

TECHNICAL STANDARD

THE SUPPLY AND INSTALLATION
OF
LOW VOLTAGE ELECTRICAL EQUIPMENT



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TS 79

The Supply and Installation

Of

Low Voltage Electrical Equipment

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SUMMARY OF CHANGES FROM PREVIOUS REVISION

TS79 has undergone a complete review and significant modifications to the 2007 edition have been made.

The list of changes is too large to include in the revised Standard.

CONTENTS

1. GENERAL	1
1.1 SCOPE	1
1.2 STANDARDS AND CODES.....	1
1.3 STANDARD DRAWINGS.....	4
2. SWITCHBOARDS AND CONTROL PANELS	5
2.1 GENERAL	5
2.2 TYPE TESTS	5
2.3 CONSTRUCTION	5
2.3.1 General	5
2.3.2 Form of Segregation	6
2.3.3 Arrangement of Cubicles and Equipment	7
2.3.4 Metal Outdoor Cubicles	7
2.3.5 Metal Indoor Cubicles	9
2.3.6 Stainless Steel Cubicles.....	10
2.3.7 Plastic Outdoor Enclosure	11
2.3.8 Plastic Indoor Enclosures	11
2.3.9 Vandal Resistant Cubicles	11
2.3.10 Cable Entry and Terminations	12
2.3.11 Mounting of Equipment	12
2.3.12 Switchboard Nameplates	13
2.3.13 Door Locks and Hinges.....	13
2.3.14 Energy Metering	14
2.4 BUSBARS	14
2.5 INTERNAL WIRING	15
2.5.1 Type	15
2.5.2 Colour Coding	15
2.5.3 Wiring Installation.....	15
2.5.4 Segregation.....	16
2.5.5 Termination	16
2.5.6 Protection	16
2.6 LABELLING	16
2.6.1 General	16
2.6.2 Main Titles and Sub Titles.....	17
2.6.3 Naming Convention	17
2.6.4 Front Panel Controls and Indications	17
2.6.5 Contactors and Relays.....	18
2.6.6 Instrumentation Equipment	18
2.6.7 Terminals	18
2.6.8 Wiring.....	18
3. COMPONENTS	18
3.1 GENERAL	18
3.1.1 Ratings	18
3.1.2 Degree of Protection	19
3.2 CIRCUIT BREAKERS	19
3.2.1 Discrimination	19
3.2.2 Air Circuit Breakers	19
3.2.3 Moulded Case Circuit Breakers	20
3.2.4 Miniature Circuit Breakers.....	21
3.3 RESIDUAL CURRENT DEVICES	21
3.4 ISOLATING SWITCHES	21
3.5 AIR BREAK SWITCHES.....	22
3.6 COMPOSITE FUSE SWITCH UNITS	22
3.7 LOW-VOLTAGE FUSES	23

3.8 MOTOR CONTACTORS	23
3.9 AUTO TRANSFORMERS	23
3.10 SOFT STARTERS	24
3.11 VARIABLE SPEED DRIVES	25
3.12 CUBICLE HEATERS	27
3.13 MOTOR PROTECTION UNITS	27
3.13.1 Thermal Overload Units	27
3.13.2 Electronic Motor Protection Relays	28
3.13.3 Thermistor Control Units	28
3.14 METERS	28
3.14.1 General	28
3.14.2 Ammeters.....	28
3.14.3 Voltmeters	29
3.14.4 Multi-function Meters.....	29
3.15 CURRENT TRANSFORMERS	30
3.15.1 Metering Current Transformers	30
3.15.2 Protection Current Transformers	30
3.16 CONTROL RELAYS	30
3.17 TIMING RELAYS	31
3.18 PROGRAMMABLE LOGIC CONTROLLERS	31
3.19 HOURS RUN METERS	33
3.20 UNDERVOLTAGE AND PHASE IMBALANCE RELAYS	33
3.21 CONTROL SWITCHING DEVICES AND INDICATOR LIGHTS	33
3.22 SURGE ARRESTERS	36
3.23 INSTRUMENTATION EQUIPMENT	36
3.23.1 General	36
3.23.2 Process Controllers.....	36
3.23.3 Scale Indicators	37
3.23.4 Digital Indicators.....	37
3.23.5 Integrators	37
3.23.6 Signal Isolators.....	38
3.23.7 Signal Alarm Units	38
3.23.8 Lightning Protection Units	38
3.23.9 Test Points and Test Injection Points.....	38
3.24 REMOTE TELEMETRY UNITS	40
3.24.1 General	40
3.24.2 Location.....	40
3.24.3 Termination.....	40
3.24.4 Power Supply	40
3.24.5 Digital Inputs	40
3.24.6 Digital Outputs.....	41
3.24.7 Pulse Inputs	41
3.24.8 Analogue Inputs	41
3.24.9 Analogue Outputs	41
3.24.10 Interface between RTU and PLC	42
3.25 TOUCH SCREEN DISPLAYS	42
3.26 EMERGENCY STOP CIRCUITS	42
3.27 AMBIENT TEMPERATURES	43
4. EQUIPMENT AND FITTINGS	45
4.1 DUTY AND RATING	45
4.2 LIGHTING FITTINGS	45
4.2.1 General	45
4.2.2 Fluorescent Fittings.....	45
4.2.3 High Intensity Discharge Fittings.....	45
4.2.4 Emergency Fittings	46
4.3 LIGHTING SWITCHES	46
4.4 SOCKET OUTLETS	46
4.5 FIELD CABLES	47
4.5.1 Power Cables.....	47

4.5.2 Control Cables	48
4.5.3 Instrumentation Cables	48
4.5.4 Data Cables	48
4.6 CABLE TRAYS AND LADDERS	48
4.7 CONDUITS AND FITTINGS	49
4.8 MOTORS.....	50
4.9 ELECTRIC VALVE ACTUATORS	51
4.10 GENERATOR SETS.....	53
4.10.1 General	53
4.10.2 Ambient Temperatures	53
4.10.3 Power Rating.....	53
4.10.4 Isolation.....	53
4.10.5 Outdoor Enclosures	54
4.10.6 Mounting Base	54
4.10.7 Guarding	54
4.10.8 Noise and Vibration Levels	55
4.10.9 Engine	55
4.10.10 Generator.....	56
4.10.11 Controls, Indications And Protection.....	57
4.10.12 Batteries and Chargers	59
4.10.13 Load Banks	60
4.11 UNINTERRUPTIBLE POWER SUPPLIES.....	61
4.11.1 General Requirements.....	61
4.11.2 Battery and Charger.....	62
4.11.3 Shutdown Operation	62
4.11.4 Isolation.....	62
4.12 BATTERY BACKED POWER SUPPLIES	63
5. INSTALLATION	64
5.1 GENERAL.....	64
5.2 FIXING.....	64
5.3 LABELLING	65
5.4 SWITCHBOARDS AND CONTROL PANELS.....	65
5.5 CABLE TRAYS AND LADDERS	66
5.6 CONDUITS.....	67
5.7 CABLES.....	68
5.7.1 General	68
5.7.2 Cable Routes and Methods of Installation	68
5.7.3 Cable Pits.....	68
5.7.4 Cable Joints	68
5.7.5 Cable Handling.....	68
5.7.6 Cable Termination.....	69
5.7.7 Instrumentation Cable Screens.....	69
5.7.8 General Power and Lighting Cables	70
5.7.9 Cable Fixing	70
5.7.10 Labelling.....	70
5.7.11 Cable Numbering System	70
5.7.12 Wire Numbering System	72
5.8 LIGHTING	73
5.9 EARTHING.....	74
5.10 POWER FACTOR CORRECTION	74
5.11 HARMONICS.....	74
5.12 LIGHTNING AND TRANSIENT OVERVOLTAGE PROTECTION.....	75
6. EXCAVATION AND BACKFILLING OF TRENCHES FOR UNDERGROUND CONDUITS	76
6.1 GENERAL.....	76
6.2 CLEARING.....	76
6.3 TRENCH EXCAVATION	76
6.4 trench WIDTH AND CONDUIT SPACING	76

6.5 FILL MATERIALS	76
6.5.1 Sand.....	76
6.5.2 Quarry Rubble.....	77
6.6 BEDDING AND BACKFILL	77
6.6.1 Bedding.....	77
6.6.2 Backfill Around Conduits.....	77
6.6.3 Backfill in Roadways and Footpaths	78
6.6.4 Backfill in Other Locations	78
7. PAINTING	78
7.1 GENERAL	78
7.2 INDOOR CUBICLES	78
7.3 OUTDOOR CUBICLES	79
7.4 OTHER EQUIPMENT	79
7.5 COATING REINSTATEMENT	79
8. INSPECTION AND TESTING	80
8.1 GENERAL	80
8.2 INSPECTION	81
8.3 WORKS TESTS	81
8.3.1 General	81
8.3.2 Test Results	81
8.3.3 Dispatch of Equipment.....	82
8.3.4 Power Switchboards	82
8.3.5 Control Panels.....	82
8.3.6 Motors	82
8.3.7 Generator Sets.....	84
8.3.8 Uninterruptible Power Supplies.....	84
8.3.9 Other Equipment.....	85
8.4 SITE TESTS	85
8.4.1 General	85
8.4.2 Test Results	85
8.4.3 Switchboards, Control Panels, Associated Equipment and Cabling.....	86
8.4.4 Motors	87
8.4.5 Generator Sets.....	87
8.4.6 Other Equipment.....	87
8.4.7 Power Factor and Harmonic Distortion	88
8.5 COMMISSIONING AND RUNNING-IN	88
9. TECHNICAL INFORMATION AND DRAWINGS	88
9.1 GENERAL	88
9.2 DRAWINGS	88
9.2.1 Tender Drawings.....	88
9.2.2 Prior to Manufacture	88
9.2.3 Drawing Details.....	89
9.3 MANUALS	92
9.3.1 General	92
9.3.2 Installation Manual	92
9.3.3 Operating Manual.....	92
9.3.4 Maintenance Manuals.....	93
9.3.5 Delivery of Manuals.....	93
9.4 TEST CERTIFICATES	94
9.4.1 Information to be Submitted With Tenders	94
9.4.2 Information to be Submitted Prior to Commencement of Manufacture	95

1. GENERAL

1.1 SCOPE

This Standard Specification covers the general requirements for the supply and installation of low voltage electrical equipment and extra low voltage equipment where it applies to control and instrumentation.

This Standard Specification shall be read in conjunction with the associated project specification, drawings and any documents annexed to the project specification. The provisions of this Standard Specification shall apply unless they are specifically deleted or amended in the project specification or drawings which shall then take precedence.

1.2 STANDARDS AND CODES

Any Standard referred to in this Specification shall be of the latest edition (including amendments) of that Standard at the date of calling of tenders.

The following Standards are referred to in this Specification:

Standards Association of Australia

AS 1023	Low voltage switchgear and controlgear - Protection of electric motors
Part 1	Built-in thermal detectors and associated control units
AS 1152	Specification for Test sieves
AS 1158	Lighting for roads and public spaces
AS 1217	Acoustics - Determination of sound power levels and noise sources
Part1	Guidelines for the use of basic Standards for the preparation of noise test codes
Part 5	Engineering methods for free-field conditions over a reflecting plane
Part 7	Survey method
AS 1289	Methods of testing soils for engineering purposes
AS 1307	Surge arresters
Part 2	Metal-oxide surge arresters without gaps for ac systems
AS 1359	Rotating electrical machines - General requirements
Part 5	Three-phase cage induction motors - High efficiency and minimum energy performance standards requirements
Part 20	Classification of type of enclosures
Part 40	Characteristics of synchronous generators
Part 101	Rating and performance
Part 102	Methods of determining losses and efficiency
Part 106	Methods of cooling (IC Code)
Part 109	Noise limits
Part 114	Vibration measurement and limits
AS/NZS 1554	Structural steel welding
Part 1	Welding of steel structures

Part 6	Welding stainless steels for structural purposes
AS 1627	Metal finishing - Preparation and pretreatment of surfaces
Part 1	Cleaning using liquid solvents and alkaline solutions
AS 1675	Current transformers - Measurement and protection
AS 1668	The use of Ventilation and Air-conditioning in buildings
AS 1768	Lightning Protection
AS 1930	Circuit breakers for distribution circuits (up to and including 1000 V ac and 1200 V dc)
AS 1931	High voltage test techniques
Part 1	General definitions and test requirements
Part 2	Measuring systems
AS/NZS 2053	Conduits and fittings for electrical installations
Part 1	General Requirements
Part 2	Rigid plain conduits and fittings of insulating material
Part 4	Flexible plain conduits and fittings of insulating material
Part 5	Corrugated conduits and fittings of insulating material
Part 7	Rigid metal conduits and fittings
Part 8	Flexible conduits and fittings of metal or composite material
AS 2184	Low voltage switchgear and controlgear - Moulded-case circuit-breakers for rated voltages up to and including 600 V ac and 250 V dc
AS/NZS 2293	Emergency evacuation lighting for buildings
Part 3	Emergency luminaires and exit signs
AS/NZS 2381	Electrical equipment for explosive atmospheres - Selection, installation and maintenance
AS 2625	Rotating and reciprocating machinery - Mechanical vibration
Part 1	Basis for specifying evaluation standards
Part 2	Test and measurement conditions for rotating electrical machines
Part 4	Measurements and evaluation of vibration severity of small rotating machines
AS 2643	Fluorescent lamp ballasts of the reactive type - Performance requirements
AS/NZS 2648	Underground marking tape
Part 1	Non-detectable tape
AS 2700	Colour standards for general purposes
AS 2768	Electrical insulating materials - Evaluation and classification based on thermal endurance
AS/NZS 3000	Wiring Rules
AS/NZS 3008	Electrical installations - Selection of cables
Part 1.1	Cables for alternating voltages up to and including 0.6/1 kV
AS 3010	Electrical installations – Supply by generating set
Part 1	Internal combustion engine driven set
AS 3111	Approval and test specification - Miniature overcurrent circuit-breakers
AS/NZS 3112	Approval and test specification - Plugs and socket-outlets
AS 3133	Approval and test specification - Air break switches
AS 3137	Approval and test specification - Luminaires (lighting fittings)
AS 3168	Approval and test specification - Fluorescent lamp ballasts
AS 3190	Approval and test specification - Residual current devices (current-operated earth-leakage devices)
AS/NZS 3439	Low voltage switchgear and controlgear assemblies
Part 1	Type-tested and partially type-tested assemblies (IEC 60439-1:1999 MOD)
AS/NZS 3760	In-service safety inspection and testing of electrical equipment

AS 3947 Part 3	Low voltage switchgear and controlgear Switches, disconnectors, switch-disconnectors and fuse-combination units
AS 4024 Part 1	Safeguarding of machinery General principles
AS 4070	Recommended practices for protection of low voltage electrical installations and equipment in MEN systems from transient overvoltages
AS 4252 Part 1	Electromagnetic compatibility - Generic immunity standard Residential, commercial and light industrial
AS 4594	Internal combustion engines - Performance
AS/NZS 4680	Hot-dip galvanised (zinc) coatings on fabricated ferrous articles
AS/NZS 5000 Part 1	Electric cables Polymeric insulated – For working voltages up to and including 0.6/1 (1.2) kV
AS/NZS 60269 Part 1	Low voltage fuses General requirements
Part 2.0	Supplementary requirements for fuses for use by authorised persons (fuses mainly for industrial application)
Part 4.0	Supplementary requirements for fuse-links for the protection of semiconductor devices
AS 60529	Degrees of protection provided by enclosures (IP Code)
AS 60947 Part 2	Low voltage switchgear and controlgear Circuit breakers
Part 4.1	Contactors and motor-starters - Electromechanical contactors and motor-starters
Part 4.2	Contactors and motor-starters - AC semiconductor motor controllers and starters
Part 5.1	Control circuit devices and switching elements - Electromechanical control circuit devices
AS/NZS 61000 Part 3.6	Electromagnetic compatibility (EMC) Limits – Assessment of emission limits for distortion loads in MV and HV power systems (IEC 61000.3.6:1996 MOD)
AS/NZS 62040 Part 2	Uninterruptible power systems (UPS) Electromagnetic compatibility (EMC) requirements
Part 3	Method of specifying the performance and test requirements
AS/NZS CISPR 11	Industrial, scientific and medical (ISM) radio frequency equipment – Electromagnetic disturbance characteristics – Limits and methods of measurement

International Electrotechnical Commission Standards

IEC61131 Part 1	Programmable controllers General Information
Part 2	Equipment requirements and tests
Part 3	Programming languages

SA Water Technical Standard Specifications

TS 95	Requirements for Technical Drawings
TG 110	Safety in Design

1.3 STANDARD DRAWINGS

The following SA Water Standard Drawings are referred to in this Specification:

96-0110-01A	Example of electrical drafting quality standards
04-0734-01	Pipe and instrumentation diagram standard symbols legend.

2. SWITCHBOARDS AND CONTROL PANELS

2.1 GENERAL

Switchboards, control panels and cubicles housing electrical equipment shall be constructed in accordance with this Specification, AS/NZS 3000 and AS/NZS 3439.1. Individual components shall comply with the relevant standards.

All work shall comply with the requirements of the electricity supplier and shall be suitable and approved for connection to a 400/230 V 50 Hz earthed neutral (MEN) supply.

2.2 TYPE TESTS

Switchboards and control panels shall be either:

- (1) a type tested assembly or
- (2) a partially type tested assembly.

The assembly shall be in accordance with AS/NZS 3439.1.

Type test certificates and, for partially type tested assemblies, details of areas of extrapolation from the type test certificates, shall be provided in accordance with Clause 9.4. Type test certificates must be deemed satisfactory by SA Water Engineering.

2.3 CONSTRUCTION

2.3.1 General

Switchboards and control panels shall comply with the following general requirements:

- (1) The form of segregation shall be in accordance with Clause 2.3.2.
- (2) Protective measures against electric shock shall be provided by means of barriers or enclosures in accordance with AS/NZS 3439.1.
- (3) Switchboards and control panels which have a rated current of 100 A per phase or greater shall be provided with adequately rated main busbars.
- (4) Assemblies shall conform to the forms of construction as defined in AS/NZS 3439.1:
- (5) The cubicles and equipment shall be arranged in accordance with Clause 2.3.3.

- (6) Adequate derating of equipment and/or ventilation of the cubicles shall be provided to protect the equipment against the effects of excessive temperature rises within the cubicles. Any ventilation shall not compromise the IP rating and form of segregation of the cubicles.
- (7) All components which are mounted on the outside of any switchboard or control panel shall be selected and installed so that the degree of protection specified for that switchboard or control panel is maintained.
- (8) In-service accessibility for inspection and similar operations and for maintenance shall be provided in accordance with Clause 7.4.6 of AS/NZS 3439.1.
- (9) Main switchboards shall be provided with a surge arrester in each phase of the incoming supply in accordance with AS 4070. The surge arresters shall be in accordance with Clause 3.22.
- (10) Provided with rigid stays of robust construction to hold all doors in a not less than 90° open position. It shall be possible to open all doors simultaneously.
- (11) Doors shall be mechanically interlocked with the power supply isolators such that the door cannot be open with the isolator closed and the isolator cannot be closed with the door open. The interlock shall be defeatable by use of a tool.
- (12) With the doors open, all accessible internal live parts shall be protected against accidental contact to not less than IP2X.

If alternative enclosures are tendered, then full details of such equipment shall be submitted and must be approved by the SA Water Principal Electrical Engineer.

2.3.2 Form of Segregation

The form of segregation shall be in accordance with the following:

- (1) Switchboards and control panels which have a rated current less than or equal to 250 A per phase shall be, as a minimum, Form 1 assemblies in accordance with AS/NZS 3439.1.
- (2) Switchboards and control panels which have a rated current of greater than 250 A per phase shall be, as a minimum, Form 3b or 3bi assemblies in accordance with AS/NZS 3439.1, with segregated compartments for each of the following:
 - Incoming functional unit (main switch)
 - Busbars
 - External cable terminals
 - Outgoing functional units
 - General power and lighting panel
 - Common control panel.

In addition, the switchboards and control panels shall be provided with increased security against the occurrence or the effects of internal arcing faults in accordance with Annex ZC of AS/NZS 3439.1. The alternative Form 3bih segregation indicated in Annex ZF of AS/NZS 3439.1 is precluded.

2.3.3 Arrangement of Cubicles and Equipment

The cubicles and equipment comprising the switchboard or control panel shall be arranged in accordance with the following:

- (1) The incoming cubicle shall be located on the left hand end of the assembly, unless otherwise agreed by SA Water's Principal Electrical Engineer.
- (2) Cubicles and compartments housing switchgear and control gear for the plant equipment shall be grouped into functional groups, or arranged in the same order as the process sequence of the plant equipment, as far as practical. Similarly, control and indication devices on the front of individual cubicles and compartments shall be arranged to correspond with the physical layout or process sequence wherever practical.
- (3) Switchboards shall be readily extendable at either end.
- (4) Provision shall be made for the ready addition of minimum 20% spare power circuits, or as specified in the project specification, whichever results in the greater spare space requirement. Adequate spare space shall be provided in and on the cubicles or compartments to accommodate all future equipment associated with the spare circuits including circuit protective devices, motor starters, control equipment and front panel control and indicating devices.
- (5) All controls, operating handles, meters and indicators shall be mounted not less than 500 mm and not greater than 2000 mm above ground or floor level.
- (6) All HMIs shall be mounted not less than 1400mm and not greater than 1700mm above ground or floor level. For HMIs greater than 300mm in height, the HMI shall be mounted with its vertical centre between 1500mm and 1600mm.
- (7) Each drive shall be provided with an isolator on the front of the switchboard, or control panel, and shall be lockable in the Off position.

2.3.4 Metal Outdoor Cubicles

Metal outdoor cubicles for switchboards and control panels shall be in accordance with the following additional requirements:

- (1) Painted G2 Galvabond steel enclosure with a minimum galvanised coating of Z275, or 316 stainless steel in accordance with Clause 2.3.6.

Front access for all outdoor switchboards shall be provided by hinged lockable doors. Opening the doors shall give access to a dead front panel

on which controls and indications are mounted. Locks and hinges shall be in accordance with Clause 2.3.13.

This clause is applicable for control panels, where required by the project specification.

- (2) The sheet steel shall have a minimum thickness of 1.5 mm for all floor mounted cubicles. Small wall or post mounted cubicles not exceeding 400 mm high x 400 mm wide may have a minimum thickness of 1.0 mm.

Doors greater than 800mm in width, or doors where the total combined cutouts exceed 25% of the door area, shall have additional thickness or shall have stiffeners added to ensure rigidity.

An exemption from the above may be granted for fully type tested enclosures. However to obtain an exemption, type test certificates must be provided on each occasion and the enclosure deemed satisfactory by SA Water Engineering and the appropriate Region Operations representative.

- (3) Sunshields, where required by the project specification, shall have a minimum of 50mm air gap between the enclosure and sunshield.
- (4) Rain hoods, where required by the project specification, shall be constructed such that the top surface shall slope to prevent accumulation of water and the slope shall be such so as to direct water away from the front of the cubicle.
- (5) With doors and covers in position, provide a degree of protection in accordance with AS 1939, of not less than IP56.
- (6) Equipment which is installed within outdoor cubicles shall be protected against the effects of excessive temperature by either:
 - (a) the equipment being derated to accommodate the higher ambient temperatures which are to be expected within the cubicles or
 - (b) the cubicles being ventilated to ensure that the cubicle internal temperatures do not exceed the temperature ratings of the equipment (any ventilation shall not decrease the IP rating of the enclosure) and/or the fitting of a metal sun shield of appropriate design allowing for orientation when installed.
- (7) Ground and floor mounted cubicles shall be provided with a bolt-on, painted hot-dip galvanised (to AS/NZS 4680) rolled steel channel plinth 100mm high. Alternatively stainless steel plinths may be used for stainless steel cubicles. The toes of the plinth shall turn outwards at each end and each shall have two 15 mm diameter holes to facilitate the bolting of the plinth to the floor or concrete pad. A sheet of bitumen impregnated felt or other approved moisture barrier shall be placed under the plinth.
- (8) Switchboards and floor mounted control panels shall be provided with an interior switchable fluorescent or LED lamp(s) and a switched socket outlet, accessible when the front door is open.

- (9) Switchboards and control panels shall be provided with thermostatically controlled anti-condensation heaters in accordance with Clause 3.12.

2.3.5 Metal Indoor Cubicles

Metal indoor cubicles for switchboards and control panels shall be in accordance with the following additional requirements:

- (1) Painted Zincseal sheet steel construction, or 316 stainless steel in accordance with Clause 2.3.6, with controls and indications mounted on hinged lockable doors.

Locks and hinges shall be in accordance with Clause 2.3.13.

- (2) The sheet steel shall have a minimum thickness of 1.5 mm for all floor mounted cubicles. Small wall mounted cubicles not exceeding 400 mm high x 400 mm wide may have a minimum thickness of 1.0 mm.

Doors greater than 800mm in width, or doors where the total combined cutouts exceed 25% of the door area, shall have additional thickness or shall have stiffeners added to ensure rigidity

An exemption from the above may be granted for fully type tested enclosures. However to obtain an exemption, type test certificates must be provided on each occasion and the enclosure deemed satisfactory by SA Water Engineering and the appropriate Region Operations representative.

- (3) Cubicles shall provide a degree of protection in accordance with AS 1939 as follows:
- (a) Not less than IP51 in areas where the ingress of water is excluded.
 - (b) Not less than IP54 in areas where the ingress of water is likely (eg due to possible hosing down operations or the close proximity of pumps or pipework).
 - (c) Not less than IP56 for 316/316L stainless steel cubicles.
- (4) All floor mounted cubicles shall be provided with a bolt-on, painted hot-dip galvanised (to AS/NZS 4680) rolled steel channel plinths not less than 75 mm high. Alternatively stainless steel plinths may be used for stainless steel cubicles.

Where the cubicles are mounted directly onto a floor without a concrete plinth and which may be subjected to dampness (eg due to possible hosing down operations or the close proximity of pumps or pipework) a sheet of bitumen impregnated felt or other approved moisture barrier shall be placed under the plinths.

- (5) Switchboards and floor mounted control panels shall be provided with an interior switchable fluorescent or LED lamp(s) and a switched socket outlet, accessible when the front door is open.

- (6) Switchboards and control panels shall be provided with thermostatically controlled anti-condensation heaters in accordance with Clause 3.12.

2.3.6 Stainless Steel Cubicles

2.3.6.1 *Required Application*

316/316L stainless steel cubicles shall be provided:

1. For installations in corrosive areas.
2. For indoor installations located in the same room as chlorination equipment,
3. Where required by the project specification.

2.3.6.2 *General*

All parts of the cubicles shall be manufactured from grade 316 or 316L stainless steel in accordance with the following sub-clauses.

Cubicles, doors and panels shall be fabricated from a stainless steel sheet with a minimum thickness of 1.5 mm. Bracing, stiffening, internal brackets, plinths and other structural components shall be manufactured from type 316/316L stainless steel of minimum 2.0 mm thickness.

2.3.6.3 *Welding*

Any welding shall be carried out in accordance with AS 1554 Part 6. The weld quality and surface finish for the welds shall be:

- (1) Internal welds 2B, II (a)
- (2) External welds 2B, I (120#).

2.3.6.4 *External Surface Treatment*

The external surface finish for the cabinets shall be a No. 4 finish with a final surface polish of 120 to 150 grit in accordance with AS 1449. The cabinets shall be manufactured with the polish directionality in the vertical direction.

Where the original machine polishing lines are parallel to the line of a weld, the weld bead shall be dressed down by grinding and then finished by polishing with 120 grit polishing wheel driven by a portable machine. The traversing of the wheel should be kept in line with the run of the weld bead so that its cut lines are kept parallel to those of the original machine polished surface. Care shall be taken to bring the metal joint flush with that of the base metal in order to avoid residual ridges or grooves.

Where the machine polished lines are not parallel to the lines of the weld, the final manual polishing shall be conducted in the original direction of the machine polishing.

Where the original polished lines on the two sides of a joint are not parallel, the final manual polishing shall be in the direction which has the least visual impact on the component.

Any heat tint on the external surfaces as a result of internal welding shall be removed and the original external surface finish reinstated.

The internal surfaces of the cubicles require no special surface finish other than cleaning as specified above for the internal welds.

2.3.6.5 *Fasteners*

All fasteners shall be type 316 stainless steel.

2.3.6.6 *Hardware*

All hinges shall be type 316 stainless steel.

Locks and handles shall be type 316 stainless steel or chrome plated brass.

2.3.7 Plastic Outdoor Enclosure

Plastic outdoor enclosures shall only be installed when approved for use by SA Water's Principal Electrical Engineer.

If used the plastic enclosure must have a degree of protection not less than IP56 to AS 1939 when the covers are in position.

2.3.8 Plastic Indoor Enclosures

Plastic indoor enclosures shall be in accordance with following:

- (1) Made from high impact resistant, flame retardant plastic material.
- (2) Totally insulated.
- (3) Degree of protection not less than IP56 to AS 1939 when the covers are in position.
- (4) Covers which, when removed, give access to live equipment shall require the use of a tool in the removal of the covers.

Plastic indoor cubicles shall only be installed when approved for use by SA Water's Principal Electrical Engineer.

2.3.9 Vandal Resistant Cubicles

Vandal resistant cubicles shall be manufactured from sheet steel in accordance with Clause 2.3.4.

Additional design and construction features to improve the security of the cubicles from theft and vandalism shall include the following:

- (1) No switches, indicators, etc. on the outside of the cubicle unless required by the project specification.
- (2) Concealed or vandal resistant hinges.
- (3) Doors and covers designed to eliminate, as far as is practicable, leverage points which would enable the doors or covers to be forced open.
- (4) Doors to be provided with high security swing type handles (Emka 1107SBC01 or approved equivalent) with locking facility for SA Water approved security padlocks. All padlocks to be keyed alike, as per SA Water security requirements. Switchboard doors shall comply with TS 107 for security requirements.
- (5) Fixing bolts, screws, etc. shall, as far as practicable, be concealed to prevent unauthorised removal. Fastener heads, which are accessible from the outside of the cubicle, shall be of a type which will not allow the unscrewing of the fastener from the outside of the cubicle.

2.3.10 Cable Entry and Terminations

Cable entry and termination facilities shall be suitable for the number and sizes of cables specified or alternatively, if sizes are not specified, for cables rated for the full load current of the connected load. Appropriate deratings for temperature and grouping of cables shall be allowed when determining cable sizes, as per AS 3008.

Incoming and outgoing wiring termination shall comply with Clause 2.5.5 of this Specification.

Cubicles shall be protected from the entry of vermin larger than 1 mm across the smallest body dimension by glanding of the cables and sealing any duct beneath the cubicles.

2.3.11 Mounting of Equipment

All equipment within a switchboard or control panel shall be installed on mounting plates affixed to the interior rear of the panel.

All equipment, with the exception of cable ducts, shall be installed not less than 300 mm and not greater than 2000 mm above ground or floor level.

No equipment shall be installed on top, side or bottom panels, unless approved by SA Water's Principal Electrical Engineer.

2.3.12 Switchboard Nameplates

In addition to the requirements of AS/NZS 3439.1, low voltage switchboards and control panels which have a rated current of 100 A or more per phase, or a rated prospective short circuit current of 5 kA or more, shall have a label fitted which shall include the following information if not already provided on other labels:

- (1) The number of the Standard (including country of origin) with which the equipment complies.
- (2) Manufacturer's name or trade mark.
- (3) Identification of the assembly, eg. model, type, catalogue number, etc.
- (4) Assembler's name or trade mark, if different from that of the manufacturer.
- (5) Degree of protection in accordance with AS 1939.
- (6) Form of segregation.
- (7) Rated operational voltage.
- (8) Rated frequency.
- (9) Rated current.
- (10) Type tested short circuit rating.
- (11) Incoming supply origin,
- (12) Temperature of incoming and outgoing conductor termination facilities if greater than 75 °C when the equipment is carrying the rated current and referenced to 40 °C ambient.
- (13) Any other information required to be marked on the equipment by the Standard with which the equipment is purported to comply.
- (14) Additional information required to be provided by the relevant standards must be provided in the form required by the relevant standard.

The nameplate shall be manufactured from brass, laminated plastic or other approved material and shall be attached to the front structure (not door) of the switchboard by means other than an adhesive, eg pins, screws etc.

2.3.13 Door Locks and Hinges

Locking of cubicle doors shall be 3 point for all doors of height greater than 1000mm.

Unless otherwise agreed by SA Water's Principal Electrical Engineer, locks shall be keyed alike to the Lenlock key code 320, except for vandal resistant cubicles, which shall be in accordance with Clause 2.3.9.

Hinges and handles on outdoor cubicles shall be of heavy duty stainless steel or chrome plated brass.

2.3.14 Energy Metering

Where energy metering is required, a meter box complying with the requirements of Clause 2.3.4 shall be provided and located preferably on an external wall of the building. Where the meter box is to be located indoors, the meter box shall comply with the requirements of Clause 2.3.5. The meter shall comply with the requirements of ETSA's service installation rules.

Metering shall be upstream of all switchboard equipment.

For main switchboards which have a full load current rating of 100A or more, adequate arrangements shall be made within the switchboard to mount the electricity supplier's metering current transformers in an enclosure which is capable of being sealed by the electricity supplier. The facilities shall be acceptable to the electricity supplier and shall allow for the onsite fixing, connecting and changing of the metering transformers without the need to disturb the incoming cables. The metering transformers shall be supplied and installed by the Contractor to the electricity supplier's requirements.

Potential wiring for the electricity supplier's metering shall be protected by 100A busbar mounted fuses or approved equivalent, in accordance with the electricity supplier's requirements. The fuses shall be enclosed within the sealed current transformer enclosure and shall be located such that they do not interfere with the installation of the main service cable or the installation and/or removal of the current transformers.

Adequate provision shall be made for the outgoing potential and current transformer secondary wiring to the electricity supplier's meters.

Metering current transformers and potential fuses are generally not required on main switchboards rated at less than 100A.

2.4 BUSBARS

Busbars shall be air insulated and constructed from high conductivity copper.

The order of phasing of the busbars shall be red, white, blue from top to bottom, left to right and back to front, all relative to the front of the panel. The neutral conductor shall occupy an outer position.

Each individual busbar section shall be colour coded to correspond with the phase to which it is connected.

Mechanical joints between busbars shall be by means of properly made bolted or clamped joints. Bolted joints shall use high tensile steel bolts with plain washers, nuts and lock nuts used to complete the joint. Care shall be taken to ensure that all contact surfaces are clean and flat, and that adequate pressure is obtained to ensure that a low resistance, trouble free joint is obtained.

2.5 INTERNAL WIRING

2.5.1 Type

Wiring shall be of PVC or XLPE insulated stranded copper conductor in accordance with AS/NZS 5000.1.

The wiring shall be adequately sized to carry the current and the minimum conductor size shall be as follows:

- Signal wiring to PLCs and similar devices – 0.75 mm²
- Control relays and timers – 1.0 mm²
- Current transformers – minimum of 1.0 mm² and sized in accordance with AS/NZS 3008.
- Contactors and other power circuits – Conductor sized in accordance with AS/NZS 3008.

2.5.2 Colour Coding

The insulation of cables and wires shall be used to provide colour coding as follows:

- (1) Low voltage three phase ac power circuits and CT wiring to be colour coded in accordance with the phase to which they are connected, ie RED, WHITE, BLUE with neutrals coloured BLACK.
- (2) Low voltage single phase ac power circuits and control cables to be colour coded in accordance with the phase to which they are connected, until they terminate into a protection device (eg. circuit breaker, fuse, etc) at which point the active colour will change to WHITE with BLACK neutral.

Note: Control supplies shall be derived from the white phase unless otherwise indicated.

- (3) Low voltage dc and extra low voltage dc circuits to be coded GREY (+) and PINK (0V).

Note: For two wire dc systems a brown wire shall be used for the earth wire and a grey or pale pink conductor used for the supply wire, depending if the supply is positive or negative with respect to earth.

- (4) Extra low voltage ac circuits to be BROWN with BLACK neutral.
- (4) All analogue signals (eg. 4-20 mA, 0-10 V) to be coded VIOLET where not included within screened cables. Core colours within screened cables may be to the manufacturer's standard.
- (5) Critical digital signals between the PLC and RTU to be coded ORANGE.
- (6) Earth cable to be GREEN/YELLOW.

2.5.3 Wiring Installation

Wiring of size 2.5 mm² or less shall be run wherever possible in side slotted PVC ducts with snap on covers. Ducts shall be adequately sized to accommodate the wiring, plus at least an additional 20% spare capacity. Where ducting is impractical, wiring may be loomed using proprietary looming or sleeving.

2.5.4 Segregation

Low voltage ac power and control circuits shall be segregated from:

- Low voltage dc circuits
- Extra low voltage ac and dc circuits.
- Analogue signal wiring.

2.5.5 Termination

The boundary between internal and outgoing wiring shall be a DIN rail mounted clip-on type terminal strip within the control panel or switchboard.

Outgoing low voltage circuits with conductors 25 mm² or above and general purpose power and lighting circuits may terminate directly on the switchgear provided that the cable selected can be accommodated by the terminal arrangement provided.

Terminals for control and instrumentation signals shall be grouped in a logical manner according to the signal types (ie digital inputs, digital outputs, pulse inputs, analog inputs and analog outputs). The following spare terminals shall be provided for each group of signals as a minimum:

- 20% for total installed I/Os of up to 100
- 10% for total installed I/Os exceeding 100.

Extra low voltage terminals shall be segregated from low voltage terminals. Ac voltages shall be segregated from dc voltages. All low voltage terminals shall be adequately shrouded to prevent accidental contact.

2.5.6 Protection

Small wiring which feeds directly from the busbars (eg voltmeter wiring, wiring to voltage operated protection relays) shall be protected by means of fuses which shall be in accordance with Clause 3.7. The fuses shall be located as closely as is practicable to the point of tee-off from the busbar system, but shall be located in a position which allows access for maintenance.

2.6 LABELLING

2.6.1 General

Labels shall be made of engraved traffolyte, or approved equivalent, giving white lettering on a red background for warning labels and black lettering on a white background for all other labels. Embossing tape shall not be used. Labels for outdoor equipment shall be resistant to corrosion and sunlight.

Labels shall be fixed by pins, screws or an approved adhesive. Labels which are fixed to the outside surfaces of outdoor switchboards, control panels and other equipment shall be fixed with corrosion resistant (preferably stainless steel) pins or screws. Adhesives shall not be used for fixing outdoor labels.

2.6.2 Main Titles and Sub Titles

Switchboards, control panels and their sub-sections shall be labelled with the titles provided in the project specification and drawings or, where these are not specified, titles which adequately and accurately describe the units.

Minimum lettering height shall be as follows:

Main Titles	20 mm
Sub Sections	10 mm.

Nameplates for switchboards and control panels shall be in accordance with Clause 2.3.12.

2.6.3 Naming Convention

The Main switchboard shall be labelled as MSB, followed by a unique number to differentiate the switchboard from other switchboards on site. (For an example, refer to Figure 2.1.)

Distribution boards shall be labelled as DB, followed by the Main Switchboard or Distribution board number from which the distribution board is fed, followed by a unique number to differentiate the distribution board from other distribution boards within that supply circuit. (For an example, refer to Figure 2.1.)

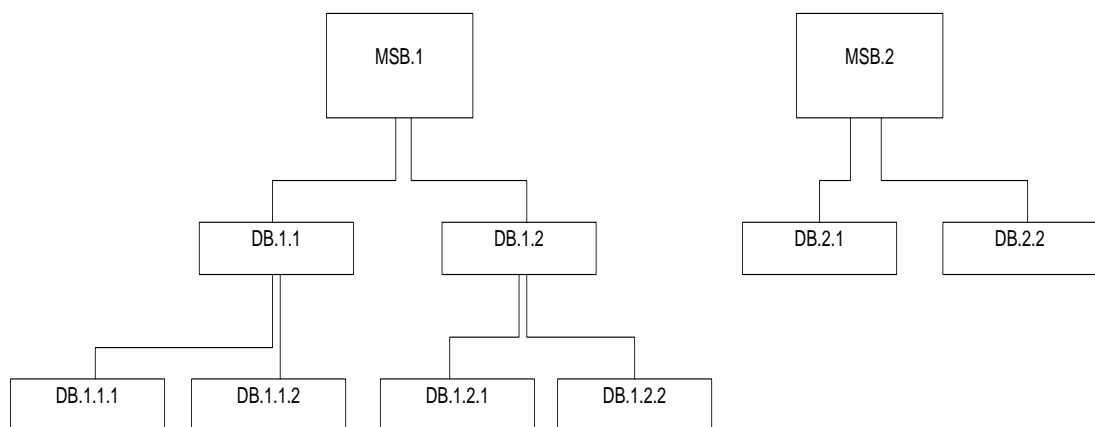


Figure 2.1 – Example of Switchboard and Distribution Board naming Convention

2.6.4 Front Panel Controls and Indications

Front panel controls, indications and features shall be labelled with the titles provided in the project specification and drawings or, where these are not specified, titles which adequately and accurately describe the function of units.

The manufacturer's standard escutcheon plates may be used for front panel items.

The minimum lettering height for purpose made labels shall be 4 mm.

2.6.5 Contactors and Relays

Contactors, relays and other components shall be labelled with the designations or label names used in the control circuits. Where plug-in relays are used, the labels shall be fixed on or adjacent to the associated sockets and not on the relays or other removable parts such as cable duct covers.

The minimum lettering height shall be 4mm.

2.6.6 Instrumentation Equipment

Instrumentation equipment shall be labelled with the loop number and loop description in accordance with the instrumentation loop diagrams. Front panel displays shall be labelled with the variable description and engineering units.

The minimum lettering height shall be 4mm.

2.6.7 Terminals

Terminal blocks shall be labelled as per termination schedules.

2.6.8 Wiring

Wiring shall be labelled by means of slip on ferrules or similar, numbered to correspond with wire numbers generated from schematic diagrams, as per Clause 9.2.3. Jumper wires of less than 50 mm length and which are visible for their entire length need only be labelled once, but other wiring shall be labelled at each end.

3. COMPONENTS

3.1 GENERAL

3.1.1 Ratings

Where current and/or voltage ratings for components are specified and/or shown on the specification drawings, components shall have ratings not less than those specified or shown.

Where current and/or voltage ratings are not specified or shown then components shall have current and voltage ratings adequate for the duty which they are to perform.

When determining the ratings allowance shall be made for:

- (1) frequency of usage,
- (2) making and breaking currents,
- (3) power factor (where applicable),
- (4) prospective fault current and
- (5) ambient temperatures which will occur at the point of installation.

Components which are not characterised by current ratings (eg multi-function meters, programmable logic controllers, protection relays, instrumentation equipment) shall have temperature ratings suitable for the point of installation.

3.1.2 Degree of Protection

The degree of protection of components which are mounted on the outside of switchboards or control panels shall be suitable for the location and application and shall not be less than that of the switchboards or control panels.

3.2 CIRCUIT BREAKERS

3.2.1 Discrimination

Where circuit breakers are installed in series, discrimination shall be provided for tripping currents up to the maximum prospective fault current for the installation.

3.2.2 Air Circuit Breakers

Air circuit breakers shall be in accordance with either AS 1930 or AS 60947.2 and the following:

- (1) Three pole air insulated.
- (2) Suitable for 400 volt 3 phase 50 Hz operation.
- (3) Withdrawable with service, test and isolated positions being available and clearly indicated.
- (4) Provided with padlockable automatic shutters over both the live and load side connections.

- (5) Provided with interlocks to:
 - (a) prevent movement of the unit to or from the service position whilst the breaker is closed and
 - (b) prevent the compartment door from being opened whilst the breaker is in the service position and the breaker is closed.
- (6) Manual closing.
- (7) Trip free.
- (8) Manual and overcurrent opening.
- (9) Provided with mechanical indication of status, ie open, closed and fault.
- (10) Lockable in the open position.
- (11) Padlockable in the test and isolated positions.
- (12) Designed to be maintained.
- (13) Suitable for uninterrupted duty.
- (14) Rated for the full load current.
- (15) Have an interrupting capacity of not less than the prospective fault current of the supply.
- (16) Provided with adjustable instantaneous and adjustable inverse time delay tripping.
- (17) Provided with auxiliary contacts for indication of circuit breaker open, closed and tripped status.

3.2.3 Moulded Case Circuit Breakers

Moulded case circuit breakers shall be in accordance with either AS 2184 or AS 60947.2 and the following:

- (1) Three pole.
- (2) Suitable for 400 volt 3 phase 50 Hz operation.
- (3) Quick make manual closing.
- (4) Quick break manual opening.
- (5) Trip free.
- (6) Automatic opening on overcurrent and short circuit.
- (7) Provided with mechanical status indication, ie open, closed and fault.

- (8) Lockable in the open position.
- (9) Provided with safety interlocks to prevent the compartment door from being opened with the breaker in the closed position and to prevent the breaker from being closed with the compartment door opened.
- (10) Suitable for uninterrupted duty.
- (11) Rated for the full load current of the circuit.
- (12) Have a rated short circuit making capacity not less than the prospective short circuit current of the supply.
- (13) Have a rated service short circuit breaking capacity not less than the prospective short circuit current of the supply.
- (14) Provided with instantaneous tripping.
- (15) Provided with inverse time delay tripping.

3.2.4 Miniature Circuit Breakers

Single pole and multi-pole miniature circuit breakers shall be in accordance with AS 3111 and the following:

- (1) Shall have a current interrupting capacity suitable for the prospective fault current and not less than 5 kA symmetrical.

3.3 RESIDUAL CURRENT DEVICES

Residual current devices shall be in accordance with AS 3190 and the following:

- (1) Type II devices in accordance with AS 3190 unless otherwise specified.
- (2) Tested in accordance with the requirements of Clause 8.4.3 before being placed into service.
- (3) Either one of the following configurations shall be provided:
 - (a) Combined miniature circuit breakers/residual current devices which shall be in accordance with the requirements of AS 3111 and Clause 3.2.4.
 - (b) Protected on the supply side against overcurrent and short circuit by miniature circuit breakers or fuses which shall be in accordance with the requirements of Clause 3.2.4 or 3.7 respectively.

3.4 ISOLATING SWITCHES

Isolating switches shall be in accordance with AS3133. Any switch which is used to directly isolate its associated electric motor by switching the phase conductors shall be a motor control switch as defined in the Standard and shall, in addition, be provided with facilities to padlock the switch in the OPEN or OFF position.

The requirement for locking facilities detailed above shall also apply to crane isolator switches.

All single phase isolating switches which are rated at 20A and above and all multiphase isolating switches shall include a positive indication, which shall include the words 'ON' and 'OFF', of the position of the switch.

3.5 AIR BREAK SWITCHES

Air Break switches shall be in accordance with AS 3947.3 and the following:

- (1) Fast make/fast break, independent manual operation preferably with double break contacts on each pole of the switch.
- (2) Fitted with a positive indication of the position of the switch which shall include the words 'ON' and 'OFF' or the symbols 'I' and 'O' to indicate the switch position.
- (3) Provided with facilities to padlock the switch in the OPEN or OFF position.
- (4) Equipment used for the direct switching of an associated electric motor shall have a utilisation category AC-23. Other equipment shall have a minimum utilisation category of AC-22.

3.6 COMPOSITE FUSE SWITCH UNITS

Composite Fuse Switch (CFS) units shall be in accordance with Clause 3.5 and the following:

- (1) Accommodate HRC fuses in accordance with Clause 3.7.
- (2) Triple pole units.
- (3) Individual contacts separately and fully shrouded.
- (4) Barriers included between fuse cartridges to reduce the possibility of a phase to phase or phase to earth fault occurring.
- (5) Shrouds, barriers and the complete moving contact assembly shall be removable from the CFS enclosure for maintenance purposes.
- (6) Provided with facilities to padlock the unit in the OPEN or OFF position.
- (7) Provided with safety interlocks to prevent the compartment door from being opened with the CFS unit in the closed position and to prevent the CFS unit from being closed with the compartment door opened.

3.7 LOW-VOLTAGE FUSES

Low voltage fuses shall be in accordance with the general requirements of AS/NZS 60269.1, applicable requirements of AS/NZS 60296.2 and AS/NZS 60269.4 and the following:

- (1) Suitable for use on a 400/230V 50 Hz supply.
- (2) Fuse links shall:
 - have a rated breaking capacity of not less than 50 kA at 400 volts 50 Hz or the prospective fault level at the point of installation whichever is higher and
 - be of the 'gG' or 'gM' type unless otherwise approved by SA Water's Representative.
- (3) Fuse holders shall:
 - have a rated current and a rated power acceptance suitable for the fuse links and
 - have a protection rating of not less than IP2X in accordance with AS 1939 with the fuse carriers removed.
- (4) Labels shall be fitted on, or immediately adjacent to, each fuse base or each 3 phase set of bases to identify the function and designation of the fuses and to specify the current ratings of the fuse links.

3.8 MOTOR CONTACTORS

Motor contactors shall be in accordance with the following:

- (1) 3-pole or where necessary 4-pole, air break, electromechanical type in accordance with AS 60947.4.1.
- (2) Provided with Type 2 co-ordination with short-circuit protective devices in accordance with AS 60947.4.1.
- (3) Utilisation category AC-3 and intermittent duty not less than Class 12 as defined in AS 60947.4.1, or a higher category and/or duty class to suit the specified operation requirements if required.
- (4) A mechanical endurance of not less than 1 million operating cycles.
- (5) Operating coils shall operate at either 24 volts dc or 230 volts ac, unless otherwise agreed by SA Water's Principal Electrical Engineer.

3.9 AUTO TRANSFORMERS

Auto transformers shall be in accordance with the following:

- (1) Naturally air cooled two or three coil type.

- (2) Suitable for use with contactors to provide automatic closed transition auto transformer starting of the motors. The transformers shall have an intermittent duty not less than Class 12 as defined in AS 60947.4.1 or higher to suit the specified operation requirements if required, and shall be adequately rated for the maximum temperature which will occur inside the cubicle.
- (3) Each coil stack shall be fitted with one positive temperature coefficient thermistor which shall be in accordance with AS 1023.1 to protect the winding against overtemperature.
- (4) Steel portions of the auto transformers shall be protected from corrosion by painting. After assembly the coils shall be thoroughly impregnated with moisture proofing varnish or an epoxy resin.
- (5) A label which shall be of engraved laminated plastic, brass or stainless steel shall be attached to each auto transformer frame. The label shall provide:
 - (a) the rating of the auto transformer in accordance with AS 60947.4.1 and
 - (b) the connection diagram for the auto transformer.

3.10 SOFT STARTERS

Soft starters shall be ac semiconductor type in accordance with the following:

- (1) Form 1 where both soft-start and soft-stop are required or Form 2 where soft-start only is required.
- (2) Stepless variable voltage output adequately rated for the maximum temperature which will occur inside the cubicle.
- (3) Adjustable start and stop ramp times and ranges in accordance with the project specification.
- (4) In-built fault indications with diagnostics and a changeover voltage-free contact for remote fault indication.
- (5) Provided with a bypass contactor to minimize energy loss and/or heat generation during operation unless otherwise specified in the project specification.
- (6) Where an emergency stop is required by the project specification, a contactor shall be provided in series with the soft starter with the emergency stop pushbutton hard-wired directly in the contactor circuit. The resultant hybrid starter shall be of Form H1A (soft-start and soft-stop) or H2A (soft-start only).
- (7) Protection against short-circuit with fast acting semi-conductor fuses for starters rated at 22kW and above in accordance with manufacturer's recommendation.

- (8) Provide overload protection of the connected motors with Type 2 co-ordination with the short-circuit protective devices in accordance with AS 60947.4.2.
- (9) Electromagnetic compatibility in accordance with Clause 8.3 of AS 60947.4.2.
- (10) Utilisation category AC-53a as defined in AS 60947.4.2, or AC-53b where bypass contactors are provided.
- (11) Intermittent duty as defined in AS 60947.4.2 with the number of operating cycles per hour (S value) of not less than 10 or to suit the specified duty whichever is higher. The ratio of the on-load period to the total period (F value) shall be not less than 70% or to suit the specified duty whichever is higher.

3.11 VARIABLE SPEED DRIVES

Variable speed drives (VSDs) shall comply with the following requirements:

- (1) Variable voltage variable frequency type rated for continuous operation at full load under the specified maximum ambient temperature.
- (2) Electromagnetic and Harmonic disturbances shall comply with the requirements of AS/NZS CISPR11 and AS/NZS 61000 and ETSA Utilities Service and Installation rules.

Harmonic filtering shall be required to comply with the requirements of ETSA Utilities Service and Installation rules. Mitigation techniques shall be approved by the SA Water Principal Electrical Engineer.
- (3) Electromagnetic immunity in accordance with AS/NZS4252.1.
- (4) Capable of sustaining not less than 110% rated output current for a minimum duration of 1 minute.
- (5) Infinitely variable speed control over the required speed range directly proportional to a 4~20mA control signal.
- (6) Adjustable minimum and maximum speed limits.
- (7) Adjustable current limits.
- (8) Soft start with adjustable acceleration and deceleration ramp rates.
- (9) In-built PID controller for closed-loop control.
- (10) Power loss ride through to allow continued operation of a rotating motor after a short power interruption.
- (11) Where an emergency stop is required by the project specification, a contactor shall be provided in series with the VSD with the emergency stop pushbutton hard-wired directly in the contactor circuit.
- (12) Galvanic isolation between remote and internal circuits to not less than 1kV dc.
- (13) Provided with the following minimum controls and indications available on the front of the VSD unit:
 - Running

- Fault
- Output current
- Output voltage
- Output frequency (or speed)
- Power
- Adjustment of all drive parameters.

(14) Provided with the following minimum protection, with indications available on the front of the VSD unit:

- Lightning and voltage transients
- Overvoltage
- Undervoltage
- Overcurrent
- Short circuit
- Earth fault
- Input phase failure
- Output phase failure
- Overtemperature
- Motor overload
- Motor winding overtemperature (where applicable)
- Loss of 4~20mA control signal.

(15) Additional protection against short-circuit, for drives rated at 22kW and above, if required in accordance with manufacturer's recommendation.

(16) Provided with the following minimum remote interfaces:

Digital Inputs

- Local/ Remote selection
- Start/Stop (or Run) control
- Preset speed selection (where applicable)

Digital Outputs

- VSD Running
- VSD Fault (incorporating all the protection in (14) above)

Analogue Input

- 4~20mA speed control signal

Analogue Outputs

- Not less than two programmable 4~20mA outputs to enable any two parameters to be selected (eg power, current, frequency or speed). Each analogue output shall be capable of driving a load of not less than 600 ohms.

Network Interface (where applicable)

- Communications port to interface with other devices such as PLCs. Where this facility is required, the minimum requirement of analogue outputs can be incorporated into the network interface communications.

3.12 CUBICLE HEATERS

Cubicle heaters shall be in accordance with the following:

- (1) Shall be provided for all electrical cubicles where the internal cubicle temperature is expected to drop to 10°C or below, or where the cubicle is installed in a damp location. Justification must be provided for not providing cubicle heaters, otherwise heaters must be installed in all cubicles.
- (2) Black heat strip heaters rated at approximately 20 watts per square metre of cubicle surface area and suitable for operation at 230 volts.
- (2) Shall be of such a number and shall be installed so that heat from the heaters can readily circulate throughout the cubicles and that heat energy from the heaters will not damage materials or components adjacent to the heaters.
- (3) Provided with a thermostat which will energise the heaters when the air temperature inside the cubicle is below 10°C. The thermostat can be either built-in or separate and shall preferably be adjustable. On long panels additional thermostatically controlled heaters shall be supplied and installed, if required, to ensure adequate temperature control within the switchboard or control panel.
- (4) Heater and thermostat terminals shall be IP2X in accordance with Clause 2.3.1(12) to eliminate the possibility of accidental personal contact.
- (5) Provided with an isolation switch and label adjacent to the heater. The label shall indicate:
 - (a) the switch function and (if applicable) the status of the heater(s) when the associated equipment is de-energised and
 - (b) the origin of the supply.

3.13 MOTOR PROTECTION UNITS

3.13.1 Thermal Overload Units

Thermal overload units shall be provided for the protection of motors rated at less than 15kW or where required by the project specification. Thermal overload units shall be in accordance with AS60947.4.1 and the following:

- (1) Triple pole, differential action to enhance the performance of protection against phase imbalance or phase failure.
- (2) Incorporate ambient temperature compensation.
- (3) Include a provision to allow the trip setting to be adjusted.
- (4) Suitable for alternative manual or automatic reset and initially selected to automatic reset if the control circuit has a separate RESET pushbutton.

3.13.2 Electronic Motor Protection Relays

Electronic motor protection relays shall be provided for the protection of motors rated at 15kW and above or where required by the project specification. The protection relays shall be in accordance with the following:

- (1) Provide protection and separate indication for each of the following:
 - (a) Overload
 - (b) Winding overtemperature by means of thermistors
 - (c) Single phasing and asymmetry.
- (2) Have selectable current and trip time settings.
- (3) Have a test feature.
- (4) Suitable for operation from a 230V ac supply.
- (5) Provide finger protection for the terminals (IP 2X) other than the main connections.
- (6) Unaffected by the passage of short circuit currents through the unit.

Directly connected units (ie without the need for external current transformers) are preferred.

3.13.3 Thermistor Control Units

Thermistor control units shall be used to monitor the operation of thermistors built into motors and auto-transformers unless the thermistors are monitored by an electronic motor protection relay.

The control units shall be in accordance with AS1023.1 and the following:

- (1) Suitable for a 230V ac supply voltage.
- (2) Provide a visual indication that a trip has occurred.
- (3) Match the type of thermistor, ie positive or negative coefficient type.

3.14 METERS

3.14.1 General

Ammeters and voltmeters shall be provided where required by the project specification and drawings. These may be either square bezel pattern type, of nominal size 96 mm with an approximate 120° movement, or a multi-function meter to measure and display the required parameters in a single unit.

3.14.2 Ammeters

Ammeters shall be in accordance with the following:

- (1) Provided with a selector switch to allow selection of individual phase currents. An OFF position shall be provided.
- (2) Accuracy of $\pm 2.5\%$ or better.
- (3) Scaled to correspond to the rated primary current.
- (4) Where used for measuring motor current, be overscaled to approximately 6 times the rated current of the associated motor. Full load current shall occur between 60% and 90% of full scale.
- (5) Where used for other than measuring motor current, be overscaled to approximately two times the rated current of the circuit.

3.14.3 Voltmeters

Voltmeters shall be in accordance with the following:

- (1) Provided with a voltmeter selector switch and potential fuses to allow selection of individual phase to phase voltages. No OFF position shall be provided.
- (2) Accuracy of $\pm 2.5\%$ or better.
- (3) Scaled to read between 0 and 500 volts.

3.14.4 Multi-function Meters

Multi-function meters shall be in accordance with the following:

- (1) Measure and display voltage, current and power in a single integral unit at not less than $\pm 1\%$ accuracy.

Additional parameters (energy, power factor, individual and total harmonic distortions etc) shall be included as required by the project specification and/or drawings. The display shall be retained during power failure where used for energy measurement.

The multi-function meter shall be capable of measuring, storing and displaying maximum load.

- (2) Panel mounting.
- (3) Suitable for monitoring a 3 phase unbalanced supply and load.
- (4) Operation from a 230V ac auxiliary supply.
- (5) Provided with the following remote interfaces where required by the project specification:

- Digital and analogue inputs/outputs programmable to represent the selected parameters.
- A communications port with industry standard protocol.

3.15 CURRENT TRANSFORMERS

3.15.1 Metering Current Transformers

Metering current transformers shall be in accordance with AS1675 and the following:

- (1) Accuracy not lower than Class 2M or, where used with test sockets, kW meters, kWh meters or multi-function meters, not lower than Class 1M or higher as required by the project specification.
- (2) Rated secondary current of 5A.
- (3) Rated burden sufficient to cover the burden imposed by the connected equipment including cables. Where a test socket is required (see Clause 3.23.9) an additional burden of 5VA shall be allowed for external equipment which may be plugged into the socket.

3.15.2 Protection Current Transformers

Protection current transformers shall be in accordance with AS1675 and the following:

- (1) Designated as 10P150F20 unless otherwise specified or required to suit the protection relay.
- (2) Rated secondary current of preferably 1A.
- (3) Transformer ratio shall be determined for correct operation of the associated relay under fault condition taking into consideration the rated accuracy limit factor of the transformer and the burden of the connected circuit.
- (4) Provided with test taps where required to be used in conjunction with a test socket.

3.16 CONTROL RELAYS

All control, interposing, latching and auxiliary relays shall be in accordance with AS60947.5.1 and the following:

- (1) Operating coils shall be suitable for the voltage shown on the control circuit drawings or specified in the project specification. If there is no control circuit or the voltage is not specified then 24V dc shall be used unless otherwise agreed by SA Water's Representative.

- (2) Contacts shall be suitable for the voltage and type of duty required, and shall have a current rating adequate for the load and, in any case, not less than 1A.
- (3) The operational life shall be not less than 10,000,000 cycles.
- (4) Finger protection for terminals (IP2X in accordance with AS1939).
- (5) Provided with a LED status indicator.

Relays selected shall be suitable for purpose, and shall be rated to carry the appropriate voltages and maximum current as designed for each individual application.

3.17 TIMING RELAYS

Timing relays shall be in accordance with the following:

- (1) Electronic type with an adjustable range.
- (2) Suitable for operation on the voltage shown on the control circuit drawings or specified in the project specification. If there is no control circuit or the voltage is not specified then 24V dc shall be used unless otherwise agreed by SA Water's Representative.
- (3) Contacts shall be suitable for the voltage and type of duty required, and shall have a current rating adequate for the load and, in any case, not less than 1 A.
- (4) Accuracy Class 1.5 or better.
- (5) The operational life shall be not less than 10,000,000 cycles.
- (6) Finger protection for terminals (IP2X in accordance with AS 1939).
- (7) Provided with a LED status indicator.

3.18 PROGRAMMABLE LOGIC CONTROLLERS

Programmable logic controllers (PLCs) shall comply with the requirements of IEC61131 and the following:

- (1) Programming language shall be in accordance with IEC61131.3.
- (2) Programmable with a personal computer.
- (3) Programming software and hardware shall be supplied for the PLC and shall provide full editing, debugging, monitoring, testing and documentation functions in accordance with IEC61131.1.
- (4) An industrial communication protocol may be used for communications (e.g. Ethernet, Profibus, ControlNet, etc.).

- (5) Ethernet communications shall preferably be used for PLC communications with a host SCADA system where applicable.
- (6) Provided with self-test and diagnostic functions in accordance with IEC61131.2.

Individual LEDs shall be provided on the front of the CPU module to indicate the following as a minimum:

- Power Supply On
- Run status
- Battery status
- CPU Fault
- Communications status
- I/O status (per each digital input & output)

In addition, internal diagnostics and system monitoring with the ability to access this information for alarming to the host SCADA system (where applicable) shall be provided including the following:

- Scan time watchdog error
- I/O faults
- Communication channel faults
- Program faults
- System clock (where applicable)

- (7) Facility for program download to the PLC via either random access memory (RAM) and/or non-volatile memory (EPROM or EEPROM). Where RAM is installed an inbuilt plug-in lithium battery to retain RAM contents for a minimum of 1 year on loss of power supply shall be provided.
- (8) Shall operate from 24Vdc or 230Vac unless otherwise specified.
- (9) Provided with a minimum of 50% spare memory capacity.
- (10) Provided with the following minimum spare inputs and outputs of each type installed:
 - 20% for total installed I/Os of up to 100
 - 10% for total installed I/Os exceeding 100.
- (11) Digital inputs and outputs shall be in accordance with IEC61131.2.
 - Digital input signals to the PLC shall be failsafe for fault indications.
 - Digital outputs shall be protected and short-circuit proof. The type of output selected shall be chosen in accordance with the voltage, current and the type of load.
- (12) Analogue inputs and outputs shall be in accordance with IEC61131.2.

Analog input signals to the PLCs shall be linear 4~20mA dc signals consisting of two wires per signal, screened, with the screen earthed at the source end. Each signal shall be electrically isolated from the source, where the source signal is used in a local control loop.

PLC analog outputs shall be linear 4~20mA dc signals consisting of two wires per signal with each output electrically isolated from other outputs, the power supply and earth. Each output shall be capable of driving the total impedance of all equipment connected in the output loop. Signal boosters in accordance with Clause 3.23.6 shall be provided if necessary to achieve the required load capacity. Facility shall be provided for earthing the screen of each analog output signal cable.

- (13) Provided with a spare communications port suitable for programming the PLC.
- (14) Critical signals between PLC and RTU shall be either independently hardwired or transmitted via an approved dual redundant industrial communications protocol.
- (15) Non-critical signals between PLC and RTU may utilise an approved single channel industrial communications protocol.

3.19 HOURS RUN METERS

Hours run meters shall be synchronous motor driven units with a display capable of registering not less than 9999 hours and shall be non-resettable.

3.20 UNDERVOLTAGE AND PHASE IMBALANCE RELAYS

The relay shall be a combined phase imbalance and undervoltage type with a contact opening for the following:

- (1) Voltage below 80% of nominal 400 V.
- (2) Phase imbalance greater than value set. This value shall be adjustable from 5-15% and initially set at 10%.

3.21 CONTROL SWITCHING DEVICES AND INDICATOR LIGHTS

Pushbuttons, rotary switches and indicator lights shall be in accordance with AS60947.5.1.

Indicator lights shall be clearly visible under all indoor and outdoor ambient light conditions. Suitable sunshields or other means shall be provided for outdoor situations to improve the visibility if necessary. Indicator lights shall be high intensity LEDs.

The colours of pushbuttons and indicator lights shall be in accordance with Table 3.1 and Table 3.2 respectively.

Table 3.1 - Colours of Pushbuttons

Colour	Application
RED	Action in case of EMERGENCY STOP, STOP or OFF <ul style="list-style-type: none"> • Emergency stop (mushroom head) • Emergency close a valve (mushroom head) • Stop or Off • Combined stop and reset • Open a circuit breaker or switch (only on the switchgear panel)
YELLOW	Intervention (eg to avoid danger or unwarranted change) <ul style="list-style-type: none"> • Sound a horn • Interrupt an automatic sequence • Bypass an inhibit
GREEN	START or ON <ul style="list-style-type: none"> • Start • Close a circuit breaker or electrical switch (only on the switchgear panel)
BLUE	Not used unless required by the project specification.
BLACK	No specific meaning. To be used for all other applications, eg: <ul style="list-style-type: none"> • Reset • Acknowledge • Lamp Test • Open (a valve) • Close (a valve) • Forward • Reverse • Raise • Lower

Table 3.2 - Colours of Indicator Lights

Colour	Application
RED	<p>Danger or alarm</p> <ul style="list-style-type: none"> • Chlorine extraction fan not running • Fire alarm • High fluoride dose rate alarm • Alarms which automatically shut down the plant or process. For example: <ul style="list-style-type: none"> - Motor winding overtemperature - Pump discharge failure - Tank overflow • Circuit breaker or switch closed (only on the switchgear panel)
YELLOW	<p>Caution</p> <ul style="list-style-type: none"> • Stage 1 alarm (Stage 2 being shutdown) • Alarm which allows operation in an abnormal mode (eg: non vital fault which allows a variable speed controller to operate in fixed speed as backup) • Machinery with exposed moving parts operating
GREEN	<p>Safety or authorised to proceed</p> <ul style="list-style-type: none"> • Circuit breaker or switch open (only on the switchgear panel) • Earth switch closed
BLUE	<p>The following have been assigned:</p> <ul style="list-style-type: none"> • Off • Stopped • Valve Closed • Remote • Local • Automatic • Manual • Normal • Standby • Circuit breaker or switch open (remote from the switchgear panel)
WHITE	<p>The following have been assigned:</p> <ul style="list-style-type: none"> • On • Available • Running • Valve Open • Electrical supply available • Circuit breaker or switch closed (remote from the switchgear panel)

3.22 SURGE ARRESTERS

Surge arresters for limiting voltage surges on ac power circuits shall be in accordance with following:

- (1) Comply with the requirements of AS1768.
- (2) Non-linear metal-oxide type in accordance with AS1307.2.
- (3) Provided with failure indication.

3.23 INSTRUMENTATION EQUIPMENT

3.23.1 General

Instrumentation loops shall comply with the following:

- (1) Signals shall be linear with respect to the measured variables and shall be 4~20mA, or may be 0~10 V if generated from within the cubicle suite.
- (2) Provided with a diode test point and a test injection point in each primary loop where required by the project specification or drawings. Where test injection points are required, each individual plant item that paces a 4-20mA control signal shall also have a test injection point for plant testing or maintenance purposes.
- (3) Equipment which is of the plug-in type shall be capable of being unplugged without open circuiting the instrumentation loop.
- (4) Where a primary loop is required to drive a number of secondary loops, a signal isolator shall be provided for each secondary loop to maintain the integrity of the primary loop so that a fault in a secondary loop does not affect the primary loop and other secondary loops.
- (5) Where it forms a control loop with other equipment (eg RTU, PLC, VSD, SCADA) the loop shall be electrically isolated from other loops, power supply and earth and be capable of driving the total loop impedance.
- (6) Provided with lightning protection, if required, at each end of the cable where the equipment at each end is installed in separate buildings or structures, or the field transducer is located outdoors at a distance of 50 metres or greater from the secondary instruments.

A decision on the requirement for lightning protection shall be made in consultation with the Regional Maintenance representative and the Principal Electrical Engineer.

3.23.2 Process Controllers

Discrete process controllers shall be in accordance with the following:

- (1) Microprocessor based programmable type providing proportional,

derivative and integral controls.

- (2) Analog input measurement accuracy shall be not less than $\pm 0.1\%$ of span.
- (3) Analog output accuracy shall be not less than $\pm 0.2\%$ of span.
- (4) Bargraph and digital displays shall be in engineering units.
- (5) Adjustable high and low output limits.
- (6) Controller constants and other configuration data shall be retained on power failure.
- (7) Shall be of plug-in type and shall allow removal of the controller without affecting the instrument loop.
- (8) All deviation alarms as required shall each be provided with an adjustable time delay of 0-2 minutes.
- (9) Analog output signal shall be held at zero until the equipment it is to control is in the operating mode.

3.23.3 Scale Indicators

Scale indicators shall be in accordance with the following:

- (1) Accuracy of $\pm 1.5\%$ or better.
- (2) Dial type indicators shall be square bezel pattern of 96 mm nominal size and having a concentric scale with an approximately 90° movement.
- (3) Scaled in engineering units.
- (4) Suitable for use with a 4-20mA signal.

3.23.4 Digital Indicators

Digital indicators shall be in accordance with the following:

- (1) Number of digits to suit the appropriate displays.
- (2) Accuracy not less than $\pm 0.2\% \pm 1$ count.
- (3) Height of digits not less than 12.5 mm.
- (4) Suitable for panel mounting.
- (5) Zero suppression or elevation capability not less than full scale.
- (6) Readout in percent or engineering units as appropriate.
- (7) Suitable for 4-20mA input.
- (8) Voltage drop in current loop shall not exceed 2.5V.
- (9) Shall not earth the instrument loop at either input.

3.23.5 Integrators

Flow integrators shall be in accordance with the following:

- (1) Direct reading digital type with 7 digits.

- (2) Calibrated to display total flow in the specified units.
- (3) Inhibited from operation when the flow rate is below 5-15% (adjustable) of the maximum flow.
- (4) Reading shall be retained during a power failure.
- (5) Shall not earth the instrument loop at either input.

3.23.6 Signal Isolators

Signal isolators shall be in accordance with the following:

- (1) Complete electrical isolation between the input, output and power supply.
- (2) Provide a boosting capacity to suit the load requirements.
- (3) Provide a 4-20mA output proportional to a 4-20mA input with an accuracy of $\pm 0.25\%$ of span or better.
- (4) Shall not earth the instrument loop at either input or output.

3.23.7 Signal Alarm Units

Signal alarm units shall be in accordance with the following:

- (1) Provide the contact operation required.
- (2) Fully adjustable operating point for each alarm unit over the 4-20mA range.
- (3) Adjustable differential over the full range.
- (4) Repeatability of alarm operation shall be $\pm 0.5\%$ or better.
- (5) Shall not earth the instrument loop at either input or output.

3.23.8 Lightning Protection Units

Lightning protection units shall be in accordance with the following:

- (1) Discharge current rating of not less than 20kA for surges with a characteristic corresponding to a standard as defined in AS1931
- (2) Protection against both differential and common mode transients extending from the power supply input where applicable to all signal inputs and outputs.
- (3) Include both voltage limiting devices and overcurrent fuses.

3.23.9 Test Points and Test Injection Points

Where required by the project specification or drawings, test points for instrumentation loops shall be Type A, B or C in accordance with Figure 3.2, or as specified in the project specification. Test injection points shall be provided with a NORMAL-TEST selector switch (see example in Figure 3.3). Test points

and test injection points shall be located inside the cubicles and incorporate sockets that are approved by the region's representative.

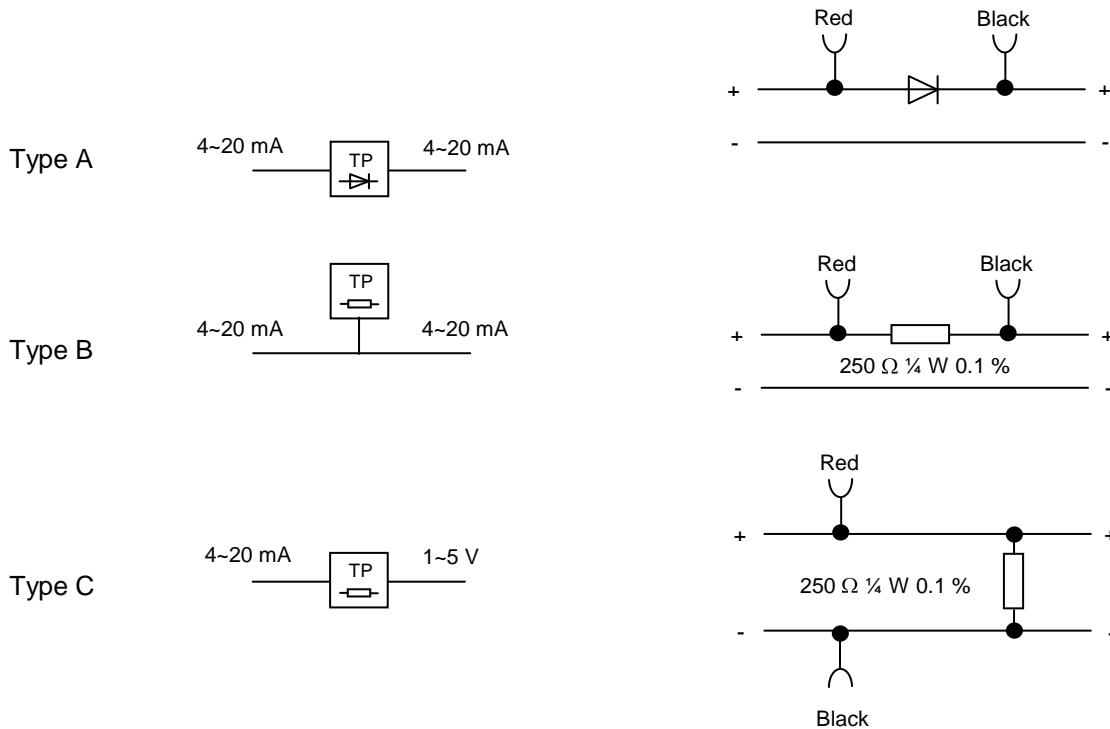


Figure 3.2 - Test Points

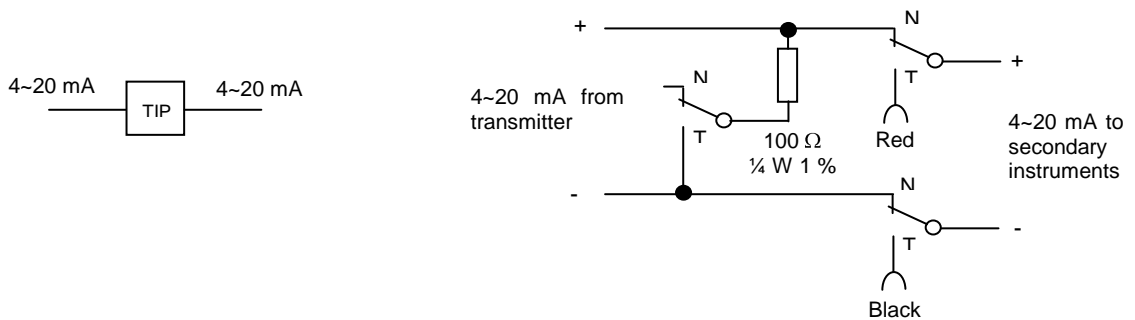


Figure 3.3 - Test Injection Point

3.24 REMOTE TELEMETRY UNITS

3.24.1 General

Remote telemetry units (RTUs) and associated equipment will be supplied and installed to be integrated with SA Water's Statewide SCADA Network (SCADANet). A suitable physical environment, power supply and input/output interface arrangement shall be provided for the RTUs in accordance with the following clauses. Reference shall be made to the project specification for other details specific to the particular site (eg a list of the actual inputs and outputs required).

3.24.2 Location

The RTU and associated equipment will be installed in a cubicle inside a building or outdoor in a weatherproof and vandal resistant enclosure (refer to Clause 2.3.9)

The space requirements for RTU cubicles and enclosures shall be as per that outlined in Section 2, for Switchboards and Control Panels.

3.24.3 Termination

Input and output signals for the RTU shall be provided at a terminal block located inside the RTU cubicle. Terminals shall be of the hinged link type to facilitate testing.

All signals including spare signals shall be grouped and terminated in a logical and orderly manner according to the signal types (ie DI, DO, PI, AI, AO). A minimum of 20% spare terminals shall be provided for each group of signals.

Terminal, wire and cable labelling shall be as per Clauses 2.6.7 and 2.6.8 respectively.

Unused analog input terminals shall be shorted together by links on the RTU side which will be removed when the input is utilised.

3.24.4 Power Supply

A suitably rated power supply shall be provided for the RTU and associated equipment via a dedicated final subcircuit protected by a miniature circuit breaker in the distribution board.

The supply shall be terminated at an isolator mounted inside the RTU cubicle.

3.24.5 Digital Inputs

Digital input signals to the RTU shall be failsafe for fault indications.

Fault contact inputs other than *Power Failure* shall be inhibited on power failure or when the control supply is isolated to prevent multiple false alarms being generated (eg due to alarm relays being de-energised). In addition, momentary operation of fault contacts shall be inhibited when the control supply is first switched on.

3.24.6 Digital Outputs

The control system shall be capable of accepting the RTU digital outputs which will generally consist of individual voltage free contacts each rated at 24Vdc 1A.

3.24.7 Pulse Inputs

Pulse input signals to the RTU shall be 24Vdc with a pulse width of not less than 50ms.

3.24.8 Analogue Inputs

Analogue input signals to the RTU shall be in accordance with the following:

- Linear (with respect to the measured variable) 4~20mA dc signals consisting of two wires per signal, screened, with the screen earthed at the source end.
- Capable of driving the RTU input (nominal impedance of 250 ohms) and other loads where required by the project specification.
- Each signal shall be electrically isolated from the source, other loops, power supply and earth.
- Provided with lightning and transient overvoltage protection in accordance with Clause 3.23.1(6).

The transducer shall be provided with a backup power supply where the measured variable is required to be monitored during a supply failure (eg tank level, sewage sump level). Alternatively, the transducer may be loop powered via the RTU battery supply (12V nominal) where permitted by the project specification.

3.24.9 Analogue Outputs

The control system shall be capable of accepting the RTU analogue outputs which will generally be:

- Linear (with respect to the measured variable) 4~20 mAdc signals consisting of two wires per signal, screened, with the screen earthed at the RTU.
- Capable of driving an impedance of 300 ohms.
- Electrically isolated from other outputs, power supply and earth.

3.24.10 Interface between RTU and PLC

The interface between a site PLC and RTU shall be in accordance with Clause 3.18.14 and Clause 3.18.15.

3.25 TOUCH SCREEN DISPLAYS

Touch screen displays shall comply with the following:

- (1) Colour TFT screen adequately sized to accommodate and display clearly all the specified functions or sized in accordance with the project specification where applicable.
- (2) An industrial communication protocol may be used for communications (e.g. Ethernet, Profibus, ControlNet, etc.), unless otherwise specified in the project specification.
- (3) Shall include but not be limited to the following functionalities (refer to project specification for detailed requirements):
 - Real time clock.
 - Alarm indications and message displays.
 - Security to prevent unauthorised access to configuration facilities.
- (4) Provided with configuration software and all necessary device drivers for operation with other vendor PLCs or similar equipment, if required in the project specification. Software must be compatible with SA Water's standard operating environment (SOE).
- (5) IP rating to suit the requirements of the switchboards and control panels on which the displays are mounted (refer to Clause 2.3).

3.26 EMERGENCY STOP CIRCUITS

Emergency stop circuits shall comply with the requirements of AS4024, AS3000:2007 and any other relevant Australian Standards. A risk assessment for the requirements of the Emergency stop circuits shall be carried out on a project by project basis.

Emergency Stop pushbuttons shall be:

- a. Red, palm or mushroom headed with a push to operate motion and a twist to release action, in order to release it from its operated position.
- b. Mounted on a yellow backing plate and clearly labelled, identifying its function and what equipment it relates to, e.g. "EMERGENCY STOP AERATOR No 1".
- c. IP rated to at least that of the panel/enclosure to which the Emergency Stop is installed, in accordance with Clause 2.3.
- d. Mounted in a position that will not impede its use (to be approved by Operations).

- e. Hard wired directly into a contactor control circuit (for Category 1 installations only) or into a safety relay (for installations other than Category 1).

Emergency Stop lanyards shall be:

- a. Pull to operate motion and a pushbutton to release action, in order to release it from its operated position.
- b. Clearly labelled, identifying its function and what equipment it relates to, e.g. "EMERGENCY STOP AERATOR No 1".
- c. A minimum IP56 rated.
- d. Mounted in a position that will not impede its use (to be approved by Operations).
- e. Hard wired directly into a contactor control circuit (for Category 1 installations only) or into a safety relay (for installations other than Category 1).

Emergency stops circuits shall be:

- a. A minimum category 1.
- b. Designed such that releasing an Emergency Stop button will not cause any equipment to move/start.
- c. Only capable of being reset by pressing a dedicated Emergency Stop reset button. The reset function shall be provided by either hardwired panel mount or via local HMI.
- d. Provide local visual indication that the Emergency stop circuit has been tripped. This indication shall be either hardwired panel mount or via local HMI.
- e. Provide a signal(s) to the control system, indicating the status of the Emergency stop/Emergency stop circuit. The status signal(s) shall be displayed/alarmed in SCADA.

Emergency Stop Installations:

- a. A risk assessment shall be performed to determine whether more than one Emergency stop pushbutton is required for large equipment or equipment where access may be restricted, and the location of additional Emergency stop pushbuttons.

The field cabling shall be of selected dependent on the site conditions. A risk assessment of the physical cable runs needs to be carried out and any hazards that may affect the type of cable to be used identified.

3.27 AMBIENT TEMPERATURES

All equipment in an exposed outdoor environment shall be suitable for continuous operation with an ambient temperature range of -5°C ~ 50°C. Outdoor enclosures shall be adequately ventilated/cooled to ensure that the maximum temperature will not exceed the equipment design temperature.

All equipment in an indoor environment shall be suitable for continuous operation with an ambient temperature range of 0°C ~ 40°C. Indoor environments and electrical enclosures shall be ventilated/cooled to ensure that the maximum temperature will not exceed the equipment design temperature.

VSDs shall be capable of being operated up to a maximum ambient temperature of 40°C.

4. EQUIPMENT AND FITTINGS

4.1 DUTY AND RATING

Electrical equipment shall be adequately rated for the specified duty and operating conditions. Adequate derating shall be applied where the operating conditions exceed those for which the equipment is designed (eg high ambient temperatures).

4.2 LIGHTING FITTINGS

4.2.1 General

Lighting fittings shall be supplied and installed as detailed in the project specification and/or drawings. Where applicable, all lighting fittings shall be in accordance with AS3137.

Lighting fittings in the following locations shall have a degree of protection of not less than IP56 in accordance with AS1939:

- Indoor locations which are subject to dampness or ingress of water.
- Corrosive environments.
- All outdoor locations.

Lighting fittings in hazardous areas shall be certified for the appropriate classification of the hazardous areas in accordance with AS/NZS2381.

Lighting fittings in corrosive environments shall be constructed of a material suitable for that environment.

4.2.2 Fluorescent Fittings

Fluorescent lighting fittings shall be supplied and installed complete with all necessary auxiliary equipment, including reflectors, louvres or diffusers (if specified). Each fluorescent tube shall be provided with a separate electronic ballast which shall be in accordance with AS3168 and AS2643.

The internal wiring of fluorescent fittings shall have a temperature rating of not less than 105°C. Each terminal in the connector block shall be suitable for the connection of not less than 3 x 1.5 mm² PVC insulated conductors.

4.2.3 High Intensity Discharge Fittings

High intensity discharge lighting fittings shall be supplied and installed in accordance with the project specification and/or drawings.

The fittings shall be power factor corrected so that the power factor is not less than 0.8 lagging. Capacitors shall be located so as not to be affected by heat generated by the lamp or ballast.

The internal wiring of the fittings shall have a temperature rating of not less than 105 °C. Each terminal in the connector block shall be suitable for the connection of not less than 3 x 1.5 mm² PVC insulated conductors.

4.2.4 Emergency Fittings

Emergency luminaires and exit signs shall be type tested self-contained fittings in accordance with AS/NZS2293.3. Emergency luminaires shall preferably be non-maintained type integrated within normal fluorescent lighting fittings.

4.3 LIGHTING SWITCHES

Lighting switches shall be in accordance with AS3133 and the following:

- (1) Switches in office areas shall be white and flush mounted with concealed wiring.
- (2) In other areas switches may be either flush mounted or surface mounted and shall be either white with white mounting blocks or shall match the colour of the associated wiring conduit.
- (3) Lighting switches in the following locations shall have a degree of protection of not less than IP56 in accordance with AS1939:
 - Indoor locations which are subject to dampness or ingress of water.
 - Indoor locations where additional mechanical protection is required.
 - Corrosive environments.
 - All outdoor locations.
- (4) Lighting switches in hazardous areas shall be certified for the appropriate classification of the hazardous areas in accordance with AS/NZS 2381.
- (5) Lighting switches in corrosive environments shall be constructed of a material suitable for that environment.

4.4 SOCKET OUTLETS

Socket outlets shall be in accordance with AS/NZS3112 and the following:

- (1) Socket outlets shall be switched.
- (2) Outlets in office areas shall be white and flush mounted with concealed wiring.
- (3) In other areas outlets may be either flush mounted or surface mounted and shall be either white with white mounting blocks or shall match the colour of the associated wiring conduit.

- (4) Socket outlets supplied by UPS shall be colour coded and/or appropriately labelled.
- (5) Socket outlets in the following locations shall have a degree of protection of not less than IP 56 in accordance with AS 1939:
 - Indoor locations which are subject to dampness or ingress of water.
 - Indoor locations where additional mechanical protection is required.
 - Corrosive environments.
 - All outdoor locations.
- (6) Plugs and socket outlets in hazardous areas shall be certified for the appropriate classification of the hazardous areas in accordance with AS/NZS 2381.
- (7) Plugs and socket outlets in corrosive environments shall be constructed of a material suitable for that environment.
- (8) Fitted with a phase coloured and numbered stud matching that of the associated circuit breaker feeding the outlet.
- (9) Wiring to three phase outlets shall be such that, when viewing the socket from the front and reading the phases clockwise from the earth pin, the phases shall be red, white and blue. The neutral pin, where fitted shall be the central pin.

4.5 FIELD CABLES

4.5.1 Power Cables

Power cables shall be in accordance with AS/NZS5000.1. Sheathed cables shall have a PVC sheath unless otherwise specified and shall be suitable for use underground.

Power cables shall be screened in the following situations:

- Where required to comply with the specified electromagnetic emission limits or as required by the manufacturer of the connected equipment (eg variable speed drives).
- Where the power cables are installed in close proximity to data or signal cables and it is not possible to provide adequate separation between the power cables and data or signal cables to prevent interference in the data or signal cables.

All cables shall be of multi-strand construction and of copper conductor unless otherwise specified.

The minimum cross sectional area of any cable core shall be 1.5mm^2 except for current transformer wiring which shall be a minimum of 4mm^2 .

The Contractor shall be responsible for selecting cable sizes, where not shown on the specification drawings, in accordance with AS/NZS3008.1.1.

4.5.2 Control Cables

Control cables which are required to operate at low voltages shall be stranded PVC insulated PVC sheathed copper conductor cables manufactured in accordance with AS/NZS5000.1 and having a minimum conductor cross sectional area of 1.5mm².

Control cables which are required to operate at extra low voltage shall be rated for the voltages and currents which they have to carry. Conductor cross sectional area shall be not less than 1.5mm² for single-core and two-core cables and not less than 0.75mm² for multi-core cables.

Multi-core cables shall be provided with a number of spare cores, not less than two, or 20% of the total number of installed cores rounded to the next higher whole number, whichever is the greater.

Control cables shall be screened where required by the manufacturer of the connected equipment (eg variable speed drives).

All spare cores shall be terminated in accordance with Clause 5.7.6.

4.5.3 Instrumentation Cables

Instrumentation cables shall consist of either single pair or multiple pairs with each pair being of twisted PVC insulated stranded copper conductors in either case.

Each instrumentation cable shall have an overall screen with a stranded copper drain wire and PVC sheath.

The conductors of each pair shall have a minimum conductor area of 0.75mm².

Multi-pair cables shall be provided with a number of spare pairs equal to not less than 20% of the total number of installed pairs rounded to the next higher whole number.

All spare pairs shall be terminated in accordance with Clause 5.7.6.

Where the cables are connected to output equipment with a potentially damaging high current output under short circuit condition, the cables and output equipment shall be protected against short circuit unless the output equipment is inherently current limited or short circuit proof.

4.5.4 Data Cables

Cables used for data transmission shall be suitable for the transmission rate, route length and installation conditions and as specified by the equipment suppliers.

4.6 CABLE TRAYS AND LADDERS

Cable trays, ladders and fittings (eg brackets and supports) shall be in accordance with following:

- (1) General indoor and outdoor locations - Hot-dip galvanised to AS/NZS4680.
- (2) Corrosive environments (eg marine, sewage pumping stations and sewage treatment plants) - Marine grade aluminium, fibreglass, GRP or Grade 316 stainless steel.

Where aluminium is in contact with concrete surfaces less than 12 months old, a suitable material (eg bituminous sheet) shall be used to isolate the contact areas.

4.7 CONDUITS AND FITTINGS

Electrical conduits and conduit fittings shall comply with one or more of the following:

- (1) Heavy duty rigid UPVC conduits and fittings in accordance with AS/NZS2053.2.
- (2) Flexible PVC conduits and fittings in accordance with AS/NZS2053.4.
- (3) Corrugated conduits and fittings in accordance with AS/NZS2053.5.
- (4) Rigid screwed steel conduits and fittings in accordance with AS/NZS2053.7.
- (5) Flexible steel conduits and fittings in accordance with AS/NZS2053.8.

UPVC conduits and fittings installed in locations which are subject to direct sunlight shall be protected by one of the following methods:

- (a) Complying with high protection classification against solar radiation in accordance with AS/NZS2053.1.
- (b) Painted with an exterior gloss acrylic paint complying with GPC-L-28. The surface shall be degreased and lightly sanded prior to application.
- (c) Provided with sun shields.

Steel conduits and fittings shall have the following protection classifications against corrosive or polluting substances in accordance with AS/NZS2053.1 as follows:

- (a) Medium Protection or higher for indoor locations.
- (b) High Protection for outdoor locations.

Generally, conduit runs shall be rigid steel or rigid UPVC, with flexible or corrugated conduits used for special or difficult points in the installation (eg connection to vibrating or moveable equipment).

4.8 MOTORS

Electric motors shall comply with the following:

- (1) Three-phase, four-pole, high efficiency squirrel cage induction motors in accordance with Table 3.1 or 3.2 of AS/NZS1359.5.

Single phase motors can only be used for applications of 1.5kW or less.

- (2) Three phase motors shall be rated for connection to a 400V 3-phase 50Hz supply. Single phase motors shall be rated for connection to a 230V single phase 50Hz supply.
- (3) Constructed to withstand direct-on-line starting forces.
- (4) Adequately derated for the effects of ambient temperature, harmonics and unbalanced supply.
- (5) After the appropriate derating in accordance with (4) above, have a maximum continuous rating of not less than 110% of the maximum load in accordance with the S1 duty rating provisions of AS1359.101 rounded to the next larger size.
- (6) Provide adequate accelerating torque to the load under worst conditions of load and electricity supply.
- (7) Totally enclosed air cooled as defined by IC411 to AS1359.106 with a degree of protection to AS 1359.20 as follows:
 - (a) Indoor motors - Not less than IP54.
 - (b) Indoor motors which are subject to ingress of water and all outdoor motors - Not less than IP56.
- (8) Provided with winding insulation Class 130 or higher in accordance with AS2768.
- (9) Provided with anti-condensation heaters for all indoor and outdoor motors rated at 15kW and above and for smaller outdoor motors where required by the project specification.

A warning label shall be provided at the switchboard or control panel and at the motor with the wording 'MOTOR HEATERS ON WHEN MOTOR STOPPED'. In addition, an appropriately labelled isolating switch shall be provided at the switchboard or control panel.

- (10) Provided with positive temperature coefficient thermistors, RTDs or thermostats embedded in each phase winding to protect the motor windings from the effects of overload and, if possible, stalling for motors rated at 15kW and above in accordance with AS1023.1. The overtemperature detectors shall be wired to the motor auxiliary terminal box.
- (11) Provided with a terminal box for stator power cables with all 6 winding terminals available and a separate terminal box for auxiliaries (eg motor heaters, thermistors). Cable entries shall be from below unless otherwise

specified. The position of the terminal boxes shall be in accordance with the projection specification and drawings.

- (12) Unless otherwise specified, motors which are directly coupled to the loads shall be provided with grease lubricated steel caged ball bearings at both the drive ends and non-drive ends. Roller bearings shall be used at the drive ends where the motors are coupled to the loads via gears or belts due to the high radial loads. Each bearing housing shall be fitted with a grease nipple and with a pressure relief system to prevent overfilling of the bearing with grease. Bearings shall be designed for an L10 life of not less than 60,000 hours.
- (13) Rating plates shall show the direction of rotation and bearing identification and grease type in addition to the details specified in AS1359.101. Rating plates shall be made of stainless steel for outdoor motors and corrosive environments.
- (14) Sound power level limits shall be in accordance with AS1359.109 or lower as required to meet the combined noise level limits of the motor and coupled equipment in accordance with the project specification.
- (15) The limits of vibration severity shall be in accordance with AS1359.114 Table 1 Vibration N for both transverse and axial vibrations.
- (16) Provided with vibration measurement points at both drive-end and non-drive-end bearing housings for motors rated at 110kW and above. If the non-drive-end bearing housing is not accessible, then the vibration measurement point shall be located on the motor casing as near as practical to the bearing housing.

Each vibration measurement point shall consist of three machined pads of 25mm diameter with a centrally located spot drill point nominally 6mm in diameter. The machined pads shall be located such that a studded accelerometer with its wiring can be easily screwed into a hole tapped into the pad at a later date (ie sufficiently clear of guards) and to allow measurement points to be positioned in the horizontal-radial, vertical-radial and axial directions. However, the radial measurement points need not necessarily be horizontal and vertical provided that they are perpendicular to each other and to the motor axis.
- (17) Provided with a lifting facility. The weight of the motor shall be clearly visible on the nameplate.
- (18) Motors installed outdoors in direct sunlight shall be adequately derated for the maximum external ambient temperature or provided with a sun shield which shall not obstruct the motor terminal boxes.

4.9 ELECTRIC VALVE ACTUATORS

Electric valve actuators shall be of adequate capacity to open and close the associated valves under all operating conditions and shall incorporate the following features:

- (1) Electric motor operation from a 400V 3-phase 3 wire 50Hz electricity supply

unless otherwise specified in the project specification. The actuator internal control circuit shall operate at 230V or lower, single phase, derived from the 3-phase supply.

- (2) Either a phase rotation discriminator operating such that the actuator motor can only operate when the electricity supply is connected with the correct phase rotation or an actuator which is insensitive to the direction of phase rotation.
- (3) Motor winding insulation shall be not less than Class 130 to AS2768.
- (4) Inbuilt reversing starter for the actuator motor. The starter shall incorporate thermal overload protection for the actuator motor, preferably on all three phases. The starter shall have a utilization category AC4 and an intermittent duty of not less than Class 30 as defined in AS60947.4.1, or a higher duty class to suit the operation requirements where specified.
- (5) Inherently self-locking.
- (6) Incorporate a hammer blow device which allows the motor to reach full speed before the load is engaged.
- (7) A LOCAL-OFF-REMOTE selector switch lockable in any position.
- (8) Local control by means of an integral control station providing OPEN, STOP and CLOSE functions.
- (9) Remote controls to suit the specified control systems.
- (10) Over-travel and over-torque protection. It shall be possible to drive the actuator out of the overtorque limit.
- (11) Local open, closed and fault indications. A separate voltage free changeover contact for each of the open and closed positions operated from adjustable travel limit switches shall be provided for remote indications and controls.
- (12) Anti-condensation heater.
- (13) Enclosure with a degree of protection of not less than IP56 in accordance with AS1939, or higher as required by the project specification.
- (14) Cable entries from below.
- (15) Fully numbered wiring terminals, suitable for the above cables corresponding to those in the wiring diagrams.
- (16) An auxiliary manual handwheel mechanically independent of the electric drive for emergency operation incorporating automatic disconnection if the actuator is energised electrically. The handwheel shall operate clockwise to close the valve.
- (17) An integral valve position indicator which gives continuous indication of valve position in addition to OPEN and CLOSED indications. This indicator shall be visible while operating the manual handwheel.
- (18) 4~20mA valve position input/output signals for controls and indications where required by the project specification.

4.10 GENERATOR SETS

4.10.1 General

Generator sets shall be in accordance with AS3010.1 and shall comprise a diesel engine and a generator mounted on a common skid base complete with engine cooling radiator, automatic starting system, control equipment, battery and charger, fuel storage tank and lifting facility as specified in the following clauses.

Permanently installed generator sets shall be suitable for fully automatic unattended operation and shall provide automatic changeover between the mains and generator supplies.

4.10.2 Ambient Temperatures

Generator sets shall be suitable for continuous operation over the following ambient temperature ranges unless otherwise specified in the project specification:

Indoor: 0 °C ~ 40 °C
Outdoor: -5 °C ~ 50 °C

Equipment housed in outdoor enclosures shall be adequately derated to allow for increase in ambient temperature inside the enclosures.

4.10.3 Power Rating

Generator sets shall have a power rating not less than that specified in the project specification or drawings. Where the power rating is not specified, the Contractor shall determine the required power rating based on the following criteria:

- Continuous operation at full rated load under the maximum ambient temperature specified in Clause 4.10.2.
- Capable of running at the intermittent rating of 10% overload for 1 hour.
- Ability to start the largest motor with the associated starter (DOL, auto-transformer, soft starter or VSD whichever is applicable that will result in the highest starting kVA) when this motor is the last load added to achieve full load, with a voltage dip of not exceeding 20%.

To avoid problems associated with running the engine on light loads over long periods of time, the Contractor shall recommend the frequency, duration and load of running the engine to overcome these problems. A load bank shall be provided in accordance with Clause 4.10.13 if recommended by the manufacturer or required by the project specification.

4.10.4 Isolation

An isolating switch shall be provided at a readily accessible location to isolate the generator supply. The generator circuit breaker specified in Clause 4.10.11.5 may be used for this purpose provided that it is readily accessible.

4.10.5 Outdoor Enclosures

Where generator sets are installed outdoors, they shall be enclosed in a weatherproof enclosure with a degree of protection of not less than IP46 in accordance with AS1939. The enclosure shall be vandal resistant and shall provide sound proofing to comply with the requirement of Clause 4.10.8. The top of the enclosure shall be sloped to prevent accumulation of water. Lifting points shall be provided to allow the complete removal of the enclosure.

A window shall be provided for viewing all instruments and indicator lights. Access for operation shall be available by opening lockable hinged doors only. Access for all adjustments and routine service and maintenance shall be available by opening doors or hand removal of covers by one person, the doors or covers being lockable or requiring the use of special tools for opening or removal. Removable doors or covers shall not exceed 15kg.

Acoustic louvred air vents shall be provided to allow air circulation through the enclosure. Any opening in the enclosure shall not reduce the enclosure IP rating and shall be protected against the ingress of birds and vermin.

4.10.6 Mounting Base

The base frame shall be in accordance with the following:

- Robust steel construction protected against corrosion by fuel, oils and other agents.
- Allow 4 point hoisting of the complete generator set. The lifting points shall be located such that the base frame remains horizontal when the generator set is being lifted. The weight of the complete generator set shall be clearly visible on the nameplate.
- Resiliently mounted on a concrete plinth with anti-vibration mountings selected to minimize noise and vibration transmission. There shall be a clearance between the underside of the base frame and the concrete base to give access for handling equipment. Where anti-vibration mounts are provided between the base frame and the engine/generator as an alternative, the base frame shall be levelled on the concrete base with grout. Details of the lifting method shall be provided with this alternative.

4.10.7 Guarding

The internal operations of the generator set shall be protected by machine guarding in accordance with AS4024 in addition to the guarding provided by the acoustic enclosure.

4.10.8 Noise and Vibration Levels

The maximum sound pressure level of the generator set within the plant shall not exceed 85dB(A) at a distance of 1 metre from the generator set when operating at the full rated load. The noise level limit at the plant property boundary shall be in accordance with the Environment Protection Act 1993. An acoustic enclosure shall be provided if necessary to meet the requirements of the Act. Noise tests shall be carried out on the generator set at the manufacturer's works and on site in accordance with Clauses 8.3.7 and 8.4.5 respectively.

The generator set shall not suffer from excessive internal vibrations. The out of balance, torsional vibrations and critical operating speeds are the manufacturer's responsibilities and shall be subject to guarantee by the Contractor. Factory performance vibration tests shall be carried out on the generator set in accordance with Clause 8.3.7. The vibration root mean square velocity shall not exceed 2.8 mm/s in accordance with AS2625.

4.10.9 Engine

The engine shall be in accordance with AS4594 and the following unless otherwise agreed by SA Water's Representative:

- (1) Water cooled, turbocharged or aftercooled compression-ignition (diesel) type with a power rating suitable for the specified duty and a rated speed of 1500rpm.
- (2) Provided with a thermostatically controlled 230Vac water jacket heater with a labelled isolating switch on the set. The Supplier shall recommend the coolant treatment (anti-freeze/corrosion inhibitor) required to suit the specified ambient temperature range without the jacket heater on, and any water conditioning required to minimize scale formation and corrosion. Coolant filling and draining facilities shall be secured within the acoustic enclosure (where provided) and shall be accessible without removing the enclosure. Ready but secured access for checking the coolant level shall also be provided without the need to remove any equipment or covers.
- (3) Fuel type shall be Class A1 in accordance with BS2869. The fuel tank shall be located on the base with a minimum storage capacity of 8 hours continuous operation at full rated load, or a longer period as specified in the project specification. A biological additive ('Diesel Extra' or equivalent) shall be added to the fuel tank to prevent slime formation in accordance with the manufacturer's instructions. Fuel heaters shall be provided to assist starting at low temperatures if considered necessary by the manufacturer. The bottom of the fuel tank shall slope to one point to allow complete draining of the tank. Tank filling and draining facilities shall be secured within the acoustic enclosure (where provided) and shall be accessible without removing the enclosure.
- (4) Speed governor of accuracy Class M3 in accordance with AS4594.4.
- (5) Replaceable dry type air cleaner, fuel filter and oil filter which shall be secured within the acoustic enclosure (where provided) and shall be accessible without removing the enclosure. A moisture sensor shall be incorporated in the fuel filter.

- (6) Readily removable drip trays under the engine and fuel tank.
- (7) The exhaust system shall be fitted with a spark arrestor and a muffler to comply with the noise level requirement of Clause 4.10.8. The exhaust pipe shall be routed to the outside of the enclosure or building terminating in a weatherproof cap. The connection between the exhaust pipe and engine shall be made by a suitable stainless steel flexible connector and shall be oil tight. The full length of the exhaust pipe and silencer shall be lagged to minimize heat and noise rejection.
- (8) Provided with the following instruments and sensors:
 - Coolant temperature gauge
 - High coolant temperature sensor
 - Coolant low level sensor
 - Fuel level gauge
 - Oil pressure gauge
 - Oil low level sensor.

4.10.10 Generator

The generator shall be in accordance with the following:

- (1) Type tested, 4 pole 400/230 volts 50Hz, 3-phase, 4 wire star connected, horizontal, self exciting and brushless type.
- (2) For permanent installations the star point must be solidly earthed.
- (3) Ingress protection of not less than IP22 to AS1939. An additional IP46 enclosure is to be provided where required for weatherproofing and soundproofing in accordance with Clause 4.10.5.
- (4) Winding insulation not less than Class 180 in accordance with AS2768. All windings shall be impregnated with moisture proofing varnish or epoxy resin and provided with anti-condensation heaters.
- (5) Solid state voltage regulator with the following functions:
 - Automatic voltage regulation to Class VR2.23 in accordance with AS1359.40
 - Short circuit field forcing to at least 300% of rated output current
 - Under frequency protection
 - Manual voltage adjustment of ± 10 % of nominal voltage.
- (6) Fitted with grease lubricated steel caged ball bearings. Each bearing housing shall be fitted with a grease nipple and a pressure relief system to prevent overfilling. Grease nipples shall be accessible for filling by a hand operated grease gun.
- (7) Limits of electromagnetic interference shall not exceed those specified in AS/NZS CISPR 11.
- (8) Total harmonic distortion of the output waveform shall not exceed 2.5% at full rated load.

4.10.11 Controls, Indications And Protection

4.10.11.1 Control Cubicle

A control cubicle shall be provided for mounting either on the generator set or inside the switchroom in accordance with the project specification.

The cubicle shall be constructed in accordance with Clause 2.3 and shall house all the electrical equipment required for the control (including automatic transfer control), indication and protection of the engine, generator and ancillary equipment.

All control switches, indicator lights, instruments and meters shall be mounted on the front of the cubicle and shall be readily accessible, clearly labelled and visible.

4.10.11.2 Controls

The following minimum control facilities shall be provided on the front panel of the control cubicle:

- A key-operated five-position switch with the following functions or similar:
OFF
AUTO
TEST WITH NO CHANGEOVER
TEST WITH CHANGEOVER
MANUAL (with spring return to start the engine)
- Latched off EMERGENCY STOP pushbutton
- LAMP TEST pushbutton
- RESET pushbutton.

With the key switch in the OFF position, the starting circuit shall be isolated so that the generator set cannot be started. In addition, the generator set shall stop if running when the switch is turned to the OFF position.

With the key switch in the AUTO position, the generator set shall be on automatic standby and shall be under the control of the automatic transfer sequence. An AUTO ENABLED indicator light shall be illuminated on the front panel.

The TEST WITH NO CHANGEOVER position shall start the generator set and enable the complete automatic operation to be tested without transferring the loads.

The TEST WITH CHANGEOVER position shall start the generator set and enable the complete automatic operation including the automatic transfer sequence to be tested by simulating a mains power failure. The loads shall be automatically transferred to the generator set for testing.

The MANUAL position shall be used in an emergency to bypass all automatic control functions and incorporate a spring return contact to start the generator set manually. The transfer contactors shall be controlled manually in this position.

4.10.11.3 Automatic Operation

Control equipment shall be provided for the automatic start and stop of the generator set, and the automatic transfer between the mains and standby supplies. Electrical and mechanical interlocks shall be provided to ensure that feedback cannot occur between the two supplies. Where the generator sets are required to operate in parallel with the mains supply, all necessary control, metering and protection equipment shall be provided to enable the generator supply to be connected to and synchronised with the mains supply in accordance with the requirements of the electricity supplier.

A minimum run-on timer shall be provided after the restoration of the mains supply. If the mains supply fails again while the set is running-on or stopping, the set shall, after the preset mains failure time delay, immediately be re-started if stopping. All time delays in the automatic sequence shall be readily adjustable.

4.10.11.4 Indications

The following minimum indications shall be provided on the front panel of the generator set control cubicle:

- MAINS AVAILABLE indicator light
- GENERATOR ON indicator light
- AUTO ENABLED indicator light
- Generator Synchronised to Mains (where applicable)
- Mains Circuit Breaker status
- Generator Circuit Breaker status
- Emergency Stop activated indication
- Individual fault indicator lights (see Clause 4.10.11.5)
- Load bank fault indicator light (where provided)
- Frequency meter (45~55 Hz)
- Voltmeter (0~500 V phase to phase) with phase selector switch
- Ammeter with 1.5 times overload scale and phase selector switch
- Wattmeter
- Hours run meter
- Engine oil pressure gauge (provided on generator set)
- Engine coolant temperature gauge (provided on generator set)
- Engine fuel level gauge (provided on generator set)

Voltage free contacts and 4~20mA outputs for remote indications shall be provided at readily accessible terminals as required by the project specification.

4.10.11.5 Protection

The generator set shall be provided with the following minimum automatic protection against:

- Failure to start
- Engine oil pressure low
- Engine coolant temperature high
- Engine overspeed/underspeed
- Generator armature overcurrent
- Generator field overcurrent
- Generator over voltage/under voltage

Each fault shall open the generator contactor control contact, stop the set, illuminate a fault indicator light and operate a changeover common fault contact for remote indication. Manual fault reset shall be provided.

Protective devices shall be fitted with suitable time delays if required to prevent them from operating during acceptable transient conditions in normal service.

In addition, short circuit and sustained overload protection of the generator output shall be provided by means of a suitably rated automatic circuit breaker. The circuit breaker shall be located on the front of the control cubicle in a readily accessible position.

The circuit breaker shall be in accordance with Clause 3.2.3.

4.10.12 Batteries and Chargers

4.10.12.1 Batteries

Separate batteries for control and engine starting purposes shall preferably be provided.

The batteries shall be in accordance with the following:

- Lead acid, pure lead pasted positive plate, specially designed for the intended application and float charging with a life expectancy of not less than 5 years.
- Starting battery adequately sized to provide at least two successive 20 second cranking periods with a cold engine, and not less than two further successive 20 second cranking periods not more than two hours later.
- Installed on the set (not in the charger cubicle) protected from the weather, ventilated and readily accessible for inspection and maintenance.
- Electrolytic level indicator for each cell.
- Provided with explosion-proof vent plugs.

4.10.12.2 Chargers

Either a common charger with two separate outputs, or two separate chargers shall be provided for the batteries in addition to the integral generator driven

battery charger to maintain battery charges when the generator set is not being used for extended periods.

The battery charger(s) shall be in accordance with the following:

- Constant voltage, current limited type providing automatic boost and float charge facilities.
- Adequately rated for the ambient conditions.
- Capable of recharging fully the battery within 24 hours following a full discharge.
- Ensure battery is fully charged at all times and maintain optimum battery life.
- Suitable for operation from a 230V +10% -6% 50Hz single phase supply.
- Provided with the following indications on the charger cubicle front panel:
 - Charger output current (ammeter)
 - Battery voltage (voltmeter)
 - AC SUPPLY ON indicator light
 - BOOST CHARGE indicator light
 - FLOAT CHARGE indicator light
 - CHARGER FAILURE indicator light
 - LOW BATTERY VOLTAGE indicator light
 - HIGH BATTERY VOLTAGE indicator light
- Provided with a common voltage free changeover fault contact for remote indication.
- Provided with a battery tester to indicate the battery condition.
- Provided with the following protection:
 - Input overcurrent.
 - Output overcurrent and short circuit.
 - Lightning and transient overvoltages.
- Charger cubicle shall be set mounted or wall mounted in the building and may be integral with the generator set control panel.

4.10.13 Load Banks

Load banks shall be in accordance with the following:

- Multi-stage or continuously adjustable to provide a minimum load to avoid engine glazing as recommended by the manufacturer taking into consideration the operation of the plant loads.
- Automatic controls to maintain the minimum load in response to the varying plant loads.
- Adjustable set points for both minimum and maximum loads.
- Resistance elements shall be made of a durable material and shall be individually replaceable.
- Located so as not to obstruct the removal or maintenance of the generator set and to comply with requirements of AS4024.1. The location shall be agreed with SA Water's Representative.
- Enclosure shall be constructed in accordance with the appropriate requirements of Clause 2.3. External covers shall be removable to provide maintenance access and shall be secured with locks keyed alike to the generator set enclosure.
- Adequate heat dissipation to prevent excessive temperature rise within the enclosure. All accessible external surfaces shall be insulated if necessary

to ensure that they are safe to touch. The temperature of the discharge air and the manner it is discharged shall not create an Occupational Health and Safety hazard.

- All equipment and wiring shall be adequately rated for the maximum temperature within the enclosure.
- Overtemperature protection with the appropriate status and fault indications provided on the generator set control panel.

4.11 UNINTERRUPTIBLE POWER SUPPLIES

4.11.1 General Requirements

Uninterruptible power supply (UPS) units shall be in accordance with AS62040 and the following:

- (1) Provide an on-line no-break supply in the event of a mains supply failure for a continuous period of four hours, or greater if specified in the project specification.
- (2) Automatic static bypass upon a rectifier or inverter failure.
- (3) Manual bypass to allow maintenance to be carried out without disconnecting the loads.
- (4) Connected load shall not exceed 80% of the full load capacity.
- (5) Sealed batteries with integral automatic battery charger (see Clause 4.11.2).
- (6) Automatic protection of batteries in case of prolonged power outage (see Clause 4.11.3).
- (7) Suitable for continuous operation from an input voltage of 230V ac single phase or 400V ac three phase as specified in the project specification with a voltage fluctuation of +10% -20% and a frequency variation of $\pm 5\%$.
- (8) Output voltage shall be 230V ac single phase or 400/230V ac three phase in accordance with the project specification. Output voltage regulation shall be not greater than $\pm 3\%$ and output frequency variation shall be not greater than $\pm 0.5\%$.
- (9) Output power factor within the range of 0.8 lagging to 0.8 leading.
- (10) Harmonics in the mains supply caused by the UPS shall not exceed the limits specified in AS/NZS61000.3.6 and the radio frequency interference caused by the UPS shall not exceed the limits specified in AS62040.2.
- (11) Overload capacity of 110% full load for 60 minutes, 125% full load for 10 minutes and 150% full load for 60s.
- (12) Capable of performing a cold start, ie starting in the absence of ac mains supply.
- (13) The following minimum alarms shall be indicated on the front panel of the UPS unless otherwise agreed by SA Water's Principal Electrical Engineer:

LOW BATTERY VOLTAGE
UPS FAULT
OUTPUT OVERVOLTAGE
OUTPUT UNDERVOLTAGE

A voltage-free common alarm contact shall be provided for remote alarm monitoring.

(14) The following instruments shall be provided on the front panel of the UPS as a minimum unless otherwise agreed by SA Water's Principal Electrical Engineer:

- Input voltmeter
- Input ammeter
- Output voltmeter
- Output ammeter
- Output frequency meter
- Battery voltmeter
- Battery ammeter.

The meters shall be appropriately scaled to suffice the normal operating conditions and the specified one hour overload capacity.

4.11.2 Battery and Charger

The UPS shall be provided complete with an integral battery charger and battery capable of continuous operation at the full rated load (not the connected load) of the UPS for the specified duration.

The charger shall be of adequate capacity to supply the full rated load and to simultaneously charge a fully discharged battery to at least 95% fully charged state within a period of 20 hours. The output voltage and current characteristics of the charger shall be suitable for the type of battery used and for the UPS inverter. The charger shall be capable of both float and boost charge operation with changeover between the two modes being automatic with manual override. Both float and boost operating characteristics shall be in accordance with the battery manufacturer's recommendations.

Batteries shall be fully sealed lead-acid gas-recombination type with pure lead plates providing a float life of at least five years to 80% nominal capacity.

4.11.3 Shutdown Operation

During prolonged power outages exceeding the UPS backup time, the UPS shall automatically disconnect the supplied load before its output drops below that required by the load.

The disconnection of equipment shall be in a controlled manner to prevent any damage to the equipment, loss of data or malfunction of software.

After shedding its connected load, the UPS shall disconnect the battery if necessary to prevent permanent damage to the battery.

4.11.4 Isolation

Where the UPS output is reticulated, an isolating switch shall be provided at a readily accessible location to isolate the UPS supply.

4.12 BATTERY BACKED POWER SUPPLIES

Battery backed power supplies shall be in accordance with following:

1. Provide “seamless” output voltage transition when operation changes from mains power to battery and from battery power to mains power when mains power fails or is restored.
2. Be sized and installed to ensure that local controls and indications in the project specification continue to operate in the event of a power failure.
3. Be sized such that an allowance of 10% spare capacity is provided, above that of the maximum load of the existing system it is supplying.
4. Be fitted with a battery charging circuit to charge the backup battery designed to maintain the backup battery in a fully charged state.
5. Be capable of charging the backup battery from fully discharged to fully charged in a maximum of 12 hours.
6. Be fitted with a battery monitoring circuit to determine when the backup battery voltage is low which is fitted with a minimum of one change over contact.
7. The battery charging and monitoring functions shall be independent to the control system power (i.e. batteries should not be connected directly to the battery backed power supply output).
8. Be fitted with a 24 V (or 2 x 12 V) sealed lead acid battery with a capacity of not less than 1.2 Ah and a minimum design life of 5 years under the conditions in which it will operate. The battery shall be rated to supply the backed up system for a continuous period of four hours, or greater if specified in the project specification.

5. INSTALLATION

5.1 GENERAL

All items of electrical equipment which are supplied under the Contract shall be installed in the locations shown on the relevant drawings and/or as described in the project specification. Final locations shall be subject to the approval of SA Water's Representative.

All electrical work shall be in accordance with AS/NZS 3000, this document, project specification, statutory requirements and the electricity supplier's service and installation rules and applicable technical standards. The installation shall be suitable for and approved for connection to the electricity supply network.

All electrical works shall be carried out by Registered Electrical Workers and a competent person in accordance with AS/NZS3000 and a Certificate of Compliance shall be provided in accordance with the Electricity Act and Regulations.

5.2 FIXING

Items of electrical equipment shall be rigidly secured in their respective positions using fixtures provided with the equipment, or as otherwise specified. Electrical equipment mounted on concrete surfaces shall be secured by means of approved anchors.

Uncoated steel bolts, screws etc shall not be used to affix electrical equipment in the following areas:

- (1) Outdoor areas
- (2) Damp environments
- (3) Corrosive environments

Materials which may be satisfactory depending on the environment include hot-dip galvanised steel, brass or stainless steel.

Electrical equipment shall only be attached to structural steelwork with the approval of SA Water's Representative and then only in the locations and with the method of attachment approved by SA Water's Representative.

If approval for welding to the structural steelwork is given, such welding shall be in accordance with AS 1554.1. All finished welds shall have all slag removed by chipping and wire brushing and shall be ground if necessary.

For galvanised and zinc coated steelwork, the mounting brackets and weld areas shall be cleaned by abrading till bright steel is exposed. Two coats of zinc rich paint complying with GPC-P-14/1 shall be applied. For all other coated steelwork the coating system shall be the same as and match that originally applied.

5.3 LABELLING

All indoor and outdoor equipment shall be labelled in accordance with Clause 2.6.

Where applicable, the location of the main switchroom shall be clearly identified by a permanent sign on the entrance door or at the fire indicator board in accordance with AS/NZS3000.

5.4 SWITCHBOARDS AND CONTROL PANELS

Switchboards, control panels and cubicles housing electrical equipment shall be installed in accordance with this document, the project specification and AS/NZS 3000.

The following clearances shall be provided around switchboards and control panels:

- (1) Horizontal clearances shall be in accordance with AS/NZS3000.
- (2) A vertical clearance from the ground, platform or other walked-on surfaces to a height of 2 m or not less than the height of the switchboards and control panels, whichever is the greater.

In addition, the following number of exits shall be provided in the switchboard or control panel area to enable a person to leave the vicinity of a switchboard or control panel under emergency conditions:

- (1) Switchboards and control panels up to and including 3 m long - at least one exit.
- (2) Switchboards and control panels over 3 m long - at least two exits spaced well apart.

All emergency exit doors shall open outwards without the use of a key or tool from within the switchboard or control panel area.

Where provision has been made on the cubicle for lifting purposes, the Contractor shall use this provision whenever lifting is required, unless otherwise approved by SA Water's Representative.

The cubicles shall be fastened to the floor or wall as appropriate by means of bolts screwed into masonry anchors. All anchors and bolts used on external cubicles shall be hot-dip galvanised.

The Contractor shall level the cubicles and shall then grout underneath all floor and ground mounted cubicles. Unless otherwise approved by SA Water's Representative cement grouting shall have a nominal thickness of 20 mm (minimum 15 mm, maximum 30 mm).

Cubicles which are mounted directly on a concrete plinth shall be provided with a sheet of bitumen impregnated felt or other approved moisture barrier between

the underside of the cubicle and the plinth. This requirement shall also apply to cubicles on metal plinths located in areas which are damp or likely to be damp (eg due to leakage or hosing down operation) and in all outdoor locations.

Outdoor cubicles shall be positioned such that no openings are facing the prevailing weather.

At the completion of the mechanical installation of the cubicles and prior to any electrical connections being made, all mechanical and all electrical connections shall be checked for tightness to the satisfaction of SA Water's Representative. Mechanical checks shall include for tightness of bolts holding sections of the cubicle together, tightness of busbar supports and tightness of mountings of circuit breakers, composite fuse switch units, isolators and switches, fuse bases, contactors and relays. Electrical checks shall include joints in busbars and all wiring terminations. Covers shall be removed as required for these checks and shall be replaced and secured immediately after checking of connections is completed.

Any damage to painted surfaces at the completion of installation shall be reinstated in accordance with Clause 7.5. Damaged or scratched surfaces on stainless steel cubicles shall be repaired or replaced to the satisfaction of SA Water's Representative.

The Contractor shall maintain the degree of vermin proofing as required to achieve the IP rating as per Section 2.3 of this document.

5.5 CABLE TRAYS AND LADDERS

Cable trays and ladders shall be supplied and installed where required by the project specification and drawings or, if not specified, as required. Where cable routes are shown on the specification drawings these shall be followed as closely as is possible. Final locations and fastenings of cable trays, ladders and supports shall be determined on site in co-operation with SA Water's Representative.

Trays and ladders shall be run horizontally or vertically and parallel with the walls, floor or pipework as applicable and shall be shaped to generally follow the surfaces along which the trays and ladders are run.

Brackets shall be secured by a system approved by SA Water's Representative. The cable trays and ladders shall be supported at not greater than the manufacturer's recommended intervals and there shall be no discernible deflection of the trays or ladders evident to the naked eye.

Cable trays and ladders shall be separate from and not attached to the pipework.

Cover plates shall be provided to:

- protect the cables against mechanical damage where the cable trays or ladders are installed across areas in which personnel or machinery access or the like is probable,
- protect the cables against damage by sunlight,
- reduce the effect of heat gain from solar radiation which may affect the cable current rating and
- where specified or shown on the drawings.

Where cable trays or ladders are installed outdoors, any damaged surfaces shall be reinstated using zinc rich primer complying with GPC-P-14/1. Two coats shall be applied to clean, rust free surfaces.

Cable trays and ladders shall be bonded to the earthing system in accordance with AS/NZS3000.

5.6 CONDUITS

The Contractor shall supply and install conduits for cables as required. Installation shall be in accordance with AS/NZS 3000 and this document.

Conduits shall be sized in accordance with AS/NZS 3000 for the number and size of cables to be installed within each conduit. Conduits shall be a minimum size of 20mm (diameter).

Conduits shall be saddled either side of every bend and elbow. Conduit saddles and clips shall be secured using approved fasteners. In outdoor locations, fasteners shall be made of brass, stainless steel, hot-dip galvanised or other approved corrosion resistant material. Electroplated zinc fasteners may be used for indoor locations only.

Approval shall be obtained from SA Water's Representative before any holes are drilled in any structural steelwork. Conduit saddles which are attached to steelwork shall be fixed in the approved locations only and shall be fixed by means of metal thread screws either screwed into drilled and tapped holes in the steelwork or fitted to drilled clearance holes in the steelwork and fitted with nuts and lock washers.

Conduit saddles shall not be attached to pipework.

Conduit shall, wherever possible, be run in horizontal or vertical planes, shall be grouped and generally be as inconspicuous as possible. Where conduits are required to run adjacent to non-planar surfaces, the conduits shall be shaped to closely follow the surface on which they are to run.

Pull boxes shall be provided in long runs of conduit to facilitate installation of cables. Junction boxes shall be provided at all tee-offs in conduit runs. All conduits shall be installed with a polypropylene draw wire in place to facilitate the drawing in of cables. A draw wire shall also be left in place for future use after the cables have been drawn in.

In above ground situations adequate provision shall be made to allow the conduits to expand and contract with temperature, either at bends or by the use of expansion couplings.

Rigid conduits shall not connect directly to vibrating equipment. A short length of flexible conduit shall be provided for such connections. These conduits shall be installed in accordance with AS/NZS3000.

Underground conduits shall be installed in accordance with AS/NZS3000 and Clause 6. Cable route markers and cable pits shall be provided for underground conduits in accordance with Clauses 5.7.2 and 5.7.3 respectively.

5.7 CABLES

5.7.1 General

Power, instrumentation and control cables shall be installed in accordance with AS/NZS3000 and this Specification. Data and communication cables shall be installed in accordance with Austel Technical Standards.

Different wiring systems shall be segregated in accordance with Clause 3.9.8.3 of AS/NZS3000 (eg by installing power cables in separate conduits from control, instrumentation and data cables).

Cables shall not be installed on suspended ceilings unless the ceilings are designed to support the weight of the cables. All cables in ceiling spaces shall be adequately supported and protected in accordance with AS/NZS3000.

All underground cables shall be installed in Category A heavy duty underground UPVC conduits in accordance with Clause 3.11 of AS/NZS3000.

5.7.2 Cable Routes and Methods of Installation

Cable routes and installation methods shall generally be in accordance with the specification drawings where shown.

Unless specified otherwise, cables outside of and not attached to buildings or equipment shall be installed underground in conduits with pits as specified.

Approved cable route markers shall be installed to identify the location of all underground cables and conduits.

5.7.3 Cable Pits

Cable pits shall be provided for all underground conduit runs where the conduits change direction and at intervals of not exceeding 50m in straight runs so as to allow easy pulling of the cables. Cable pits shall be provided with drainage facilities.

Cable pits in footpaths or where there is no vehicle traffic shall be provided with covers equivalent to Gatic light duty category.

Cable pits located where there is vehicle traffic (or loading) shall be provided with covers equivalent to Gatic heavy duty category.

5.7.4 Cable Joints

Intermediate joints in cables shall not be permitted.

5.7.5 Cable Handling

Cables shall be installed in a manner which is not inferior to the manufacturer's instructions.

Cables shall be handled carefully from cable drums or spools. Kinks shall not be allowed to develop during unwinding or during installation. Cables shall not be subject to a bending radius greater than that specified by the cable manufacturer.

Care shall be taken during installation of cables that the insulation and/or sheathing of the cables is not cut, abraded or otherwise damaged.

Mechanical handling devices shall grip the respective cables over a wide area and shall not cut or bruise the cable sheath during use.

Any cables which are damaged during installation shall be repaired or replaced by the Contractor to the satisfaction of SA Water's Representative at the Contractor's expense.

5.7.6 Cable Termination

Cables shall be terminated at the terminals provided in the switchboards and control panels and on the various items of equipment which are supplied and/or installed by the Contractor. All spare cores shall be terminated unless otherwise agreed by SA Water's Representative.

Terminal facilities provided by the manufacturer shall be taken into account when making field terminations. Field terminations shall be mechanically and electrically effective.

Compression lugs shall be properly sized in accordance with the size of cable to be terminated and which shall be applied using approved compression tools in accordance with the manufacturer's written recommendations. Compression lugs used on control cables, instrumentation cables or small power cables shall be of the pre-insulated type, and when fitted shall support the cable insulation.

All bolted connections shall be made with cadmium plated high tensile bolts and nuts fitted with lock nuts.

Cables shall be supported as necessary at all points of termination to prevent undue mechanical strain on the terminations. Support may be by means of fittings supplied with the various items of equipment or, if these are inadequate or insufficient, additional supports, which shall be approved by SA Water's Representative, shall be provided.

5.7.7 Instrumentation Cable Screens

Screens of instrumentation cables shall be individually terminated at both ends at insulated terminals. The screen between the cable sheath and the terminal shall be insulated with heat shrink tubing. The cable screens shall then be earthed at the source end only by looping an earthing conductor between terminals.

5.7.8 General Power and Lighting Cables

Wiring for the general power and lighting installation shall commence at the appropriate general power and lighting distribution boards. For non-office areas the cables for general power and lighting shall be run along ducts, trays or in surface mounted rigid conduits. In office areas cables for general power and lighting shall be concealed and shall utilise wall cavities where available.

Wiring connection to light fittings shall be arranged such that a fitting can be readily disconnected and/or removed without having to disconnect or remove other fittings.

5.7.9 Cable Fixing

Cables which run on cable trays shall be fixed to the tray and such fixings shall be in accordance with AS/NZS3000.

Cables which are run in cable ducts or on cable trays shall run parallel to the sides of the duct or tray. Where such cables must negotiate a bend, the centre of curvature shall generally be common for all cables and shall be determined by the largest cable of the group, so that a neat installation is obtained.

Single core cables which form part of one multiphase circuit shall be run in proximity to each other.

Control and instrumentation cables may be bunched. A clearance of not less than 25mm shall be maintained between power and control or instrumentation cables.

5.7.10 Labelling

Field cables shall be labelled in accordance with the numbering system in Clause 5.7.11.

Individual cores of control or instrumentation cables shall be labelled with printed slip-on type full circle ferrules. Wire numbers shall be labelled in accordance with Clause 5.7.12.

Cables shall be identified at the ends by a corrosion resistant tag printed with the cable identification used on circuit diagrams.

5.7.11 Cable Numbering System

Cables connecting equipment external to switchboards or control panels shall be labelled as follows:

TT-XXXX-YYYY-ZZ-zz

where

TT = Cable Type

PH High Voltage Power
PL Low Voltage Power
PE Power Earth
CC Control
CE Control Earth
IA Instrumentation Analog
ID Instrumentation Digital
IX Instrumentation Mixed Analog and Digital
IP Instrumentation Power
IE Instrumentation Earth
DD Data

XXXX, YYYY = Equipment Identifications at the Points of Connection

Equipment identifications shall be the tag names as assigned to the plant.

XXXX shall precede YYYY generally in accordance with the following descending order:

- Generator/Transformer/Power Supply/Instrument Transducer
- Main Switchboard
- Area Switchboard/Motor Control Centre
- Local Control Panel
- RTU
- Field Equipment (pumps, valves etc).

Where the order of precedence cannot be distinguished (eg interlocks between two switchboards or cables carrying bi-directional signals between two locations of the same order), the tag names shall be arranged in an alphabetical/numerical order.

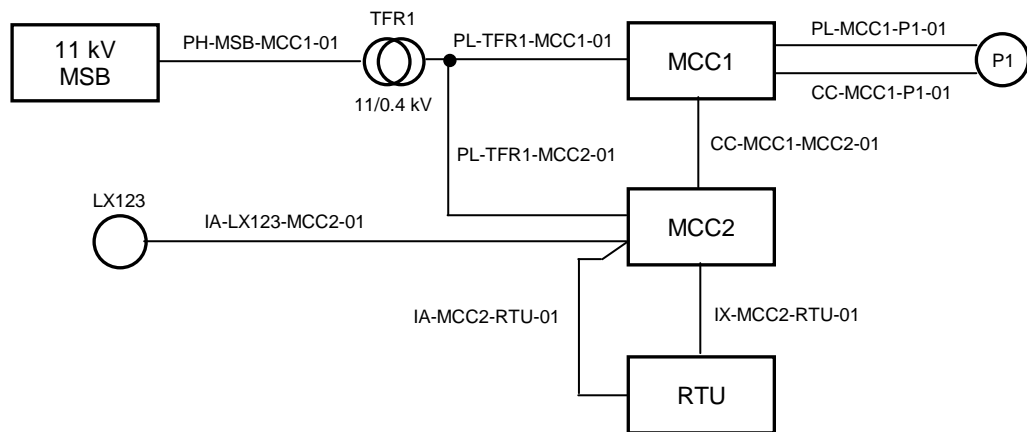
XXXX is optional where all the cables originate from a single source in the same area, eg in a simple installation consisting of a single switchboard only.

ZZ = Cable Sequential Number

A 2-digit number to differentiate two or more cables of the same type and identification.

zz = Core Sequential Number

A 2-digit suffix number to identify individual cores of a cable where required.



PH-MSB-TFR1-01	11kV feeder cable from main switchboard MSB to transformer TFR1
PL-TFR1-MCC1-01	400V supply cable from transformer TFR1 to motor control centre MCC1
PL-TFR1-MCC2-01	400V supply cable from transformer TFR1 to motor control centre MCC2
PL-MCC1-P1-01	400V motor power cable from motor control centre MCC1 to pump P1
CC-MCC1-P1-01	Control cable from motor control centre MCC1 to pump P1
CC-MCC1-MCC2-01	Interlock control cable between motor control centres MCC1 and MCC2
IA-LX123-MCC2-01	4-20mA instrumentation cable between loop powered level transducer LX123 and MCC2
IA-MCC2-RTU-01	4-20mA instrumentation cable between MCC2 and RTU
IX-MCC2-RTU-01	Instrumentation cable carrying mixed analog and digital signals between MCC2 and RTU

Figure 5.1 – Cable Numbering System Example

5.7.12 Wire Numbering System

All wire numbers shall be unique. No two wire numbers in a project set shall be the same, unless the wires are physically linked.

All wires numbers shall be generated from Schematic Diagrams such that the wire number references back to the drawing of origin and a cross reference location of the wire on that drawing.

Wire numbers shall be prefixed with the drawing number, or part thereof, or in the case where a drawing set has only one drawing number with many sheets, shall be prefixed with the sheet number, or a combination of drawing number and sheet number, as required, such that every wire number in a project set is unique.

The remaining identifier of the wire number shall be a cross reference to where the wire is located on the drawing. The cross reference shall be made at the point of origin/source. (For example, a PLC output wire number shall be generated at the PLC output end of the wire, not the field end. Whereas a PLC input wire number shall be generated from the point of source, being the field device, rather than the PLC input card.)

5.8 LIGHTING

Lighting shall be provided in accordance with Clauses 4.2 and this Specification.

Luminaires shall be of the type specified in the project specification or on the drawings and installed in accordance with the manufacturer's written instructions.

The completed installation shall have a neat and pleasing appearance.

After completion of the installation, any fittings which are considered excessively noisy by SA Water's Representative shall either be repaired or replaced by the Contractor to the satisfaction of SA Water's Representative.

All equipment which forms part of the general power and lighting installation and which, under the requirements of AS/NZS3000, is required to be earthed, shall be earthed by means of earthing conductors to the earthing bar of the relevant general power and lighting panel.

5.9 EARTHING

The installation shall be earthed in accordance with the requirements of AS/NZS3000 and in particular the multiple earthed neutral (MEN) provisions of the rules.

The floor slab reinforcement of new infrastructure shall be connected to the main earth bar of the installation.

A minimum of one copper clad, mild steel earthing rod of minimum diameter 15mm and minimum length 2400mm shall be fully driven into the ground at a distance of not less than 5m from any supply transformer installation and shall be connected to the main earth bar of the installation. The main connections at the earth rods shall be protected against damage and corrosion in accordance with AS/NZS3000.

A main earth bar shall be provided for the installation. All cables connecting to the main earth bar shall be labelled according to their functions.

The nominal size of a copper earthing conductor relative to the nominal size of the active conductor within an installation shall be in accordance with AS3000.

Enclosure doors with mounted electrical equipment shall be earthed.

All exposed metallic surfaces associated with the site's electrical infrastructure shall be earthed. Earthing protection associated with voltage differences in exposed conductive parts of electrical equipment and extraneous conductive parts shall be in accordance with Section 5.6 in AS3000 'Equipotential Bonding'.

In situations where metallic pipework is accessible, both suction and delivery pipework shall be individually connected to the installation main earth bar.

5.10 POWER FACTOR CORRECTION

The power factor caused by the completed electrical installation shall not exceed the limits specified in the electricity supplier's service and installation rules. Power factor correction equipment shall be provided if required to comply with the specified limits.

5.11 HARMONICS

Total Harmonic Distortion of an electrical installation shall be in accordance with the electricity supply authority's regulations.

Harmonic mitigation techniques shall be required when the harmonic levels do not comply with the supply authority's regulations, Australian standards and IEEE standards. The contractor is required to provide calculations to indicate that either the existing installation does not need additional mitigation techniques or that the mitigation complies with supply authority's regulations.

If harmonic mitigation techniques are required, the type of technique proposed must be approved by SA Water's Principal Electrical Engineer.

5.12 LIGHTNING AND TRANSIENT OVERVOLTAGE PROTECTION

Where lightning protection is required by the project specification, a risk assessment shall be completed. The risk assessment and lightning protection of persons and buildings shall be provided in accordance with AS1768.

Irrespective of the requirements of lightning protection of persons and buildings, all voltage sensitive equipment shall be provided with secondary protection against damage by transient and lightning induced overvoltages in accordance with AS1768.

Instrumentation equipment shall be provided with lightning protection in accordance with Clause 3.23.1.

6. EXCAVATION AND BACKFILLING OF TRENCHES FOR UNDERGROUND CONDUITS

6.1 GENERAL

The Contractor shall supply all labour, materials etc for the excavation and backfilling of trenches for the laying of electrical conduits. All underground cables shall be in conduits unless otherwise specified.

6.2 CLEARING

The Contractor shall not damage any trees or shrubs which are required to remain inside or outside the working area.

In open ground, organic topsoil shall be stripped to a minimum depth of 150mm and stockpiled for use in reinstating the surface of the trench.

6.3 TRENCH EXCAVATION

The Contractor shall ensure the material on the floor of the trench is not unduly disturbed when excavating the trenches. The Contractor shall be responsible for the location of existing buried services and shall hand dig in the vicinity of those services.

The Contractor shall be responsible for the erection of signs, barriers, covers and access ways to ensure the safety of personnel in the vicinity of open trenches.

6.4 TRENCH WIDTH AND CONDUIT SPACING

Trench width shall be adequate to accommodate all the conduits with a minimum spacing of 50mm between the outside conduits and trench wall and the space shall be filled with sand.

The spacing of conduits shall be in accordance with the design specification and drawings. Cables shall be de-rated in accordance with AS/NZS3008

6.5 FILL MATERIALS

6.5.1 Sand

The sand used for bedding and backfilling around conduits shall be free from dangerous and noxious weeds as proclaimed in South Australia by regulations under the Weeds Act with amendments. The sand shall be free from rocks and lumps and shall be non-plastic and graded in accordance with Table 6.1.

Table 6.1 - Grading of Sand for Bedding and Backfilling Conduits

Sieve Size mm (to AS 1152)	Percentage Passing
6.7 0.075	95 ~ 100 0 ~ 10

6.5.2 Quarry Rubble

Quarry rubble shall be clean, sound, hard and durable 20mm nominal size quarry rubble free from adherent coating and other foreign matter and graded in accordance with Table 6.2.

Table 6.2 - Grading of Quarry Rubble for Backfilling Conduits

Sieve Size mm (to AS 1152)	Percentage Passing
26.5	100
19.0	90 ~ 100
13.2	74 ~ 96
9.5	61 ~ 85
4.75	42 ~ 66
2.36	28 ~ 50
0.425	11 ~ 27
0.075	4 ~ 14

6.6 BEDDING AND BACKFILL

6.6.1 Bedding

Conduits shall be laid on a bed of sand not less than 100mm thick. The bedding does not require any special compaction.

6.6.2 Backfill Around Conduits

Sand shall be placed around the conduit and shall extend to not less than 200mm above the conduit. The sand backfill shall be compacted to not less than 95% of the standard maximum dry density of the sand in accordance with AS1289.5.1.1.

An orange marker tape shall be installed above the sand fill in accordance with AS/NZS2648 Part 1.

6.6.3 Backfill in Roadways and Footpaths

In roadways, road shoulders and footpaths, quarry rubble shall be placed from 200mm above the conduit to the underside of the base course. Compaction shall be to 95% of its modified maximum dry density (AS1289.5.2.1) for roadways and to 90% of its modified maximum dry density for footpaths. Unless specified or directed otherwise the formed pavement shall then be reinstated to the original condition.

6.6.4 Backfill in Other Locations

In verges, open ground etc, the trench fill shall be inorganic fill material with a maximum stone size of 75mm, either imported or obtained from the trench excavation. The trench fill shall be brought up to within 150mm of the finished surface level. The trench fill shall be placed in layers not exceeding 300mm compacted thickness and each layer given nominal compaction (eg with an excavator bucket) sufficient to eliminate long-term settlement.

The top 150mm of the trench shall be reinstated using stockpiled topsoil or imported soil similar to that in the vicinity of the trench.

7. PAINTING

7.1 GENERAL

All steel or other surfaces of items of electrical equipment which would normally be painted or are specified as requiring painting shall be protected by painting in accordance with this Section.

7.2 INDOOR CUBICLES

Following fabrication of the cubicles, all surfaces shall be degreased in accordance with AS1627.1. All welds and bare steel areas shall be ground to remove all surface rust, scale and weld spatter.

Bare steel and Zincseal surfaces where the phosphate coating has been damaged shall be coated with etch primer applied in accordance with the manufacturer's data sheets.

Custom built and modified cubicles and enclosures must be painted as per the requirements of this Clause. Exterior and interior surfaces (excluding any internal removable panels) shall be finished in high gloss air dry spraying enamel, stoving enamel or polyester powdercoat to colour Opaline G32 to AS2700. Internal removable panels (eg bolt-in panels to which electrical equipment will be mounted) shall be gloss white in colour. The coating shall be applied in accordance with the manufacturer's data sheets and shall include any primers or undercoats if recommended by the manufacturer.

Off-the-shelf cubicles and enclosures that do not require any modification prior to installation, other than fitting out with electrical equipment, do not require additional coating and may remain as per the manufacturer's factory supplied colour, except where there is a requirement to colour match with existing cubicles.

Where the cubicles are required to match the existing cubicles, as specified in the project specification, the finish colour shall match the existing colour as closely as possible.

Stainless cubicles and enclosures shall not be painted.

7.3 OUTDOOR CUBICLES

Following fabrication of the cubicles, all surfaces shall be degreased in accordance with AS1627.1. All welds and bare steel areas shall be ground to remove all surface rust, scale and weld spatter. Edges shall be rounded to a minimum 3mm radius. All surfaces shall be treated with an acid etch pre-treatment solution or two pack etch primer approved by the coating supplier.

The coating system shall consist of 125microns of epoxy followed by 50microns of two pack polyurethane complying with GPC-C-29-11A.

Custom built and modified cubicles and enclosures must be painted as per the requirements of this Clause. Colour shall be Opaline G32 to AS2700, or Rivergum G62 to AS2700 if the cubicles are located in a natural environment.

Internal removable panels (eg bolt-in panels to which electrical equipment will be mounted) may be coated in accordance with Clause 7.2 or this clause and shall be gloss white in colour.

Off-the-shelf cubicles and enclosures that do not require any modification prior to installation, other than fitting out with electrical equipment, do not require additional coating and may remain as per the manufacturer's factory supplied colour, except where there is a requirement to colour match with existing cubicles.

Where the cubicles are required to match the existing cubicles, as specified in the project specification, the finish colour shall match the existing colour as closely as possible.

Stainless cubicles and enclosures shall not be painted.

7.4 OTHER EQUIPMENT

Equipment other than custom-built switchboards and control cubicles may be finished in the manufacturers' standard colours unless otherwise specified.

7.5 COATING REINSTATEMENT

Following installation, any damaged paintwork shall be prepared by using abrasive paper to prepare the surface and feather back edges. Coatings shall be

applied in accordance with the original requirements to match the original coating system or as approved by SA Water's Representative .

8. INSPECTION AND TESTING

8.1 GENERAL

Reference shall be made to the project specification for other requirements associated with the inspection, testing, commissioning and running-in of the equipment and installation.

8.2 INSPECTION

The manufacture of equipment under the Contract shall be subject to inspection by SA Water's Representative at the manufacturer's works.

8.3 WORKS TESTS

8.3.1 General

All equipment manufactured under the Contract shall be routine tested at the manufacturer's works to ensure that the equipment complies with the project specification.

Witness tests shall be carried out in the presence of and to the satisfaction of SA Water's Representative or his nominated Inspecting Officer unless otherwise specified.

All test instruments shall have current calibration certificates, if applicable, and all certificates shall be made available for checking by the Inspecting Officer before testing commences.

The Contractor shall give SA Water's Representative a minimum of 10 working days notice of the manufacturer's intention to conduct tests.

At the same time or earlier the Contractor shall:

- (1) submit three (3) copies of the latest certified drawings of the switchboards, cubicles and control panels. This should be made up of two (2) hard copies and one (1) soft copy of the drawings.
- (2) submit for approval by SA Water's Representative two (2) copies of the proposed testing procedure and test sheets. Testing shall not commence until SA Water's Representative has approved the testing procedure and test sheets.

8.3.2 Test Results

The following test results shall be submitted to SA Water's Representative for approval:

- (1) Certificates of type tested or unwitnessed routine tested equipment.
- (2) Results of all witnessed tests recorded during the progress of the tests on the approved test sheets. A copy of the test sheets co-signed by the manufacturer and the Inspecting Officer shall be handed to the Inspecting Officer on completion of the tests.
- (3) Two (2) copies of formalised test sheets upon which all test results shall have been typed within 10 days of the equipment successfully completing the tests.

8.3.3 Dispatch of Equipment

The equipment shall not be dispatched from the manufacturer's works until authorised by SA Water's Representative. Dispatch will be authorised only after each item has been shown to comply with the specified test requirements and guaranteed performance.

8.3.4 Power Switchboards

Witnessed testing and inspection of power switchboards shall be carried out as follows:

- (1) Type tested assemblies shall be subjected to:
 - (a) Routine tests laid down in AS/NZS 3439.1 for type tested assemblies.
 - (b) Inspection and operation tests as laid down in Clause 8.3 of AS/NZS 3439.1.
- (2) Partially type tested assemblies shall be subjected to:
 - (a) Verifications and tests listed in Table 7 of AS/NZS 3439.1. Verification of temperature rise and short circuit strength shall be by extrapolation in accordance with Clauses 9.4.1 and 9.4.2 of this Specification unless separate tests are required by the project specification.
 - (b) Inspection and operation tests as laid down in Clause 8.3 of AS/NZS 3439.1.

8.3.5 Control Panels

Control panels shall be subjected to witnessed routine tests in accordance with AS/NZS 3439.1.

Each cubicle shall be put through a series of witnessed tests to thoroughly test out all functions of control, including alarm, indication, pushbutton and contactor operations. External contact operations shall be simulated by application or removal of jumper links at appropriate terminals on the outgoing terminal blocks. Outputs shall be indicated on a suitable lamp or meter across respective output terminals.

8.3.6 Motors

Motors shall be works tested generally as part of performance testing of pumping units or other coupled equipment as follows (refer to the project specification):

For motors rated up to and including 22 kW, work tests are not required.

For motors rated at 30 kW to 90 kW inclusive, work tests are required but need not be witnessed. Results of unwitnessed work tests shall be provided to SA Water's Representative in accordance with Clause 8.3.2.

For motors rated at 110 kW and above, witnessed works tests shall be carried out in accordance with the following:

- (1) One of each type of motors shall be performance tested in accordance with the relevant parts of AS 1359. The remaining motors shall be routine tested. Should a motor fail a performance test, the remaining motors of that type shall be performance tested.
- (2) Performance tests shall include temperature rise, momentary overload, dielectric, winding insulation resistance, efficiency, power factor, locked rotor current, locked rotor power factor, locked rotor torque, noise and vibration. Tests shall be carried out with the motor connected direct-on-line. Measurement of voltage, current and power shall be made for all tests.

Efficiency and power factor shall be measured at 50%, 75% and 100% loads.

The methods of measurement and test conditions for noise tests shall be in accordance with AS 1359.109. Vibration measurements shall be in accordance with AS 1359.114 (refer also to Clause 4.8 of this document).

- (3) The performance test certificate shall include all information necessary to allow the calculations to be checked and shall include motor serial numbers, normal winding configuration and winding configuration during resistance measurements.
- (4) Declared efficiencies shall be determined by the summation of losses method in accordance with AS 1359.102. The guaranteed efficiencies shall *not* include the negative tolerances specified in AS 1359.101. The declared efficiencies shall be achieved.
- (5) The performance tested motors shall be delivered to the pump manufacturer's works to test the relevant pumps or coupled equipment in accordance with the project specification.
- (6) All data required for setting of electronic motor protection relays shall be provided, including:
 - Maximum overload current
 - Earth fault current including recommended maximum time delay to overcome CT phase imbalance during motor starting inrush
 - Motor thermal capacity in seconds
 - Run-up time for the starting method proposed.

8.3.7 Generator Sets

Generator sets shall be fully run in and ready for the specified duty before the specified tests are performed at the manufacturer's works. Running in shall consist of not less than 8 hours of running at loads of 80 ~ 100 % of the continuous rating or such running as the manufacturer recommends to run the engine in.

Each complete set shall be tested for correct assembly and to prove satisfactory operation, including starting, stopping, rated output, governing, voltage regulation, transient performance, overload, short circuit current, and all control, indication, protection and alarm functions including the batteries and chargers.

The noise level of each complete set shall be measured at 100% load during the test in accordance with AS 1217 Parts 1 and 5. The radiator fan shall be running for the noise level measurement. The sound power level shall not exceed the Contractor's designed sound power level required to ensure that the specified noise levels are not exceeded.

In addition, vibration tests shall be carried out on each complete set in accordance with AS 2625 Parts 1, 2 and 4. Test certificates shall be provided to prove compliance with the Standard.

The engine shall be tested for torque, power output and fuel consumption at 1500 rpm in accordance with AS 4594.

The generator shall be routine and performance tested in accordance with AS 1359.101.

Routine tests shall be carried out to check for correct assembly and sound mechanical and electrical operation.

Performance tests shall also be carried out and shall include the following:

- Short-circuit withstand (not required if a type test certificate is provided)
- Overload
- Temperature rise
- High voltage
- Functional tests of all safety and protection devices.

8.3.8 Uninterruptible Power Supplies

Each UPS shall be routine tested in accordance with AS 62040.3 and the tests shall include but not be limited to the following:

- All control, indication and protection functions.
- Operation of the static bypass and maintenance bypass.
- Verification of the backup duration with the UPS operating at full load current from the batteries without mains supply input. The battery protection system shall be checked during this test.

8.3.9 Other Equipment

Works testing of other equipment shall be in accordance with the project specification where applicable.

8.4 SITE TESTS

8.4.1 General

At the completion of the installation or at the completion of agreed subsections of the work, the Contractor shall, in the presence of SA Water's Representative (or his nominated Inspecting Officer) conduct site acceptance tests on all equipment which has been supplied and/or installed as part of the Contract. The tests shall demonstrate to the satisfaction of SA Water's Representative that the installation is in accordance with the specified requirements and that the installation operates correctly.

Unless otherwise specified, equipment which has been satisfactorily performance tested or witness tested in the manufacturer's works need not be site tested except to:

- (1) check the installation and interconnections,
- (2) check for any damage or deterioration which may have occurred since the works tests and
- (3) demonstrate that the system functions in accordance with the project specification.

The Contractor shall give SA Water's Representative not less than ten (10) working days notice of his intention to undertake the tests.

At the same time or earlier the Contractor shall:

- (1) submit three (3) copies of the latest drawings and PLC program listings for the equipment to be tested where applicable and
- (2) submit for approval by SA Water's Representative two (2) copies of the proposed testing procedure and test sheets. Testing shall not commence until SA Water's Representative has approved the testing procedure and test sheets.

The provision of all necessary equipment for testing shall be the responsibility of the Contractor. All test instruments shall have current calibration certificates, if applicable, and all certificates shall be made available for checking by the Inspecting Officer before testing commences.

8.4.2 Test Results

The results of all witnessed site tests shall be neatly and legibly recorded during the progress of the tests on the approved test sheets. A copy of the test sheets,

co-signed by the Contractor and the Inspecting Officer, shall be handed to the Inspecting Officer on completion of the tests.

8.4.3 Switchboards, Control Panels, Associated Equipment and Cabling

Site tests shall be carried out in accordance with the relevant Standards and shall include the following where applicable:

- insulation resistance
- earth resistance
- earth fault loop impedance
- continuity
- polarity
- calibration checks
- control sequencing
- functional tests

to demonstrate the integrity and correct operation of the system including protective devices and remote operations, indications and controls.

The sequencing of control circuits etc shall be checked against the control schematic drawings and not against the formalised test sheets. The test sheets shall state that the circuits were tested against the drawings and list any defects.

All adjustable parameters shall be properly setup and recorded for each equipment or device and the record submitted to SA Water's Representative at the completion of the tests.

Devices which cannot be adjusted (eg miniature circuit breakers) shall not have calibration tests performed. However, fixed residual current devices shall be tested before being placed into service to ensure that:

- (1) the tripping current is set to the appropriate value and
- (2) the unit trips in less than 40 milliseconds at a test current of 10 mA for a Type I device or in less than 300 milliseconds at a test current of 30 mA for a Type II device.

Protective units, relays etc which allow current injection or similar to check their settings shall, during testing, have each function tested and calibrated.

Units which may be adjusted (eg thermal overload relays) shall be adjusted to the appropriate settings in accordance with the manufacturer's written instructions. To test the accuracy of the settings, a maximum of one from each style and size of units or 5% of the total, whichever is the greater, shall be calibrated. All units shall be calibrated if the tests indicate that the settings are inaccurate and that the associated equipment is inadequately protected.

Equipment which:

- (1) is connected via a flexible power supply cord and plug and
- (2) comes under the scope of AS/NZS 3760 and

(3) is provided by the Contractor

shall be inspected and tested in accordance with AS/NZS 3760 prior to being placed in service.

8.4.4 Motors

Site tests shall be conducted in accordance with the project specification to verify the system performance under site conditions.

8.4.5 Generator Sets

Site tests for generator sets shall include the following as a minimum:

- Running of each set over the full load range to establish that the installation is satisfactory and complies with guaranteed performance.
- Continuous running of at least 8 hours at a power output equivalent to the continuous engine rating, but including 1 hour of running at the specified intermittent rating to prove the onsite engine cooling system.
- Three actual or simulated power failure startups with continuous running of at least one hour after each startup.
- Noise tests in accordance with AS 1217.7. Noise measurements shall be taken at the generator set and at the property boundary at the specified times when the generator set is running at full rated load.

Fuel for the site acceptance tests shall be supplied by the Contractor.

The plant loads and load bank (where provided under the Contract) may be used for site tests. Any additional test load or equipment required shall be the responsibility of the Contractor.

The total run-in time for the generator set shall be 24 hours of running accumulated during the site acceptance test period and Run-in period and shall include at least one continuous running period of at least 8 hours. The generator set shall be run for at least one hour every week during the Run-in period.

Service at the completion of the Run-in period shall include replacement of air, fuel and oil filters, valve tappet adjustment, sump oil change and alternator bearing lubrication. A labelled sample of the drained sump oil shall be supplied to SA Water's Representative, who at his discretion may have it tested for evidence of premature wear.

8.4.6 Other Equipment

Site testing of other equipment shall be in accordance with the project specification where applicable.

8.4.7 Power Factor and Harmonic Distortion

The power factor of, and harmonic distortion caused by, the complete installation shall be measured to check compliance with the specified limits.

8.5 COMMISSIONING AND RUNNING-IN

The commissioning and running-in of equipment shall be in accordance with the project specification.

9. TECHNICAL INFORMATION AND DRAWINGS

9.1 GENERAL

Reference shall be made to the project specification for other requirements associated with the supply of drawings, manuals and technical information.

9.2 DRAWINGS

9.2.1 Tender Drawings

Drawings which shall clearly explain the proposed construction, layout and physical size of the electrical switchboards, control panels etc shall be submitted with the tender.

9.2.2 Prior to Manufacture

The Contractor shall, at the earliest practical date but not later than four (4) weeks prior to the construction of any relevant portion of the works or commencement of manufacture of equipment or placing firm orders for any components, provide two (2) copies of detailed drawings which shall contain all necessary information for the manufacture and installation of the equipment including the following where applicable:

- (1) Dimensioned general arrangement drawings including critical tolerances.
- (2) Equipment layout drawings.
- (3) Single line diagrams.
- (4) Control circuit schematic drawings.
- (5) Layouts for switchboards, control panels and other cubicles.
- (6) Materials and parts listings.

The details required in Clause 9.2.3 shall be shown on the appropriate drawings.

These drawings will be examined to determine general compliance with the specified requirements but this shall not absolve the Contractor from the responsibility to achieve a fully workable installation. Work shall not proceed on the manufacture or supply of equipment, components or structure until the relevant drawings have been approved by SA Water's Representative. If manufacture or assembly is commenced prior to the approval of the drawings, any restoration or modification work shall be at the Contractor's expense.

Should SA Water's Representative require additional information and/or drawings or any amendments to the previously submitted drawings, the Contractor shall supply two (2) copies of the additional information and/or drawings or amended drawings within two (2) weeks of being requested to do so. The cost of providing the additional information, drawings and amendments shall be borne by the Contractor.

The Contractor shall allow a period of at least one day per drawing or ten working days after each submission, whichever is the longer, for the examination or re-examination of the information or drawings unless otherwise agreed.

The drawings shall be prepared in accordance with TS 95 as they will form the basis of drawings to be submitted as final contract drawings.

9.2.3 Drawing Details

Final contract drawings shall include the following details where applicable:

- (1) Single line diagrams which shall detail
 - all cables types and sizes,
 - ratings of all components and
 - fault rating of switchboards and control panels.
- (2) Full schematic diagrams of control circuits including terminal and wire numbers.

A system of mnemonics shall be used in the labelling of contacts and coils. The system shall follow the guidelines laid down on Drawing 96-0110-01A, Table 9.1 and as outlined below:

- Schematics shall be drawn as vertical ladders with each line (rung) numbered.
- Each wire shall be numbered with the line number suffixed by a sequential number indicating the horizontal position of the wire. The wire adjacent to the coil shall have the suffix number 9.
- Components shall be numbered by device type, line number and mnemonic (eg K56RN).
- Cross referencing of remote contacts etc shall be shown using line numbers and other drawing numbers as appropriate.
- Spare cores of field cables shall be identified by their respective cable, core and terminal numbers where applicable.

NOTE: Drawing 96-0110-01A and Table 9.1 are included for information and as a means of establishing quality standards only. The circuitry shown shall not be taken as an indication of the facilities required or as an indication of the methods to be adopted to achieve specified requirements.

- (3) Instrument loop diagrams which shall be drawn using the standard PID symbols shown on Drawing 04-0734-01.
 - Preferably one loop per A3 drawing sheet shall be provided.
- (4) Layouts for switchboards and control panels.
- (5) Any other details specified in the project specification to be provided (either tender, acceptance or final contract).
- (6) All final drawings shall include the 'as constructed' information.

Table 9.1 Mnemonics for Electrical Schematic Drawings

Mnem	Description	Mnem	Description
AA	Audible Alarm	NF	No Flow
AC	Acknowledge Accept	OB	Open (Circuit) Breaker (action)
		OC	Overcurrent
AE	Air Exchange	OE	Overcurrent and Earth Fault
AI	Air Inhibit	OF	Over-frequency
AL	Alarm	OL	Over-load
AM	Auto-Manual	OP	Over-pressure
AS	Auto Start	OS	Over-speed
AT	Air Temperature	OT	Over-travel
BC	(Circuit) Breaker Closed (indication)		Over-temperature
BO	(Circuit) Breaker Open (indication)	OV	Open Valve (action)
BT	(Circuit) Breaker Tripped (indication)		Overvoltage
	Bearing (Over) Temperature	PC	Power Contactor
BW	Backwash	PI	Phase Imbalance
CB	Close (Circuit) Breaker (action)	PF	PLC Fail
CF	(Battery) Charger Fault		Power Fail
CK	Clock	PL	Pressure (Vessel) Level (High, Low)
CL	Coolant Leakage	PS	Priming System
CO	Cut Out Change-over	RC	Run Contactor
		RE	Restricted Earth Fault
CT	Coolant (Over) Temperature	RI	Run Interlock
CV	Close Valve (action)		Run Inhibit
DC	Delta Contactor	RN	Run
Dn	Duty Number (n = 1, 2, 3 etc)	RT	Reset
DP	Discharge Pressure (High, Low)	SC	Star Contactor
DS	Duty-Standby		Starting Contactor
DT	Discharge Tank (Level, Pressure)	SD	Start Delay
DU	Duty Selector	SF	Supply Fault
EF	Earth Fault	SI	Start Interlock
EO	Emergency Operation		Start Inhibit
ES	Emergency Stop	SP	Stop
FA	Fault	SR	Start Run
FF	Floor Flooded	SS	Supply Selector
GF	Generator Fault	ST	Start
GL	Gas Leakage	SW	Sealing Water
GO	Generator Operating	TB	Trip (Circuit) Breaker (action)
GT	Gas Temperature	TC	Transformer Contactor
HA	Hazard	TE	Tank Empty
HC	Heater Contactor	TF	Tank Full
HL	High Level	TL	Tank Level (High, Low)
IP	Inlet Pressure	TP	Tank Pressure (High, Low)
IS	Incomplete Start	TT	Transformer Temperature
IT	Inlet Tank (Level, Pressure)	UV	Undervoltage
LC	Line Contactor	VC	Valve Closed (indication)
LL	Low Level	VE	Vessel Empty
LM	Limit	VF	Vessel Full
LT	Lamp Test	VL	Vessel Level (High, Low)
Ln	Level Number (n = 1, 2, 3 etc)	VO	Valve Open (indication)
MC	Main Contactor	VP	Vessel Pressure (High, Low)
	Motor Contactor		Vacuum Pump
MF	Motor Fault	WD	Watch Dog
MP	Motor Protection	WF	Well Flooded
MT	Motor Temperature	WT	Water Temperature

9.3 MANUALS

9.3.1 General

The Contractor shall supply to SA Water's Representative two (2) copies of installation, operating and maintenance manuals in accordance with the following requirements:

- (1) Wholly in the English language, clear, legible and generally only contain information on equipment relevant to the Contract. If general manufacturer's information is included, all relevant information shall be suitably highlighted.
- (2) Include complete parts listing which shall include the manufacturer's name, parts catalogue number and, where applicable, the local South Australian agent's name, address and telephone number.
- (3) Include drawings of the actual equipment supplied, including detailed ladder and schematic circuit diagrams.
- (4) Include any relevant safety procedures.
- (5) Where PLCs are supplied, hard copy program listings in ladder format shall be provided. In addition, electronic copies of the PLC programs and supporting files including full documentation shall be supplied on CDRoms.

The manuals shall be bound in accordance with the following requirements:

- (1) The manuals shall be neatly assembled and indexed, bound with protective covers and externally labelled and shall have an appendix naming all relevant drawings.
- (2) The contents shall be securely held in place (eg 4 ring binders) and the manuals, when opened, shall remain open in a flat position.
- (3) The cover and spine shall be labelled with the project name, manual name and volume number if applicable.

9.3.2 Installation Manual

The installation manual shall include all the relevant information necessary to install and set up the equipment ready for operation.

9.3.3 Operating Manual

The operating manual shall include a description of the operation of the equipment and clear and logical instructions for the operator.

The operating manual shall describe the operation of the equipment under manual and, if relevant, under remote and/or automatic control.

The instructions shall include:

- (1) starting, running and stopping procedures;
- (2) measured parameters;
- (3) interaction with other equipment and
- (4) anticipated fault conditions.

If more than one identical unit of equipment exists, only one unit shall be described stating that the operation of the other identical units are the same.

9.3.4 Maintenance Manuals

The maintenance manuals shall contain all relevant information for the maintenance and repair of the equipment and shall include:

- (1) Identification of items of equipment, including model and serial numbers.
- (2) A brief description of the equipment and its operation.
- (3) All necessary setting up procedures.
- (4) All maintenance procedures including suggested preventative maintenance schedules.
- (5) Drawings, parts listings etc which shall include the manufacturer's component numbers so as to enable replacement parts to be procured without having to dismantle the equipment.
- (6) Instructions and/or arrangement drawings giving dimensions and tolerances, where applicable, to enable the amount of wear of working parts to be assessed. The maximum allowable amount of wear for working parts shall be stated.
- (7) Instructions for the disassembly, repair and reassembly of the equipment.
- (8) A revised Schedule of Technical Data.

Circuit and contact by contact descriptions for electrical circuits are not required.

9.3.5 Delivery of Manuals

The Contractor shall make available to SA Water's Representative two (2) preliminary copies of the manuals at the time of delivery of the equipment. These preliminary manuals may be the manufacturer's manuals suitably edited to comply with Clause 9.3.1.

Final copies of all manuals shall be submitted to SA Water's Representative for examination not less than ten (10) working days prior to the site acceptance tests.

If modifications are required as a result of examination of the manuals or as a result of the site acceptance tests then the Contractor shall make all the necessary modifications and return the manuals for re-examination. The cost of these modifications shall be borne by the Contractor.

9.4 TEST CERTIFICATES

9.4.1 Information to be Submitted With Tenders

Where this Clause requires the submission by the Tenderer of certificates from a recognised Testing Authority, Tenderers need not provide additional copies of any certificates which they have previously lodged in the central file of test certificates held by the South Australian Water Corporation but reference shall be made, by number, in the Tender to the certificate(s) which apply to the switchboards covered by the Tender. Submission of certificates with previous Tenders does NOT constitute lodgement in the central file. The other requirements of this Clause shall still apply.

Information to be submitted with tenders shall include the following:

- (1) Certificate(s) from a recognised Testing Authority to verify the short circuit capacity of the switchboard.

The certificate(s) shall be complete and show all details of the tests undertaken. Only limited sections of untested busbar will be allowed (eg the connection from the main incoming unit to the main busbar) provided that short circuit capacity is extrapolated from type tested designs. The Contractor will be required to provide calculations or written justification to support any such extrapolation prior to manufacture (see Clause 9.4.2(1)).

The following details shall be provided:

- (a) which components or sections of the switchboard are covered by the certificates,
 - (b) which parts of the various certificates apply to specific components or sections of the switchboard,
 - (c) which components or sections of the switchboard are not covered by the certificates and will be subject to extrapolation and
 - (d) drawings and sketches which show the proposed busbar arrangement and detail which certificate(s) apply to individual sections of busbar.
- (2) Either:
 - (a) full copies of relevant certificates from a recognised Testing Authority to verify the temperature rise of the switchboard busbars or
 - (b) a guarantee shall be provided that the busbars are adequately rated for the specified full load currents without exceeding the specified maximum temperatures. The Contractor will be required to justify any such guarantee prior to manufacture (see Clause 9.4.2(2)).

- (3) A guaranteed maximum temperature rise above ambient at full load of the incoming and outgoing power conductor termination facilities. The Contractor will be required to justify any such guarantee (see Clause 9.4.2(3)).

9.4.2 Information to be Submitted Prior to Commencement of Manufacture

The Contractor shall supply two copies of the following to SA Water's Representative (refer also to Clause 9.2.2):

- (1) Full calculations and/or written justification (and any associated drawings) to prove that any extrapolation or departure from the type tested design as allowed for under Clause 9.4.1(1) is capable of withstanding the specified fault conditions.
- (2) Full calculations (and any associated drawings) to prove that the busbar temperature rise is within the specified range if certificates were not provided (see Clause 9.4.1(2)).
- (3) Full calculations (and any associated drawings) or other documented evidence that the temperature rise of the incoming and outgoing conductor terminations are within the limits guaranteed under Clause 9.4.1(3).

Calculations (together with any associated drawings) will be examined to determine general compliance with the specified requirements, but this shall not absolve the Contractor from the responsibility to achieve a fully workable installation. If modifications are required as a result of the examination of the calculations (and drawings), a further two copies of modified or further calculations or modified drawings shall be delivered for further examination. The cost of these modifications shall be borne by the Contractor.

The Contractor shall allow a period of at least ten (10) working days after each submission of the calculations (and drawings) for the above examination or re-examination.

The Contractor shall not commence manufacture until SA Water's Representative has given written approval to do so. If manufacture commences prior to approval then any restoration or modification work shall be at the Contractor's expense.

<h3>LINE SYMBOLS</h3> <p>— MAIN PROCESS LINE - - - SECONDARY PROCESS LINE - - - ELECTRICAL SIGNAL ▬ OPEN CHANNEL ▬ INSTRUMENT SUPPLY or CONNECTION TO PROCESS ▬ UNDEFINED SIGNAL ▬ PNEUMATIC SIGNAL ▬ ELECTRICAL SIGNAL (Digital) ▬ CAPILLARY TUBING ▬ HYDRAULIC SIGNAL ▬ SOFTWARE LINK</p> <p>EXISTING NEW </p> <p> TIE IN POINT NO. IN LEFT/OUT RIGHT OUT LEFT/IN RIGHT FLOW ARROW</p>	<h3>SELF ACTUATED REGULATORS AND VALVES</h3> <p> PRESSURE RELIEF or SAFETY VALVE SHOWING PRESSURE SETTING PRESSURE RELIEF or SAFETY VALVE SHOWING PRESSURE SETTING PRESSURE REGULATING BACK PRESSURE REGULATING PRESSURE REGULATING BACK PRESSURE REGULATING RESTRICTION ORIFACE</p>	<h3>ACTUATOR FAIL POSITIONS</h3> <p> TWO WAY VALVE, FAIL OPEN TWO WAY VALVE, FAIL CLOSED THREE WAY VALVE, FAIL OPEN TO PATH A-C FOUR WAY VALVE, FAIL OPEN TO PATHS A-C & D-B ANY VALVE, FAIL LOCKED ANY VALVE, FAIL INDETERMINATE</p> <p>ISA - SS.1</p> <p>THE FAILURE MODES INDICATED ARE THOSE COMMONLY DEFINED BY THE TERM 'SHELF POSITIONS' AS AN ALTERNATIVE TO THE ARROWS AND BARS, THE FOLLOWING ABBREVIATION MAY BE EMPLOYED: FO - FAIL OPEN FC - FAIL CLOSED FL - FAIL LOCKED (LAST POSITION) FI - FAIL INDETERMINATE</p>	<h3>FITTINGS</h3> <p> FLEXIBLE COUPLING REDUCER (CONCENTRIC) REDUCER (ECCENTRIC) CAP BLIND FLANGE NOZZLE FLANGE JOINT FLANGE VALVE HOSE COUPLING FLEXIBLE HOSE CAP</p>	<h3>EQUIPMENT</h3> <p> PUMP, GENERAL SYMBOL PUMP, CENTRIFUGAL PUMP, RECIPROCATING PUMP, HELICAL ROTOR PUMP, ROTARY VANE FAN BLOWER / AIR COMPRESSOR GENERATOR EJECTOR or EDUCTOR BELLOW SILENCER STRAINER, Y-TYPE (FLANGED) STRAINER, GENERAL SYMBOL TRAP AIR DRYER WATER TRAP LUBRICATOR AFTER COOLER BUTTERFLY DAMPER MIXER INLINE MIXER FLAME ARRESTOR ACTIVATED CARBON ODOUR CONTROL TRAP</p>	<h3>INSTRUMENTS</h3> <table border="1" style="width:100%; border-collapse: collapse;"> <thead> <tr> <th></th> <th>FIELD MOUNTED</th> <th>PRIMARY LOCATION NORMALLY ACCESSIBLE TO OPERATOR</th> <th>AUXILIARY LOCATION NORMALLY ACCESSIBLE TO OPERATOR</th> <th>NORMALLY INACCESSIBLE TO OPERATOR (BEHIND THE PANEL)</th> </tr> </thead> <tbody> <tr> <td>DISCRETE INSTRUMENTS</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>COMPUTER FUNCTION</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>SHARED DISPLAY SHARED CONTROL</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>PROGRAMMABLE LOGIC CONTROL</td> <td></td> <td></td> <td></td> <td></td> </tr> </tbody> </table>		FIELD MOUNTED	PRIMARY LOCATION NORMALLY ACCESSIBLE TO OPERATOR	AUXILIARY LOCATION NORMALLY ACCESSIBLE TO OPERATOR	NORMALLY INACCESSIBLE TO OPERATOR (BEHIND THE PANEL)	DISCRETE INSTRUMENTS					COMPUTER FUNCTION					SHARED DISPLAY SHARED CONTROL					PROGRAMMABLE LOGIC CONTROL																																																																																																																																										
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<h3>PIPING VALVES</h3> <p> VALVE, GENERAL SYMBOL VALVE, NORMALLY CLOSE GATE VALVE BALL VALVE GLOBE VALVE KNIFE GATE VALVE NEEDLE VALVE DIAPHRAGM VALVE BUTTERFLY VALVE PINCH VALVE PLUG VALVE ANGLE VALVE NON-RETURN VALVE GAS RELEASE VALVE PENSTOCK VALVE FIRE PLUG VALVE STOPLOG VALVE</p>	<h3>ACTUATORS</h3> <p> PISTON PISTON ACTUATOR WITH POSITIONER or POSITION SWITCHES DIAPHRAGM DIAPHRAGM, PRESSURE BALANCED SPRING, FOR PRESSURE RELIEF or SAFETY VALVE ONLY HAND ACTUATED or HANDWHEEL POSITIONER SHOWN ON UNSPECIFIED ACTUATOR ROTARY MOTOR ELECTRIC, HYDRAULIC or PNEUMATIC SOLENOID WEIGHT FLOAT</p>	<h3>GENERAL EQUIPMENT ITEMS</h3> <p> ROTARY MOTOR AGITATOR, FAN, PROPELLER EXPANSION JOINT (UNRESTRAINED) DISMANTLING JOINT (RESTRAINED) OPEN VENT (GIVE NOTE IF RUN TO GRADE) TUNDISH SPECTACLE BLIND NORMALLY OPEN SPECTACLE BLIND NORMALLY CLOSED SPADE BLIND (or SLIP BLIND) SPACER RUPTURE DISK for BURSTING DISK RUPTURE DISK for BURSTING DISK VACUUM RELIEF PIPING SPECIALITY (ref. PIPING SPECIALITIES LIST) TRAPPED DRAIN TRAPPED VENT CONTROL FLOW REGULATOR BELLMOUTH SPONGE PIPE</p>	<h3>FLOW RATE (PRIMARY ELEMENT SYMBOLS)</h3> <p> GENERAL SYMBOL (UNSPECIFIED) PITOT TUBE or ANNUBAR VORTEX METER MAGNETIC FLOWMETER POSITIVE DISPLACEMENT TYPE FLOWMETER C/W FLOW TOTALIZING INDICATOR THERMAL MASS FLOWMETER VARIABLE AREA FLOW INDICATOR TURBINE or PROPELLOR METER FLUME VENTURI TUBE</p>	<h3>GENERAL INSTRUMENT or FUNCTION SYMBOLS</h3> <p> PILOT LIGHT DIAPHRAGM SEAL UNDEFINED INTELLOCK LOGIC PURGE or FLUSHING DEVICE INSTRUMENT AIR SUMMING ELECTRIC / PNEUMATIC SIGNAL CONVERTER PUMP DRIVEN BY A VARIABLE SPEED MOTOR F.O. FAIL OPEN F.C. FAIL CLOSED</p>	<h3>PIPE SPECIFICATION INDEX</h3> <table border="1" style="width:100%; border-collapse: collapse;"> <thead> <tr> <th>FLUID CODE</th> <th>FLUID</th> <th>MAT'L CODE</th> <th>MATERIAL</th> </tr> </thead> <tbody> <tr> <td>AEA</td> <td>AERATION AIR</td> <td>316L</td> <td>316L STAINLESS STEEL</td> </tr> <tr> <td>ANT</td> <td>ANTI-SCALEANT</td> <td>ABS (F/P)</td> <td>ABS</td> </tr> <tr> <td>ASW</td> <td>AIR SATURATED WATER</td> <td>ASBESTOS</td> <td>ASBESTOS</td> </tr> <tr> <td>CMA</td> <td>COMPRESSED AIR</td> <td>CICL</td> <td>CAST IRON CEMENT LINED</td> </tr> <tr> <td>DBS</td> <td>DAFT BOTTOM SLUDGE</td> <td>CS</td> <td>CARBON STEEL</td> </tr> <tr> <td>DPS</td> <td>DAFT FLOAT SLUDGE</td> <td>CSG</td> <td>CARBON STEEL GALVANIZED</td> </tr> <tr> <td>DGS</td> <td>DIGESTED SLUDGE</td> <td>CU</td> <td>COPPER TUBE</td> </tr> <tr> <td>DRN</td> <td>DRAIN</td> <td>DICL</td> <td>DUCTILE IRON CEMENT LINED</td> </tr> <tr> <td>DRW</td> <td>DAFT RECYCLE WATER</td> <td>GRP</td> <td>GLOSS FILAMENT REINFORCED PLASTIC</td> </tr> <tr> <td>DTE</td> <td>(Not air saturated) DAFT EFFLUENT</td> <td>HDPE</td> <td>HOPE (PE80 LIQUID SERVICE)</td> </tr> <tr> <td>DTS</td> <td>DAFT SLUDGE</td> <td>HDPE</td> <td>HOPE (GAS SERVICE)</td> </tr> <tr> <td></td> <td>(Combined float and bottom sludge)</td> <td>HDPS</td> <td>HOPE (PE100 LIQUID SERVICE)</td> </tr> <tr> <td>EFW</td> <td>EFFLUENT WATER</td> <td>MSCL</td> <td>MILD STEEL CEMENT LINED</td> </tr> <tr> <td>FLA</td> <td>FOUL AIR</td> <td>NVL</td> <td>NYLON TUBE</td> </tr> <tr> <td>GAS</td> <td>NATURAL GAS</td> <td>PVC1</td> <td>UPVC AS1477 SERIES 1, CLASS 9</td> </tr> <tr> <td>GSJ</td> <td>GRIT SOLUTION</td> <td>PVC2</td> <td>UPVC AS1477 SERIES 2, CLASS 16</td> </tr> <tr> <td>GSN</td> <td>GRIT SUPERNATANT</td> <td>PVC3</td> <td>UPVC AS1477 SERIES 1, RRJ, CLASS 12</td> </tr> <tr> <td>HTW</td> <td>HOT WATER</td> <td>RCRJ</td> <td>REINFORCED CONCRETE RUBBER RING</td> </tr> <tr> <td>INA</td> <td>INSTRUMENT AIR</td> <td>SSWS</td> <td>STAINLESS STEEL SPIRAL WELD</td> </tr> <tr> <td>LCS</td> <td>SODIUM HYDROXIDE</td> <td>VC</td> <td>VITRIFIED CLAY</td> </tr> <tr> <td>LSH</td> <td>SODIUM HYPOCHLORITE</td> <td></td> <td></td> </tr> <tr> <td>MLO</td> <td>MIXED LIQUOR</td> <td></td> <td></td> </tr> <tr> <td>MLR</td> <td>MIXED LIQUOR RETURN</td> <td></td> <td></td> </tr> <tr> <td>ODS</td> <td>ODOUR SCRUBBER EFFLUENT</td> <td></td> <td></td> </tr> <tr> <td>PRW</td> <td>PROCESS WATER</td> <td></td> <td></td> </tr> <tr> <td>PTW</td> <td>POTABLE WATER</td> <td></td> <td></td> </tr> <tr> <td>RSC</td> <td>SBR REACTOR SCUM</td> <td></td> <td></td> </tr> <tr> <td>SEW</td> <td>SANITARY SEWER</td> <td></td> <td></td> </tr> <tr> <td>SRS</td> <td>SCREENED RAW SEWAGE</td> <td></td> <td></td> </tr> <tr> <td>SWW</td> <td>SCREENINGS WASH WATER</td> <td></td> <td></td> </tr> <tr> <td>WAS</td> <td>WASTE ACTIVATED SLUDGE</td> <td></td> <td></td> </tr> </tbody> </table> <p>PIPE LINE DESIGNATION P 100 EFW S1 01 ABS LOCATION CODE PIPE SIZE LINE NUMBER PIPE MAT. 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