Electrical Installation

TMS1200

Standard Technical Specification

REVISION CONTROL

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01	June 2015	Issued for Use – Stakeholder Comments Updated	Steve Bourke
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DOCUMENT CONSULTATION

Revision	Name	Position	Comments Received	Date
2	Gerard Anderson	Senior Electrical Engineer	Y	May 2017
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2	Jeremy Torpy	Senior Program Engineer	Y	May 2017
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Contents

1 INTRODUCTION

This specification details the minimum requirements for installation and testing of electrical equipment installed on Queensland Urban Utilities facilities.

1.1 SCOPE

This Specification shall be read in conjunction with the General and Specific Conditions of Contract. The Contractor shall be responsible for the supply of all labour, equipment, and materials necessary to construct the works in accordance with the Project Documentation. The Contract may exclude the supply only of items specified as being supplied by QUU.

The Contractor shall be responsible for obtaining all necessary approvals, permits, licences and certificates required by Statutory Authority, Local Ordinances or other regulatory authorities covering scope of work.

1.2 DEFINITIONS

In this document, the following definitions apply:

Project Documentation	Governing technical documents for the specific item(s) for the specific works included or referenced in the Contract
Contractor	The entity bound (including sub-contractors appointed by the contractor) to execute the work having responsibility for design, manufacture and supply, installation, delivery, documentation and other functions as further defined in the documents related to the work.
Contract:	The agreement between QUU and the Contractor to which this specification pertains.

1.3 ACRONYMS AND ABBREVIATIONS

Term	Definition
ACB	Air Circuit Breaker
CT	Current Transformer
CAD	Conformity Assessment Document
CEMP	Construction Environment Management Plan
DC	Direct Current
ELV	Extra Low Voltage
FAT	Factory Acceptance Test
FIP	Fire Indicator Panel
EMC	Electro-Magnetic Compatibility
EWP	Elevated Work Platform
Ex	Explosion Protection
HDD	Horizontal Directional Drilling
HSE	Health, Safety and Environment
HVAC	Heating Ventilation and Air Conditioning

IEC	International Electro-technical Commission
I/O	Input / Output
IP	Ingress Protection
ISO	International Standards Organisation
ITP	Inspection and Test Plan
LED	Light Emitting Diode
LV	Low Voltage
LCP	Local Control Panel
LME	Liquid Metal Embrittlement
MCC	Motor Control Centre
MEB	Main Earth Bar
NC	Normally Closed
NCC	National Construction Code
NO	Normally Open
NMI	National Meter Identifier
MCCB	Moulded Case Circuit Breaker
MSDS	Material Safety Data Sheet
O&M	Operation and Maintenance
OEM	Original Equipment Manufacturer
PLC	Programmable Logic Controller
PPE	Personal Protective Equipment
PTC	Positive Temperature Coefficient
PVC	Polyvinyl Chloride
RCD	Residual Current Device
RFI	Radio Frequency Interference
RMS	Root Mean Square
RTU	Remote Telemetry Unit
QA	Quality Assurance
QUU	Queensland Urban Utilities
SAT	Site Acceptance Test
SDRL	Supplier Data Requirements List
SLD	Single Line Diagram
SWA	Steel Wire Armour
TOL	Thermal Overload
UPS	Uninterruptible Power Supply
UV	Ultra-violet

VLF	Very Low Frequency
VSD	Variable Speed Drive
VT	Voltage Transformer

1.4 REFERENCE DOCUMENTS

Document Number	Title
FOR279	Site Details & Test Sheet – Electric Motors
CA-17 c-h	Site Inspection Tests
CHE68	Site Inspection Checks – Cables
CHE69	Site Inspection Checks - Electric Motors
CHE70	Site Inspection Checks - Instruments
CHE71	Site Inspection Checks – Switchboards
CHE72	Site Inspection Checks – Cable ladder/ Tray / Ducts
CHE136	Site Inspection Checks – Field Equipment
MP71	Electrical Safety Management Plan
MP183	Hazardous Area Management Plan
PRO307	Procedure Drafting Guidelines – Contract Requirements
PRO395	SEQ Water Supply and Sewerage- D&C Code Asset Information QUU Addendum
PRO450	Electrical Safety SOP
PRO521	Safety in Design SOP
SWMS2	Safe Work Method Statement Confined Space Entry
TEM336	Power System Analysis Guidelines
TEM518	Hazardous Area Verification Dossier Template
TMS60	Low Voltage Switchboards - Technical Specifications
TMS62	Preferred Equipment List – Electrical and Instrumentation
TMS76	Corrosion Protection for Electrical and Mechanical Equipment and Structures
TMS78	Typical Switchboard Changeover Commissioning Plan.
TMS117	Security, Access, Control and CCTV – Technical Specification
TMS1151	Preferred Equipment List – Control Systems
TMS1185	Distribution Power Transformers(Less than 5MVA) – Technical Specification
TMS1186	High Voltage Switchboards – Technical Specification
TMS1187	AC Uninterrupted Power Supply – Technical Specification
TMS1188	Transportable Switchroom – Technical Specification
TMS1201	Instrumentation Installation Specification

TMS1202	Control System Implementation - Technical Specification
TMS1203	General Requirements Hazardous Area Installation Specification
TMS1221	DC Power Supply Systems – Technical Specification
TMS1222	Control Panels – Technical Specification
TMS1404	HV Motors – Technical Specification
TMS1406	LV Variable Speed Drives – Technical Specification
TMS1436	Safety in Design Report Requirements
TMS1589	LV Diesel Generator – Technical Specification
TMS1595	Pipeline and Structures Cathodic Protection – Technical Specification
TMS1621	Typical Pump Station Maximum Demand Template
TMS1625	Dry Type Distribution Transformers – Technical Specification
TMS1637	LV Motors – Technical Specification
TMS1639	General Mechanical Works – Technical Specification
TMS1645	Packaged Plant Electrical, Instrumentation and Control System Requirements - Technical Specification
TMS1647	Equipment Tag Naming – Technical Specification
TMS1648	Electrical, Instrumentation and Control Systems Design Criteria – Technical Specification
TMS1651	Machine Safety Implementation– Technical Specification
WI58	Arc Flash Assessment and PPE Selection

2 STANDARDS & REGULATIONS

All equipment and workmanship shall conform to the most recent requirements of the relevant statutory Local, State and Commonwealth Authorities and current applicable Australian Standards. Alternatively, where no Australian Standard exists, work shall conform to the most current and applicable International standard.

Where conflict exists between different Codes, Standards or Regulations, the most onerous conditions of specification shall apply unless accepted otherwise in writing by QUU.

The Contractor shall not deviate from the provisions of the relevant standard without first obtaining agreement in writing from QUU.

Particular standards and regulations relevant to the work include but are not necessarily limited to the following:

2.1 AUSTRALIAN STANDARDS

The equipment shall be designed, manufactured and tested in accordance with the latest edition of all relevant Australian and International Standards, Codes and Regulations except where modified by this specification.

AS/ISO 1000	International system of units (S.I.) and its applications
AS1020	Control of undesirable static electricity
AS 1101	Graphical symbols for general engineering
AS 1192	Electroplated coatings, nickel and chromium.
AS/NZS 1158.3.1	Lighting for roads and public spaces Pedestrian area (Category P) lighting - Performance and design requirements
AS 1275	Metric screw threads for fasteners
AS 1284	Electricity meters – All Parts
AS 1307.2	Surge arresters – Metal-oxide surge arresters without gaps for A.C. systems
AS 1319	Safety signs for the occupational environment
AS 1324	Air filters for use in air conditioning and general ventilation – All Parts
AS 1345	Identification of the contents of piping, conduits and ducts.
AS 1359	Rotating electrical machines – General requirements – All Parts
AS 1428	Design for access and mobility – All Parts
AS1429.1	Electric cables- polymeric insulated – For working voltages 3.6kV up to and including 36kV
AS 1530	Methods for fire tests on building materials, components and structures – All Parts
AS 1603	Automatic fire detection and alarm systems – All Parts
AS1627	Metal finishing – Preparation and pre-treatment of surfaces – All Parts
AS 1657	Fixed platforms, walkways, stairways and ladders
AS 1660	Test methods for electric cables – All Parts
AS 1668	The use of ventilation and air-conditioning in buildings – All Parts

AS 1670	Fire detection, warning, control and intercom systems – All Parts
AS 1680	Interior lighting - All Parts
AS 1682	Fire dampers – All Parts
AS 1767	Insulating liquids – All Parts
AS/NZS 1768	Lightning protection
AS 1789	Electroplated zinc (electrogalvanized) coatings on ferrous articles (batch process)
AS 1841	Portable fire extinguishers – All Parts
AS 1897	Fasteners – Electroplated coatings
AS 1905	Components for the protection of openings in fire resistance walls – All Parts
AS/NZS 2053	Conduits and fittings for electrical installations – All Parts
AS 2067	Substations and high voltage installations exceeding 1 kV A.C
AS 2239	Galvanic (sacrificial) anodes for cathodic protection
AS 2293	Emergency escape lighting and exit signs for buildings – All Parts
AS 2374.1.2	Power transformers – Minimum energy performance standard (MEPS) requirements for distribution transformers
AS 2374.8	Power transformers – Application guide
AS 2467	Maintenance of electrical switchgear
AS 2700	Colour standards for general purposes
AS 2832	Cathodic protection of metals – All Parts
AS/NZS 2857	Timber drums for insulated and bare cables
AS 2865	Safe working in a confined space.
AS/NZS 3000	Electrical installations (known as the Wiring Rules)
AS/NZS 3008.1.1	Electrical installations – Selection of cables – Cables for alternating voltages up to and Including 0.6/1kV – Typical Australian installation conditions
AS/NZS 3010	Electrical installation – Generator sets
AS 3011	Electrical installations – Secondary batteries installed in buildings – All Parts
AS 3017	Electrical installations—Verification guidelines
AS/NZS 3100	Approval and test specification - General requirements for electrical equipment
AS/NZS 3111	Approval and test specification- Miniature overcurrent circuit breakers
AS/NZS 3133	Approval and test specification – air break switches
AS/NZS 3190	Approval and test specification – Residual current devices (current-operated earth-leakage devices)
AS 3808	Insulation and sheathing materials for electric cables
AS 3863	Galvanised mild steel wire for armouring electric cables

AS 3894	Site testing of protective coatings – All Parts
AS 3983	Metal drums for insulated and base electric cables
AS 4024	Safety of machinery – All Parts
AS 4044	Battery chargers for stationary batteries
AS 4070	Recommended practices for protection of low voltage electrical installation and equipment in MEN systems for transient over voltages
AS/NZS 4325.1	Compression and mechanical connectors for Power Cables - Test methods and requirements
AS 4398	Insulators- Ceramic or glass- Station post for indoor and outdoor use – Voltages greater than 1000V AC – All Parts
AS 4428	Fire detection, warning, control & intercom systems – All Parts
AS 4436	Guide for the selection of insulators in respect of polluted conditions
AS 4509	Stand-alone power systems – All Parts
AS/NZS 4534	Zinc and zinc/aluminium-allow coatings on steel wire
AS/NZS 4680	Hot-dip galvanised (zinc) coatings on fabricated ferrous articles
AS 4761.1	Competencies for working with electrical equipment for hazardous areas (EEHA) – Competency Standards
AS 4777	Grid-connections of energy systems via inverters
AS/NZS 4792	Hot-dip galvanised (zinc) coatings on ferrous hollow sections, applied by a continuous or specialised process
AS/NZS 4805	Accessories for electric cables-Test requirements – Power cables from 3.6kV up to 36kV – All Parts
AS 4853	Electrical hazards on metallic pipelines
AS/NZS 5000	Electric Cables- Polymeric insulated – All Parts
AS 5033	Installation of photovoltaic (PV) arrays
AS 6183	Fire protection equipment – Carbon dioxide extinguishing systems for use on premises – Design and installation
AS ISO 14520	Gaseous fire-extinguishing systems – All Parts
AS 60034	Rotating electrical machines
AS 60038	Standard voltages
AS 60044	Instrument Transformers - All Parts
AS 60060.3	High-voltage test techniques Part 3: Definitions and requirements for on-site testing
AS 60076	Power transformers – All Parts
AS/NZS 60079	Explosive atmospheres – All Parts
AS/NZS 60137	Insulated bushings for alternating voltages above 1000 V
AS 60146	Semiconductor converters – General Requirements and Line Commutated Converters
AS 60214.1	Tap-changers – Performance requirements and test methods
AS 60265.1	High voltage switches Part 1: Switches for rated voltages above 1kV

	and less than 52kV
AS 60422	Mineral insulating oils in electrical equipment – Supervision and maintenance guidance
AS 60470	High-voltage alternating current contactors and contactor-based motor-starters
AS 60529	Degrees of Protection Provided by Enclosures (IP Code)
AS 60849	Sound systems for emergency purposes
AS/NZS IEC 60947	Low-voltage switchgear and control gear – All Parts
AS 61000	Electromagnetic compatibility (EMC) – All Parts
AS IEC 61131	Programmable controllers – All Parts
AS/NZS 61439	Low-voltage switchgear and control gear assemblies All Parts
AS 61508	Functional safety of electrical/electronic/programmable electronic safety-related systems
AS 61558.1	Safety of power transformers, power supplies, reactors and similar products – general requirements and tests
AS 62040	Uninterruptible power supply (UPS) – All Parts
AS 62061	Safety of machinery - Functional safety of safety-related electrical, electronic and programmable electronic control systems
AS 62271	High-voltage switchgear and control gear – All Parts
AS/NZS CISPR 11	Industrial, scientific and medical equipment – Radio-frequency disturbance characteristics – Limits and methods of measurements
CCM	Communications Cabling Manual (CCM) Volume 2 - 2007
(ENA) EG 1-2006	Substation Earthing Guides

2.2 INTERNATIONAL STANDARDS

IEC 60034	Rotating electrical machines – All Parts
IEC 60038	Standard voltages
IEC 60044.7	Instrument transformers - Part 7: Electronic voltage transformers
IEC 60044.8	Instrument transformers - Part 8: Electronic current transformers
IEC 60050	International Electro-technical Vocabulary – All Parts
IEC 60051	Direct acting indicating analogue electrical measuring instrument and their accessories – All Parts
IEC 60060-1	High-voltage test techniques Part 1: General definitions and test requirements
IEC 60060-2	High-voltage test techniques Part 2: Measuring systems
IEC 60071	Insulation coordination
IEC 60228	Conductors of insulated cables
IEC 60255	Measuring relays and protection equipment – All Parts
IEC 60269	Low voltage fuses – All Parts

IEC 60282	High voltage fuses
IEC 60296	Fluids for electro-technical applications – Unused mineral insulating oils for transformers and switchgear
IEC 60332	Tests on electric and optical fibre cables under fire conditions – All Parts
IEC 60417	Graphical symbols for diagrams – IEC database edition
IEC 60445	Basic and safety principles for man-machine interface, marking and identification - Identification of equipment terminals, conductor terminations and conductors
IEC 60502	Power cables with extruded insulation and their accessories for rated voltages from 1 kV (Um = 1,2 kV) up to 30 kV (Um = 36 kV) – All Parts
IEC 60660	Tests on Indoor post insulators of organic material for systems with nominal voltages greater than 1000V up to but not including 300kV
IEC 60694	Common specifications for high-voltage switchgear and control gear standards
IEC 61158	Industrial communication networks - Fieldbus specifications – All Parts-
IEC 61243-5	Live working - Voltage detectors - Part 5: Voltage detecting systems (VDS)
IEC TR 61641	Enclosed low-voltage switchgear and controlgear assemblies - Guide for testing under conditions of arcing due to internal fault
IEC 61643	Low-voltage surge protective devices – All Parts
IEC 61850	Communications networks and systems for power utility automation – All Parts
IEC 62444	Cable glands for electrical installations
IEC 62443	Security for industrial automation and control systems.– All Parts
IEC 62541	OPC unified architecture – all parts
IEC TS 62941	Terrestrial photovoltaic (PV) modules - Guideline for increased confidence in PV module design qualification and type approval
IEEE 519	Recommended practices and requirements for harmonic control in electrical power systems
IEEE Std 1815	Electric power systems communications – Distributed network protocol (DNP3)
IEEE 802.3	Ethernet
ISO 13849	Safety of machinery - Safety-related parts of control systems – All Parts
ISO 9001	Quality management systems – Requirements
NFPA 70E:2015	Standard for electrical safety in the workplace

2.3 REGULATIONS

The current regulations and statutory requirements of the State of Queensland, Australia, shall be complied with, including:

- Queensland Electricity Act (1994)
- Queensland Electricity Regulations (2006)

- Queensland Work Health and Safety Act 2011
- Queensland Work Health and Safety Regulations 2011
- Queensland Work Health and Safety Codes of Practice
- Queensland: Environmental Protection Act - 1994 and Amendment Act – 1997
- Queensland Electrical Safety Act 2002 and its latest amendments
- Queensland Electrical Safety Regulations 2013
- Queensland Electrical Safety Code of Practice 2013
- Queensland Professional Engineers Act 2002
- Queensland Professional Engineers Regulation 2003
- Queensland Workers' Compensation and Rehabilitation Act 2003 and Amendment Act 2015
- National Construction Code 2016, volumes 1, 2, 3 and The Guide
- Australian Work Health and Safety Act 2011
- Australian Work Health and Safety Regulation 2011
- Australian Work Health and Safety Codes of Practice 2015
- Queensland Electricity Connection and Metering Manual (QECMM) Version 11

2.4 UNITS AND LANGUAGE

AS/ISO 1000 (metric SI system) shall be used. All documentation and correspondence shall be in the English language.

2.5 SUB-CONTRACTORS

The Contractor shall disclose, at the tender stage, all sub-contractors they intend to use as part of the contract works. The Contractor shall not sub-contract any work to any party without the prior written consent of QUU. It shall remain the Contractors' responsibility to audit and co-ordinate the performance of their sub-contractor with results being disclosed to QUU. All requirements applicable to the Contractor are applicable to their Sub-contractors.

2.6 CONTRACTOR EXCEPTIONS

The Contractor shall be responsible to submit, together with the Tender, a list of deviations or exceptions to this Specification. In the absence of any exceptions, it will be construed that the Contractor fully complies with this Specification.

2.7 ORDER OF PRECEDENCE

In the event of any conflict arising between this Specification and other documents listed herein, refer comments to QUU for clarification before the works commences. The order of precedence that applies is as follows:-

1. Purchase Order or Contract
2. Project Data Sheets
3. This Specification
4. Project Drawings
5. Project Specifications
6. Standards, Codes and Regulations

3 GENERAL REQUIREMENTS

3.1 OPERATION AND DESIGN LIFE

The electrical installation and associated materials shall be designed and installed for minimum life duration of 20 years continuous service in the environment and for the duty specified herein and in the relevant Project Documentation.

3.2 LOCATION AND ENVIRONMENTAL CONDITIONS

All electrical equipment shall be designed and installed for the site conditions defined as follows:-

Location	South East Queensland	
Altitude	above mean sea level.	0-300m
Ambient Temperature	Minimum	-5°C
	Maximum (dry bulb)	45°C
Relative Humidity	Minimum	26%
	Maximum	100% condensing
Solar Radiation	Black bulb design temperature - minimum mechanical design temperature for equipment exposed to solar radiation	85°C

Note: Corrosive environments are locations where H_2S gas or other corrosive chemicals and gasses can exist under normal operating conditions and can be both indoor and outdoor areas. This is applicable to all wet wells installations. All areas including inside air conditioned switch rooms at Sewerage Treatment Plants are considered corrosive environments. All materials installed shall be suitable for the environment.

3.3 UTILITY DATA

The electrical system may have the following voltage levels:

High Voltage Power Supply	33 kV AC, three phase 3 wire, 50 Hz, 11 kV AC three phase 3 wire 50 Hz, 6.6 kV AC, three phase 3 wire, 50 Hz
Low Voltage Supplies	3 ph, 4 Wire, 400 Volt +10,-6% 50 Hz ± 2%, MEN System Voltage Unbalance <5%
Single Phase Power Supplies	230 V AC, +10,-6%, 2 wire, 50Hz ± 2%,
Control Power Supplies	UPS 230 V AC, single phase 2 wire, 50 Hz Regulated 24 V DC
Special Purpose Power Supplies	Regulated 48VDC and 110VDC

The equipment shall be designed to operate continuously under the following conditions:-

- HV Distribution: Steady State Voltage ± 5% nominal voltage

- LV Distribution: Steady State Voltage +10,-6% nominal voltage
- Steady State Frequency ± 2.5% nominal frequency
- Transient Voltage ± 20% nominal voltage
- Transient Frequency ± 5% nominal frequency
- Total harmonic voltage distortion < 5 %

3.4 SAFE WORKING IN CONFINED SPACES

All work in confined spaces shall be performed in accordance with the requirements of AS2865 Safe Working in a Confined Space and SWMS2 Safe Work Method Statement Confined Space Entry.

The Contractor's operatives including its employees and subcontractors and their operatives on site must be trained in confined space entry in accordance with the requirements of AS 2865.

Before commencing work on site, the Contractor shall fully assess the confined space entry requirements of the Works and provide QUU with current certificates for confined space training of all its personnel who will be undertaking confined space entry.

3.5 PERSONAL PROTECTIVE EQUIPMENT

The Contractor shall ensure all workers accessing live electrical equipment at voltages levels exceeding ELV shall comply with the minimum requirements of NFPA 70E:2015 or alternatively comply with WI58 Arc Flash Hazard Assessment and PPE Selection. Any departures from this work instruction or NFPA 70E:2015 shall only be permitted where accepted in writing by QUU. A risk assessment and supporting information shall be submitted with the request for any departures.

3.6 QUU'S SITE INDUCTION TRAINING

The Contractor shall attend a Site Induction Training course managed and arranged by QUU, prior to being granted site access by QUU. Arrangements for attendance at this training by the Contractor's operatives shall be coordinated though QUU.

Attendance at the Site Induction Training will require the Contractor's operatives to firstly provide evidence of certification in relation to Lock-out/Tag-out LOTO training.

QUU shall administer the Site Induction Training course at no cost to the Contractor, unless special training sessions are requested by the Contractor at short notice. The cost of attendance at the Site Induction Training by the Contractor's operatives shall be the responsibility of the Contractor.

3.6.1 Lock-out/Tag-out (LOTO)

PRO379 Energy Lock Out Tag Out Procedure applies to all QUU employees and contractors in QUU controlled workplaces. Contractors are to adhere to the requirements of this procedure unless a contract detailing control of a workplace has nominated a principal contractor other than QUU.

Contractor's operatives accessing live electrical equipment shall undergo Lock-out/ Tag-out (LOTO) training and satisfy the requirements of this training prior to obtaining access to QUU live electrical equipment. Evidence of satisfactory completion of the training shall be provided to QUU before undertaking the QUU's Site Induction Training.

3.7 WORKMANSHIP AND PERSONNEL

Personnel engaged in the construction of electrical installations shall be accredited, suitably experienced, competent and skilled in the particular field of work in which they are engaged. All works shall be completed by or under the direct supervision of fully qualified tradespeople holding trade qualifications and certificates adequate for the work and licensed under the Queensland Electricity Board regulations.

Persons employed on the work shall be directed by experienced qualified supervisors who shall be responsible for the works and for ensuring that the Contractor's personnel are conversant with and comply with QUU's Safety Rules and Regulations, particularly those rules controlling the use of work permits.

Welders shall be suitably qualified and accepted by QUU's Representative prior to commencing any welding works.

QUU's Representative reserves the right to inspect all works and direct re-work in the case that the works are not in compliance with the project specifications or commensurate with acceptable trade practice.

3.8 RECTIFICATION OF EXISTING INSTALLATIONS

The Contractor is responsible for ensuring that the electrical equipment and installation is electrically safe in accordance with AS3000 and the Queensland Electrical Safety Act.

The Contractor is responsible for safe installation of electrical equipment, circuits and installations within the Contractor’s scope of works.

If the Contractor discovers out of scope equipment, circuits or electrical installations that do not meet current standards, cannot be safely energised or are otherwise electrically unsafe the Contractor shall notify QUU, describe the issue in detail, propose a solution and seek direction from QUU.

Note that QUU expects Contractors to identify potential issues early, either during initial condition assessments or construction work. Late identification of defects that were capable of being identified earlier shall not be accepted as grounds for extension of time claims and costs.

3.9 WEATHER AND INGRESS PROTECTION

All electrical equipment shall be Ingress Protection (IP) rated as specified in the Project Documentation. All installation works shall be completed so as to ensure the ingress protection integrity of the equipment is maintained.

Equipment containing wiring or devices that are susceptible to damage or failure due to moisture or dust ingress shall be IP rated as follows unless otherwise specified:

- For outdoor installations - minimum IP56
- For indoor installations - minimum IP42

All outdoor equipment and installations shall be suitable for un-protected exposure to the weather, direct sunlight and hose-down cleaning. Where specified in the Project Documentation weather hoods and/or sun-shades shall be provided for UV and weather protection.

3.10 CONSTRUCTION DESIGN

Construction design shall capture the final element of design required to complete the electrical installation and shall be completed by the Contractor. All such design works shall complement and not contradict or modify the intent of the design as provided in the Project Documentation.

All construction design undertaken by the Contractor shall be approved by an RPEQ and shall be reviewed and accepted by QUU's Representative prior to the commencement of the installation works associated with the design.

The design shall provide a fit for purpose installation that ensures satisfactory operation of the equipment and facilitates future inspection, maintenance and repairs of equipment.

For instances where not specified in the Project Documentation, construction design includes but is not limited to the following:

- Final equipment mounting location;
- Final equipment mounting arrangements and brackets;
- Earthing and bonding of equipment, including earth tails and connections to structures, concrete reinforcement and earth grids where required.
- Cable ladder and conduit/pipe sizing;
- Cable ladder and conduit/pipe routing;
- Cable ladder/tray and cable/conduit support brackets;Above ground cable protection
- Cable glands and cable terminations
- Underground cable trench cross-sectional layout and dimensions;
- Underground cable trench routing (including the coordination of these works);
- Building penetrations and sealing;
- Junction box selection and sizing;
- Equipment stands and sunshades;
- Label types and fixing methods for cables and equipment.

Construction design shall comprise the provision of suitable sketches, schedules and descriptive information clearly identifying the information required for review.

3.11 USE OF CORRECT TOOLS

All equipment and tools to be utilised in the electrical installation works shall be safe, suitable for the task and in good working order. In all instances tools and equipment shall be selected to maximise safety of equipment and personnel during the execution of the works as well as providing a quality installation.

All tools and appliances furnished with installed equipment shall be maintained in good condition and handed over to QUU's Representative on completion of the works.

3.12 MOUNTING BRACKETS AND SUPPORTS

The Project Documentation will include standard bracket and support arrangements for the installation of electrical equipment. All brackets and supports to be procured or fabricated shall be in accordance with the materials and arrangements specified in these documents unless otherwise accepted by QUU's Representative. For any brackets and supports that are not defined in these documents, the Contractor shall design and submit a proposed arrangement to QUU's Representative for approval. No procurement, fabrication or installation shall be completed without the receipt of approval from QUU's Representative.

Brackets and supports to be fixed to the plant steel structure shall be either welded to the steelwork or bolted through holes punched or drilled in the steelwork. Unless specifically detailed in the Project Documentation, brackets and supports shall not be clamped.

All brackets and supports shall be fabricated from hot dipped galvanised steel angle, channel or tube unless otherwise specified in the Project Documentation. All welded, cut or drilled materials shall have the exposed metal cleaned and painted with zinc enriched cold galvanising paint to the satisfaction of QUU's Representative.

Site fabricated steel supports and brackets shall be properly fabricated and fitted. All drillings shall be made with minimum tolerances. All sharp edges shall be de-burred. Under no circumstances shall any welding or fixing operations be carried out on any process plant equipment, vessels, pipelines or structures unless specifically detailed in the Project Documentation. Fixings to the above shall normally be made with purpose designed brackets provided by the plant supplier.

All mounting plates shall have sufficient space for fitting of equipment nameplates.

Mounting brackets shall not be fixed to plant or steelwork that will be subject to excessive vibration during plant operation.

3.13 FASTENERS AND FIXINGS

All fasteners and fixings shall be zinc or cadmium plated for indoors and either hot dipped galvanised steel or 316 stainless steel for outdoors unless specified otherwise in the Project Documentation. For sewerage treatment plants, only 316 stainless steel shall be used for both indoors and outdoors.

Spring and flat washers shall be provided under all nuts and flat washers under bolt heads. Lock nuts are an acceptable alternative to nuts and spring washers. Washers shall be the correct size for the bolt. Each bolt or stud shall have the shortest standard length which shall expose at least one full thread beyond the nut after assembly. Bolts shall be driven home (inserted) a minimum distance of 1.25 x bolt diameter.

All bolts, nuts, and stud screw threads shall be ISO metric threaded.

Fixings into masonry shall be made using an accepted type of expansion bolt. Fixings into concrete shall be by means of an expansion bolts or anchors suitable for the purpose.

Plastic or metal fibre expansion plugs shall only be used for light duty fixings in office buildings in line with quality commercial installation practices. Nylon mushroom anchors are not permitted in outdoor areas.

Fixings into timber or metal shall be made using zinc or cadmium plated screws driven into drilled holes sized to suit the screw.

Equipment shall generally be secured by the following methods and materials:

- Expanding masonry bolts;
- Grouted holding down bolts;
- Chemical anchors;
- Welded to structural steel;
- Bolted through holes drilled/punched in structural steelwork

3.14 CUTTING, DRILLING AND WELDING

All surfaces altered via cutting, drilling or chasing shall be restored to the original finish after completion of the works. The structural integrity of concrete, steel and timber structures shall be maintained and ensure no cross contamination of dissimilar metals.

Where possible holes shall be drilled, not cut with a flame, and drilling shall be made with minimum tolerances.

All sharp edges shall be de-burred.

Structural steelwork shall not be cut, drilled or welded without approval from QUU's Representative, except as detailed in the Project Documentation.

Pre-cast concrete slabs shall not be cut or drilled without approval from QUU's Representative, except as detailed in the Project Documentation. Exposed reinforcement structural steel in concrete slabs shall be sealed with an accepted rust prevention coating system.

All welds shall comply with the appropriate welding code and shall be primed and painted on completion. All stainless steel welds shall be pacified to prevent corrosion.

Penetrations for the purpose of cables, conduits or cable ladder entries shall be installed using proprietary and purpose made jigsaws and drills. Penetrations shall be fitted with kick plates and/or flashings to provide a neat finish.

3.15 SEALING PENETRATIONS AND CONDUITS

All building penetrations shall be sealed after completion of the installation to:

- Match surface finishes;
- Maintain Ingress Protection rating (as required);
- Prevent vermin entry;
- Maintain fire rating (as required) with an accepted fire sealant compound;
- Comply with the requirements of hazardous area classifications (as required).
- Meet National Construction Code Regulations

Expanding foam type fillers and silicone sealants shall not be used seal penetrations. Sealants shall be a non-deteriorating, non-setting weatherproof sealant capable of being removed at a later date for future cable installation. Cloth rags, cement grout or other alternative methods accepted to QUU can be accepted.

Concrete floor penetrations shall be sealed with non-shrink grout in accordance with the Supplier's recommendations.

After the installation of cables all buried cable conduits exiting the ground shall be sealed to prevent the ingress of water or oil. A waterproof seal shall be provided by the application of a permanently plastic waterproof compound. All spare conduits shall be similarly sealed. The sealing compound shall be capable of being removed to enable additional cables to be installed if required at a later date.

After the installation of cables all outdoor surface conduits shall have both ends sealed using heat shrink tubing or a suitable sealing compound as accepted by QUU's Representative.

All penetrations in areas with a hazardous area classification shall be in accordance with the TMS1203 General Requirements Hazardous Area Installation Specification and accepted by QUU's Representative and shall be suitably certified as required and in accordance with the manufacturer's specifications.

3.16 SETTING OUT WORKS

The Project Documentation will include installation locations for electrical equipment. For instances where the exact location is not clearly defined in the Project Documentation the Contractor shall site assess the area to confirm the best location.

Following this assessment the Contractor shall submit a proposed exact installation location to QUU's Representative for approval.

Installation locations shall take into consideration the following:

- Relevant regulations, codes and standards;
- Accessibility of equipment for routine inspection and maintenance tasks;
- Safe access for personnel;
- Clashes with other services, plant and structures;
- Suitability for equipment to perform intended function;
- Appearance;
- Not to impede walkways and access to equipment;
- Not to impede maintenance works on nearby plant;
- Not to expose equipment to higher than normal risk of damage (vibration, material spillage, wet areas, chemical lines etc);
- Electrical clearances
- Induced voltages
- Hazardous areas
- Thermal loads and ventilation
- The design intent of the Project Documentation.

3.17 ERECTION

All electrical equipment shall be installed strictly in accordance with the Supplier's instructions and the relevant Project Documentation. Where such instructions are not available, details of the proposed installation method shall be accepted by QUU's Representative prior to commencement of the work.

Plant of significant weight or size shall be installed by suitably qualified personnel utilising specialised plant (cranes etc). For all such installations a customised lifting study shall be completed by the Contractor and accepted by QUU's Representative prior to commencement of the works.

3.18 FOUNDATIONS AND CONCRETE STRUCTURES

All concrete foundations and structures shall be installed in accordance with the relevant Project Documentation.

The Contractor shall ensure that any items to be cast into the concrete (i.e. rag bolts, conduits, earthing connections etc) are correctly positioned for alignment prior to pouring of concrete. All items to be cast into the concrete shall be adequately fixed to the reinforcement steel or formwork to ensure they are not disturbed during the concrete pour. Any items to be cast into the concrete that have critical tolerances (<±50mm) shall be surveyed prior to the concrete pour. Appropriate expansion joints in concrete slabs shall be provided using Ableflex where required or as directed by QUU.

Where required, earthing or lightning protection bonds to reinforcement steel shall be completed in accordance with the relevant Project Documentation and Section 7 of this specification.

The Contractor shall be responsible for coordinating all such works with other related parties to ensure all necessary works are completed in preparation for the concrete pours.

The Contractor shall ensure that all quality assurance checks, ITP checksheets and witness points associated with the works are completed prior to the concrete pours.

3.19 COATINGS

3.19.1 Painting

Electrical equipment to be painted shall be as specified in the Project Documentation.

The surface protection and painting shall be in accordance with the SSM006 Standard Specification - Steel Protective Coating Systems.

Where an alternative painting system is proposed, the following details shall be provided:

- The surface preparation, paint process, paint type and thickness;
- A description of how the alternative paint system is equal to or superior to the specified requirements.

The Contractor's proposed surface protection treatment will be evaluated by QUU for acceptability, provided the above details are provided.

3.19.2 Hot Dipped Galvanising

Steel items to be galvanised shall be as specified in the project documentation.

Hot dipped galvanising shall be in accordance with the SSM006 Standard Specification - Steel Protective Coating Systems.

Minor damage to galvanised materials shall be made good by touch-up using zinc enriched cold galvanising paint. Pre-drilled hole sizes shall allow for the zinc coating thickness.

3.20 CARE AND MAINTENANCE

The Contractor shall ensure that all personnel within their control are fully aware of and comply with the requirements for good housekeeping on the site.

For all electrical installation activities safe house-keeping procedures shall be utilised for managing the necessary tools, equipment and accumulated rubbish so as to ensure a safe working environment for all personnel executing and in the vicinity of the works.

Switchrooms and similar areas shall be kept free of cut cable ends, cable strippings and other accumulation of rubbish. Rubbish in these areas shall be collected and disposed of in accordance with the accepted site procedure on a daily basis. Materials and equipment required for immediate use only shall be stored within these particular areas.

All flammable debris shall be removed prior to working with naked flame tools, welding, cutting or grinding equipment. Equipment shall be protected from damage by grinding, drilling, swarf, grit blasting etc. Where flame cutting or welding is being undertaken fire blankets shall be used to protect all electrical equipment and materials. Cable gland plates provided with equipment shall not be drilled in-situ, but shall be removed to preclude the risk of drilling debris entering the associated equipment.

Particular attention is drawn to the need for care when cutting and removing the armouring on braided cables within switchgear enclosures.

All equipment not being actively worked on shall have all doors closed and all covers and gland plates firmly in position to prevent rubbish, dust and moisture entering the equipment.

Tools and loose items shall not be left or stored inside equipment or switchboard cubicles.

After completion of the terminations to any panel or item of equipment, such equipment shall be thoroughly cleaned out using suction cleaners and all dust and rubbish removed. The equipment shall be inspected for internal moisture and adequately dried-out prior to energisation. All HV equipment and insulators shall be wiped down with a lint free cloth to remove dust.

Prior to the removal of access equipment (scaffolding, EWPs and the like) from site all elevated cable pathways shall be inspected to ensure all cable pulling equipment and debris is removed, cable covers are properly installed and equipotential earths applied.

3.21 TEMPORARY POWER INSTALLATIONS

Power distribution systems installed for the express purpose of providing temporary power for construction works shall be subject to the same standards of workmanship and specification requirements as permanent installations except where otherwise allowed for in the Contract or authorised by QUU's Representative . In all instances the works shall be completed in accordance with the relevant codes, standards and regulations.

3.22 ELECTROLYTIC CORROSION

For all electrical installations suitable measures as accepted by QUU's Representative shall be adopted to minimise the effects of electrolytic corrosion such as:-

- Use of stand-off washers when mounting equipment of dissimilar metals onto structure.
- Coatings of proprietary compounds, specially manufactured for the purpose, when mounting equipment of dissimilar metals onto structure.
- Use of bi-metallic lugs for the termination of conductors of dissimilar material onto switchgear or similar.
- Segregation of dissimilar metals during lay-down and storage.

All site works undertaken shall ensure the integrity of the Cathodic Protection system where installed is not compromised.

3.23 ENVIRONMENTAL OBLIGATIONS

All works shall be in accordance with the Contractor's accepted Construction Environmental Management Plan (CEMP).

The Contractor shall develop a CEMP in accordance with the objectives and requirements of the project environmental conditions of approval.

The Contractor's CEMP shall provide detailed information on how the Contractor will manage the site works to ensure that they are undertaken in an environmentally responsible manner, in accordance with all regulatory/project specific environmental requirements. Environmental controls should be specified for issues such as the management of soils; trenching and backfilling; erosion and sedimentation; watercourse crossings; and waste management.

In addition, the requirements of relevant accepted environmental plans shall be considered by the Contractor when developing their CEMP, including (but not limited to):

- The Soil Management Plan
- The Remediation, Rehabilitation, Recovery and Monitoring Plan

4 MATERIALS AND EQUIPMENT

4.1 SUPPLY

QUU shall supply the equipment and materials defined in the Project Documentation as being supplied by QUU.

The Contractor shall supply all other materials and equipment necessary to make a complete and fully functional installation in accordance with the Project Documentation. It shall be the Contractor's responsibility to define all Contractor supplied materials and equipment and to ensure the timely ordering and delivery of such to site so as to not impact on the construction schedule.

All Contractor supplied materials and equipment shall be of manufacturer, type and model as specified in the Project Documentation. For all non-specified equipment the TMS62 Preferred Equipment List – Electrical shall nominate the preferred suppliers and/or equipment. The Contractor shall not deviate from these requirements without prior written approval from QUU's Representative. Where the materials are not specified the Contractor may offer standard materials suitable for the application, environment and operating/design conditions. Non-specified equipment shall be of the same type, grade and quality as similar items specified in the Project Documentation. Corresponding parts of similar equipment shall where possible be interchangeable.

All materials and equipment shall be of standard manufacture and readily available from suppliers unless specified otherwise in the Project Documentation. All equipment supplied shall be sourced from local OEM (Original Equipment Manufacturer) Authorised Distributors within Australia.

The selected equipment shall be suitably rated for the application with particular attention given to the following:

- Power rating
- Voltage rating
- Frequency rating
- Duty rating
- IP rating
- Hazardous Area certification

All materials shall be new and comply with the relevant specifications, regulations, codes and standards.

All materials shall be free from:

- Asbestos (all types)
- Ceramic fibre
- Chlorofluorocarbons
- Polychlorobiphenyls (PCB) and their isomers
- Radioactive materials(unless specified otherwise in Project Documentation)
- Mercury

Dangerous goods shall be labelled and identified in accordance with the project requirements. All hazardous materials shall be supplied with a material safety data sheet (MSDS).

4.2 IMPACT RECORDERS

Impact recorders (if fitted) to equipment for transport shall be inspected and results recorded by QUU's Representative at the following instances:

- On delivery to site, but before unloading
- Immediately after unloading
- Immediately after installation into the final installed position

Impact recorders (if fitted) shall not be removed by the Contractor until authorised to do so by QUU's Representative.

4.3 HANDLING AND STORAGE

All materials shall be stored, handled and preserved in accordance with the relevant Project Documentation.

The Project Documentation will define all material and equipment to be received and stored by the Contractor. All such equipment shall be immediately inspected by the Contractor upon receipt for damage sustained during transit. Any damage shall be notified in writing to QUU's Representative and suitable action agreed with QUU's Representative to minimise any work schedule delays.

The Contractor shall be responsible for the safety, security and preservation of all equipment and materials received for the duration of the Contract. All such equipment and materials shall be stored in a suitable location and environment in accordance with the supplier's recommendations to prevent any damage, deterioration or corrosion prior to installation. As a minimum the following shall be provided for storage locations of electrical equipment:

- Lockable fenced all weather compound;
- Adequate lighting for security and safe access;
- All weather hardstand surface;
- Suitable all weather vehicle access.

Storage locations for electrical equipment that are susceptible to deterioration from the outdoor environment shall further comply with the following:

- shaded, dry, weather protected area;
- ambient temperatures within the range of 5°C to 45°C ;
- humidity not more than 95%.

Storage locations for electrical equipment designed for indoor installation shall further comply with the following:

- air conditioned , temperature controlled;
- dust free;
- for batteries, ambient temperatures within the range of 15°C to 25°C

Storage facilities shall have provision for the safe handling and storage of potentially hazardous materials in accordance with the project safety and environmental requirements.

Any equipment broken or damaged during storage by the Contractor shall be immediately brought to the attention of QUU's Representative to advise suitable action to minimise any potential impact on the construction schedule.

The Contractor shall be responsible for continuous monitoring and reporting of all equipment and materials stored by the Contractor. Adequate levels of Contractor supplied materials shall

be maintained at all times to ensure that the installation schedule is not delayed due to material shortages. Similarly, the Contractor shall advise QUU's Representative of any possible future shortages in QUU supplied materials to ensure replacement stocks can be ordered and delivered without impacting on the installation schedule.

4.4 EQUIPMENT PRESERVATION, PROTECTION AND LUBRICATION

The Contractor shall be responsible for temporary supplies to anti-condensation heaters for motors, alternators, switchgear and the like for any such equipment to be stored by the Contractor. The Contractor shall also provide temporary supplies to these heaters once the equipment has been installed prior to the facility being handed over to QUU. Care shall be taken to ensure that the supplies are of the correct voltage and to ensure that adequate warning signage is provided to AS3000.

The Contractor shall ensure that all equipment and materials (i.e. motors, cable glands, circuit breaker carriages, etc.) are correctly and adequately lubricated and maintained, in accordance with the supplier's instructions while in storage and after installation. Equipment shall be maintained and protected such that hinges, locks, etc., are fully operable at all times. Where required motor shaft rotations shall be also be completed as per the supplier recommendations.

Temporary power supplies shall be provided to switchrooms once they have been installed in their permanent location. These temporary supplies shall ensure that the air-conditioners are operational to pressurise the rooms and minimise the dust ingress once the transportation dust seals are removed to enable the installation works to be completed. These temporary supplies shall also provide switchroom lighting and power for the installation works.

Equipment for installation in exposed external areas shall be protected until handed over to QUU. During installation temporary provisions shall be made to protect equipment from any damage, or deterioration, which may be caused by exposure to the environment. Additional temporary protection shall be provided when necessary to guard against adverse conditions which may arise.

Equipment for installation in enclosed areas shall not be exposed to the external environment at any time after unpacking. If necessary, during installation temporary air-conditioning shall be erected in accordance with supplier's preservation requirements.

Adequate protection shall be provided for installed equipment to prevent damage from work in progress in the same or adjacent areas. All covers, caps, weather protection, etc., shall be replaced at the end of each working day.

Extreme care shall be exercised in the protection of equipment against mechanical damage during the course of erection.

Delicate instruments, protective gear and items of porcelain, glass and other material which can be easily fragmented, shall be protected by temporary wooden frames or covers until all risk of damage is removed.

All equipment is to be protected against the ingress of moisture, dust, dirt and foreign bodies during installation.

Care shall be taken to protect finished, painted surfaces.

4.5 SURPLUS AND SCRAP MATERIALS

Any surplus materials shall remain the property of QUU and throughout the works shall be collated, sorted and delivered to the locations as advised by QUU's Representative.

Any scrap materials shall remain the property of QUU unless advised otherwise in the Project Documentation. All scrap materials shall be handled in accordance with the project procedures or as agreed with QUU's Representative.

All waste materials shall be disposed of in accordance with the Contractor's accepted CEMP.

4.6 HAZARDOUS AREAS

Refer to TMS1203 General Requirements Hazardous Area Installation Specification.

5 EQUIPMENT INSTALLATION AND DECOMMISIONING

5.1 GENERAL

All materials and installation arrangements shall be in accordance with the standard installation documentation unless otherwise accepted by QUU's Representative. For any equipment or installations that have not been defined in these documents, the Contractor shall design and submit a proposed arrangement (as per section 3.10) to QUU's Representative for approval. No procurement, fabrication or installation shall commence without the receipt of approval from QUU's Representative.

The Contractor shall ensure that the supplier's installation recommendations are available and reviewed prior to the commencement of any installation works. All supplier installation recommendations shall be strictly followed. Any conflict between the standard installation documentation and the supplier's recommendations shall be brought to the attention of QUU's Representative for resolution. Unless otherwise specified in the Project Documentation, all brackets and fixings provided by the supplier shall be utilised.

All equipment shall be levelled, squared with building lines and adjusted for operation. Anchors, gaskets, spacers, nuts, bolts, washers, shims, packers and all other similar materials shall be used as required.

A sufficient number of brackets, supports and fixings shall be provided to solidly mount or fix the equipment without imposing excessive strain on the equipment or structure.

All equipment with cable entries shall be arranged so that cabling is bottom entry unless otherwise specified in the Project Documentation.

5.2 SWITCHROOMS AND PRE- FABRICATED BUILDINGS

Pre-fabricated Switchrooms complete with pre-installed switchgear, distribution boards, VSD’s, UPS, FIP, battery chargers, PLC panels, communications equipment, lighting, power outlets and ancillary equipment will be supplied by QUU unless stated otherwise in the Project documentation.

Switchrooms will be supplied complete with split system HVAC units. Switchroom support structures will be supplied separate to the switch room by QUU (via switchroom supplier) unless stated otherwise in the Project documentation.

The Contractor shall install all items required to complete the installation of the Switchrooms in accordance with the Supplier's instructions, Project Documentation and site requirements.

The switchroom footings shall be located as per the accepted site set-out drawings. These footings and the stair landings shall comply with the site civil standards for earthworks and concrete works and shall be in accordance with the specific switchroom footing design drawings. The top of the switchroom footings shall be scabbled prior to the installation of the steel switch room supports.

The galvanised steel switch room supports supplied by the switch room vendor shall be installed square and level in accordance with the installation and set-out instructions as detailed in the supplier's drawings. These switchroom supports shall be fixed onto the concrete footings as detailed in these drawings. Levelling nuts shall be installed under the switchroom supports to assist in levelling the footings where required. It may be necessary to provide temporary bracing of the switch room supports to stabilise the structure during erection.

Prior to lifting each switchroom into position a detailed lifting study shall be completed and submitted to QUU's Representative for approval.

No drilling or modifications shall be permitted to the switchroom support structures unless accepted by QUU's Representative. All structural supports, bracing, cable ladder support brackets, bolts and fixings shall be installed as detailed in the Supplier's drawings.

Any damage sustained to either the galvanised finish or powder coat finish of the switch rooms or associated supports during installation shall be repaired in accordance with the site accepted procedure.

Transport bracing and packaging shall not be removed until the Switchrooms are in final position. Once in position the bracing/packaging shall be removed and the switchroom shall be checked for visible damage sustained during transit, any such findings shall be reported to QUU's Representative immediately.

The switchroom stairs, landings and handrails shall be installed in accordance with the supplier's drawings. The galvanised steel switch room supports shall be non-shrink grouted after installation of each switch room.

On-site the Switchrooms shall remain closed and locked with the transport dust seals in place to prevent the ingress of dust into the switch rooms.

Temporary protective floor coverings in Switchrooms shall not be removed until the switchroom has been commissioned. Upon completion of the switchroom commissioning the temporary floor covers shall be removed and disposed of by the Contractor.

Cable entry drop down boxes shall be installed to the underside of the Switchrooms where required to facilitate the installation of bottom entry cabling. The installation shall be in accordance with Suppliers instructions using the fixings and fasteners defined in the instructions. Suitable gaskets and sealing materials shall be installed to provide the necessary IP rating.

Penetrations for cable and other services access ways to new LV switchrooms and all HV Switchrooms (new and existing) shall be fire rated FRL 120/120/120. The penetrations shall be designed under the supervision of an RPEQ Fire Systems Engineer and the final installation of the penetrations and method of fire sealing shall be certified by a fire system engineer. Penetrations to HV switchrooms shall comply with relevant clauses of AS2067.

5.3 SWITCHROOM AIR CONDITIONING COMPRESSORS

Where required the switchroom air conditioning compressor concrete pads shall be located as per the accepted site set-out drawings. These pads shall comply with the site civil standards for earthworks and concrete works and shall be in accordance with the specific compressor pad design drawings. Concrete pads shall not be rigidly connected to the switchroom structure by cable or pipework supports, so as to allow for differential movement of the pad and structure.

The outdoor compressor units shall be installed and fixed into position on rubber feet and as per the supplier's recommendation. The units shall be orientated to ensure the fans/vents are clear of obstruction and to ensure suitable access for maintenance work (i.e. removal of filters etc.). The installation shall comply with the minimum clearances as per the Supplier's recommendations.

The refrigerant pipework shall be installed by a qualified air conditioning fitter. All refrigerant pipework shall be adequately supported and braced and installed clear of ground level. The refrigerant pipework shall be insulated as per industry best practice.

Each outdoor compressor shall be equipped with a local isolator suitably rated for the application.

Provide slack in connecting cables and pipework to allow for differential movement of the switchroom structure and air conditioning compressor unit.

Each outdoor compressor shall be charged on site with refrigerant gas regardless of whether or not the units have been pre-charged prior to site delivery.

5.4 SWITCHGEAR AND SWITCHBOARDS

Switchboards shall be erected and assembled strictly in accordance with the Project Documentation and the supplier's installation instructions.

Switchboards supplied in a number of shipping sections shall be carefully aligned and joined together at all points from which the bolts have been removed. Busbar joints shall be fitted to phase, neutral and earth busbars. Bolts used to make joints in the busbars shall be torqued to the supplier's recommendations and marked with a cross with a waterproof marker pen. Busbar joints shall be "Ductor" tested and results recorded as part of the pre-commissioning checks. Control wiring across shipping splits shall be re-terminated and point-to-point tested.

Each switchboard shall be positioned correctly in accordance with the Project Documentation and aligned with the cable entry plinth/drop-down boxes and checked to confirm the level is within the Supplier's tolerances. Where required, shims and packers shall be installed to level the switchboard to provide a square finish and avoid distortion of the frame. Switchboards shall be fixed to the floor using an appropriate anchoring system suitable for the floor surface. After installation a check shall be completed to ensure that all hinged components open freely, that all removable panels fit correctly and that withdrawable switchgear runs freely into position without scraping or damaging the switchroom floor surface.

All switchboards and switchgear shall be thoroughly cleaned of dust and contaminants prior to energisation.

5.4.1 Pre-fabricated Switchroom Installation

Pre-fabricated Switchrooms shall be supplied complete with pre-installed switchboards, switchgear and MCCs. All switchgear not pre-installed or removed for transport shall be installed on site by the Contractor.

5.4.2 Site Installation

Where switchboards are to be installed on concrete plinths, at the completion of installation the switchboard base shall be grouted using a grout and procedures accepted by QUU's Representative.

5.4.3 Consumer Mains and Metering

As part of the switchboard changeover strategy the Contractor shall make all necessary arrangements with the relevant Supply Authority for the power supply connection to the new switchboards. This includes the acquisition and installation of metering equipment, CT's, test block, fuses, electrical testing prior to energisation and certification, etc, as detailed on the drawings and/or as required by the Supply Authority.

The Contractor shall acquire and install CT's (and other metering equipment as may be required by the Supply Authority) on sites with this requirement from the relevant Supply Authority before switchboard manufacture.

The Contractor shall be responsible for submitting the "*Electrical Work Request – Request for Initial Connection, Metering Change or Service Alteration"* (Form 2) with the relevant Supply Authority.

Prior to completing and submitting this form, the Contractor shall consult with QUU Representative to verify the name of the relevant retailer for each site, together with any other information for each site that the QUU may have available (such as NMI details, name of the QUU's Authorised Person, etc). Within 24 hours of submitting the Form 2 for each site to the relevant Supply Authority, the Contractor shall also forward a copy of the completed and signed form to the QUU Representative.

5.4.4 Switchboard Changeover

The Contractor is required to submit an individual switchboard Changeover Commissioning Plan for each site for the approval of QUU. The plan shall include input and constraints advised by QUU stakeholders. The QUU approval to each Changeover Commissioning Plan is required before Site Acceptance Testing for that site can commence.

The Contractor shall submit, for each site, a draft version of the switchboard Changeover Commissioning Plan at least ten (10) working days prior to the commencement date for Site Acceptance Testing. *TMS78 Sample Typical Changeover Commissioning Plan* informs the Contractor as to the minimum standards for the switchboard Changeover Commissioning Plan documentation.

Site telemetry if installed must be maintained at all times when the site is unmanned. An independent battery backed, audible and visual alarm must be maintained onsite at all times during the switchboard changeover. The switchboard changeover Commissioning Plan must document all stages of the changeover process including use of the temporary pumping system.

Refer Section 5.13 regarding requirements for decommissioning and disposal of switchboards.

5.5 FLOOR AND WALL MOUNTED PANELS AND EQUIPMENT

Miscellaneous floor mounted equipment such as control panels, VSDs, cabinets, battery chargers and UPSs shall be positioned in accordance with the layout drawing and fixed to the floor with the appropriate fixings. Space for air circulation shall be allowed according to the supplier's instructions.

A minimum of 600mm shall be allowed between adjacent units on sides which have removable panels for maintenance access. Clearance between the unit being installed and any equipment on the opposite side of the access way shall be a minimum of 600mm with the doors of equipment on both sides of the access way being open.

Wall mounted equipment shall be mounted on "Unistrut" channel (or equivalent) using spring type nut fastenings. For brick or block work walls the Unistrut shall be fastened to the wall using the appropriate fixings. For tilt-up, pre-fabricated concrete panel walls, equipment shall be mounted on stands bolted to the floor or brackets fixed to structural steel. Holes shall not be drilled in tilt-up panels without approval from QUU's Representative. Cable access to the wall mounted equipment shall be provided by installing cable ladder or cable tray.

5.6 DISTRIBUTION BOARDS AND CONTROL PANELS

Where these boards/panels are floor mounted they shall be installed as per installation of switchboards. Where they are wall mounted they shall be firmly bolted into position using Unistrut channel (or equivalent) such that the top of the board/panel is approximately 2m above floor level unless otherwise specified. The top of adjacent wall mounted units shall be aligned.

All external mounted boards/panels shall be fitted with a rain shedding solar protection cover to provide all seasons shielding.

Cable entry to all external boards/panels shall be from the bottom only, unless otherwise accepted in writing by QUU's Representative.

5.7 TRANSFORMER COMPOUNDS

The transformer compounds shall be located as per the site set-out drawings. These compounds and associated plinths and footings shall comply with the site civil standards for earthworks and concrete works and shall be in accordance with the specific transformer compound design drawings.

Transformer compounds shall have 2 hour fire rated fire walls as detailed in the Project Documentation. All cable penetrations within the fire walls are to be cast in-situ, no drilling or cutting penetrations in these fire walls shall be permitted. The Contractor shall be responsible for the coordination of the necessary electrical services penetrations in any pre-cast fire walls. All penetrations through the fire walls shall be fire rated upon completion of the works.

5.8 POWER TRANSFORMERS

Transformers shall be erected on prepared foundations in accordance with the Supplier's instructions. Each transformer shall be set level and the installation wheels removed (if provided).

Sealed transformers which have been filled with oil, sealed and pressurised shall not be opened in any manner that would enable the pressurising gas or oil to escape.

Non-sealed type transformers delivered filled with oil shall have any accumulated sludge drained from the bottom of the tank and a clean sample taken for testing.

Any transformers delivered to site filled with nitrogen shall be handled and prepared for energisation strictly in accordance with the suppliers recommendations.

For transformers that are to be oil filled on site the oil shall be filtered and filled under vacuum utilising the appropriate purpose designed vacuum/filtering equipment. All such operations shall be completed in strict accordance with the manufacturer's recommendations.

All oil coolers, conservators and oil pipes transported loose shall be flushed with clean oil until all scale and foreign matter is removed. The components shall be tested for oil leaks where possible and then assembled. Any component discovered to be leaking shall be reported to QUU's Representative. Any other auxiliary equipment removed for transport shall be fitted in accordance with the Supplier's instructions.

The Contractor shall supply the oil for flushing and final filling. Immediately following flushing, the assembled transformer shall be filled with oil as necessary. Oil shall not be introduced until it has been accepted by QUU's Representative and tests have been witnessed to confirm adequate dielectric strength and water content.

Moisture content of new oil delivered separately shall not exceed 10 ppm. Moisture content of oil delivered within oil filled transformers shall not exceed 20 ppm. Oils and transformers with excessive moisture content shall be processed (dried) on site until achieving acceptable moisture content.

Dehydrating (silica gel) breathers shall be fitted (if removed for shipping) and oil added to the bowl of the breather. The silica gel shall be checked for moisture and dried out if contaminated with moisture

The Contractor shall check phasing before connections are made.

Prior to lifting each transformer into position a lifting study shall be completed and submitted to QUU's Representative for approval. The exact location and orientation of each transformer shall be as detailed in the relevant transformer drawings. The transformers shall be fixed into position onto the concrete plinths using suitable sized anchors.

Transport bracing and packaging shall not be removed until the transformers are in final position. Once installed in position the bracing/packaging shall be removed and each transformer shall be checked for visible damage or leaks and any such findings shall be reported to QUU's Representative immediately.

The cable termination boxes shall be sealed at all times to prevent the ingress of dust into the boxes prior to the installation of the cables.

Prior to energisation, transformers shall be checked and valves opened/closed as recommended by the supplier. The final checks shall include checking for oil leaks and confirming the dielectric strength, moisture content and dissolved gasses in the oil. All types of transformer oil sample testing shall be undertaken by test laboratories nominated by QUU. Final moisture content of filled transformer oil shall not exceed 20 ppm.

5.9 MOTORS AND GENERATORS

The installation of rotating machinery, including lining up and final fixing to foundations, is not covered by this specification and is deemed to be a mechanical function.

Before connecting the supply to any motor an insulation test shall be completed to ensure the insulation resistance level is in accordance with the applicable standards and the supplier’s data. Should any motor be identified to have a low insulation resistance reading a motor test report shall be generated and issued to QUU as well as a procedure to dry-out and re-test the motor must be agreed with QUU.

Care shall be exercised when insulation testing motors fitted with thermistors, RTDs or thermocouple over-temperature protection devices. The insulation testing shall be undertaken so as to prevent any damage to these devices.

The Contractor shall ensure that the correct phase connections for the desired motor rotation direction are made during final connection.

Large motors and generators may require barring at periodic intervals, and supplier's instruction shall be followed in this regard.

The installation shall allow for removal of motors, generators and associated equipment with minimal disturbance to cables, associated electrical equipment and supporting steelwork.

5.10 UPS, BATTERIES AND CHARGERS

UPS, batteries and battery chargers shall be installed in accordance with the drawings and the supplier's instructions.

All links and connections shall be checked for tightness.

All terminals and connections shall be protected with a liberal greasing of a lubricant such as petroleum jelly or to supplier's recommendations.

Cable polarity between batteries and respective chargers shall be checked before connection.

Battery chargers, other than those fitted within equipment, shall be positioned to ensure a free flow of cooling air and that the ventilation entries/exits are clear of obstructions. A free clear space of 150mm is required from sides containing vents. Mechanical and natural ventilation shall be made ready before battery charging begins.

5.11 LOCAL CONTROL PANELS

LCPs shall be manufactured in accordance with TMS60 LV Switchboards and Enclosures Technical Specification. All external mounted LCPs shall be fitted with a rain shedding solar protection cover to provide all-season shielding.

Typically, the positioning and mounting arrangements of local motor control equipment shall be as defined in the Project Documentation. For instances where the location is not defined it shall be installed in a position agreed with QUU's Representative to provide a clear view of the driven machinery for reasons of safety, accessibility and practicality. Local pushbutton stations, local isolators, etc. shall be mounted as close as practicable to the driven items. In all cases, the motor shall be visible from the LCP.

LCPs shall not be installed within confined spaces.

Cable entry to LCPs shall be from the bottom only.

A nameplate shall be installed on each station with the Drive Name and Equipment Number engraved as detailed in the Project Documentation. Labels and nameplates shall be fixed with stainless steel screws to the LCP.

The LCP for groups of drives may be located on a common stand in a central location with labelling clearly identifying each LCP.

Where pedestal mountings are required, the support column shall be manufactured from 100 x 40 mm channel and have a 250 x 250 mm base plate with four mounting holes. The height of the pedestal mounting shall be such that the base of the panel is approximately 1200 mm above finished floor level. The pedestal mounting shall be hot dipped galvanised. The base plate shall be raised by 50 mm and the void filled with non-shrinkable grout.

For hazardous areas the LCS equipment and installation configuration shall be in accordance with TMS1203 General Requirements Hazardous Area Installation Specification.

5.12 FIELD JUNCTION BOXES

The larger field junction boxes shall comply with the following requirements:

- be of an accepted design, fabricated from grade 316 stainless steel or aluminium
- IP65 enclosure rating;
- vermin proof
- be equipped with an aluminium or brass minimum 3mm thick gland plate, earth stud, label, terminal rail, terminals, ducting and all other equipment in accordance with the Project Documentation;

- be equipped with door latches of the recessed quarter turn type with standard 7mm, slotted, square operating mechanism. Each junction box shall be equipped with two tools for opening the door latch;
- be mounted on brackets fixed to the steel work or on a suitable stand manufactured by the Contractor;
- be fitted with vertical terminal strips of sufficient length to accommodate the termination of all cable cores with 20% spare unused DIN rail space ;
- component assembly and fit-out works shall be in general accordance with the TMS60 Technical Specification for LV Switchboards and Enclosures.

Junction boxes for through connections to small field equipment, equipment provided with permanent wiring, general purpose power and lighting circuits shall be weatherproof, minimum IP65 rated, impact, corrosion and UV resistant glass reinforced polyester compound (CCG range or equivalent) . They shall be equipped with accepted DIN rail mounted terminal strips and bottom cable entry only.

Junction boxes located outdoors shall be SS316 and IP65 enclosures. Indoor junction boxes that are not subject to harsh environments and not in the vicinity of potential high AC or DC fault currents may be fibre reinforced plastic.

Harsh environments include any one or combination of the following conditions:-

- Corrosive
- High temperature
- Low temperature
- High humidity
- Dusty
- High vibration

The terminal blocks shall be mounted on DIN rail. Interconnection of several terminals shall be made by means of terminal links. Partition plates shall be installed between adjoining bridged terminals.

End plates shall be provided at the end of each terminal block.

If earthing connections are required, these shall be via earthing terminals or an earthing bar. Junction boxes shall be equipped with an adequate number of cable glands and plugs for unused cable gland openings. Junction boxes shall be fitted with a stainless steel name plate engraved with the junction box tag number.

When fibre reinforced plastic terminal boxes are used and in the case of large metal glands, internal metal plates shall be used to reinforce the terminal box wall. These metal plates shall be connected to the earthing terminals.

Smaller metal glands that do not require reinforcing plates shall likewise be connected to earthing terminals.

5.12.1 Field Junction Boxes for Hazardous Areas

For hazardous areas, field junction box equipment and installation configuration shall be in accordance with TMS1203 General Requirements Hazardous Area Installation Specification.

Junction boxes for hazardous areas shall not be modified. Drilling or screwing (other than for hazardous area rated cable glands) into hazardous area junction boxes is not permitted.

Ex'de' type terminal blocks shall be used where the junction boxes are located in HAs.

5.13 DECOMMISSIONING OF EQUIPMENT AND CABLES

Switchboards, including all equipment contained within the switchboards, shall remain the property of QUU and shall be locked, packaged, labelled, loaded and removed from site, and delivered to and unloaded at a location indicated in the Project Documentation.

The Contractor shall ensure that any Cathodic Protection wiring which exists within the wet well shall remain in-situ during the switchboard changeover and removal of the existing switchboard.

The Contractor shall be responsible for the safe and effective removal and off-site disposal of all decommissioned cables and conduits, waste plant and/or equipment in accordance with all current legislation and local, regional and state/national statutory requirements.

Decommissioned cables shall be completely removed (unless specifically determined otherwise by QUU in project documentation). Decommissioned cables, or parts of cable, shall not be left buried, on cable ladder, on cable trays or in conduits and pits. Conduits and pits shall be retained, unless specified otherwise in project documentation. Draw wires shall be pulled into empty conduits and pits in accordance with section 6.10.3. Conduits shall be sealed as per section 6.10.3. In special cases and as determined by QUU, certain decommissioned cables may be left in situ. In such cases cables shall be disconnected, cut off below ground level and tagged at both ends with a stainless steel engraved tag stating the cable number and text “CABLE DECOMMISSIONED”. Decommissioned cables left in situ shall be identified on as built cable route drawings and cable schedules.

6 CABLES

6.1 GENERAL

The Project Documentation cable schedules and/or drawings shall define the exact cable type to be installed for each application.

Generally all LV power cables shall be circular, 0.6/1 kV, copper conductor, PVC sheathed, PVC insulated, V90 type cables manufactured in accordance with the requirements of AS/NZS 5000.1 unless otherwise noted in the cable schedules specified in the Project Documentation.

All existing single insulated wiring (particularly in dry well installations) shall be replaced with double insulated cables.

All power, control and communications cables installed underground shall be run in heavy duty orange conduit. Refer section 6.10.3.

Direct buried cables shall not be accepted unless accepted in writing by QUU. Refer Section 6.10.2

All above ground cables shall be reticulated along pathways that provide suitable mechanical protection. Typically, this shall be achieved using cable ladder or heavy duty rigid or heavy duty flexible conduit. Where cables leave the cable ladder to terminate at field equipment heavy duty flexible conduit shall be installed to provide the mechanical protection of the final length of cable. Running cables inside Unistrut channel is not accepted. Refer to sections 6.19 and 6.20.

It is not acceptable to run process pipework on cable ladders.

All cables shall be installed in accordance with the cable supplier's recommendations with particular attention to minimum cable bending radii, maximum cable pulling tensions and resistance to UV radiation.

All non UV resistant cables shall be installed in either cable ladder with a cover, continuous conduit or similar to prevent exposure to UV damage. Cable sheaths or conduit shall be suitably rated for exposure to chemicals if present in the area.

All connections to portable/moveable equipment (i.e. pumps or motors with decontactor plugs) and to equipment subject to excessive vibration shall be completed using flexible cables with sufficient slack to take-up movements and vibrations.

Suitable segregation between cables for different services using either distance or continuous mechanical barrier as per Section 6.7 shall be maintained for all cable installations.

All cables shall be glanded at both ends (where practical) with glands selected to suit the cable type (i.e. SWA, EMC, Hazardous Area Rated). Refer Section 6.16.

Cables to motors, control stations, junction boxes and all outdoor equipment shall enter the equipment from below. In the event that bottom entry is impractical, side entry to the equipment may be permitted subject to approval from QUU's Representative. Top entry of cables to outdoor equipment is not permitted.

Where cables and/or conduits and ladders are run across structural points intended to allow for expansion, contraction or differential settlement, provision shall be made for such movement to ensure that the cables and their support accessories are not subject to stress.

Refer to section 5.13 for requirements of decommissioning and disposal of cables.

Refer to TMS1203 General Requirements Hazardous Area Installation Specification for the additional requirements for cables in hazardous areas.

6.2 CABLE ROUTES

The electrical drawings shall detail the general route for cables, with the exact route to be defined on- site by the Contractor. For cables not defined on the layout drawings it shall be the Contractor's responsibility to field route. The Contractor shall also define the exact route for all final cable runs from the main cable ladders (detailed on the layout drawings) to the final cable destination. In all instances it shall be the Contractor's responsibility to coordinate the cable routes with other services. All cable routes shall be accepted by QUU's Representative prior to commencing the cable or cable pathway installation.

All cable lengths where defined in the cable schedules or listed in the drawings are estimated 'route' lengths (unless specified otherwise) and are approximate only. Exact final lengths shall be verified by the Contractor prior to installing and/or cutting of cables. Significant difference in designed versus final cable lengths (>10m or >30% longer) shall be referred to the designer for verification before cutting and installation, as cable sizes may be affected.

All main cable routes above and below ground shall be shown on cable route drawings superimposed on the site layout drawing. Cable route and pit layout drawings shall be updated to As Built with GPS co-ordinates of the installed cable routes.

It shall be the responsibility of the Contractor to ascertain that adequate space exists on the cable ladders and conduits for the intended cable installation prior to commencing the cable, ladder or conduit installation.

All cables shall be installed in accordance with the method of installation (including spacings, bedding material and backfill) as defined in the Project Documentation. Cable sizes have been calculated based on the method of installation as defined and as such neither cable size nor installation detail shall be changed without approval from QUU's Representative. Cables shall be installed neatly to ensure they can be readily traced and identified from origin to destination. Cables shall be installed so as to avoid cross-overs with other cables. All installations shall be in accordance with the requirements of AS/NZS 3000 and AS/NZS 3008.1.1.

6.3 CABLE HANDLING AND INSTALLATION

Due to the significant size, type and lengths of cables to be installed it may be necessary to utilise specialised equipment for handling and installing the cables. Accompanying this specialised equipment will be the need for the use of experienced personnel and proven work procedures. All cable handling and installation plant and equipment shall be accepted by QUU's Representative prior to use. Under no circumstances shall metal levers or tools be used in direct contact with cables during installation unless of a proprietary type specially designed for the purpose.

Care shall be taken to protect cable, cable drums, equipment and personnel at all times during handling and installation operations. Cable drums shall be rolled only in the direction indicated on the side of the drum.

Cable shall be unrolled from reels, under controlled tension in a manner that will prevent kinking and crushing of the conductors. External protective sheathing, serving or jacket shall remain intact and undamaged.

During installation cable drums shall be braked to avoid over-running. At no time shall a cable be handled such that it takes up a radius less than its permissible bending radius.

Any winch used to draw cables shall have an adjustable setting to limit the pulling tension. The pull tension adjustment shall be set to ensure that the cable supplier's maximum pulling tension is not exceeded. Any cable jacks or lifting equipment shall be sized and rated for the weight and size of the cable drum.

Cables shall be drawn into position on rollers unless otherwise accepted by QUU's Representative. Sufficient rollers shall be used to ensure that the cable is kept clear of the ground and other obstructions. Purpose designed change of direction rollers shall be used at changes in direction.

Cables shall not be pulled using the conductors. HV and larger LV cables shall be pulled using suitably rated swivels, pulling eyes, cable stockings and/or other load spreading means to prevent distortion and/or damage to the cable end.

Cable pulling lubricants shall be checked for compatibility with the cable prior to use.

Protective battens and covers on cable drums shall not be removed until immediately prior to installation.

Cable installation lengths shall be carefully measured and cut to ensure sufficient cable length to effect the termination whilst minimising cable off-cuts. The ends of all high voltage cables shall be sealed immediately after cutting using suitably sized resin filled heat shrink cable caps. Sealing of LV and control cables shall be done immediately if exposed to severe dampness but, in any case, shall be sealed if the next cut will not be made during the following seven (7) days.

All cables during pulling shall be clearly labelled with temporary labels at both ends.

6.4 CABLE MANAGEMENT AND CABLE RECORDS

When cable is supplied in drum lengths allocated for particular circuits it is the Contractor's responsibility to ensure that the correct cable drums are used for the nominated circuits.

Unless otherwise agreed, the Contractor shall maintain a cable pulling schedule and cable drum schedule (or similar) to record the actual lengths installed. These records shall be used to monitor the efficient usage of cable and to predict any shortfalls. Final installed cable lengths are to be recorded on the cable schedule as 'As- Built' information.

The Contractor shall be responsible for continuous monitoring and reporting of cables stored by the Contractor. Adequate levels of Contractor supplied cables shall be maintained at all times to ensure that the installation schedule is not delayed due to cable shortages. Similarly, the Contractor shall advise QUU's Representative of any possible future shortages in QUU supplied cable to ensure replacement stocks can be ordered and delivered without impacting on the installation schedule.

The Contractor shall provide "As-Built" drawings of cable routes including any deviations and their approval documentation. The Contractor shall also provide digital photos of underground cable installations where defined in the ITP's as part of the hand-over documentation.

6.5 SINGLE CORE CABLES AND CLAMPING

Where three phase circuits are direct buried or run on cable ladder using single core cables the A, B and C phase cables shall be grouped together touching in a trefoil formation with the

trefoil formation being maintained as far as possible up to the cable glands. For direct buried installations, nylon cable ties shall be utilised to maintain the trefoil formation. For cable ladder installations, cable cleats shall be utilised to provide the trefoil formation. All trefoil cable cleats shall be accepted by QUU's Representative and under no circumstances shall improvised devices be used for clamping cables in trefoil formation.

Cable cleats shall comply with the following:

- be in accordance with IEC 61914be type tested to be suitable for the prospective peak fault level of the cable and the spacings between adjacent cleats
- be installed at intervals such that there shall be no cable damage on faultbe installed at intervals to prevent flexing of cables on fault.

Parallel runs of single core cables shall maintain a three phase trefoil configuration with a minimum of one cable diameter spacing between trefoil groups, and with each group being a mirror image of adjacent trefoil group. On cable runs longer than 50m, the phases shall be transposed at a maximum of 50m intervals to minimise mutual inductance.

Single core cables serving as neutral conductors shall be run adjacent to the respective trefoil group and secured by stainless steel cable ties with plastic sheathing (for cable ladder installations only) at intervals as per section 6.6.

Single conductor cables carrying alternating current shall not pass through any closed ferrous circuits unless accepted by QUU's Representative.

6.6 CABLE SECURING

HV multi-core cables installed on cable ladders shall be fixed using stainless steel cable ties with plastic sheathing.

LV multi-core cables installed on cable ladders shall be fixed using nylon cable ties.

Cable ties shall be applied as follows:

- The ties shall be fixed with a specialist tension and cutting tool.
- At each rung on ladder for a distance of 2000 mm either side of a change of direction.
- Every 300 mm on ladder of either sloping or vertical direction.
- Every 3000 mm for LV cables and every 600mm for HV cables if installed in single layer on ladder horizontally fixed and rungs orientated horizontally.
- Every 1000 mm for direct buried single core cables grouped in trefoil formation.
- Stainless Steel cable ties with plastic sheathing shall be applied for LV cables as follows :
- Every 600mm for cables greater than 70mm2 on ladder of either sloping or vertical orientation.

The maximum number of cables tied together shall be no greater than four (4).

Cables installed in vertical conduits shall be tied at intervals not exceeding 4m to prevent excessive weight bearing on the cable.

Cables supported from catenary wires shall be secured using stainless steel plastic sheathed cable ties at intervals of not more than 1m.

6.7 CABLE SEGREGATION

Wherever practicable, critical cables for duplicate feeds and equipment shall run via separate routes to increase security of supply.

Cables dedicated for emergency services signals and safety systems shall as far as practicable be in separate routes to cables used for other services. Special consideration shall be given to the routing and segregation of cables, to minimise the effects of fire on emergency and essential supplies and production operation.

Cables shall be segregated into separate groups according to the level of susceptibility as follows:

- Level 1 - High Susceptibility - Intrinsically safe analogue and digital instrumentation and fire and gas signals;
- Level 2 - Medium Susceptibility - Non-Intrinsically safe analogue and digital instrumentation and fire and gas and telecommunications signals, ELV power and control;
- Level 3A - Low Susceptibility - LV Power and Control under 20 amps;
- Level 3B - LV Power above 20 amps
- Level 4 - High Voltage Power;

Generally, each group shall be allocated to a separate cable ladder or conduit. Cables installed on common cable ladders shall have earthed solid metal segregation barriers between the cable groups. Barriers shall comprise purpose manufactured galvanised steel sheet mounted in accordance with the manufacturer's instructions on the ladder and earthed.

Earth cables shall run alongside the power cable when earthing associated electrical equipment.

Unless otherwise specified, the segregation of groups shall not be less than the distances shown below unless a segregation barrier is utilised:

Susceptibility Level	Level 1	Level 2	Level 3A	Level 3B	Level 4
Level 1	0	450mm	450mm	450mm	900mm
Level 2	450mm	0	*450mm	450mm	900mm
Level 3A	450mm	*450mm	0	50mm	450mm
Level 3B	450mm	450mm	50mm	0	450mm
Level 4	900mm	900mm	450mm	450mm	0

* within cable pits the segregation distances between cables of susceptibility 2 and 3A may be reduced to 50mm.

Level 1 cables shall not be installed on a common cable ladder with level 4 cables regardless of barrier strip segregation.

6.8 CABLE SPACING

Unless otherwise specified, the spacing between individual cables shall be as follows on cable ladders:

- LV power cables 16mm2 and below shall be installed bunched to a maximum of two layers;
- LV power cables 25mm2 and above shall be installed single layer touching;
- LV trefoil groups shall be spaced a minimum of one cable diameter apart, single (triangular) layer. Neutral conductors where required shall be located between trefoil groups;
- HV cables, including trefoil groups, shall be spaced a minimum of one cable diameter apart, single layer with triangular trefoil formation for single core cables;
- Control, lighting and small power cables may be multi-layered up to 75% of cable ladder depth.

For power cables installed underground the following minimum requirements apply (unless specified otherwise):

- HV power trefoil arrangement spaced a minimum of 150mm apart;
- HV power multi-core cables spaced a minimum of 150mm apart.
- LV power trefoil arrangement spaced a minimum of one cable diameter apart, single (triangular) layer. Neutral conductors where required shall be located between trefoil groups;
- LV power multicore - single layer touching;
- LV control, lighting and small power - multi-layer bunched.

All cable installation designs shall be supported by calculations.

6.9 CABLE BENDING RADII

In general, cable bending radii shall be as large as practical, and shall not be less than the supplier's recommended minimum bending radii. It shall be the responsibility of the Contractor to ensure the relevant Cable Data Sheets are available so the bending radii can be taken into consideration when completing the installation. Particular attention shall be given to the minimum installation bending radii to ensure it is maintained for all cables while under tension during cable pulling.

6.10 UNDERGROUND CABLES

6.10.1 General

Underground cables shall be run in heavy duty PVC conduit/pipe as specified in the Project Documentation or as directed by QUU's Representative.

Underground conduits shall have a minimum size of 50mm.

Conduits shall be sized to have a minimum 25% spare cable installation capacity after completion of the designed works.

Cable trenches and conduits shall be straight and even throughout their entire route.

Trenches shall be treated with an accepted chemical treatment to prevent termite attack on cable sheaths and conduits.

Where existing or proposed cables, pipes or sewers intrude into or pass over the route, the trench shall be excavated to enable a crossing to be completed that maintains both the minimum segregation distances between services as defined in section 6.10.5 as well as the minimum underground depths of the electrical services as defined in section 6.11.

All underground cables and conduits shall be installed on a layer of accepted bedding material free of large and/or sharp materials. Cabling and conduits shall be covered with an accepted bedding material. The selected bedding material shall be a clean, consistent, friable material with suitable test records confirming the thermal properties to be in accordance with the requirements defined in the relevant project documentation. The trench shall be backfilled with a good quality clean fill. Both the bedding material and clean backfill shall be accepted by QUU's Representative before use. Buried cable marker tape shall be laid along the full length and width of all cable trenches.

Cables located in areas such that the gradient of the intended installation is sufficient to stress or cause movement of the cables, shall incorporate the following additional provisions as accepted by QUU's Representative:

- suitable measures to prevent the bedding and backfill materials from washing-out during heavy rain events;
- suitable measures for securing the cables to prevent excessive weight bearing on the cable.

Buried earth grids shall not require bedding material or polymeric protection covers but shall include cable warning tape.

Cables leaving the ground shall be mechanically protected by heavy duty flexible or heavy duty rigid PVC conduit of adequate diameter secured in position, extending from 400mm below ground level to a minimum height of 100mm above ground. Rigid PVC conduit used for this purpose shall be treated for exposure to direct sunlight or be painted with a light coloured water-based acrylic paint.

Where cables are to pass under roads, railway lines, equipment or structure foundations, the cable shall be installed in heavy duty conduit and additional mechanical protection provided to protect conduits from the loads that will transition over the cable routes.

The standard installation drawings for underground cables shall detail the typical arrangement for underground road crossings, including clearances and cross sections. In all instances, an additional means of mechanical protection shall be provided in the form of one or more of the following:

- Additional installation depth;
- Use of concrete encased conduits (or similar);
- Use of pre-cast concrete covers;
- Use of heavy duty steel or concrete conduits (or similar).

All road crossings shall be equipped with spare (empty) conduits for future.

The Contractor shall advise QUU's Representative of the following stages of installation:

- When trenches have been excavated and bedding material laid in readiness for cable installation.
- When cables have been laid in trenches prior to backfilling.
- When mechanical protection has been laid over the cables prior to backfilling.
- When a HV cable joint is to commence.
- Prior to all testing of cable so QUU's Representative may witness the test.

The exact details of the testing for underground cabling shall be defined in the relevant Inspection and Test Plan (to be accepted by QUU's Representative) and shall include as a minimum pre- backfill cable testing and post-backfill cable testing for all underground cables. Where required in the relevant ITPs the Contractor shall provide digital photos of underground cable routes to clearly show penetrations, bends, depth, bedding and other important aspects of the installation.

Prior to the backfilling of cable trenches the trench shall be surveyed for future reference and marked- up on the relevant drawings detailing the "as installed" route and the locations of the cable markers.

The location of the trench shall be referenced back to fixed structures or relevant survey coordinates defined.

Where joints in buried cables occur, a sign post shall be installed indicating that there is a cable joint below. The cable joint location shall be surveyed for future reference and marked-up on the relevant drawings.

6.10.2 Direct Buried Cables

Direct buried cables shall only be accepted where specified in the project documentation or directed by QUU in writing; and to an installation method approved by QUU.

Direct buried cables shall be laid in an accepted compacted bedding material, free from stone or chemically active material. The depths and volume of bedding material shall be as detailed in the relevant underground cable cross-sectional drawings. As minimum, direct buried cables shall be installed on a layer of 75mm compacted bedding material and covered on top and at both sides with a 75mm layer of compacted bedding material. The bedding material shall be tested to confirm the material properties (i.e. thermal resistivity and moisture levels) are suitable for the application as detailed in the relevant Project Documentation.

For all direct buried cables mechanical protection covers of minimum width 150mm shall be provided on top of the bedding material along the full length and width of the direct buried cables. The protection covers shall extend a minimum of 40mm on either side of the cable and shall be installed not more than 75mm above the buried cable. Cable protection covers shall be in accordance with AS3000 and AS4702. Broken or damaged cable protection covers shall not be used over the cables.

After cable covers have been placed in position, the trench shall be backfilled and compacted.

A continuous strip(s) of 150mm wide orange PVC marker tape in accordance with AS/NZS 2648.1 shall be laid above all buried cables. The marker tape shall be buried at a depth of approximately 50% of the depth of the buried cables unless detailed otherwise on the relevant underground cross-sectional drawings. Multiple parallel runs of marker tape shall be used where required to cover the full width of the trench and shall extend a minimum of 40mm on either side of the cables. The marker tape shall overlap for 2m at the ends of consecutive strips.

6.10.3 Underground Conduits

Underground cables shall be installed in heavy duty PVC conduit to allow removal or addition of cables with minimum disturbances to existing installed cables.

All underground conduits shall be heavy duty rigid PVC in accordance with AS/NZS 2053 and shall be bedded in sand (or similar accepted bedding material). Conduits shall be coloured orange for all electrical applications such as HV, LV, ELV and control cables.

Telecommunications conduits shall be preferably white (if available in heavy duty rigid PVC), otherwise orange is acceptable. Austel type medium duty white telecommunications conduit is not acceptable.

Corrugated underground conduits of any type are not acceptable, including those with internal smooth bores such as "Corflo".

All underground conduit runs shall be continuous with all joints completed using conduit bell ends (or couplings) and PVC conduit joining compound as per the supplier's recommendations. Generally, changes in direction shall be completed using cable pits however, with approval from QUU's Representative large sweeping conduit bends shall be acceptable provided that the bends are sized to suit the minimum bending radii of the cables to be installed.

All conduits shall be installed at a depth not less than 500mm below the finished ground surface level (Unless under concrete - refer AS3000 for details).

The bottom of cable conduits entering cable pits shall enter at a distance of no less than 100mm from the bottom of the cable pit.

Conduits shall be located not less than 2 metres behind the kerbline or shoulder where applicable except where shown on the drawings.

The conduits shall be, as far as practicable, in a direct line between pits.

Where the conduits enter the cable pits, a clearance hole (-0 +5mm) to suit the conduit size shall be cut in the pit using a hole cutter or similar tool.

Pits with holes knocked in with a hammer or similar tool shall be rejected.

Only one hole for each conduit entering the box shall be cut.

The conduit shall be sealed to the pit with Sika-Flex construction Polyurethane Joint Sealant or similar accepted sealant.

All conduits unless otherwise specified shall be provided with a cable draw wire. A 3-core polyethylene or polypropylene rope, with 5.0 mm nominal diameter and orange or yellow in colour, shall be installed in each conduit and suitably anchored at each end.

Each underground conduit system shall be complete with suitably sized pull pits as is necessary to facilitate installation and possible future replacement of cables. Unless specified otherwise, cable draw pits shall be spaced a maximum of 25 metres apart and at all changes in direction for underground conduit runs.

Separate conduits are required for HV power cables, LV power cables, ELV power and control cables and ELV instrumentation and communications cables.

Each conduit shall either stub up directly into or below the equipment to be connected.

All conduit stub-ups, entries into cable pits or underground terminations (i.e. road crossings) shall be sealed after the installation of cables to prevent the ingress of water and other materials. This sealant shall be a non-deteriorating, non-setting weatherproof sealant capable of being removed at a later date for future cable installation. The Contractor shall be responsible to ensure that the positioning of the stub up is correct before pouring of concrete. The stub ups shall project 100mm above finished floor/ground level.

The Contractor shall ascertain at an early stage in the construction the underground conduit requirements and shall co-ordinate with the civil construction work.

Underground conduits shall be laid in an accepted compacted bedding material, free from stone or chemically active material. The depths and volume of bedding material shall be as detailed in the relevant underground cable cross-sectional drawings. As a minimum, conduits shall be installed on a layer of 75mm compacted bedding material and covered on top and at both sides with a 75mm layer of compacted bedding material. The bedding material shall be tested to confirm the material properties (i.e. thermal resistivity and moisture levels) are suitable for the application as detailed in the relevant Project Documentation.

A continuous strip(s) of 150mm wide orange PVC marker tape in accordance with AS/NZS 2648.1 shall be laid above all buried conduits. The marker tape shall be buried at approximately 50% of the depth of the buried conduits unless detailed otherwise on the relevant underground cross-sectional drawings. Multiple parallel runs of marker tape shall be used where required to cover the full width of the trench and shall extend a minimum of 40mm on either side of the conduits. The marker tape shall overlap for 2m at the ends of consecutive strips.

Buried conduit systems shall be sized to have a minimum of 25% spare cable installation capacity in each conduit after completion of cable installation. A minimum of 25% spare number of conduits must be made available.

Conduits shall be capped at each end prior to installation to prevent foreign material entering the conduit. Special care shall be taken at all times to ensure that all conduits are free of foreign material.

6.10.4 Underground Cable Ducts

All underground cable ducts shall be structurally designed to suit the particular application.

The configuration shall ensure adequate working space as well as safe access and egress for the construction works and any future cable repair works.

A suitable drainage system shall be incorporated into the duct system.

Typically, cable ladders shall be utilised for the reticulation of cables within cable ducts.

Cable ladders shall be installed a minimum of 150mm clear of the floor level to ensure cables are kept clean and dry.

The cable duct shall be designed to facilitate the installation of cable ladder support systems via cast- in channels (or similar) or shall be suitable for the installation of drilled masonry fixings.

The cable duct design shall incorporate cable penetrations that can be adequately sealed upon completion of the installation.

6.10.5 Cable Separation from Underground Services

Cables shall maintain minimum separation distances from underground services in accordance with AS3000, as follows:

Type of Service	Minimum Separation to LV Electrical Service (mm)	Minimum Separation to LV Electrical Earthing Electrode (mm)
Water service not greater than DN65	100	500
Water service greater than DN65	300	500

Type of Service	Minimum Separation to LV Electrical Service (mm)	Minimum Separation to LV Electrical Earthing Electrode (mm)
Sanitary drainage	100	500
Stormwater drainage	100	600
Gas	100	500
Telecommunications	100	-

HV electrical services shall maintain a minimum separation distance of 300mm from all underground water, drainage, gas and telecommunication services.

6.10.6 Cable Route Markers

The route of significant underground power and control cables shall be identified using clearly visible above ground cable route markers.

Cable route markers shall indicate the direction of cables in the ground and shall be installed where defined in the Project Documentation and at the following locations:

- at road reserve boundaries on either side of road crossings;
- at foreign service easement boundaries on either side of foreign services crossings;
- at banks/high points on either side of significant water course crossings ;at each end of the route;
- at all changes of route direction;
- and at the below listed maximum intervals in-between
- within facility perimeter fence lines - 50 metres;

outside facility perimeter fence lines - 100 metres;In any case route markers shall be sized, spaced and located to ensure that each cable route marker shall be visible with the human eye from the adjacent before and after markers.

Cable route markers shall be constructed and installed to a standard installation drawing accepted by QUU.

Cable route marker shall be adhesively attached to a post or bollard. The post or bollard shall be a 76 x 38 x 2 RHS, 1300mm long and finished in Matt Golden Yellow Y14 in accordance with AS 1743, with a yellow cap inserted into the top of the post or bollard

The post or bollard shall be of durable materials of either UV resistant heavy-duty plastic or aluminium.

Optionally, cable route marker plinths at ground level may be considered for in-plant cabling only. Markers shall comprise engraved stainless markers embedded in concrete plinths. Markers shall be placed at the end of each route, at each change of direction and at maximum intervals of 25 meters. Detailed locations and marker plinth design to be accepted by QUU.

Cable joint markers shall be installed to identify the location of all underground cable joints.

6.11 CABLE TRENCHES

Prior to the commencement of cable trench excavation all relevant permits and approvals shall be attained and all existing in-ground services identified as per the project site requirements.

In areas where exact location of underground services cannot be located or as directed by QUU, the Contractor shall use water blasting at maximum 2000kPa pressure to locate underground services. The excavation works shall be planned to minimise disruption to the day-to-day operations of the site and to minimise the period of time that excavations are to remain open and to minimise the length of open trench at any one time.

All excavation and backfilling activities shall adhere to the requirements detailed in the Contractor's accepted CEMP, especially requirements relating to general soil management and subsoil management.

In all instances the excavation equipment shall be selected to suit the application. Particular attention shall be given to the size of the excavation equipment with respect to the trench size and the suitability of the excavation equipment for the work location.

All trenches shall be excavated to accommodate the cables, cable spacing/segregation, bedding materials and cable installation configuration (trefoil etc) required to complete the installation. The depth of the excavation shall be sufficient to ensure that the minimum statutory and project cover between the uppermost cable and ground surface is maintained for the entire length of the trench. The Contractor shall be responsible for ascertaining the finished ground level for the areas to be excavated.

Trenches shall be cut squarely and the bottom shall be flat and free from stones or hard projections. Trenches shall be cordoned off with protective barricades and shall be maintained clean and free of water, collapsed wall material and foreign materials. Trenches of depth greater than 1.5 metres (or in accordance with the requirements of the project safety procedures) shall be shored, benched, shielded or similar to mitigate/manage the risk of trench collapse to personnel working within the trench.

Trenches shall be excavated to an adequate depth to provide the following minimum cover over the cable or underground duct unless detailed otherwise in the project documentation:

- bare earth cables 500mm
- LV cables with active conductors 600mm
- HV cables 750mm
- all cables below road crossings (LV and HV) 1000mm

All trenches to be excavated to a depth greater than 1300mm shall be accepted by QUU's Representative.

The radius of a change of trench direction shall not be less than 30 times the overall diameter of the largest cable being laid along the inside of the trench, with a minimum of 1m radius.

Any paving, drainage, road surface or similar disturbed by trenching shall be reinstated to the original condition.

All backfilling and compaction (including compaction levels) of trenches including the re-instatement of the finished surface shall be in accordance with the requirements of the Project Documentation.

Trenches must be backfilled as soon as practicable after laying cables/ducts. During backfilling, subsoils should be re-instated in the same order as excavated where practicable, particularly where salinity and/or sodicity increase at depth. The subsoil shall be reinstated to the same subsoil level as surrounding soils, and the original profile of topsoil shall be reinstated.

Excavations not in paths or roadway shall be backfilled and compacted to match the surrounding soil density and graded to match surrounding surface level. The top 100mm

layer above the top of the conduits shall be top soil and the surface finished off in the existing surrounding surface.

All surplus material and spoil remaining after completion of the backfilling shall be removed and disposed of as directed by QUU's Representative and in accordance with the Contractor's CEMP, or stockpiled for future site rehabilitation as directed by QUU's Representative.

Excavations in proximity to paved areas shall be suitably shored to prevent the sides of the excavation from collapsing. Paved areas shall not be undermined by excavations from work under the Contracts. Any damage caused to paving and other structures due to excavation activities shall be repaired by the Contractor.

Pavement surfaces, including turf, concrete or brick paved areas and pathways, shall be reinstated by the Contractor.

6.12 HORIZONTAL DIRECTIONAL DRILLING

For all Horizontal Directional Drilling (HDD) cable crossing installations, the Contractor shall perform all engineering analysis, specify appropriate plant, design temporary works and installation aids, and develop detailed calculations to facilitate construction of the works. All engineering design shall be accepted by QUU's Representative and where necessary, by the owner of the structure being crossed before drilling operations commence. In addition, the survey and geological data requirements shall be in accordance with AS 2885.1 Clause 10.2.3.

The scope of work to be performed by the Contractor as defined in the Scope of works contract documents shall include but not be limited to the following activities:

- Detailed HDD design;
- Validation of detailed HDD design;
- HDD drilling and site set-up;
- Cable installation and testing;
- Post installation integrity test.

As part of the HDD engineering design work, the following shall apply:

- Installation related loads on the cables when being pulled through the HDD holes which have not been considered in the preliminary QUU design. These shall be calculated by Contractor and submitted for approval;
- The preliminary HDD profiles and cross-sections developed by QUU shall be reviewed and altered as deemed necessary by the Contractor to ensure the technical feasibility of installing the cables within the HDD holes;
- Contractor shall submit to QUU for approval the specifications of the drilling fluid and confirm that it complies with Government regulations and permits;
- QUU has carried out a detailed geotechnical survey. This information will be included in the Scope of Works package.

In the event of any leakage or spillage of drilling fluids they shall be contained within suitable bunds. Fluids shall be disposed of in accordance with the Contractor's CEMP in line with the Land Release Management Plan requirements.

Spoil or waste material generated shall be disposed of in accordance with the Contractor's CEMP.

6.13 CABLE PITS

Cable pits shall be provided at all changes of direction greater than 45 degrees for cables installed underground in conduit unless detailed otherwise in the Project Documentation. The maximum distance between cable pits shall be 25 metres. Cable pits shall be provided on either side of any road crossing unless detailed otherwise in the Project Documentation. Cable pits shall be sized to allow the installation of cables without exceeding the bending radius of cables to be installed. Cable pits shall also be sized to maintain the necessary segregation between different electrical services if sharing a common pit.

Depending on the application cable pits and associated covers shall be as follows unless detailed otherwise in the Project Documentation:

- Glass-fibre reinforced concrete of load class A (as per AS3996) - for non-trafficable areas;
- Pre-cast concrete of load class D (as per AS 3996) - for trafficable areas;
- Structurally designed cast-in-situ formed concrete - for trafficable areas where pit dimensions exceed 1200mm x 1200mm.
- Where pits exceed 600mm x 600mm the covers shall be split.
- Pit cover shall have weight of cover indicated
- Steel pit covers to be greased with manufacturers recommended lubricant

In non-paved areas, the top of each pit shall be above the design surface level or natural level by 50mm +/- 10mm with the localised soil within 1 metre graded up to the top of the pit.

When installed in paved areas, pit lids shall be at the same level as the surrounding pavement surface.

Pits that are installed in other than paved areas (concrete or bitumen) shall have 150mm concrete mowing strips installed around the pit.

Lids shall be fitted with suitable facility for lifting. Suitable supports shall be provided to ensure the lid cannot fall into the cable pit. Pits shall be orientated so the covers can be safely removed.

In all instances cable pits shall be traffic rated to suit the application. The traffic rating shall be defined in the Project Documentation or as directed by QUU's Representative. For cable pits used for road crossings the pits shall be traffic rated to at least that of the traffic on the road.

For all underground conduits entering/exiting cable pits the outside of the conduits shall be sealed with a suitable sealing compound to prevent the ingress of water. For cast-in-situ concrete pits bell ends shall be cast into the pit walls to facilitate the conduit entries.

For cast-in-situ concrete pits facility shall be provided for earthing the re-enforcement steelwork (re-bar).

All cable pits shall be equipped with suitable drainage (as defined by QUU's Representative) which shall be in the form of a separate soak well or similar for large cable pits.

All foreign material including sand and dirt shall be removed from the pit after installation.

All pits shall have a minimum depth of no less than 800mm below the finished ground surface level.

At the conclusion of works and before hand over to QUU, accepted poisonous rat baits shall be left in all pits.

6.14 CABLE JOINTING

Cables shall be installed in continuous un-broken lengths without joints unless detailed otherwise in the Project Documentation or accepted by QUU's Representative.

Where possible, cables shall be designed and procured in sufficient lengths to preclude the need for cable joints. In instances where excessive cable route lengths are unavoidable, the limitations on cable drumming lengths shall constitute the need for cable joints. All such instances shall be defined in the Project Documentation. Any such occurrences not defined in the Project Documentation shall be brought to the attention of QUU's Representative for approval of cable jointing.

In the event of any existing cables being too short for termination into a new switchboard, then the cable shall be replaced throughout its entire length.

Joins in LV power cables are not accepted, except in special circumstances and where specified by QUU. Junction boxes or other methods to join cables are subject to review and acceptance by QUU.

Joints in underground LV cables shall be completed in a pit fitted with a clearly marked cover and designed to minimise water ingress.

Joints in lighting and power final sub-circuits are not permitted, except in junction boxes or terminal strips.

All joints in control cables shall be made at labelled terminal blocks in junction boxes, marshalling cubicles or control panels.

Multicore cables to be jointed shall be installed such that the spiral lay of the cable cores shall be in the same rotation throughout the complete cable length.

QUU shall specify the cable jointing kits for all applications. These kits shall be selected specifically to suit the voltage grade, configuration and type of cable. The Contractor shall have available for on-site reference, the Supplier's installation instructions for the jointing kits.

Joints in HV cable are only accepted when repair or extension to an existing installed HV cable is required and is not feasible to replace the entire length of the HV cable. QUU will determine the feasibility. Joints in new HV cables are not accepted, except where the route length exceeds the maximum practical drum size and where accepted by QUU.

All HV cable jointing kits shall be in accordance with the requirements of IEC 60502-4.

Underground HV cable joints shall be direct buried and bedded in a large volume of accepted bedding material. The joint shall be arranged so as to provide some cable slack to minimise stress on the joint caused by the expansion/contraction of the cable due to operating and environmental temperature variations. Above ground joint markers and buried electronic markers shall be provided for each buried HV joint. Additionally, survey locations and GPS coordinates shall be recorded as part of the as-built documentation. The relevant standard installation drawings shall detail the requirements for underground HV cable jointing.

Above ground joint markers, GPS co-ordinates and survey records shall be recorded as part of the as-built documentation for all buried cable joints.

Underground jointing kits shall be suitable for installation in saline, permanently saturated soil and shall be termite resistant regardless of whether the joint is to be located in a pit or direct buried.

Armour cages shall be utilised for all armoured cables to maintain the continuity of the armour across joints.

All cable joints shall be completed by suitably qualified and experienced personnel.

The location of all cable joints on above ground cable ladder shall be detailed on the cable layout design drawings to form part of the as-built information. On-site these locations shall be identified with suitable markers or signage.

6.15 CABLE TERMINATIONS

6.15.1 General

The cores and screens of all cables shall be terminated in accordance with the recommendations of the supplier of cables, glands, switchgear and lugs.

All terminations shall be completed in a neat and tidy tradesman like manner as per best practice. All cables shall be adequately dressed and supported into the point of termination with a generous sweep to ensure minimal stress on the termination and sufficient slack to re-terminate the cable if required.

The Contractor shall be responsible for the correct phasing/connection of all cables. Motor cable terminations shall be completed so as to enable at least two cable core connections at the motor terminal box to be interchanged without having to make off the cable again

Cables terminating to equipment with significant vibration or operational movement shall have sufficient slack to facilitate the anticipated movements in the equipment without placing any undue strain on the cable or termination.

Pre-insulated bootlace ferrules shall be used to terminate conductors up to and including 10mm2.

Conductors greater than 10mm2 shall be terminated using electro-tinned copper lugs.

Hexagonal crimping dies shall be used for multi-strand conductor cables. Crimping dies shall emboss the size of die used on the cable lug. Crimped lugs where the metal has extruded radially shall not be accepted. The Contractor shall have available for on-site reference, the supplier's operating instructions for the crimping tools detailing the method for crimping the different types of lugs.

The maximum clearance diameter of any cable lug or busbar hole, shall not be more than 110% of its mating stud or bolt diameter. All cable lugs shall be sized and suited specifically for the application with no modifications to the cable lugs permitted. Flat and spring washers or similar accepted locking devices shall be used on all stud terminations.

Lugs on cables exposed to the weather shall be sealed to prevent ingress of moisture and corrosive gas into the cable. Suitable lug sealant systems are typically heat shrink and/or bituminous products. Contractor’s proposed sealing systems shall be accepted by QUU before use.

All armoured cables shall have the armour earthed at both ends unless specified otherwise in the Project Documentation. Typically the earthing of the armour shall be completed via the gland plates using proprietary purpose designed armoured cable glands.

All screened power cables (i.e. VSD cables) shall have the screen earthed at both ends unless specified otherwise in the Project Documentation or by the equipment manufacturer. All screened cables shall be installed with metal glands.

In instances where multiple cables are to be terminated into a termination box with a single entry a local breakout box and flexible heavy duty PVC conduit shall be utilised to facilitate the termination. Similarly, where oversized cables are to be terminated into a small termination box a local breakout box and flexible heavy duty conduit (not steel) shall be utilised to facilitate the termination. Such arrangements shall be accepted by QUU's Representative prior to commencement of works.

The TMS60 Technical Specification for LV Switchboards and Enclosures further details the requirements for power and control cable terminations within electrical enclosures.

6.15.2 Termination of HV Cables

The standard termination drawings will provide the detail of the various types of HV cable termination arrangements.

The Project Documentation will specify the HV cable termination kits for all applications. These kits shall be selected specifically to suit the voltage grade, configuration, type of cable and type of switchgear.

All HV cable termination kits shall be in accordance with the requirements of IEC 60502-4.

The Contractor shall have available for on-site reference, the supplier's installation instructions for the termination kits.

All HV cable terminations shall be completed by suitably qualified and experienced personnel.

Prior to commencing HV cable terminations the Contractor shall ensure that the system phase rotation on the switchboard is as per the site standard.

Suitable compression dies and tools sized for the application shall be utilised during the cutting and crimping operations.

Cables shall be adequately clamped and supported at the termination to minimise stress on the cable, gland and terminations caused by the weight of the cable and the expansion and contraction of the cable due to operating and environmental temperature variations.

For bolted lug connections stainless steel bolts, nuts and Belleville washers shall be utilised. A torque wrench shall be used to tighten termination bolts to the required setting as defined by the supplier.

All cores shall have colour heat shrink on termination lugs or similar to identify the phase.

Cables shall be glanded as detailed in the standard installation drawings utilising the cable glands specified in the Project Documentation. Unless detailed otherwise in the Project Documentation each cable gland shall be effectively bonded to the earth bar and each HV cable screen shall be connected only to the equipment earth bar at each end (i.e. the screen shall remain insulated from the earth system up to the point of connection).

The Contractor shall be responsible for identification and procurement of all miscellaneous materials and consumables necessary for the termination of the cables in a timely manner prior to commencement of the termination works.

Prior to commencing termination works, all high voltage cable terminations shall be reviewed and any issues (i.e. the need for drop-down boxes at Switchrooms etc) identified early so as not to impact on the construction programme. Particular attention shall be given to the tail lengths of the termination kits to ensure there is sufficient space available within the cable termination compartment to facilitate the termination. Such issues shall be brought to the attention of QUU's Representative for resolution.

Specialised tools, accessories and techniques shall be utilised for the termination of cables with aluminium conductors. Bi-metallic lugs shall be used where aluminium conductors are to be terminated onto switchgear of dissimilar metal. Deep indent crimp lugs shall be used for the termination of all aluminium conductors.

6.15.3 Termination of LV Cables

LV cables shall be terminated through a gland entry and the tails shall be fitted with crimped cable lugs of the correct type and size for the cable. Heat shrinkable plastic sleeves shall be fitted to seal cable insulation to lug only after continuity tests are completed and after the joint has been inspected by QUU's Representative if required. The heat shrink on each lug shall be colour coded to identify the phase.

Lugs shall be of the full circle type and shall be tinned copper. Utilux or equivalent pre-insulated lugs are not accepted.

The Contractor shall use compression tools recommended by the supplier of the lugs. Where hand operated, the tools shall be of the type which will not release until full compression is applied.

Hexagonal crimping dies, which emboss the lug with the size of die used, shall be used on all cables of size 16mm2 and above.

The Contractor shall be responsible for ensuring correct phasing, polarity and conductor identification throughout the installation.

For large power cables the cores shall be arranged to ensure minimal stress on the termination and cable. For bolted lug connections stainless steel bolts, nuts and Belleville washers shall be used.

Where required a torque wrench shall be used to tighten termination bolts to the required setting as defined by the equipment supplier. Torque marks using permanent marker or other accepted method shall be provided for all termination bolts.

The earth conductor of each power cable shall be connected at each end to the earth bar of the switchboard or equipment to which the cable is connected.

Each cable core shall have sufficient spare length to allow for replacement of lug or swapping of phases.

All large power cable terminations shall be reviewed and any issues (i.e. the need for drop-down boxes at Switchrooms etc) identified early so as not to impact on the construction programme. Such issues shall be brought to the attention of QUU's Representative for resolution.

6.15.4 Termination of Control Cables

Control cable cores connected to tunnel-type terminals shall be terminated using pin lugs and Grafoplast (or accepted equivalent) 'TRASP' full circle label carriers, of the correct size for the conductor. The lug shall be crimped using a ratchet crimping tool (Grafoplast YAC-5 or accepted equivalent) prior to insertion into the terminal. Crimping shall not be effected using the terminal screw alone.

For terminals requiring ring or fork lugs, Utilux or accepted equivalent pre-insulated lugs and 'TRASP' label carriers shall be used.

Not more than two wires shall be terminated on any one stud type terminal. Not more than one wire shall be terminated in any tunnel type terminal. Where multiple connections are

required on tunnel terminals, multiple terminals linked with proprietary terminal link bars shall be used.

Cores for each single cable shall be terminated in consecutive terminals and in logical order, where possible.

The Contractor shall terminate every core in every control and instrument cable at spare terminals in switchboards and LCS unless specifically indicated otherwise on termination drawings issued as part of the Contract.

All cables which terminate to field devices shall have a single or double coil of cable approximately 150 mm diameter before the cable gland. The cable loop may be within the cable ladder or duct if within 2m of the cable field termination, appropriate for the installation and accepted by QUU.

Where insufficient equipment terminals are provided to terminate all cables including spare cores, additional terminals shall be installed.

The tails of multi-core control cables shall be of sufficient length to allow connection of each core to any terminal on the associated terminal strips. The tails of cables shall be neatly laced up using nylon cable ties. Excess cable tie lengths shall be cut with a specialist cable tie trimming tool and side cutter pliers are not permitted for trimming cable ties.

All screened control cables shall have the screen earthed as detailed in the relevant Project Documentation. The screen on all control cables shall maintain continuity through all intermediate junction boxes between the device and the marshalling/control panel. Where practical the screen shall remain on control cables within the enclosures (i.e. not stripped at the gland) up to the termination destination.

RTD breakout boxes and flexible steel conduit shall be installed where required to facilitate the termination of the RTD cables at the motors.

6.15.5 Termination of Earthing Cables

All earthing cable terminations shall be made using compression lugs for bolted connections, except where tunnel-type terminals are provided inside electrical equipment. Utilux or equivalent pre-insulated lugs are not accepted.

All earth cables shall be terminated on a copper busbar, or an equipment earth terminal. Not more than one earth cable shall be terminated on any one terminal.

Where cable shields are present, they shall be earthed at one end only and usually the PLC Panel or MCC end.

6.16 CABLE GLANDS

All cables entering into equipment shall do so through cable glands conforming to IEC 62444 (or equivalent).

Cable glands shall be standardised across the entire installation and supplied from a single supplier as defined in the project documentation. The gland supplier range shall include a suitable gland guaranteed to fit every type and size of cable for the project.

In general, cable glands shall be of the mechanical compression type and shall include integral facilities for securing and earthing the cable braid, screen or armour where required.

All cable glands for outdoor use other than treatment plants shall be of nickel-plated brass.

Cable glands in treatment plants shall be stainless steel.

PVC glands shall only be permitted for gland sizes up to and including 20mm diameter in indoor areas.

Cable glands shall be of a type which is fully inspectable without the need to disturb cable terminations or the earth continuity of screen or armour clamping and earthing. Cable glands shall include seals to outer cable sheath as a minimum and maintain at least the same degree of protection against ingress of dust and moisture as the equipment enclosure. Glands shall be equipped with nylon sealing washers to be installed between the gland and the outer face of the equipment or gland plate. Cable glands shall have ISO metric threads.

Where adaptors or reducers are required to match cable glands to entry sizes or thread forms, these shall be made of the same material as the gland. Adaptors and reducers shall maintain the IP rating of the gland. Adapters for treatment plants shall be stainless steel.

To prevent vermin ingress conduit and cable glands shall be shrouded and shrouds fixed with cable ties or other method accepted by QUU.

Correct sized cable shrouds shall be used to suit the cable size. All personnel who make off the cable glands shall be fully conversant with the supplier's procedures before making off any gland. The correct gland and installation procedure shall be selected for each cable to the supplier's recommendations and confirmed by the on-site measurement of cable dimensions.

Cables shall be suitably supported where they approach gland entries to ensure a perpendicular entry into the gland and to prevent any forces on glands which may render the IP seals ineffective.

The equipment gland entry or gland plate shall be punched, drilled or tapped as necessary for the installation of the glands. Cable glands shall be fitted with a nylon sealing washer and secured with a lock nut and serrated washer or screwed into the equipment. For drilled and tapped entries the same accessories shall be used where practical to do so. All glands shall be securely fixed to the gland plate or cable entry facility.

The Contractor shall be responsible for ensuring the correct entry point for cables into equipment. Where multiple cable entries occur each cable gland shall be located to facilitate a neat installation and minimise cable and cable core inter-weaving. The glanding and termination of cables in enclosures and panels shall be completed so as to provide sufficient facility for future additional cables to be installed and terminated. Any spare or unused gland penetrations shall be plugged using metallic sealing plugs to maintain the IP rating of the equipment.

Purpose designed glands shall be used for RFI screened power cables (i.e. LV VSD cables) to provide suitable earthing of the screens and armour. It shall be necessary to earth both ends of the screen or armour unless specified otherwise in the project documentation.

Typically this shall be achieved through the use of proprietary purpose built VSD/armour cable glands and the gland plate. However in certain applications (i.e. painted gland plates) it may be necessary to use a gland equipped with a brass earthing tag or serrated washers to ensure a good earth bond.

Where non-metallic enclosures are used, means shall be provided to preserve the electrical continuity of the armouring of cables by bonding the cable glands to each other and to the earth. Generally this shall be achieved using brass earthing tags.

In all instances glands shall be equipped with a suitable thread length to suit the application to ensure accessories such as serrated washers, earthing tags, lock nuts and the like can be securely fixed.

All cable glands to be used in hazardous areas shall be rated for the HA zone classification and protection technique for the particular application and shall have IEC Ex or Aus Ex certification provided in the HA Dossier. Refer TMS1203 General Requirements Hazardous Area Installation Specification for cable glands required in Hazardous Area.

6.17 CABLE INDENTIFICATION

Cables shall be numbered and tagged in an accessible position at both ends of the cable by means of tags bearing the cable numbers listed in the cable schedule. These shall be stainless steel, 12mm wide by 0.5mm thick, stamped laser etched with the number and attached to the cable with plastic coated stainless steel cable ties through holes at each end of the label. Cable ties shall be tensioned and trimmed with a specialist tool.

Tags as per the Project Documentation shall be installed on each cable:

- At start and end of cable;
- On either side of floor and wall penetrations and transit frames;
- At the equipment entry point just before the gland.

Within equipment (e.g. MCCs, marshalling panels and field junction boxes), plastic numbered tags attached with nylon cable ties shall identify groups of cores with the number of the cable to which they belong. The cable inner sheath shall be terminated as close to the relevant terminals as possible in order to make it easy to ascertain the cable identification of the cores. If necessary, additional cable tags shall be installed on groups of cores for complete identification.

Where two or more labels occur at a common point then all such labels shall be readable from the same direction being left to right and bottom to top.

At switchboards and other places where both sides of a cable gland plate cannot be viewed from the one location, cable number tags shall be fitted to cables both above and below thegland plate.

Refer to TMS1647 Equipment Tag Naming Technical Specification for cable tag naming requirements.

6.18 CORE IDENTIFICATION

Numbered core markers as detailed in the relevant Project Documentation shall be fitted to each end of all wires and cores of control and LV cables.

Power cable core identification will be by cable number, and core colour or number (core insulation).

The TMS60 Technical Specification for Low Voltage Switchboards and Enclosures details the requirements for core identification and ferrules within electrical enclosures.

The cores of every control cable, including those at switchboards, marshalling boxes and junction boxes and wherever such cables are connected, shall be ferruled with wire numbers which correspond with the relevant termination diagrams, equipment drawings and schedules.

'Grafoplast' or accepted equivalent ferrules as described above shall be fitted to each end of each core. Ferrules shall have black letters on a background of white insulating material. Circular type, clip-on ferrules, or saddle type clip-on numbers shall not be used.

The same ferrule number shall be used on wires forming connections directly in series or parallel in the same panel.

Where cables for different items of equipment are terminated at the one location (eg. field marshalling box) and wire numbers are the same for the different items, then each wire number shall be prefixed with the item equipment number to distinguish between the cores. This shall be done whether or not it is shown on Contract drawings.

6.19 CABLE LADDERS

Cables routes shall be incorporated into pipe racks where practical. New cable support systems shall allow for 20% spare capacity at the completion of detailed design.

Cable ladder systems including covers shall be capable of withstanding the conditions outlined in the Project Documentation.

Cable ladder shall be designed in accordance with manufacturer's recommendations and standard installation drawings developed for the project.

Unless otherwise specified, all cable ladders shall be NEMA 20C heavy duty, hot dipped galvanised steel (2mm steel) with inward folded rails (i.e. toe-in) of accepted manufacture.

Cable ladders installed in corrosive environments shall be marine grade (6061) aluminium. All nuts, bolts and cable supports shall stainless steel 316, and to prevent electrochemical corrosion and they shall be separated from aluminium components using UV resistant insulating spacers/washers.

Heavy duty fibre glass ladders with stainless steel 316 fasteners are also accepted in corrosive environments where location is not exposed to mechanical damage. Ladders must be installed strictly to the manufacturer's recommendations.

The cable ladder installation shall be designed to eliminate the effects of galvanic corrosion by the use of spacers where aluminium ladder is in contact with galvanised steel or stainless steel.

Cable ladder sections shall be bolted together using splice plates with a full wrap-around sleeve design (to give structural continuity) to form a continuous run. The splice connection shall be designed to transfer the full structural capacity of the cable ladder rail section and accordingly shall be capable of being positioned anywhere along the ladder span.

Proprietary cyclone rated hold down clamps shall be utilised for the fixing of cable ladders to brackets with provision to enable the cable ladder system to expand and contract. Expansion joints shall be fitted according to the cable ladder supplier's recommendations.

Cable covers shall be fixed by screws or bolts, unless otherwise accepted by QUU.

For other than treatment plants, cable ladders shall be supported on fabricated hot dip galvanised mild steel brackets welded or bolted to building structures. For treatment plants cable ladder supports shall be stainless steel welded or bolted to building structures.

Cable ladders shall not be supported directly under splice plates. Thermal expansion gaps shall be provided every 50 metres on straight runs exposed to direct sunlight.

Each splice plate shall be connected to the individual ladder sections using at least two (2) bolts.

Cable ladder rung spacing shall not exceed 300mm.

Cable ladder installations shall be equipped with 20% spare capacity upon completion of the cable installation. The routing of other services including pipes for compressed air or water on cable ladders is not permitted.

All proprietary cable ladder fittings (bends, risers, tee pieces, etc) are to be structural with the fitting rails following the same profile as the cable ladder to form a more self-supporting assembly and improve the rigidity of the large radius bend fittings. The ladder and fittings are to be connected with bolted wrap-around sleeve type splice plates for additional strength. All cable ladder fixing hardware (nuts, bolts, washers, etc) are to be hot dipped galvanised steel. Bolts shall not protrude into cable ladders such as to cause damage to cables during installation. Bolts used for cable ladder joints shall be cup head bolts, with the bolt head inside the run of cable ladder.

Cable ladder sections and fittings shall be designed to span between supports as detailed in the Project Documentation. The design loads for cable ladders shall be suitable for the following criteria:-

- For general loading and cable loading including spare future capacity
- For wind loading design parameters specific to the site conditions

Fabricated non-proprietary steel bends and tee fittings where indicated in the Project Documentation shall be supplied as part of the structural steelwork.

Each length of ladder and all fittings are to be equipped with an earth hole at each end for earth strap connections.

Where it is necessary to drill, cut or weld cable ladders and/or the associated support brackets, the exposed metal shall be cleaned, burrs and sharp edges removed and painted with zinc enriched cold galvanising paint which shall be to the satisfaction of QUU's Representative.

All cable ladders shall be supported as detailed in the standard installation drawings unless otherwise stated in the Project Documentation.

Generally, cable ladders shall be installed with rungs horizontal at the locations and levels detailed on the project drawings. Significant cable ladder clashes or route deviations shall be resolved in conjunction with QUU's Representative.

The installation of cable ladders shall not interfere with access to equipment or passage ways nor subject the cables to excessive heat or the possibility of mechanical damage resulting from adjacent services or equipment.

Ladders shall be run true, straight and squared with the structure and follow the natural line of the structure. As far as practical all cable ladder runs are to be continuous with bends, risers and reducers used for change of directions or change of ladder sizes. Except where detailed in the Project Documentation, ladders shall run in parallel or perpendicular directions only - diagonal or sloping sections shall not be used.

Cable ladder shall be mounted to maintain 450mm clearance (bottom to bottom) between ladders stacked vertically and at least 150mm clearance under structural steel sections when crossing at right angles and 250mm when running parallel and below structural steel or floor plate.

Cable ladder shall be installed to maintain a minimum head clearance of 2200mm in walkways. All cable ladders shall be installed to allow unimpeded access to one side of the ladder.

When fully loaded the sag of cable ladders shall not exceed 1/100 of the span.

In addition to the cable ladders detailed in the Project Documentation the Contractor shall be responsible for the installation of all cable ladders required to reticulate cables from the main ladder routes detailed on the drawings to the final device/equipment locations.

Unless detailed otherwise, all cable ladder brackets and supports shall be configured as detailed in the standard installation drawings. Typically, all brackets shall be fixed via welding or using bolts through holes punched/drilled in the steelwork. Unless specifically detailed in the Project Documentation, or as accepted by QUU, cable ladders and the associated brackets/supports shall not be clamped. The configuration of any non-typical cable ladder installations shall be accepted by QUU's Representative prior to installation.

Proprietary fittings (bends, tees, risers etc) shall be selected to suit the bending radii of the cables on the ladder. Where suitable proprietary fittings are not available customised welded fittings shall be on- site fabricated. Any such on-site fabricated cable ladder fittings shall be to the satisfaction of the QUU's Representative.

Cable ladders shall be fitted with a segregation barrier strip as defined in the Project Documentation. All barrier strips are to be of similar material and finish as the ladder to which it is fitted, and shall be fixed in accordance with the supplier's recommendations.

All cable ladders shall be bonded across all joints and sections to maintain electrical continuity. All cable ladders shall be bonded to the equipotential earthing system. Refer to the section 8.10 for cable ladder earthing detail.

Generally all cable on ladders shall be protected from direct sunlight and dust loading with cable ladder covers. All horizontal cable ladder covers shall be vented and peaked (30° pitch) in the middle. Additionally, all vertical mounted cable ladders shall have perforated backing plates fitted on both sides of the ladder. All cable ladder covers and backing plate shall be heavy duty of similar material and finish as the ladder to which it is fitted and shall be securely fastened in accordance with the supplier's recommendations.

Cable ladder covers shall be installed on cable ladder under the following circumstances.

- All horizontal cable ladders shall have vented peaked cable ladder covers.
- All vertical cable ladders shall have vented peaked cable ladder covers and perforated backing plates.
- All side mounted cable ladders shall have vented peaked cable ladder covers and perforated backing plates.
- Covers are not required within or below substation buildings or similar.
- Covers shall be installed on cable ladder sections, tees, crosses, risers and bends where required above.
- For multiple tiered horizontal cable ladders only the top cable ladder shall require covers unless a greater than 1000mm distance between ladders. For multiple tiered vertical cable ladders only the outside ladders shall require covers/backing plates.

Perforated cable trays as a substitute for cable ladder is not permitted unless accepted under special circumstances by QUU.

Cables to final devices shall be provided with heavy duty mechanical protection where they leave cable ladders, typically using heavy duty flexible conduit.

PVC corrugated and flexible conduits (medium or light duty) are not accepted as adequate mechanical protection

6.20 SURFACE CONDUIT

Surface conduits shall be heavy duty rigid or heavy duty flexible conduits in accordance with AS/NZS 2053.

For all changes in direction draw boxes shall be installed or large sweeping bends fabricated to suit the minimum bending radii of the cables to be installed. Offsets and bends shall be uniform and symmetrical. All bends shall be made without kinking or destroying the circular cross sectional profile of the conduit. "Elbow" and "Tee" fittings shall not be used unless otherwise accepted.

The minimum size of surface conduit permitted throughout the installation shall be 20mm.

In applications where the conduit is to be installed strictly for mechanical protection of the cable it shall be acceptable for the conduit runs to be discontinuous. However, unprotected cable sections shall be minimised and located only where the unprotected cable is not exposed to the risk of mechanical damage. All conduit ends shall be de-burred, smoothed and finished with some means of cable protection (knock-on, threaded bush or similar) and shall be sealed to prevent the ingress of moisture and material after the cable installation has been completed.

PVC corrugated and flexible conduits (medium or light duty) are not accepted as adequate mechanical protection.

In applications where the conduit is to be installed to provide UV protection, weatherproof protection or EMC protection of the cable the conduit run shall be continuous. Unless otherwise specified, double sided saddles or proprietary conduit clamps and channel shall be used for fixing of all conduits. All conduits regardless of the length shall be fixed using conduit support brackets. All fixings and support brackets shall be as per section 3.10 and 3.11 of this specification.

All surface conduit runs shall installed true, straight and squared with structural lines and shall follow the natural lines of the building or structure.

All conduits, unless accepted otherwise by the QUU's Representative, shall be provided with a draw wire.

In special applications flexible steel conduit may be installed. In such instances both the application and the flexible conduit shall be accepted by QUU's Representative prior to installation. All flexible steel conduits shall have an outer PVC sheath.

Only where nominated by QUU's Representative or Project Documentation shall surface conduit be continuous from outlet to outlet, and from fitting to fitting. In such instances fittings and conduit shall be so connected that electrical continuity shall be maintained from start to finish.

All conduit runs shall be cleaned and swabbed to remove foreign matter and moisture prior to pulling in wire or cable.

Medium duty PVC conduit and fittings (in accordance with AS/NZS 2053) shall be acceptable for surface conduit applications within buildings (i.e. control rooms).

In all instances where conduits are to be installed between a hazardous and non-hazardous area, the conduit end in the hazardous area shall be sealed to prevent the propagation of gas. Installation requirements are outlined in TMS1203 General Requirements Hazardous Area Installation Specification.

Conduits, both flexible and rigid, installed outside shall be sealed or installed so as to prevent to accumulation of water and entry of water entry into junction boxes and equipment.

6.21 CAST-IN SITU CONDUIT

Unless specified otherwise, all conduit to be cast into concrete shall be heavy duty rigid PVC in accordance with AS/NZS 2053.

All cast-in-situ conduit runs shall be continuous with all joints completed using conduit bell ends (or couplings) and PVC conduit joining compound as per the suppliers recommendations. "Elbow" and "Tee" fittings shall not be used unless otherwise accepted. For all changes in direction draw boxes or large sweeping bends shall be installed. The minimum size of conduit permitted throughout the installation shall be 25mm. Conduits shall be suitably sized and the number of bends kept to a minimum to facilitate cable installation.

All conduits and fittings shall be adequately fixed to the reinforcement steel or formwork to ensure the installation can withstand the rigors of a concrete pour.

All conduits, unless accepted otherwise by the QUU's Representative, shall be provided with a draw wire. Once cables have been installed (or for spare conduits) both ends of the conduits shall be sealed to prevent the ingress of water, vermin and materials. This sealant shall be a non-deteriorating, non- setting weatherproof sealant capable of being removed at a later date for future cable installation.

Generally conduits shall stub up either directly below or adjacent to the equipment to be connected. The Contractor shall be responsible to ensure that the positioning of the stub up is correct before pouring of concrete. The stub ups shall project 100mm above finished floor/ground level.

In all instances where conduits are to be installed between a hazardous and non-hazardous area, the conduit end in the hazardous area shall be sealed to prevent the propagation of gas. Installation requirements are outlined in TMS1203 General Requirements Hazardous Area Installation Specification.

7 ETHERNET AND FIBRE OPTIC CABLING

7.1 ETHERNET CABLING

Category 6A (Cat6a) Ethernet copper communication cabling (designed for transmission frequency to 500 MHz) shall be used to connect Ethernet capable devices located indoors (e.g. within switchrooms, switchboards, PLC enclosures and network cabinets).

a) Distances for internal Cat6a cable (within buildings) shall not exceed 90 metres total in route length, including patch and fly leads.

b) Distances for external Cat6a cable (outside buildings) shall not exceed 10 metres total in route length.

c) Ethernet cabling shall be installed with the following minimum clearances if not installed within the conduits, or cable ladder metal barrier:

   i. 150mm from Piping

   ii. 450mm from LV Electrical Cabling

   iii. 900mm from HV Electrical Cabling

d) Cat6a cables shall be plenum rated and Teflon coated.

e) Standard RJ45 quick connectors shall be provided to connect to LAN devices.

f) RJ45 connectors shall meet class E characteristics.

g) Supplier approved cable and cable connectors shall be used for fabricating Ethernet patch cables. The UTP cables shall have molded snagless boots, unless otherwise specified.

h) Patch cables shall only be installed within cabinets and shall not bridge equipment or cubicles, unless otherwise accepted.

i) A site certification for installation and supply of UTP cables and associated equipment shall be provided by the Contractor and included in final documentation.

j) The communications rack supplied shall have dimensions to accommodate the minimum bending radius of Cat6a cabling. To accommodate this, the rack shall provide extra deep horizontal cable managers (e.g. for Panduit) and provisions for vertical cable management.

k) Ethernet cables installed for outdoor applications i.e. outside the buildings shall be UV sunlight resistant.

l) Ethernet cables shall be individually glanded into each cubicle, cabinet, panel or equipment.

m) Ethernet cables where installed in LV or HV switchboards shall be industrial grade with the following specifications:

   i. Shall utilise bonded pair technology

   ii. Shall be shielded

   iii. Shall contain solid conductors

   iv. Installation stress resistant

   v. Shall contain industrial grade jacket

Security and CCTV Ethernet cables shall be labelled at the patch board with text "SECURITY SYSTEM DO NOT DISCONNECT"

The requirement of colour code for Ethernet cabling is listed in the below table:

Application	**Standard Colour**
Fire systems	Red
SCADA, electrical protection and process control	Yellow
Telephony (e.g. VOIP/PSTN)	Blue
Corporate LAN and intranet	Blue
Profinet Cable	Green
Security LAN (e.g. Site Access, CCTV)	White

7.2 FIBRE OPTIC CABLING

In this section:

- in-plant cables refer to cables installed and connected end to end within a site fence boundary.
- out-of-plant cables refers to cables installed between sites, typically over longer distances and with routes in publically accessible areas.

The fibre optic cables installed in duct, external tray, pits or direct buried shall comply with the following requirements as a minimum;

a) Unless otherwise specified, for all out-of-plant control systems networks (SCADA & WAN), fibre optic cabling shall be 9/125 μm (OS2) single mode glass fibre type cable.

b) Single mode fibre-optic cabling design shall provide sufficient bandwidth to support 1 gigabit communication.

c) For all in-plant control systems networks and patch leads (Remote I/O LAN, PLC LAN, SCADA LAN), fibre optic cabling shall be 50/125 μm (OM2) multi-mode glass fibre type cable

d) Fibre cables and terminations shall be physically separate for the different applications (Control network, building security, CCTV, SCADA WAN etc.)

e) Fibre optic cabling shall be installed with the following minimum clearances if not installed within conduits or mechanically separated in cable ladder:

   i. 150mm from Piping

   ii. 150mm from LV Electrical Cabling

   iii. 450mm from HV Electrical Cabling

Fibre optic cables shall have the following construction and features:

a) Complete non-metallic loose tube construction

b) Tubes shall be gel-filled to prevent ingress and axial migration of water, strengthened with flexible non-metallic armour bonded to the inner polyethylene sheath

c) Fibres and tubes shall be colour coded

d) An outer protective jacket (nylon or polyurethane) and sacrificial sheath to protect the smooth, hard nylon jacket from being damaged during installation

e) A strain bearing, non-metallic member

f) For in-plant cables and regardless of installation method (duct, external tray, pits or conduits) the cable supplied shall offer a polyamide insect resistant jacket and metal taped rodent resistant armour

g) Surface printing includes marking at 1-metre intervals

h) A minimum of five (5) metres of spare cable shall be left at the termination ends (at both sides) of all cable installations

i) Fibre Optic cabling shall be installed in separate trays, segregated trays, or conduits and in accordance ACIF (Australian Communication Industry Forum) S009 (Installation requirements for customer cabling)

j) Site based underground fibre optic cabling shall be installed in separate underground conduits and secured to the side of cabling pits with additional aluminium protective covers to prevent possible damage.

k) Fibre optic cabling shall be designed in a ring topology for Class 2 & Class 3 architectures as per requirements specified in TMS1202 Control System Implementation Standard Technical Specification. Fibres forming each part of the ring shall be in separate fibre cables, not cores in the same cable. The network shall be configured so that any single fault in the fibre network shall not result in loss of communication.

l) Fibre cables shall provide a minimum of 25% spare core capacity (or four (4) spare cores, whichever is greater) in all fibre cables installations.

m) Fibre optic devices shall use pre-manufactured fibre patch leads for the connections to the patch panels.

n) Fibre connectors shall be LC type for new installations and patch leads.

o) In-plant patch leads shall be ruggedized military specification (mil spec) type where required to transition outside of an electrical enclosure.

p) Fibre patch leads and in-plant fibres cables shall be glanded on entries to equipment and cubicles.

q) Underground fibre optic cable shall include spare length at every second pit. Minimum 50mm conduit shall be used for underground installation of fibre optic cables.

r) Fibre service loops shall be maintained in cable pits, communications cabinets and cable racks. Cable pit lids must fit securely with service loops neatly secured in place.

s) The specifications for all fibre optic cables shall be submitted to the QUU for final approval prior to procurement of the cabling.

7.2.1 Out-of-Plant Buried Installation of Fibre Optic Cables

Single mode optical fibre used for either SCADA or WAN applications or fibre optic cables installed between two sites shall be a water blocked single loose tube non-metallic cable designed for long haul applications. These fibre optic cables shall be suitable for external tray, duct and direct burial applications by either trenching or direct plowing.

The minimum requirements of installation for the underground fibre optic cable shall be:

a) Cables to be installed in heavy duty conduit unless specified otherwise in the project documentation.

a) Cable shall be suitable for direct burial.

b) Minimum depth of cover shall be 600mm

c) Cable sheath shall be rodent and termite resistant.

d) Provide a minimum 100m wide warning tape, 300mm above the conduits / buried cable. The warning tape shall be marked "Danger – Buried Communication Cable Below" and include a 316 grade stainless steel tracer wire to enable detection of the fibre optic cable route along the entire length.

7.2.2 Fibre Optic Cables Installation in Pits

Cable pits shall be adequately sized to allow for fibre optic cable bending radius and service loops.

The fibre optic cable is to be installed in one continuous length to avoid splicing in cable pits.

Fibre optic cables shall be kept clear of power cables (minimum 150mm from LV electrical cables & 450mm from HV electrical cables) in pits to maintain clear access to the power cables and for jointing work on the power cables. This includes avoiding the creation of restrictions to access to the pit, such as cables being passed too close to access ladders.

7.2.3 Fibre Testing

All fibre cores shall be tested after installation as per requirements specified in Communications Cabling Manual (CCM) Volume 2 - 2007. Test sheets shall be submitted to QUU for acceptance. Test results shall include the following as a minimum:

a) Details of test instruments and method used for fibre testing

b) Date of testing

c) Identification number for cables, fibres and fibre cores

d) Measured length of fibres

e) Loss in dB

7.3 FIBRE OPTIC BREAK OUT TRAYS (FOBOT)

Refer to TMS 1202 for selection and installation of FOBOTS.

8 PROTECTIVE EARTHING AND LIGHTNING PROTECTION

8.1 EARTHING SYSTEM OVERVIEW

All earthing works shall be compliant with AS3000 and the associated purpose specific directives detailed in the Project Documentation. The works associated with cathodic protection are not detailed in this section and shall be included elsewhere.

Buried bare copper grading rings shall be installed around the perimeter of the plant areas as detailed in the Project Documentation. Additionally, buried mesh-type earthing grids shall be installed within the facilities at all significant plant that may be subject to substantial fault levels (i.e. Switchrooms, transformers, large packaged plant).

A main earth bar (MEB) shall be provided within the electrical substation at each facility. A switchroom earth bar shall be provided for each switch room and shall be utilised for the equipotential bonding of equipment within the switchroom. Each switchboard/MCC/distribution board/UPS within the switch room shall be equipped with an integral earth bar that shall be bonded to the switchroom earth bar.

A transformer earth bar shall be provided for each transformer compound and shall be utilised for the equipotential bonding of equipment within the transformer compound. The switchroom and transformer earth bars shall be bonded to the facility MEB via 120mm2 PVC insulated earth cables installed in cable ladder unless specified otherwise in the project documentation.

An equipotential earthing loop shall be installed throughout the plant area unless otherwise detailed in the Project Documentation. This earthing loop shall consist of a 120mm2 PVC earth cable that shall start and finish at the substation main earth bar and shall be run throughout the plant on the power cable ladder system. This earthing loop cable shall be used for equipotential bonding of the equipment and structure throughout the plant.

At locations of high density electrical equipment (i.e. equipment skids) dedicated field earth bars shall be provided for earthing equipment within the area. A direct earthing system shall be used for the LV distribution at all facilities. Neutral points at the low voltage transformer windings shall be solidly earthed as detailed in the Project Documentation (typically via an MEN link located in the main LV distribution switchboard) or where not detailed shall be earthed to the transformer earth bar.

All non-current carrying metallic parts and enclosures of electrical equipment and metallic structures used for mounting electrical equipment shall be effectively bonded to earth throughout the plant so as to ensure that all exposed conductive parts are at substantially equal potential during normal operation and under fault conditions. All exposed conductive parts of equipment, piping, vessels and structural items shall be effectively bonded so as to prevent the accumulation of static charge and for lightning protection.

The following conductive equipment shall be solidly connected to the earthing system, but not limited to:-

- Motor frames;
- Transformer tanks;
- Fan housings;
- Process tanks and vessels;
- Pipelines and large valves;
- Structural and reinforcing steelwork;
- Pipe and cable ladder racks;

- Fences and gates;
- Cable ladders;
- Large equipment termination boxes;
- Gland plates;
- Cable glands;
- Metallic cable armours, sheaths and screens (unless detailed otherwise);
- Metallic cable cleats and trefoil clamps;
- Metallic stands, plinths and junction boxes;
- Metallic light fittings and light poles;
- Switchboards, motor control centres, distribution boards and electrical enclosures.

8.2 EQUIPOTENTIAL EARTHING

The buried earth grids shall utilise radial taps for bonding to the following where detailed in the Project Documentation:

- significant equipment (motors, tanks, vessels, etc);
- structural steelwork;
- reinforcing steelwork in the concrete footings;
- field earth bars;
- fences and gates.

The project installation drawings may detail the specific arrangement of these bonds.

The equipotential earth loop cable that runs throughout the plant on the cable ladder system shall utilise radial taps for bonding to the following where detailed in the Project Documentation:

- significant equipment (motors, tanks, vessels, etc);
- structural steelwork;
- cable ladder;
- field earth bars.

The earthing standard installation drawings shall detail the arrangement of these bonds.

The ends of each full length of cable ladder and cable ladder fittings shall be supplied with an earthing hole for earth bonding connections.

Motors, process tanks and vessels and transformer tanks shall be supplied with suitable earthing lugs/bosses and shall not be welded or modified on-site to facilitate earth bonding unless accepted by QUU's Representative.

8.3 BURIED EARTH GRIDS AND GRADING RINGS

Unless otherwise stated in the Project documentation the buried earthing grids and grading rings shall consist of a series of buried earth electrodes interconnected using bare 120mm2 copper earth cable, installed at a depth of 0.5m below finished ground level.

All buried earth grid connections shall be exothermically welded (cad-welded) or made by QUU accepted “C” compression connectors. Refer Section 8.7.

Buried bare copper earth grid cables shall be provided with orange PVC cable warning tape (in accordance with AS/NZS 2648.1) buried over the top of the bare copper cable at approximately 300mm below finished ground level.

It shall be the responsibility of the contractor to determine the finished ground level prior to the commencement of the installation of buried earthing grids.

It shall be the responsibility of the contractor to schedule and coordinate the works to ensure suitable access and to minimise the risk of damage to the earth grid during the construction works (i.e. from earth works, foundation works and heavy construction plant). Earth electrodes/pits shall be provided with temporary barricades and high-visibility flags to prevent damage during construction works.

Any buried earthing grids that sustain damage during the construction works shall be repaired using suitable equipment, components and procedures to ensure the integrity of the earth grid is not compromised. All earth grid repairs shall be tested to satisfaction of QUU's Representative to verify the integrity of the repaired buried grid.

8.4 EARTH ELECTRODES

The earthing installation drawings for the project may detail the equipment and installation arrangement for earth electrodes.

Earth electrodes shall be steel core rods with an electrolytic coating of copper deposited over a layer of nickel (i.e. Eritech copper-bonded earth rods or accepted equivalent). Electrodes shall be a minimum 17mm diameter, provided in minimum extension lengths of 2400mm and shall be extendable via threaded couplings.

Tails shall be used to bond electrodes to buried earth grids will be detailed in the installation drawings. This configuration shall enable the electrode to be disconnected from the buried grid for testing without disconnecting the buried earth grid loop. These tails shall be bonded to the buried earth grid via exothermic (cad-weld) connections or QUU accepted “C” compression connectors.

All connections to electrodes shall be completed using proprietary purpose designed earth rod clamps and shall be primed and wrapped using Denso tape and primer (or similar) to protect the integrity of the connection from the elements.

Earth electrodes shall be protected with an inspection pit of minimum traffic load class C (in accordance with AS 3996) that shall provide suitable access to the electrode for testing purposes. All earth pits shall be clearly labelled. The label shall include the words "Earth Electrode" (or similar) and shall also include the unique electrode identification number as defined in the Project Documentation.

The Contractor shall nominate a suitable electrode numbering convention for QUU acceptance where electrode tag numbers have not been assigned in the Project Documentation.

Where holes are to be drilled to facilitate the installation of the electrode rod the hole shall be back- filled with a suitable earth enhancement compound (Erica "GEM" or equivalent). The mixture shall be thoroughly mixed, formed into a slurry and poured into the electrode hole. The electrode rod shall then be lowered into the hole. The connections on the electrode rod shall be clearly accessible within the pit above the level of the earth enhancement compound and soil.

8.5 EARTH BARS

The earthing installation drawings may detail the configuration for earth bars.

Earth bars shall be tinned copper and of minimum size 50mm x 6mm if not otherwise detailed in the Project Documentation. The earth bar length shall be sized and pre-drilled to facilitate the termination of all earthing conductors as per the contract works plus additional 10% spare terminations. Earth bars shall be mounted using stainless steel brackets, stainless steel fixing hardware and fibre-glass reinforced nylon insulators. Disconnect links shall be provided on earth bars where required to facilitate testing and the ready isolation of buried earth grid connections or different earthing systems (i.e. instrumentation earth system).

Earth bars shall be uniquely identified with QUU Equipment tag names and updated to the Project Documentations where not specified. The labels shall be engraved stainless steel in areas exposed to the elements. Traffolyte (engraved multi-layered plastic) labels are accepted at indoor areas.

8.6 EARTH CABLES

Unless otherwise specified in the Project documentation the buried earth grid cables shall be bare (no insulation or sheath) single core 120mm2 circular, stranded, annealed copper.

Earth bonds to moveable or hinged equipment shall be completed using braided, tinned, flexible copper cable. All other earth cables shall be green/yellow 0.6/1kV V-90 PVC insulated, circular, stranded annealed copper conductor unless specified otherwise in the Project Documentation. Green/yellow PVC tape shall not be used in lieu of conductor insulation.

8.7 EARTH CONNECTIONS

All above ground exposed cable taps, splices and connections shall be made via compression crimps unless otherwise specified in the Project Documentation. All crimps shall be sized to suit the cables and shall utilise the correct tool, dies and procedure as instructed by the crimp supplier. All crimp connections shall be primed and wrapped (Denso products or equivalent) to maintain the integrity of the connection. All crimped connections shall be inspected to confirm the integrity of the connection prior to wrapping.

Connections between earth bars and cables shall be completed using heavy duty copper crimp type cable lugs bolted to earth bars using stainless steel fixing hardware. All earth bar connections shall be coated with a primer (Denso product or equivalent) to protect against corrosion.

Unless otherwise detailed in the Project Documentation, all above ground joints and connections shall be visible and accessible.

Earth cables shall be uniquely identified as per section 6.17 to match the project documentation. The contractor shall assign earth cable tag numbers where not specifically identified and update the project documentation with tag numbers assigned.

Buried earth connections, cable taps, splices and connections shall be made by either exo-thermic welding (cad welding) or “C” compression connectors, unless otherwise specified in the Project Documentation.

8.7.1 Buried earth connections using exo-thermic welding

All exothermically welded connections shall be performed using products that have been qualified for substation grounding in accordance with the requirements of IEEE Std 837. Additionally, a safe and effective method for executing these connections shall be selected (i.e. Erico Cadweld Plus System).

All cad-welding and pre-welding treatment of the conductors shall be in accordance with the instructions of the supplier of the cad welding equipment. All buried connections shall be inspected to confirm the integrity of the connection prior to burial.

8.7.2 Buried earth connections using compression connectors

The Contractor shall submit to QUU for acceptance details of the compression connection system proposed for each combination of conductor types and sizes to be joined, including:

- connector type (brand and part number)
- compression die type (brand and part number)
- compression tool type (brand and part number)

The connectors shall be suitable for direct burial in the ground.

The design of the connector shall allow the laying of two cables side by side when making a conductor/conductor connection.

The "C" shaped compression fitting is the preferred compression type connector.

Compression connections shall be irreversible.

The preferred type of compression connector is Burndy Hyground.

The combination of compression connector, compression tool and die shall be compatible and suitable for the conductor sizes being joined.

The compression tool shall be of a positive locking action that shall not release until the compression joint is completed.

The compression die shall emboss the connector with markings to confirm that the correct die has been used for that connector.

Pre-treatment of conductors, compression fittings and dies shall be in accordance with the instructions of the compression fitting and tool suppliers.

Some form of anti-oxidant grease covering the inside of the connector is required for compression type fittings.

All compression connections shall be primed and wrapped (Denso products or equivalent) to maintain the integrity of the connection. All compression connections shall be inspected to confirm the integrity of the connection prior to wrapping.

8.8 EARTH LEAKAGE PROTECTION

Power outlets and luminaires shall have earth leakage protection unless detailed otherwise in the Project Documentation:

- Lighting circuits and single phase socket-outlet circuits shall be connected to 30mA earth leakage modules within the distribution boards;
- Three phase socket-outlet circuits (where the rated current of any individual socket outlet does not exceed 20A) shall be connected to 30mA earth leakage modules within the distribution boards.
- Three phase welding outlets (rated greater than 20A) shall be connected to 100mA earth leakage modules within the distribution boards or at the outlet.
- 30mA RCDs shall not be provided on the line side of UPSs

In all cases the minimum requirements of AS3000 shall apply.

8.9 CABLE EARTHING

Integral earth conductors, screens, metallic sheaths and protective metallic armours of HV and LV power and control cables shall be connected to earth at both the origin and destination ends unless detailed otherwise in the Project Documentation or equipment manufacturers' recommendations.

Typically, integral earthing conductors and screens shall be directly connected to the earthing facilities at both ends. Typically, the metallic sheathing and armouring shall be earthed via the cable gland onto the metallic gland plate which shall be bonded to the earthing facility at each end.

In some applications where defined in the Project Documentation an independent earth cable shall be installed in addition to the integral earth conductor or screen of the cable.

8.10 CABLE LADDER

All cable ladders shall be electrically continuous and shall be bonded on one side of the ladder across the splice plates using 25mm2 G/Y PVC cable bonds.

Additionally, the following cable ladders shall be bonded at 15 metre intervals to an equipotential bonding conductor (120mm2 G/Y PVC) installed within the cable ladder system:

- cable ladders within the electrical substation area;
- multi-tier backbone cable ladders;
- HV Power cable ladders;
- LV Power cable ladders (excluding small light and power).

The following minor cable ladder runs shall be bonded to the plant earth at the start and finish of the ladder runs only and shall be electrically continuous from end to end:

- single-tier lighting and small power cable ladders outside the substation area;
- single-tier ELV, control and instrumentation cable ladders outside the substation area.

The earthing standard installation drawings shall detail the arrangement of the cable ladder earthing.

8.11 LIGHTNING PROTECTION

Lightning protection as shown on the Project Documentation shall be incorporated as an integral part of the overall earthing system, and shall be installed in accordance with AS3000, AS 1768 and where applicable, manufacturers' recommended procedures.

The general principals of equipotential earthing as described in Section 8.2 shall apply, and in addition the Contractor shall take particular measures to ensure lightning protection system down conductors and earth pits are located in the closest practical proximity to the associated protected structures.

Down conductors shall be run true to building and equipment structures and shall be adequately supported to ensure no mechanical damage shall occur under the influence of a lightning event, or wear typically associated with operation in heavy industrial environments. Any such down conductor supports shall not be solely fastened to sheet metal or cladding. Down conductors shall not be routed in trafficable areas and shall be clear of areas where persons may frequently occupy in normal operations.

Surge protection devices shall be installed according to the manufacturers' recommendations, and shall in any case take due regard to minimise conductor lengths and excessive conductor bends. Surge protection devices shall be disconnected from circuit during insulation testing; any protection devices damaged during testing shall be replaced by the Contractor at his own cost.

Refer TMS1203 General Requirements Hazardous Area Installation Specification for lightning protection of areas with a Hazardous Areas classification.

9 LIGHTING AND SMALL POWER

9.1 GENERAL

The Light and Small Power Layout Drawings, Distribution Board Drawings and other Project Documentation shall detail the lighting and small power requirements to be installed throughout the site.

9.2 DISTRIBUTION BOARDS

The Project Documentation shall define the circuit configurations for all light and small power distribution boards. The Project Documentation shall define the control and switching functionality for all lighting and small power loads.

The 230V lighting and small power electrical loads shall be balanced across all three (3) phases.

The TMS60 Technical Specification for LV Switchboards and Enclosures defines the requirements for the installation and termination of all internal wiring and field cabling within distribution boards.

Any additional lighting and small power loads not defined in the Project Documentation that are to be supplied from distribution boards shall be circuited in a configuration consistent with that used for the other documented loads on the distribution board. The circuit arrangements for any such additional loads shall be accepted by QUU's Representative prior to commencing the installation works.

9.3 PLANT LIGHTING

Rows of lighting fixtures shall be accurately aligned and securely fixed such that the alignment will not be disturbed by normal plant operation, maintenance or weather conditions. The standard installation drawings shall detail the typical installation arrangements for the plant lighting. Light fittings shall be installed such that they are easily accessible and can be removed and replaced without dismantling conduit, brackets or similar.

The mounting arrangement of fittings and associated control gear and junction boxes shall be such that routine maintenance works can be completed safely. Particular consideration shall be given to light fittings that are to be located on or adjacent to handrails where maintenance work at heights may introduce the risk of falls from significant heights. In such instances hinged poles or similar shall be used so routine maintenance can be completed from the walkway level to eliminate such risks. Hinged poles shall be arranged to ensure the pole can be dropped and erected without clashing with other services or structure.

The hinged poles may be clamped to the walkway handrails using proprietary clamps unless otherwise specified in the Project Documentation. An RPEQ structural engineer shall approve the handrails suitable for fixing the light poles.

Light switches where required shall be installed at a height of 1.2m above the floor level or as otherwise specified.

Light fittings shall be mounted with a minimum 2.2m clearance below the fitting (unless detailed otherwise). If this clearance cannot be achieved the mounting of the fitting shall be accepted by QUU's Representative prior to erection. All luminaires and control gear shall be installed in accordance with the supplier's recommendations.

Generally, all light fittings shall be equipped with a dedicated junction box located adjacent to the light fitting in an accessible location. All light fittings and/or lighting junction boxes shall be clearly labelled defining the supply circuit and light fitting tag number (where applicable) in accordance with the Project Documentation. The lighting circuit identification may be achieved by cable labels if accepted by QUU's Representative.

All emergency lighting shall be circuited and installed in accordance with the relevant standards and statutory regulations. Dedicated circuits shall be used for emergency lighting and the associated distribution boards shall be equipped with facility for the necessary routine testing of the emergency lighting system. Where emergency light circuits are fed from a UPS the UPS shall be standalone dedicated to only the emergency lighting in accordance with AS 2239.1.

9.4 STREET AND AREA FLOOD LIGHTING

The free standing street and area flood lighting shall be installed to enable easy and safe access to the luminaire and the associated control gear for maintenance works (i.e. hinged street light poles or similar). Hinged poles shall be arranged to ensure the pole can be safely dropped and erected without clashing with other services or structure. Similarly, area lighting mounted on plant or structure (i.e. floodlights on buildings) shall be installed to enable easy and safe access to the luminaire and the associated control gear for maintenance works. The standard installation drawings shall detail the typical installation arrangements for the street and area flood lighting. The mounting arrangement shall enable the light fitting to be adjusted to fine-tune the area illuminated. Light fittings and control gear shall be installed such that they can be removed and replaced relatively simply (i.e. without dismantling conduit, brackets or similar)

Free standing steel light poles shall be solidly earthed by a dedicated earth cable bonding the pole to either a dedicated earth electrode or the local main earth grid. The pole shall also be bonded to the earth in the lighting supply cable via an appropriately rated Contractor supplied terminal strip.

In addition to this earth bond, street lighting poles shall be located in proximity to an associated earth pit to minimise the lightning path to earth. Street lighting and other free standing light poles above 8m shall also be fitted with lightning surge diverters as specified in the standard installation drawings. Where specified in the Project Documentation light poles shall be equipped with a lightning finial or similar for lightning protection.

For free standing light poles the footings and rag bolts shall be sized and installed in accordance with the structural foundation design. Grout shall be installed between the footing and pole structure. All poles shall be installed square and level and aligned when located in rows.

All light poles shall be clearly labelled defining the supply circuit and light fitting tag number (where applicable) in accordance with the Project Documentation. The circuit identification may be achieved by cable labels if accepted by QUU. Each light pole shall be equipped with a gear tray or similar to facilitate cable termination and mounting of a fault protection device (fuse or similar). The cable termination and local protection device shall be located in an accessible location for ease of maintenance works.

All luminaires and control gear shall be installed in accordance with the supplier's recommendations.

9.5 LUMINAIRES

Luminaires shall be LED unless specified otherwise in the Project Documentation.

Lamps and tubes of the specified type, size and manufacture shall be installed in the lighting fittings.

All luminaires shall be thoroughly cleaned after erection and shall be handed over in a clean condition and, where required, accurately focused.

All installations shall be completed to maintain the IP rating of the selected fitting.

Luminaires to be installed within hazardous areas shall be suitably certified and installed in accordance with the requirements of TMS1203 General Requirements Hazardous Area Installation Specification.

9.6 POWER OUTLETS AND SWITCHES

Unless detailed otherwise in the Project Documentation, power outlets and switches to be installed in the plant outdoor areas shall be as follows:

- heavy duty industrial grade with a solid die-cast aluminium body;
- UV and corrosion resistant;
- minimum IP65 ingress protection rated;
- have facility for pad-locking in the off position;
- have the metallic body earthed;
- have external mounting facilities to ensure integrity of IP rating when mounted;
- have an auto closing flap on the socket outlet;
- have a switch plug interlock system (i.e. plug cannot be inserted or withdrawn with switch in the on position);
- for single phase outlets be 230V 15 Amp;
- for three phase outlet applications be 5 pin;

The power/current ratings for each power outlet shall be as detailed in the Project Documentation. The power rating for light switches shall be matched to the circuit breaker rating for the supply circuit.

The standard installation drawings shall detail the typical installation arrangements for power outlets and switches in the plant. Each outlet and switch shall be labelled to indicate from which distribution board and circuit breaker it is fed and the outlet tag number. The outlet tag number shall be correlated with the associated circuit breaker number on the distribution board legend.

Where multiple outlets are supplied from a single circuit and the outlet cannot facilitate a loop-in loop- out of the nominated cable (i.e. cable size is too large to loop-in and loop-out) a break gauge junction box shall be installed adjacent to the power outlet.

Unless detailed otherwise in the Project Documentation, all power outlets (single and three phase) shall be provided with earth leakage protection incorporated into the circuit breakers within the distribution boards.

Unless detailed otherwise in the Project Documentation, for non-industrial areas (i.e. offices, control rooms, etc), 10 amp, moulded plastic, flush mounting, general purpose outlets shall be installed.

- These outlets shall be clearly and permanently labelled and coloured as follows:White - Non-essential supply
- Red - Essential or UPS supply,

Red UPS outlets shall be labelled “Not for General Use”.

9.7 WELDING OUTLETS

Welding outlets shall be in accordance with the requirements for three phase outlets installed in outdoor plant areas as detailed in section 9.6.

Unless detailed otherwise in the Project Documentation, welding outlets shall be 400 V 63A, 3P+N and E.

9.8 DECONTACTORS

Decontactors shall be installed on equipment as defined in the Project Documentation. All decontactors shall include an auxiliary contact to provide an input to the control system to define the status of connection of the equipment/decontactor. Where decontactors are to be used for local isolation they shall be equipped with a suitable facility for affixing isolation locks or hasps.

Decontactors shall have a utilisation of AC23. They shall have a polyester body where the circuit's motor has a full load current of 150 Amp. Circuit ratings >150A shall use decontactors with a metal body.

Flexible cable (PVC/PVC) shall be installed from the equipment to the decontactor.

Decontactors shall be mounted 1.2m above the operating floor unless shown otherwise in the Project Documentation.

10 SIGNS AND LABELS

Every item of electrical equipment shall be provided with a clearly visible tag label showing the unique tag identifier for the item.

Warning and indicating signs and labels shall be provided in accordance with the Project Documentation and the relevant codes, standards and regulations.

10.1 SIGNS

Warning signs shall be positioned to ensure they are clearly visible and not obscured by any other item of equipment. Signs at building entrances shall be positioned to ensure the sign is clearly visible from the approach side with the entrance door open or closed.

All danger and warning signs shall be in accordance with AS1319 and shall have zinc-anneal surface protection or equivalent.

The following signs shall be installed as a minimum:

- Signs denoting 'Danger' and applicable voltage (e.g. High Voltage, 400V, etc) at each switchroom door and each transformer or switchyard enclosure and gate;
- Signs denoting 'Danger High Voltage' at appropriate intervals not exceeding 50m, and at each change of direction along HV cable ways on cable ladder, etc. These signs shall be positioned such that they are readily visible from walkways, roadways over which HV cables pass;
- Sign posts along underground cable routes to identify the cable route and location of in-line cable joints. Labels shall be installed on pit covers, where joints are made in pits;
- Signs on cable ladder to identify the location of in-line cable joints;
- Signs for substation/switchroom entrances denoting access by authorised persons only;
- Signs denoting 'Warning Confined Space' for electrical cable pits, ducts and the like that shall be classified as confined space areas under the applicable codes and regulations.
- Signs on HV switchrooms and other HV equipment shall comply with AS2067;
- Signs on switchboard compartments indicating maximum voltage level in the compartment
- Signs on switchboards indicating where all voltage sources are fed from.
- All HV and LV switchrooms shall be fitted with an electric shock survival sign (in accordance with Australian Resuscitation Council guidelines) mounted in a prominent location.
- Signs indicating emergency routes to the nearest hospital and emergency phone numbers shall be displayed in a visible location for all high voltage switchrooms and installations (as required by section 10 of AS2067).
- Any signs not specified in the Project Documentation which may be required in order to comply with the relevant regulations, codes and standards.

10.2 EQUIPMENT LABELS

Electrical equipment shall be labelled by means of permanently attached tag labels in accordance with the Project Documentation and the equipment schedules.

The Standard Label Drawings shall identify the requirements for labelling electrical equipment. These drawings shall detail the label material, label size, text size, label configuration and fixing arrangement for each type of label.

The Contractor shall submit a typical label for each type of equipment to QUU's Representative for approval prior to ordering or manufacturing any labels.

Where it is not practical to mount labels on the equipment they shall be mounted on the adjacent steelwork or equipment mounting bracket stand. Equipment mounting stands and brackets shall be provided with provision for mounting labels. In all instances equipment labels shall be clearly visible from the walkway or equipment operating position.

Fixing shall be by a minimum of two stainless steel screws. For switchboards the screw holes shall be drilled and tapped. Labels larger than 75mm x 25mm shall have four fixing screws. Fixing of labels shall not void the IP rating or certification of the equipment. Attachment by means of adhesives shall not be permitted, except for Ex hazardous areas equipment enclosures and where accepted by QUU.

Fixing holes in labels shall be drilled oversize and screws shall not be tightened to the extent that the label cannot move under expansion caused by extremes of temperature.

11 QUALITY ASSURANCE, INSPECTION AND TESTING

The Contractor shall demonstrate that all works comply fully with the specification and all associated Project Documentation.

11.1 QUALITY ASSURANCE

The Contractor shall apply a quality assurance system accredited to AS/NZS ISO 9001 for all works. The effectiveness of the quality assurance system and the Contractor's compliance with it shall be subject to monitoring by QUU's Representative and in addition, may be audited following an agreed period of notice.

The Contractor shall submit a quality control program for QUU's Representative review at the time of Tender. The Contractor shall cooperate with QUU's Representative and QUU's nominated auditors during all stages of the works with respect to quality assurance matters.

Components and works shall be inspected and tested in accordance with quality control and assurance procedures nominated by the Contractor and accepted by QUU's Representative. The Contractor shall identify hold points for access by QUU's Representative.

11.2 INSPECTION AND TESTING

QUU's Representative shall be permitted at all times free access to all parts of the Contractor's works that concern execution of the works including on-site workshops and storage facilities.

The Contractor shall supply all test equipment, tools and materials required and shall be fit for purpose, in good working condition and calibrated. Calibration certificates shall be maintained for all relevant equipment.

11.2.1 Inspection and Test Plan (ITP)

The Contractor shall include typical Inspection and Test Plans (ITP) in their Tender documents. The ITPs shall list typical inspections and tests proposed for all elements of the works.

Prior to commencement of the relevant works the ITPs shall be customised by the Contractor for the project works and have been reviewed and accepted by QUU's Representative. QUU's Representative and the Contractor shall sign off the final version of the ITPs, which, thereafter, shall form part of the contractual documents. The ITPs shall encompass the testing requirements of all relevant standards and statutory/regulatory requirements.

The Contractor shall be responsible for the planning and execution of all inspections and tests, with QUU's Representative having the right to witness any or all of the inspections or tests.

ITPs shall be completed and signed off progressively during the execution of the works.

The Contractor shall notify QUU's Representative, at least 4 days in advance, of the date on which any of the inspections or tests nominated as Hold or Witness points on the ITP's are due to be carried out.

ITPs and Checksheets shall be completed for all works to prove it has been satisfactorily tested to meet all defined requirements whether or not witnessed by QUU's Representative.

Where appropriate, test check-sheets shall state values for all test results. Tests for which the results are indicated as pass or fail shall be qualified by the relevant acceptance criteria.

The following typical documents outline the minimum content to be completed by the Contractor where applicable to the site testing and inspection works:

- FOR279 Site Details & Test Sheet – Electric Motors
- CHE69 Site Inspection Checks - Electric Motors
- CHE68 Site Inspection Checks – Cables
- CHE70 Site Inspection Checks - Instruments
- CHE71 Site Inspection Checks – Switchboards
- CHE72 Site Inspection Checks – Cable ladder/ Tray / Ducts
- CHE136 Site Inspection Checks – Field Equipment

11.3 INCOMING EQUIPMENT INSPECTIONS

All equipment shall be inspected upon arrival at site for damage and conformance with the purchase orders, specifications and all other relevant documentation. An incoming equipment ITP shall be developed that will detail the exact inspection requirements.

11.4 CONTROL SYSTEM TESTING

Refer to TMS1202 Control System Implementation Standard Technical Specification for quality assurance, testing and commissioning requirements for all control system equipment, including PLCs, HMIs, SCADA and network devices.

11.5 CABLE TESTING - LOW VOLTAGE

The relevant Inspection and Test Plans shall detail the exact test requirements for all cables. However as a minimum the following cable tests shall be completed:

- Insulation resistance testing for LV power and control cables with a 1000V DC insulation test unit.
- Point-to-point continuity testing.
- Contact resistance/ductor testing for large power cable connections.
- Torque check for large power cable terminations.
- Cable gland inspection.
- Cable label verification.
- Phase connections

11.6 CABLE TESTING – HIGH VOLTAGE

The relevant Inspection and Test Plans shall detail the exact test requirements for all HV cables. However as a minimum the following cable tests shall be completed:

- Visual inspection for evidence of partial discharge on cables sheaths and terminations where design proposes to retain the cables in service;
- Insulation resistance testing of cables in accordance with the recommendations of the cable manufacturer. Insulation resistance shall be tested before and after the VLF test;
- VLF testing of cables in accordance with the recommendations of the cable manufacturer;
- Contact resistance / ductor testing of cable connections before and after termination;
- Torque check of HV cable connections (where relevant);
- Cable gland inspection (where relevant);
- Check excessive tension at cable connection points;

- Cable label verification;
- Screen and armour earthing inspection.
- Phase connections

Prior to finalising the ITPs and commencing the HV cable testing the Contractor shall confirm acceptance of the proposed cable testing procedures with the relevant cable vendors to ensure the testing procedures shall not damage the cables or void the manufacturer's warranties.

Existing HV cables to be relocated and retained in service shall be inspected and tested as per above after relocation and before terminating at the new location. All testing shall only be undertaken as per the cable manufacturer's recommendations.

11.7 EARTH FAULT LOOP IMPEDANCE TESTING

The characteristics of protective devices and the earthing system impedance shall be such that, if a fault of negligible impedance occurs anywhere in the electrical installation between an active conductor and a protective earthing conductor or exposed conductive part, automatic disconnection of the supply will occur within times as specified by Section 5.7 of AS3000.

Earth fault-loop impedance measurements shall be made for all circuits in accordance with Section 8.3.9 and Section B.4.6 of AS3000.

11.8 EARTH SYSTEM TESTING

The relevant Inspection and Test Plans shall detail the exact test requirements for all earthing systems. However as a minimum the following tests shall be completed:

- Visual check of earth bars, earth grids and earth electrodes.
- Visual check of connection of earth continuity and earth bonding conductors for cable ladders, motors, distribution boards, marshalling panels, process plant/vessels, mechanical equipment and structural steelwork.
- Earth continuity checks.
- Resistance to earth test of each individual earth electrode.
- Step and Touch Potential measurements
- Overall resistance to earth testing of earth grid
- Soil resistivity testing (prior to earth grid design) for Greenfield sites or where significant modification to existing earth grids are required.
- Testing shall be undertaken as per the Wenner 4 pin method outlined in AS1768

11.9 POWER TRANSFORMER TESTING

The relevant Inspection and Test Plans shall detail the exact test requirements for transformers. However as a minimum the following inspection and tests shall be completed:-

- Check for correct oil level and oil leaks.
- Test insulation resistance between windings and from each winding to ground.
- Perform primary winding resistance tests on all taps
- Perform secondary winding resistance tests
- Perform ratio and polarity tests on all taps
- Check all terminations are correct, covers applied and bolts tight
- Perform function tests on all on-board instruments
- Sample and test dielectric breakdown strength and dissolved gasses in insulating oil. Testing shall be undertaken at QUU's nominated test laboratory

- Monitor for 24 hours after energisation for oil leaks and temperature rise.

11.10 SWITCHBOARD TESTING – LOW VOLTAGE

The relevant Inspection and Test Plans shall detail the exact test requirements for each switchboard. However as a minimum the following inspection and tests shall be completed:-

- All tests as per AS3017
- Check all labels attached as per label schedule and AS3000
- Inspect for damage and missing parts
- Check the IP rating.
- Check line out of switchboard for level, vertical alignment and continuity of level between panels. Results shall be within the manufacturer's required tolerances, and no deviation will be accepted.
- Check tightness of foundation and structural bolts.
- Check tightness of power connection bolts and distribution board bus bar connection bolts.
- Check tightness of cable and wire terminations.
- Check all earth connections are correct and are connected to the earth grid. Check resistance of main earth cable from earth busbar to earth grid.
- High voltage insulation tests on busbars between all phases and from each phase and neutral to earth, and across circuit breaker and switch open contacts using 1000 V test voltage and one minute test duration.
- High current micro-ohm resistance test across incomer cable termination, across incomer switch in closed position, and from incomer to outgoing terminals of every power circuit over 150 A.
- Check phasing of all incoming and outgoing circuits.
- Operate each device (switch, circuit breaker, contactor, overload, etc,) to prove correct operation.
- Check operation of door handles, mechanical interlocks, etc and freedom of operation of electrical switches.
- Check operation of key interlocks, where installed.
- Check fuse holders for damage and fuses for continuity and correct rating.
- Check and confirm setting of circuit breakers, thermal overloads, timers etc as per the Project Documentation.
- Confirm function of all local and remote switching operations.

11.11 SWITCHBOARD TESTING – HIGH VOLTAGE

The relevant Inspection and Test Plans shall detail the exact test requirements for HV Switchboards. However as a minimum the same tests apply as per Section 11.10 for LV Switchboards and the additional testing as follows:-

- Confirm nameplate is in place and equipment is within design specification
- Confirm manual operation of switchgear
- Perform contact resistance on Isolators & Earth switches
- Perform ductor test on all bus bars
- Perform pre Hi Pot insulation resistance tests
- Perform Hi Pot (Withstand) tests
- Perform post Hi Pot insulation resistance tests
- Ensure all indication is correct

- Confirm all electrical indication to local control panel and panel lights
- Confirm all interlocks are operational
- Ensure cable boxes are clean and photos to verify before placing covers on
- Confirm switchgear's physical condition is acceptable
- Confirm function of all local and remote switching operations for circuit breakers and isolators.

11.12 HV CIRCUIT BREAKER TESTING

The relevant Inspection and Test Plans shall detail the exact test requirements for HV Circuit Breakers. However as a minimum the following inspection and tests shall be completed:-

- Confirm nameplate is in place and equipment is within design specification
- Confirm manual operation of circuit breaker
- Perform contact resistance on circuit breaker (only if circuit breaker is rackable)
- Ensure all indications are correct
- Confirm all interlocks are operational
- Confirm electrical operation of circuit breaker
- Confirm operation of the circuit breaker by secondary injection of the protection scheme
- Perform circuit breaker timing tests
- Perform circuit breaker reduced voltage tests
- Confirm switchgear's physical condition is acceptable

11.13 INSTRUMENT TRANSFORMER TESTING

The relevant Inspection and Test Plans shall detail the exact test requirements for instrument transformers. However as a minimum the following inspection and tests shall be completed:-

- Confirm nameplate is in place and equipment is within design specification
- Perform primary insulation resistance tests
- Perform secondary insulation resistance tests
- Perform winding and loop resistance tests
- Perform ratio and polarity tests
- Perform magnetisation curve tests
- Perform secondary loop tests
- Confirm wiring is as per latest schematics
- Confirm polarity of complete secondary circuits
- Perform primary injection metering checks back to protection or metering if applicable
- Confirm physical condition is acceptable

11.14 PROTECTION RELAY TESTING

The relevant Inspection and Test Plans shall detail the exact test requirements for Protection Relays. However as a minimum the following inspection and tests shall be completed:-

- Confirm settings file given is in accordance with Protection Coordination Report
- Confirm metering checks via secondary injection to confirm correct settings
- Prove protection functions operate correctly via secondary injection
- Prove protection functions operate appropriate outputs via secondary injection

- Prove stability of the Restricted Earth Fault scheme via primary injection of the current transformer,
- Confirm mechanical functions from transformer initiate appropriate protection functions
- Ensure all CT links are closed and relay ready to be put in service
- Confirm function of intertrips to and from other protective devices
- Confirm 61850 communications and network functions (if applicable)
- Confirm data communications and system integration with SCADA/PLC system

11.15 MOTOR TESTING – LOW VOLTAGE

The relevant Inspection and Test Plans shall detail the exact test requirements for all motors. However as a minimum the following motor tests shall be completed:

- Motor insulation resistance testing with a 1000V DC insulation test unit and minimum one minute test duration.
- Resistance testing of PTC devices and thermistors.
- Verification of TOL settings.
- Verification of correct phasing and phase rotation.
- High voltage resistance test across open local isolator contacts (if applicable).
- Resistance test of motor windings, between phases.
- Resistance test of motor winding for each phase compensate for 25°C.
- Earth conductor resistance measurement from motor to MCC earth busbar. Resistance shall not exceed one ohm.
- Full simulation test of all control devices, operating all devices individually and in combination to prove correct operation.
- Motor rotation direction test.

11.16 MOTOR TESTING – HIGH VOLTAGE

The relevant Inspection and Test Plans shall detail the exact test requirements for HV motors. However as a minimum the same tests apply as per Section 11.15 LV Motor Testing and the additional testing as follows:-

- Motor insulation resistance testing with a DC insulation test unit and minimum one minute test duration at voltage specified by manufacturer
- Polarisation Index Tests at 1 minute and 10 minute interval for each phase
- Confirm correct Star / Delta links fitted if applicable and in the correct configuration.

11.17 LIGHT AND SMALL POWER INSTALLATION TESTING

The relevant Inspection and Test Plans shall detail the exact test requirements for all light and small power equipment. However as a minimum the following tests shall be completed:

- All applicable tests as per AS3000 and AS3017.
- Polarity tests.
- Correct circuit connections.
- Normal and emergency horizontal plane illumination levels around operational equipment, along conveyors, walkways and stairs.
- Emergency lighting function tests.
- RCD injection test.

11.18 SIGNIFICANT ELECTRICAL PLANT TESTING

The relevant Inspection and Test Plans shall detail the exact test requirements for Switchrooms and all other electrical equipment.

For switchboard replacement the Contractor shall prepare a site specific switchboard changeover commissioning plan based on the TMS78 Typical Switchboard Changeover Commissioning Plan.

11.19 SITE ACCEPTANCE TESTING (SAT)

The Contractor shall develop a Site Acceptance Test (SAT) document (test plan/strategy and full complement of test sheets) that clearly defines the logical sequence and structured testing of the complete installation (switchboard and all field devices) in accordance with the issued drawings/documentation and standard templates. This includes preparation of a switchboard changeover commissioning plan for each site installation works. SAT documentation will be site specific and will require QUU review and approval prior to commencement of each SAT.

The Contractor shall complete testing, pre-commissioning and commissioning of the installation works to the satisfaction of the QUU Representative as per the accepted site specific SAT documentation, including each site changeover commissioning plan.

Note that the Site Acceptance Test Procedure- Checklist (CA17 a to h) will be completed by the Contractor on the day of every Site Acceptance Test. The Contractor shall review this checklist prior to Site Acceptance Testing to ensure all testing can be completed on the day of Site Acceptance Testing.

11.20 SITE FUNCTIONAL TESTING

The Contractor shall provide full Site Functional Testing in the presence of QUU Representatives. These tests include but are not limited to:

- Testing of all field devices from the field through to the QUU Telemetry Systems Control Room;
- Functionality testing of the pumps;
- Functional testing of switchboard remote operations from the QUU Telemetry Systems Control Room
- Functionality testing of the backup and changeover system;
- Failure modes and process plant recovery;
- Functionality testing of the alarms back to the Control Room; and
- Process control (automatic and manual operation).
- Correct function of telemetry and SCADA remote indication at the QUU Telemetry Systems Control Room for all digital and analogue signals.

11.21 SETTINGS AND PRE-COMMISSIONING

Settings of equipment and instruments shall be in accordance with equipment manufactures instructions and with site specific data contained within the Project Documentation.

11.22 FAILURE

Any works or equipment that fails an inspection or test shall be repaired or replaced. All inspections and tests which are affected by the rework shall be repeated.

12 TRAINING AND DOCUMENTATION

The Contractor shall be responsible for providing all documentation in accordance with the Project Documentation requirements and the Supplier Data Requirements List (SDRL) included in the Project Documentation.

As a minimum the following documentation shall be progressively maintained by the Contractor during the execution of the works:

- Quality Assurance records including ITP's and the associated check-sheets and test records for all elements of the works.
- Cable management records including cable drumming schedules to track the cable quantity utilised and cable quantity remaining for all on-site cable.
- Cable traceability records to ensure that all installed cables can be traced to a specific cable drum as supplied from the vendor.
- As-built mark-ups of all Project Documentation to reflect the completed installation.
- A record of all QUU Representative accepted changes to the Project Documentation.
- A record of all QUU Representative supplied directives or Site Instructions.
- A record of all Contractor submitted Technical Queries and the associated QUU Representative responses.
- A record of all QUU Representative accepted Contractor Design Deliverables.
- Survey records/coordinates that detail the exact route of all buried cable installations and joints.

Note: All above documentation shall be maintained at the site and available for QUU to inspect upon request.

Upon completion of the contract works the above listed documentation shall be officially submitted by the Contractor to QUU Representative as well as a complete set of the final signed-off as- built documentation.

12.1 CONTROL SYSTEM DOCUMENTATION

Refer to TMS1202 Control System Implementation Standard Technical Specification for documentation requirements for all control system equipment, including PLCs, HMIs, SCADA and network devices.

12.2 TRAINING

The Contractor shall provide a comprehensive training course for all electrical equipment, motors, switchboards and protection systems included in the Contract scope of work unless specified otherwise in the Project Documentation.

The training includes two (2) off training sessions for minimum duration of 8 hours and up to 8 staff per session held on separate days, or as otherwise agreed with QUU. The training must be tailored to the intended audience and shall be conducted on-site or at an agreed location and tailored for (electricians, operators and engineers).

The training course shall include but not necessarily be limited to the following:

- Introduction and overview of the electrical system including a site walk through;
- Description of the electrical power system including functions and features which shall be supplemented by the switchboard and electrical installation operations and maintenance manual.
- Description of protection system philosophy

- Switchboard operation
- Protection relay operation and configuration
- Configuration and fault finding of related instrumentation
- Preventative and corrective maintenance procedures;
- Engineers and technicians shall be provided a comprehensive site walk-through and inspection, showing all the electrical and protection related equipment, the installation locations, methods of connection and practical live demonstration.
- Engineers and technical staff training shall require separate training supplemented by comprehensive training notes.
- Where new proprietary or non-standard equipment has been introduced to QUU, the Contractor shall host a separate vendor specific training course conducted by the Contractor or the equipment vendor. This course shall be onsite and hosted over two sessions over two days.

The Contractor shall provide comprehensive course notes to accompany the training session which will cover each of the topics.

The course notes shall be prepared and submitted to QUU for review no less than 10 working days before the commencement of the first session.

Training sessions must be provided complete with session plans, outcomes summary and be competency based.

12.3 SITE DOCUMENTATION

12.3.1 Site Record Drawings

During the site works the Contractor shall maintain an updated set of site record drawings and make them available for inspection by QUU upon request. The drawings must not be removed from the site at any time without QUU consent.

On completion of the site works, the red-lined amended drawings are referred to as the "site red-line record drawings", and shall be copied, stamped, signed by the Contractor's site representative and dated as well as signed as approved by the nominated Electrical RPEQ and submitted to QUU.

12.3.2 Miscellaneous Documentation

The following documentation shall be maintained up to date by the Contractor during the execution of the works:-

- Quality Assurance records including ITP's and the associated check-sheets and test records for all control system hardware.
- As-built mark-ups of all Project Documentation to reflect the completed installation.
- A record of all QUU approved changes to the Project Documentation.
- A record of all QUU supplied directives or Site Instructions.
- A record of all Contractor submitted Technical Queries and the associated QUU responses.
- A record of all QUU approved design deliverables.

Upon completion of the Contract works the above listed documentation shall be officially submitted by the Contractor to QUU.

12.4 AS BUILT DOCUMENTATION

The Contractor shall maintain a set of master drawings at the construction site. During the installation phase, the master copy shall be marked in red ink with any changes implemented during the construction.

It is the responsibility of the Contractor to:

- Updated the master set of drawings weekly; and
- Store and maintain up to date inspection checksheets and test result records and certificates generated during testing of the installation works.

Test result records, certificates and drawings with the red-line mark-ups shall be kept in a safe place and will form part of the hand over documentation to QUU.

When a site query has been closed out and the change agreed with QUU, the affected drawings and other documents shall be "Red Lined" to show the revised detail.

12.4.1 As Built Drawings

Unless specified otherwise in the Project Documentation the following CAD drawings shall be back drafted to As-Built status as part of the Contractor's scope of work:

- Drawing Schedule
- Process and Instrumentation Diagrams
- Switchroom layouts;
- Equipment location drawings(instruments and electrical equipment)
- General Arrangements for all electrical enclosures(control panels, switchboards and marshalling panels and DB's)
- Single Line Diagrams
- Schematics
- Termination Diagrams
- Cable Schedule
- Label Schedule
- Network Communications Architecture drawings (inclusive of communications racks, all individual FOBOT and network switch ports, all interconnection cables)
- Cable Block Diagrams;
- Underground services and conduit route drawings
- Fire and Gas Detector location drawings and Communication Architecture
- Protection single line diagrams
- Block diagrams
- All package-plant related "As-Built" documentation inclusive of all "site-specific customisations" for all electrical and loop drawings, I/O lists, termination diagrams,

The Contractor shall mark "As-Built" corrections on construction drawings used for installation "As-Built" shall be clearly and legibly marked up on all drawings and all changes shall be marked up in RED ink, all deletions shall be marked up in cross-hatched BLUE ink.

All drawings shall be stamped, signed and dated by the Contractor. An RPEQ of appropriate discipline shall certify the as built markups.

The latest revised "As Built" marked-up drawings shall be used during all site testing and commissioning checks.

An RPEQ shall certify the final as built CAD drawing revision, with RPEQ initials and number recorded on the CAD drawing.

12.4.2 As Built Documents

Electrical Documents as listed in CHE 486 Supplier Data Requirements (SDRL) shall be as As-Built.

An RPEQ shall certify As Built documents.

12.5 FINAL COMMISSIONING, TESTING AND INSPECTION REPORTS

All finalised commissioning, acceptance testing and inspection and documentation shall be collated into final reports. The reports shall include all test results and shall be in PDF format with all inspection and testing sheets scanned in colour and table of contents provided for quick reference in each document.

The following documents shall be provided by the Contractor.

- Equipment Inspection and Test Reports
- Instrument loop check sheets;
- FAT Reports(equipment and protection report)
- SAT Reports(equipment and protection report)
- Commissioning Report(entire site)
- AS3000 Certificate of Compliance
- OTDR Fibre cable test results
- Copper cable test records
- ProfiTrace test records and report
- Functional Test Records for all equipment
- IP Address Information for all devices
- Configuration settings for all devices, controllers, protection relays and IEDs that have manually configurable settings by DIP switches, dials, links or equivalent. Typical examples include media converters and low voltage circuit breakers with integrated protection.
- Site certification for installation and supply of UTP cables and associated equipment.

All tests reports and handwritten field documentation shall be scanned at high resolution and in colour and delivered to QUU in both hard copy and as scanned electronic pdf files. Scans shall be incorporated into the O&M manual master pdf file.

12.6 SOFTWARE CONFIGURATION FILES

At completion of the commissioning phase the Contractor shall provide two off copies of the following software configuration files on either CD or DVD and upload the code to a QUU Sharefile link:-

- PLC/RTU Code and Configuration Files
- SCADA Projects, Configuration and Driver Files
- Local HMI Terminals Configuration Files
- Network Equipment Configuration Files (routers, network switches, modems etc)
- Protocol gateway converters Configuration Files
- IED LV and HV protection relay and associated network equipment Configuration Files, including for all IEC 61850 devices

- VSD and motor protection relay Configuration Files (including internal logic files)
- Field bus instrumentation and device Management and Configuration Files and all device GSD/DTM/EDD files

The control copy of all configuration and programming files must be loaded on the EWS, installed and ready for support purposes at STP's. The latest backup is also to be copied to the QUU Network Access Drive (NAS).

12.7 OPERATIONS AND MAINTENANCE MANUALS

The contractor shall provide Operations and Maintenance (O&M) Manuals for all electrical equipment, switchboards, switchrooms and installations. Manuals shall be separated into logical installation groups, such as by switchroom.

The minimum requirements of AS1359, AS2067, AS2467 and AS3000 for operation and maintenance manuals shall be met by the Contractor.

The Contractor shall provide the O&M manuals in compliance with SEQ Water Supply and Sewerage Design & Construction Code (SEQ WS&S D&C Code). The hard copy manuals shall be neatly presented in 2 ring binders, where hole punching is not suitable or the manual is not provided with supports the manual is to be restrained by use of document holder similar to Magi-clip DK3660 with annotated dividers separating the different sections.

Loose sheets and drawings not forming part of individually bound booklets within the manual shall be protected in individual plastic pockets. A maximum of two single sided sheets shall be placed back to back in each pocket, allowing them to be read without removal from the pockets.

Each folder shall have the following identifying information on the front cover giving

- Project name
- Switchboard Asset Tagname and Title
- Contract number and year of installation
- Contractor's Company name, address & phone number

The electronic copy of O&M Manual shall be supplied on CD/DVD and be sorted in directories that reflect the layout provided in the hard copy manuals.

All files shall be in one of the following formats to allow QUU easily reprint portions or all of the O&M Manual.

- Adobe Acrobat (*.pdf)
- Microsoft Word (*.doc or *.docx)
- Microsoft Excel (*.xls or *.xlsx)

O&M manuals shall be produced as searchable pdf files bookmarked by chapter. O&M manuals shall be readily printable by users without intervention. Mismatched portrait/landscape sheets and paper sizes shall be avoided.

Original native files saved to pdf shall be used wherever possible. Scans of printed documents shall not be accepted, except for signature and approval pages which may be colour scanned and merged into the rest of the pdf document.

Original pdf files available from high resolution sources such as vendor web sites shall be used otherwise, such as for sub-equipment manuals and data sheets. Original pdfs from these sources shall be merged into the O&M manual master pdf file. Scans of printed documents available as high resolution pdfs shall not be accepted.

Low resolution scans, copies of copies, faxes or otherwise degraded reproductions of documents are not acceptable.

A draft O&M manual shall be provided in electronic format for review before practical completion, including all information except for final field test results. QUU shall review the documents and provide comments. Following final testing, commissioning and completion of as built drawings the Contractor shall collate and submit the final O&M manual. Timings for draft and final deliverables shall be as the Contract.

The final manual shall be provided as two (2) hard copies and one (1) electronic copy in pdf format on CD/DVD.

The O&M manual for each installation shall include as a minimum:

- Narrative description of the installation and major equipment, by location and tag number.
- Operating instructions for each item if equipment, including switchgear, protection relays and motor controllers.
- Safety instructions
- Consolidated list of recommended maintenance and servicing schedules for all equipment in the installation.
- Preventative maintenance instructions for the overall installation in accordance with AS 2467. Refer to detailed maintenance instructions for individual equipment in other manuals.
- Drawing list showing number, title and revision,
- Reference to single line diagrams
- Reference to protection single line diagrams
- Reference to block diagrams
- Reference general arrangement and panel layouts
- Major equipment lists, cross referenced by tag number. Refer to the individual equipment manual for details part lists.
- Consolidated list of all spare parts and consumables for the installation, including lubricants and insulation oils.
- Details and names of major equipment suppliers
- Label lists
- References by QUU document number to all as built drawings, documentation, configuration files, FAT and SAT test reports relevant to the installation and equipment described by that manual. Refer to sections 12.4, 12.5 and 12.6 above.
- For high voltage installations, the O&M manual shall also include a detailed description of the normal, emergency and maintenance procedures specific to the installation.

12.7.1 Generic Manuals

Vendor generic manuals shall be modified with strike thru text or highlighted text by the Contractor to indicate the actual equipment supplied and information contained in the manual must be specific to the equipment supplied.

For pdf file sources use pdf editing tools to strike through text rather than printing, manually marking and rescanning. This will avoid loss of text searching and indexing capability from the pdf file.

12.8 CONFIGURATION FILES

All configurable electronic devices supplied in the installation shall be provided by the Contractor with the as commissioned software configuration files on CD/DVD. Programming software licences and hardware accessories required to fault find and reconfigure the devices shall also be provided by the Contractor.

13 PRACTICAL COMPLETION

Practical completion shall be in accordance with SEQ WS&S D&C Code's '*Asset Information Specification*' and the QUU addendum (refer Appendix Q, Volume 3 – Appendices).

Practical completion shall be dependent on the following items:

- Completion and commissioning of the works;
- Dismantling and removal of any temporary equipment
- Restoration of the site following the successful completion of the works in accordance with this specification
- Provision of operator training;
- Supply of operation and maintenance manuals;
- Supply of As-constructed drawings
- Removal of all obsolete equipment

14 DEFECTS LIABILITY PERIOD

The defect liability period shall be for a period of twelve (12) months commencing from the date of Practical Completion during which time the Contractor shall provide unconditional warranty for the works. The Contractor shall attend to on-site rectification of all defects attributable to the Contractor on the works for the duration of the defects liability period.

Access Authorisation by QUU shall be required for the Contractor to gain access to any live equipment and systems.

Any subsequent defects remediation works shall be performed under the QUU change management process. Modifications must be completed under controlled and fully managed conditions. No remedial changes shall occur without approval from QUU. Approval for all non-critical changes shall only be given after the submission and approval of a test plan and further test documents.

Only under critical circumstances shall the Contractor be allowed to rectify a defect without a specific pre-approved plan from QUU. All the updated documentation covering the change shall be submitted to QUU within two (2) days after the change has been made. The protection relays and IED configuration files and any wiring changes shall be made available immediately after the change has been made.

While attendance to rectify any defects will normally be scheduled for the next business day, the Contractor shall have skilled staff available on 24/7 basis to attend site to rectify a defect should QUU deem the fault to be of a critical or emergency nature. Direct contact details shall be provided from the start of the defects liability period or from when the system is deemed to be operatable.