorised Representative.

Steel cable ladder rack routes shall be bonded to the earth grid via 16mm green/yellow striped PVC covered cable at each end of the run, to the nearest available switchboard earth.

Peaked covers shall be fitted to ladder, tray and duct which are easily accessible, subject to direct sunlight or prone to build up of dust or materials, or subject to mechanical damage. For vertically-laid cable ladder tray and duct subject to the preceding conditions, flat covers shall be provided.

Where covers are fitted they shall be clamped to the ladder, tray and duct to the approval of the Principal's Authorised Representative.

Cable ladder racks shall be mounted to maintain 300 mm clearance between racks vertically and at least 150 mm under structural sections.

Where cable ladder, tray or duct is fixed to removable items of plant they shall be secured with clamps and bolts. Welding will not be permitted.

13.5.3 Cable Terminations and Wiring

Cables shall be clamped to the cubicle gland plate using approved weatherproof cable compression glands. Plastic weatherproof shrouds shall be provided and fitted for glands mounted outdoors.

All gland plates shall be drilled to the sizes required by the cable gland. The gland sizes shall conform to the manufacturer's recommendations.

Where it is required that PVC cables be connected to equipment that is too small to accommodate the gland, or if permanent wiring is provided with equipment, then cable shall be terminated in a conveniently located two way junction box. The connection to the equipment from the junction box shall be made using flexible PVC coated metal conduit and approved fittings.

The unsheathed part of multicore cables shall be neatly laced with cable ties or other approved means.

Where screened instrumentation cables are specified, screening shall be continuous from the signal source to the receiver. Earthing of the screen shall be at the auxiliary racks only and shall be achieved by connection to the instrument earth busbar.

All cable terminations shall be made using pre-insulated crimp lugs unless approval is obtained from the Principal's Authorised Representative. Crimp lugs shall be crimped with an approved crimp tool. Crimping with electricians pliers is unacceptable.

Wire stripping shall be performed using an approved wire stripper. The wire shall be stripped to an extent that prevents the covering entering the terminal connection or crimping lug but does not allow the protrusion of bared wire from the terminal block or lug.

No more than two wires shall be connected to one side of any terminal. The two wires shall not be twisted inside the connection. The correct size and type of screwdriver shall be used for making terminal block connections.

The number and size of bolts used for the terminations shall be determined by the lug requirements. Where equipment terminals are not big enough, copper flags shall be fitted.

Hand operated crimping tools shall be of the type which will not release until full compression is applied. Hexagonal crimping dies shall be used on all cables of 70 mm² cross section and above.

The cores of all control cables shall be run through, and numbered with white engraved ferrules with black numbers corresponding to the relevant termination diagrams and equipment drawings. Grafoplast or equivalent are acceptable. Wrap around adhesive markers will not be accepted. Component numbers of the identifier shall be aligned and identifier clearly visible. Numbers shall read away from the point of termination.

Ferrules shall be of a type which will not slip off the ends of the cables and shall interlock to ensure that the numbers remain tightly together. Saddle type ferrules are not acceptable.

Terminal strips shall be provided with the number of terminals required on the drawings plus 25% spare rail capacity. All spare cores shall be terminated. Each terminal shall be identified with a number.

13.6 Lightning and Surge Protection

13.6.1 General

In addition to the transient protection system at the SCA, lightning and surge protection equipment shall provide protection to instrument and electronic circuits against surges and transients induced in signal and power lines and antennas by lightning or electrical switching.

The manufacturer's instructions for earthing surge protection devices shall be rigidly adhered to. All earthing equipment required to carry out the manufacturer's instructions shall be supplied and installed. Earth resistance tests on each earth utilised for surge protection devices must be performed and results reported in writing to the Principal's Authorised Representative within five (5) working days after completion of testing.

Lightning protection units for analogue signal wiring shall be suitable for use for 4-20 mA signals at the loop power supply voltage. The units shall be rated to withstand a peak impulse current of at least 10 kA for a 8/20 microsecond pulse (8 microsecond rise time, 20 microsecond exponential decay time) for line-to-line and line-to-earth transients and shall fail to the short circuit condition.

The units are not required to be resettable and each channel shall have a resistance of less than 40 Ohms.

Lightning protection units for mains power cables shall have a continuous rating of at least 3 A at 240 V AC. The units shall be rated to withstand a peak impulse current of at least 4 kA for 8/20 microsecond pulse and shall be capable of absorbing at least 130 J of energy.

The units shall provide both differential (active-neutral) and common (active- and neutral-earth) mode protection and shall be capable of being used in conjunction with a 10 mA earth leakage circuit breaker.

13.6.2 Building Lightning Protection

Requirements for lightning protection for buildings shall be assessed in accordance with AS/NZS 1768, and if required, a lightning protection system comprising air terminations, down conductors, earthing rods, etc shall be designed to the requirements of this standard. The scope of provision of the system shall include soil resistivity and earth resistance tests.

Earth rods and bonding materials shall be selected to minimise corrosion.

Down conductors shall be provided with removable test links. Earth rods shall be housed in pits labelled "Lightning Protection Earth".

14 WORKS TESTING AND COMMISSIONING

14.1 General

Works testing and commissioning shall be carried out to ensure that the delivered works and the manner and method of all installation conform to the accepted construction and engineering practices, and that each piece of equipment is in satisfactory condition to successfully perform its functional operation.

All necessary meters, instruments, temporary wiring and labour shall be supplied to perform all required tests and adjustments of equipment and wiring installed and connected.

In general, tests shall include the following:

- Perform all tests and record results in accordance with the Supply Authority requirements;
- Check designation of all circuit labels at SCA and distribution boards;
- Check all fittings for correct polarity;
- Check earth continuity of all fittings; and
- Mandatory Tests in Section 6.3.3 of AS 3000:2000.

14.2 Earthing

- Measure the earth resistance of the main earthing conductor.
- Check the earth continuity to all equipment.
- Check the earth continuity to metallic sheathed cables.

14.3 Cabling

- Measure the insulation resistance between cores and between all cores and earth using a 1000-volt megger. Resistance values of less than 10 megohms for 415-volt cables per cable run will not be accepted. Care shall be taken during these tests to ensure that no equipment likely to be damaged by the test voltages is connected to the cables.
- On power cabling check and test correct phase rotation with numbers and colours.

14.4 Motors

- Manual turning of the rotor to ensure mechanical freedom.
- Insulation resistance at 1000V between phases and between each phase to earth.
- Check motor for run and direction of rotation.
- Record no-load currents.
- Functional check of control circuit and devices.

14.5 Lighting and Power Outlets

- Check all fittings and power outlets for correct polarity.
- Check the correct operation of all switching circuits.
- Check the power factor for all light fittings.
- Demonstrate that all lights operate for a period of 1½ hours or longer.
- Additional tests required for emergency lighting in accordance with AS 2293.

14.6 400 Volt SCA

- With cable tails disconnected, check the insulation resistance between phases and between phases to earth using a 500-volt megger. Insulation resistance readings of less than 10 megohms will not be accepted.
- Test correct operation of all circuit protection and all control circuits.
- Injection tests of all protection and metering equipment.
- Functional test of all components.
- Check power factor reading that the reading is 0.95 lagging or better and not greater than 1 at various plant loads (i.e. various plant production rates).
- Additional tests required by the Supply Authority.
- All specified operational checks and tests including rotation, polarity, fuse ratings and overload and protection settings. All operational checks and tests may be witnessed by the Principal's Authorised Representative.

14.7 Electrical Interference

- Additional tests required in accordance with AS 1044, AS 1054 and AS/NZS 61000.3.6 and Supply Authority requirements.

14.8 Calibration Certificates

Copies of Calibration Certificates shall be provided for all instruments used in providing testing and commissioning results. Submit for approval any documents required by the Supply Authority.

On completion of tests, all links must be closed and tightened, all fuses replaced, all terminations are tight, all electronic equipment, earthing, etc. have been reconnected and all covers replaced.

A minimum of five (5) working days' notice of all tests shall be given in order that such tests may be witnessed by the Principal. Submit the test results within five (5) working days after completion of testing.

14.9 Testing and Commissioning Process for Major Electrical Works

14.9.1 Introduction

The following sections indicate the typical processes for the testing and commissioning of major electrical works. The actual process(es) to be followed for each project will be subject to the complexity of the scope and nature of the electrical works. These sections are intended to provide guidelines for establishing a structured approach, plans and procedures for testing and commissioning.

14.9.2 Testing and Commissioning Plan

A "Testing and Commissioning" plan shall be developed for all works testing and commissioning. The plan shall allow sufficient time for testing (including Pre-FAT), and if necessary re-testing of equipment and fit in with the overall project completion time. The plan shall take into consideration the experience obtained from previous sites of a similar type and complexity.

The plan shall show commencement and completion date and times and the number of personnel present for the pre-FAT and FAT.

The number of commissioning staff associated with each aspect of testing and commissioning shall be indicated on the program. In addition, submit a copy of each Test Log sheet proposed to be used during the above program.

Before undertaking commissioning of the plant, all test instruments shall be calibrated by a NATA approved test authority within two (2) months of actual site usage. Test certificates shall be submitted to the Principal before commissioning commences.

14.9.3 Summary of Testing & Commissioning Process for Major Electrical Works

Testing and commissioning of major electrical works shall be carried in the following order:

- Contractor provides “Testing and Commissioning” plan;
- Contractor provides testing equipment calibration documentation, Drawings, and Operations and Maintenance Manuals;
- Contractor completes all Pre-FATs requirements and at the same time completes the “Pre-FAT Test Results Record Sheets”;
- Contractor submits the completed “Pre-FAT Test Results Record Sheets” to the Principal for review;
- Contractor completes FAT and submits the completed “FAT Test Results Record Sheets” to the Principal. The Principal will witness the FAT;
- Provided the Principal has accepted the FAT results and approved delivery, the Contractor installs the equipment on site;
- Contractor provides written notification to the Principal of the proposed commencement of a pre-SAT or a SAT;
- Contractor provides updated drawings, and Operations and Maintenance Manuals, testing strategy/plan;
- Meet with the Principal at least one week prior to a SAT on a new type of site. This meeting will discuss the proposed commissioning methodology and issues relating to the particular type of site;
- Contractor completes all Pre-SATs and the “Pre SAT Test Results Record Sheets” and submits the “Pre-SAT Test Results Record Sheets”. The Principal will witness the Pre-SAT. The Principal will advise the Contractor of the acceptance or otherwise of the Pre-SAT results;
- Contractor provides all relevant information and confirms date for the SAT;
- Contractor completes all SAT. The Principal will witness the SAT. The Contractor submits the “SAT Test Results Record Sheets”. The Principal will advise the Contractor of the acceptance or otherwise of the SAT results;
- Operator training; and
- Handover, after submission of test results, final Operations Maintenance Manual (OMM), Work-As-Executed drawings, any other documentations and operator training materials.

14.9.4 Test Results Sheets

Test sheets are to be prepared by the Contractor and forwarded to the Principal for approval one month before any testing is to be carried out.

Test sheets to be provided before testing are:-

- Pre-Factory Acceptance Test (Pre-FAT) Results Record Sheets;
- Factory Acceptance Test (FAT) Results Record Sheets;

- Pre-Site Acceptance Test (Pre-SAT) Results Record Sheets; and
- Site Acceptance Test (SAT) Results Record Sheets.

Typically, the test results sheets will include, but not be limited to the following:-

- Test title e.g. Motor Starter AUTO operation;
- Purpose of test: e.g. prove operation of interlocks;
- Test conditions or configuration: e.g. Switch in AUTO position;
- Description of each test in sequential order;
- Expected result on local panel e.g. light on, relay energised;
- Acceptance criteria;
- Duration of test e.g. 1 minute for soft starter ramp up;
- Comments;
- Pass or Fail; and
- Sign off by tester, another witness from Contractor's organisation and the Principal.

Typically, separate sheets shall be provided for:-

- SAT Confidence Tests;
- FAT/SAT visual check;
- SAT equipment location and completeness check;
- FAT/SAT Instrument Calibration;
- SAT functional check;
- FAT/SAT System Test;
- SAT equipment decommissioning checks; and
- FAT/SAT documentation check.

14.9.5 Factory Acceptance Testing

Introduction

Testing for the site shall consist of two formal tests. A Pre-Factory Acceptance Test (Pre-FAT) and a Factory Acceptance Test (FAT). The FAT will be witnessed by the Principal. The Pre-FAT will be witnessed at the Principal's discretion.

The Principal shall have the right to witness any tests and inspect any equipment at any stage of the Contract to confirm progress and conformance. This may involve re-testing if considered warranted by the Principal. This shall not relieve the Contractor of any responsibility to ensure the proper operation of any equipment;

Detailed testing procedures, commissioning procedures and check sheets are to be prepared and provided to the Principal one month prior to testing. These sheets must be completed during testing and test data submitted for approval. These sheets shall be a site specific document providing a formal comprehensive testing procedure and test record. The test sheets will be checked during formal testing and during various audits by the Principal. Any testing or recording inaccuracies must be recorded and measures put in place to prevent re-occurrence.

Resources

All testing shall be accompanied by the necessary labour, materials and test equipment required for testing, including a complete set of spare equipment for minor items, such as, relays, lamps, contactor coils, etc. so that the testing process is not delayed due to the failure of such items.

All test equipment shall have been checked for calibration prior to tests. Calibration documentation shall be made available

14.9.6 Pre-Factory Acceptance Testing

A Pre-FAT is shall be carried out when:

- Manufacturing is complete;
- The system or sub-system is fully assembled;
- The assembly is ready for transportation to site; and
- Calibration sheets are complete and available.

The Pre-FAT and FAT shall be carried out at the manufacturer's works when manufacturing is complete;

The Pre-FAT shall be carried out prior to a FAT. This is intended to check the scope of work and minimise the amount of time required to complete the FAT by eliminating wiring, labelling, workmanship and equipment functionality problems. Some Pre-FATs may be repeated during the FAT to verify correctness of the results.

The Principal will not normally witness the Pre-FAT, however, he shall have the right to do so;

The "Pre-FAT Test Result Record Sheets", shall be supplied by the Contractor and it shall detail all tests required during Pre-FAT;

Two (2) copies of the "Pre-FAT Test Results Record Sheets" shall be submitted at the start of the FAT for approval with the "FAT Test Results Record Sheets". Each test shall be dated and signed off by two representative of the Contractor.

The Pre-FATs shall itemise and cover all tests associated with the following:-

- Completeness of work to relevant standards and workmanship;
- Labelling and wiring;
- Correctness of drawing/equipment;
- Equipment rating e.g. circuit breakers, etc.;
- Firmness of equipment;
- Set overloads; and
- Functional operations of switches, circuit breakers, push buttons, etc.

14.9.7 Factory Acceptance Testing

A FAT shall be carried out when:

- All Pre-FATS have been successful/complete;
- Operation and maintenance manuals are complete;
- An updated set of all drawings are available;
- The "Pre-FAT Test Results Record Sheets" are completed;

- The FAT shall be carried out at the manufacturer's works;
- At least one (1) weeks' notice shall be given of a proposed FAT;
- Complete all tests detailed on the "FAT Test Result Record Sheets" during the FAT. Each test shall be dated and signed off by the Contractor;
- The FAT shall be a full simulated test of all operating hardwired functions. External equipment shall be connected to simulate actual field devices, e.g. switches, signal generators, etc. The FAT shall cover as much of the hardwired operational system of the site as possible;
- The Principal will witness the FAT;
- If requested by the Principal, some Pre-FAT results may be re-tested to verify the results of the Pre-FAT;
- Any drawing changes resulting from the FAT shall be recorded and incorporated into the next drawing issue;
- Two (2) copies of the "Pre-FAT Test Results Record Sheets" and "FAT Test Results Record Sheets" shall be submitted for approval at the conclusion of the FAT;
- During the FAT the Principal may issue Non Conformance Reports. These will indicate that equipment or the procedure does not conform to the Specification. In this case, the system shall be modified and re-tested. This process shall be repeated until the test is successful. It will be up to the Principal to determine whether re-testing can be carried out as part of the current FAT or re-scheduled to another date. The Contractor shall sign all NCR's;
- At the conclusion of the FAT, after all NCR are cleared and approval is given by the Principal, then the equipment can be delivered to site; and
- The FATs shall itemise and cover all tests associated with the following:-
 - Continuity tests;
 - Insulation test;
 - Three phase power up tests;
 - Hardwired status indication, control, interlocks and logic functions;
 - GPO, panel light and panel cooling fans etc;
 - Simulate and check all analog signals indicators and generation;
 - Noise test;
 - Instrument test to prove calibration, accuracy, repeatability, hysteresis checks, etc.

14.9.8 Site Acceptance Testing

Pre-Site Acceptance Testing (Pre-SAT)

- A Pre-SAT shall be carried out when:
 - All new equipment has been installed;
 - The new switchboard has been connected to the power supply (if feasible);
 - All preparation work and notifications are complete;
 - All documentation has been provided and is available on site;
 - Calibration sheets are complete and are available on site.
- The Pre-SAT is intended to minimise the amount of time required to complete the SAT by checking the scope of works and preliminary testing of wiring and eliminating workmanship or equipment functional problems.
- At least two (2) weeks' notice to all parties shall be required for a proposed Pre-SAT. The Pre-Sat will be witnessed by the Principal.
- The "Pre-SAT Test Result Record Sheets" shall detail all checks and tests required during Pre-SAT. These sheets shall be completed during Pre-SAT and submitted to the Principal at

the completion of the Pre-SAT for approval. Each test shall be dated and signed off by the Contractor, Contractor's witness and the Principal.

- Two (2) copies of the completed "Pre-SAT Test Results Record Sheets" shall be submitted at the conclusion of the Pre-SAT.
- The Pre-SATs shall itemise and cover all tests associated with the following:
 - General visual inspection of equipment mounting and location, firmness of wire terminations, tightness of busbar supports, labelling of equipment and wiring;
 - Completeness of installation work to relevant standards;
 - Accuracy of drawings;
 - Labelling and setting checks;
 - Instrumentation inspections;
 - Check that FAT test results match the site data sheets;
 - Functional test of equipment;
 - Testing new field devices and instruments that can be installed and connected without affecting the operation of the existing equipment;
 - Check for damaged or marked equipment; and
 - Check overload settings, and soft starter parameters against commissioning data sheets.

Site Acceptance Testing

- A SAT shall be carried out as soon as possible after successful completion of the Pre-SAT and when:
 - All possible Scopes of Works are completed;
 - No outstanding major NCRs;
 - All parties have been notified and are ready;
 - All documentation is available for viewing on site including latest drawings, strategy plans, data sheets, test sheets, supply authority approvals, site access, contingency plan, etc.;
 - Operation and maintenance manuals are complete;
 - An updated set of all drawings are available;
 - The "Pre-SAT test results record sheets" are completed and approved;
 - There is a period of dry weather if testing is required to be outdoors. SATs are to be cancelled if unexpected wet weather effect the ability to conduct the testing; and
 - Approval has been given to carry out the SAT by the Principal.
- At least two (2) weeks' notice shall be provided for a proposed SAT. This should allow sufficient time to co-ordinate all relevant parties associated with the SAT. It is expected that a SAT notification will be provided at the same time as a Pre-SAT notification.
- Before agreeing to a SAT the Principal may visit the site to confirm its readiness.
- The Principal will witness the SAT.
- Unless the SAT is carried out immediately after the Pre-SAT then prior to the commencement of the changeover, critical components shall be functional, and if required by the Principal, re-test some Pre-SAT results to verify their correctness. If any fault is found, it is up to the Principal to determine whether the SAT can commence or be re-scheduled to another date.
- "SAT Test Result Record Sheets" shall be supplied and all tests detailed on the "SAT Test Result Record Sheets" completed, during the FAT. Each test shall be dated and signed off by the Contractor.

- During the SAT the Principal may issue Non Conformance Reports. These will indicate that the equipment does not conform to the specification or that the correct procedure has not been followed. The Contractor shall sign all NCR. The system shall be modified and re-tested if any test is not approved. This process shall be repeated until the test is successful. It will be up to the Principal to determine whether re-testing can be carried out as part of the current SAT or re-scheduled to another date.
- No repairs or modifications shall be carried out unless agreed by all parties.
- Equipment shall not be put into operation unless all tests have been completed and approval is obtained from the Principal.
- Two (2) copies of the completed “SAT Test Results Record Sheets” shall be signed off and submitted for approval at conclusion of the SAT.
- Any drawing changes resulting from the SAT shall be recorded and incorporated into the Work as Executed drawings.
- The results of each test shall be recorded immediately after the test is performed.
- Any tests postponed from the Pre-SAT due to lack of mains power etc shall be included in the SAT. The implications that this will have on the transition time and the additional risk involved in carrying out these tests during the SAT shall be reported.
- The SATs shall itemise and cover all tests associated with the following:
 - Cable installation;
 - Supply Authority Tests;
 - Power up Test;
 - Normal operational tests;
 - Abnormal operational tests, e.g. main power fail; and
 - Decommissioning check (e.g. temporary arrangements).

14.9.9 Commissioning of Plant

Commissioning of the plant shall be carried out by the Contractor. This work shall include the adjustment of all variables to meet the specified requirements, the setting of motor overloads, safety settings, controls etc. to protect the plant from unsafe operation. In particular, the following work shall be undertaken:

- Calibration and adjustment of safety devices, overloads and other controls; and
- The correct direction of operation of motors.

14.9.10 Commissioning Data

Two copies of all data obtained from the above commissioning tests shall be submitted to the Principal’s Authorised Representative for review. All data, certificates, and performance curves, etc., must be provided and must have been received and approved prior Completion.

14.9.11 Calibration Certificates

Copies of Calibration Certificates shall be provided for all instruments used in providing testing and commissioning results.

14.9.12 System Tests

The whole of the engineering services installed under the particular project shall be tested for operation under full load, normal and emergency operations.

Coordination with other third parties shall be required via the Principal's Authorised Representative to ensure that all systems can be tested simultaneously.

15 DOCUMENTATION FOR ELECTRICAL WORKS

15.1 Documentation to be submitted

Electrical, instrumentation and control system documentation shall be prepared in accordance with the following standards:

- AS 1102 Graphical symbols for electro-technology; and
- ISA-S5.4 Instrument Loop Diagram;

Documentation to be submitted which describe the electrical, instrumentation and control system shall include but not limited to the following:

1. Drawing register or index;
2. Where relevant to the scope of the works, overall site plan showing major locations of electrical equipment and cable routes
3. Single Line Diagrams showing all equipment connected;
4. Schematic diagrams showing all equipment connected, including individual motor starter schematics;
5. Telemetry schematics;
6. Exterior switchboard layout drawings for all switchgear and control gear assemblies, enclosures, panels and equipment showing layout and mounting details of equipment and construction details;
7. Interior equipment layout drawings for all switchgear and control gear assemblies, enclosures, panels and equipment showing layout and mounting details of equipment and construction details;
8. Switchboard sectional drawings for all switchgear and control gear assemblies, enclosures, panels and equipment showing layout and mounting details of equipment and construction details;
9. PLC/RTU connection diagram;
10. PLC/RTU input and output schematics;
11. Analogue Instrument Loop Diagrams;
12. Instrument schedules listing each item of instrument and including, tag number, purpose, accuracy, input and output details such as signal type, range, etc, operating range, calibration details, maximum working pressure, flange/mounting details, manufacturer/model;
13. Cable Schedules listing each power, instrumentation and control system cable including:
 - Cable number;
 - Origin;
 - Destination;
 - Type of cable;
 - Size of conductor;
 - Number of cores; and
 - Installation details such as cable route.
14. Equipment layout and cable route drawings and installation details;
15. Site conduit layout drawings and installation details;
16. Shop Drawings; and
17. Operations and Maintenance Manuals.

15.2 Shop Drawings

The Contractor shall prepare fully dimensional and detailed working drawings for all main switchboard, motor control centre, control panels, distribution boards and conduits, cable trays and cable ladders, and to cover all aspects of the works. These drawings shall also include the complete set of design drawings. All drawings shall be in the format of the Principal's current version of AutoCAD.

Site work shall only be carried out based on "Shop Drawings" that have been formally approved. All access and required penetrations within the building structure shall be marked on drawings. Drawings shall be adequate to illustrate all installation requirements and shall include details of all equipment to be installed. The scale of the drawings shall be not less than 1 to 100 for building plans and 1 to 20 for details and shall be clearly legible and an A3 sheet.

Shop drawings are required for the following items:

- Switchboards layout drawings showing the arrangement of equipment within the switchboard, busbar arrangements and methods of achieving segregation, dust proofing, etc. complete with all necessary dimensions;
- Single line diagrams;
- Typical termination arrangement(s) for incoming supply outgoing wiring;
- Distribution board general arrangement drawings;
- Detailed layout drawings showing the arrangement of equipment, provisions for the termination of all-incoming cables, etc., complete with all necessary dimensions;
- Coordinated layouts of all conduits, cable trays, cable ladders, duct, light fittings, socket outlets etc., including all penetrations through walls, beams, slabs and underground;
- Physical layout of distribution frames and racks showing locations of termination modules and cables;
- Proposed termination sequence and labelling;
- Final details of circuiting including modified single line diagrams;
- Schematic diagrams of lighting control systems and emergency lighting including individual wire and cable numbering;
- Workshop drawings for all associated equipment panels and engraving details; and
- Equipment listings for all electrical components, the number required, ratings, make, model, catalogue number, etc.

15.3 Operations and Maintenance Manuals

15.3.1 General

The Contractor shall compile comprehensive operating and maintenance manuals for the mechanical and electrical equipment supplied.

A draft of the proposed manuals, complete with binders and all fully complete, shall be provided for the approval of the Principal's Authorised Representative not later than 6 weeks prior to the due date for practical completion of the work. Practical completion will not be granted until such time as the Principal's Authorised Representative provides written approval.

After approval three (3) copies of each volume shall be compiled and supplied to the Principal's Authorised Representative prior to the issue of the Certificate of Practical Completion. Each volume shall also be provided in an electronic format readable by Microsoft Word and PDF.

All diagrams and tables are to be numbered and the pages shall be numbered. A comprehensive index is to be included. The text shall be written in clear concise English and easily understood by a trained operator.

15.3.2 Contents

The Operation and Maintenance manuals shall include a full system description, component data, trouble shooting, spare parts, maintenance procedure schedule and reference drawings and document list. Subsections of the manuals shall be logically organised into:

- Switchboards and Controlgear Assemblies;
- Earthing System;
- Luminaires;
- Socket Outlets;
- Cables and Cable Support System;
- Other Equipment; and
- Trouble shooting procedures and fault finding recommendations for equipment.

Each subsection shall cover the following details:

- A full system description of installation;
- List and component data (brochures), where relevant;
- Records of settings and calibration of equipment (such as protection settings, timers, sensors, etc.);
- Maintenance operations and schedules;
- Recommendations for adjustments and routine maintenance procedures;
- Instructions for dismantling (where applicable); and
- Reference drawings.

The manuals shall also include the following:

- Safe Work Method (SWM) statements for operating each item of electrical plant. This shall include start up sequences, changeover sequences and shut down sequences. SWM's shall also include descriptions and operation procedures for shunt trips and interlocks;
- Test Certificates and Commissioning Reports for all tests including a list of tests to be carried out and shall contain signed test reports and certifications;
- All guarantees and warranties on all equipment supplied; and
- As-Built Drawings produced by the Contractor for approval, Shop drawings, final marked-up As-Built drawings and other relevant drawings not submitted for approval.