

**MOKOLO AND CROCODILE
WATER AUGMENTATION PROJECT
PHASE 2 (MCWAP-2)**

TENDER NO 054/2024/PMID/MCWAP2/RFB

**PART C3.1
SPECIFICATION**

SECTION 41

**CONTROL AND INSTRUMENTATION –
PLANT AND INSTALLATION**

PART C3.1
SPECIFICATION

SECTION 41
CONTROL AND INSTRUMENTATION -
PLANT AND INSTALLATION

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SECTION 41

CONTROL AND INSTRUMENTATION – PLANT AND INSTALLATION

This Section is a standard specification for control and instrumentation Plant installations and shall be read in conjunction with Section 40, which covers particular installation requirements in this Contract and relevant control and instrumentation design standards.

This Specification shall be interpreted as the Employer's requirements for aspects designed by the Contractor.

41.1 MEASURING INSTRUMENTS

41.1.1 Scope

Clause 41.1 covers the procurement, manufacture, delivery, installation, calibration, testing, commissioning and maintenance of instruments for the measuring of various process variables. This is a performance Specification focusing on instruments. These instruments form part of a larger system partly designed by the Employer and partly designed by the Contractor.

The Employer's designer is responsible for the design of the bulk water storage and conveyance system and the location of measurement instruments. This Clause also defines the Employer's Requirements with regard to these measuring instruments. The Contractor is responsible for the design of the primary and secondary communication systems and the integration of the signals from these instruments with the Control System.

This Section shall be read in conjunction with Section 40.

41.1.2 Definitions

Except as indicated below, the definitions given in SANS 10044 and SANS 719 shall apply:

- a) **"Flow meter system"** means the complete installation required to measure, display, totalise the flow in a pipeline at a point as specified inclusive of the surge protection, all cabling and telemetry interface.
- b) **"Flow sensor (primary element)"** means that section of the magnetic flow meter system comprising the pipe section, energising coils and measuring transducers that form an integral part of the pipeline.
- c) **"Signal converter (electronics)"** means the unit that energises the primary element or transducers and converts the flow signal to a numerical flow reading.
- d) **"Transducers"** mean the units that transmit and receives a high frequency signal that enables the signal converter to determine the velocity of the water.
- e) **"Totalising counter"** means an electro-mechanical non-resettable counter as specified and totally separate from the signal converter.
- f) **"Digital indicator"** means an electronic indicator as specified that is a separate unit from the signal converter.

- g) **“Surge protection”** means any Plant used for the earthing, common bonding and surge diversion of any electrical surge as induced and/or generated by the electrical supply or weather systems.

41.1.3 References

When reference is made to a Code of Practice, Specification or Standard, the reference shall be taken to mean the latest edition or replacement at time of tender of the Code, Specification or Standard; including addenda, supplements, modifications and revisions thereto. Where a previous version is intentionally used, it will be indicated as such. Where reference is made to a Code, Specification or Standard that has subsequently been withdrawn and not replaced, the intended content will remain relevant unless confirmed otherwise in writing by the Engineer.

41.1.4 Temperature Instruments

41.1.4.1 General

Temperature instruments shall be of the resistive temperature device (RTD) type.

The temperature instrument consists of two parts, namely the RTD and a temperature transmitter.

41.1.4.2 Operating Principle

The RTD works using a platinum sensor (Pt 100, Pt 250, and Pt 1000) that changes its resistive properties as the temperature changes. The temperature transmitter sends a constant measuring current which generates a voltage drop over the sensor element that is in turn measured.

It is very important that the current be kept to a minimum to prevent self-heating.

41.1.4.3 Construction

The sensor elements shall be of the wire wound or thin film type. The tolerance shall be Class A, 1/3 DIN, 1/10 DIN or Premium Grade. The instrument shall be able to measure between the ranges -200°C to 1000°C.

The sensor manufacturer shall ensure that the insert is sealed completely to prevent any moisture penetration. The sensor shall be of a small mass and volume in order to ensure good measurement accuracy.

The output measuring current being sent to the RTD from the transmitter shall be less than 1 mA. The output range shall be 4 – 20 mA. The RTD shall be of the 3 – wire connection type.

The temperature transmitter shall be of the 2 – wire transmitter type. The temperature transmitter shall allow the user to set an arbitrary value for a sensor break.

The temperature transmitters shall have a low isolation detection function. The temperature transmitter shall have temperature linearization and be able to switch between linear resistance and linear temperature output.

The signal convertor shall have different interface languages available to the user.

41.1.4.4 Installation

The RTD shall make very good heat contact with the material to be measured. This is critical in ensuring that the temperature value measured is a true reflection of the actual temperature of the material being measured.

The Contractor shall ensure a low thermal conductivity to the surrounding area of the installation of the RTD.

41.1.5 Pressure Instruments

41.1.5.1 General

Pressure instruments shall consist of two parts, namely a pressure sensor and a pressure transmitter.

41.1.5.2 Operating Principle

The process variable acting under a certain pressure acts on a diaphragm and deflects it. This causes a change in capacitance which is measured by the electrodes and the ceramic carrier.

41.1.5.3 Construction

The pressure sensor shall be made of ceramic material. It shall consist of a ceramic carrier, electrodes and a metal diaphragm.

The pressure sensor shall have a guaranteed overload resistance of up to 35 times the nominal pressure. The pressure sensor shall also have a very high mechanical stability factor and a very high chemical stability. It shall be able to work in a vacuum.

The communication protocol shall be 4 – 20 mA.

The display unit of the transmitter shall be pluggable and shall be of the LCD type. The display shall be able to be rotated for ease of viewing.

The electronic insert of the transmitter shall have a potentiometer for calibrating the lower range value and one for the upper range value. There should be DIP switches for the coarse adjustment of the span.

The pressure instrument shall also have a slot for the optional display unit and there shall also be a test point where the 4 – 20 mA signal could be picked up and measured without interrupting the operation of the instrument.

The signal convertor shall have different interface languages available to the user.

41.1.5.4 Installation

The pressure instrument shall be installed in a pipe fitting welded on to the main pipeline with an isolation valve installed between the instrument and the main pipeline.

The isolation valve shall be used to isolate the pressure instrument from the main pipeline for maintenance purposes and to facilitate the replacement of the instrument.

41.1.5.5 Accuracy

The maximum measured error comprising of non-linearity inclusive of hysteresis and non-reproducibility as per IEC 60770 shall be:

- $\pm 2\%$ of the set span.

41.1.6 Level Instruments

41.1.6.1 General

The level instrument shall be of the non-contact radar range of level type.

The level instrument shall consist of two parts namely the measuring sensor and the signal convertor.

41.1.6.2 Operating Principle

The instrument uses a high frequency signal which transmits signals which in turn reflect off the measured surface and back to the instrument. The larger the difference between the transmit frequency and receive frequency, the greater the distance to the measured surface and vice versa.

41.1.6.3 Construction

The instrument shall conform to the standards for vibration resistance, IEC 60068-2 and EN 50178. The protection category shall conform to IP67/NEMA 6.

The housing shall be manufactured from aluminium.

The output signal shall be 4 – 20 mA.

The signal convertor shall have an integrated LCD display with 9 lines, 160 X 160 pixels at least.

The signal convertor shall have at least a 4- button access keypad.

The signal convertor shall have different interface languages available to the user.

The instrument shall be of the 2-wire loop powered type. The instrument shall have a range of at least 80 metres.

41.1.6.4 Installation

The installation bracket needs to be slightly larger than the head of the instrument which shall be mounted perpendicular to the measured surface.

41.1.6.5 Accuracy

The measuring accuracy, resolution and repeatability of the level instrument shall be:

- Resolution - 1 mm;

- Repeatability - ± 1 mm;
- Accuracy - ± 3 mm when the distance is <10 m; and
- $\pm 0.03\%$ of measured distance when distance is >10 m.

41.1.7 Analysis - PH Instruments

41.1.7.1 General

The pH instrument shall be used to measure the acidity or alkalinity of a liquid medium. The pH instrument shall consist of both a pH sensor and a Pt 100 temperature sensor built into the same housing.

41.1.7.2 Operating Principle

The instrument uses an electrode with a glass membrane which supplies an electrochemical potential. The potential is dependent on the pH value of the medium it is in contact with. This electrochemical potential is referenced against a reference system using a reference electrode and the electromechanical signal is converted into a corresponding pH value using an equation.

41.1.7.3 Construction

The protection category shall conform to IP68/NEMA 6P.

The electrode shaft shall be made of process glass.

The instrument shall consist of a PTFE diaphragm.

The instrument shall have a Pt 100 temperature sensor included as part of the instrument.

The instrument shall be supplied with a cable of 15 metres in length.

41.1.7.4 Installation

The electrode shall not be installed upside down.

The electrode shall be installed at least an angle of 15 degrees or more from the horizontal position.

41.1.7.5 Measuring Ranges

- pH - 1 to 12 pH; and
- Temperature - -15°C to 80°C .

41.1.8 Analysis - Conductivity Instruments

41.1.8.1 General

The conductivity instrument shall be used to measure the conductivity of a liquid medium. The conductivity instrument shall consist of both a conductivity sensor and a Pt 100 temperature sensor built into the same housing.

41.1.8.2 Operating Principle

The conductivity instrument works using two electrodes that are immersed in a liquid medium. An AC voltage is applied to these electrodes which in turn generates an electric current in the medium. The conductance G of the medium is calculated using Ohm's law. The specific conductivity K is determined using the cell constant which is dependent on the geometry of the sensor.

41.1.8.3 Construction

The instrument shall conform to IP68/NEMA 6P.

The instrument shall consist of electrodes, temperature sensor and other components.

The instrument shall be supplied with a cable of 15 metres in length.

The electrodes shall be made from graphite.

The sensor shaft shall be made from polyether sulfone.

The thermal conductivity socket for the temperature sensor shall be made from titanium.

41.1.8.4 Installation

The complete measuring surface of the electrodes shall be totally immersed in the medium to be measured. The instrument can either be installed in a flow assembly or directly into the medium.

41.1.8.5 Performance Characteristics

- Measuring ranges - 10 micro Siemen/cm to 20 micro Siemen/cm for conductivity;
 - -20°C to 135°C for temperature; and
- Measured error - 1.0% maximum.

41.1.9 Analysis - Turbidity Instruments

41.1.9.1 General

The turbidity instrument shall consist of a turbidity sensor that shall contain an infrared transmitter, reference diode and scattered light receivers amongst other components.

41.1.9.2 Operating Principle

The instrument uses light beams that are sent through a medium and is then diverted from its original path by optically denser particles. The different paths the light signals take as a result of the light signals hitting the optically denser particles cause the light signals to strike different light receivers. The angle between the different signals' paths, those ones going through the optically denser particles and the ones that would have travelled straight and are referenced to a reference receiver is taken and this angle is used in the calculation of the turbidity in the water.

41.1.9.3 Construction

The instrument shall conform to IP68/NEMA 6P.

The housing shall be manufactured from PVC.

The instrument shall conform to ISO 7027 and EN 27027.

The instrument shall be supplied with a cable of 15 metres in length.

The cable shall be made of a polyolefin based elastomer and work between the temperature ranges of -40°C to 130°C.

The instrument shall be supplied with an integrated wiper for cleaning the window on the instrument.

41.1.9.4 Installation

The turbidity instrument shall be installed according to the following:

- a) The instrument shall be installed in places with uniform flow conditions;
- b) Ensure that the instrument is mounted against the flow of the medium thus ensuring a self-cleaning effect;
- c) The instrument shall not be installed in areas where pockets of air may collect, or foam bubbles can form or particles can settle on it;
- d) The instrument shall not be installed vertically in an upright or downward position on a horizontal part of the pipe;
- e) The instrument shall be installed either horizontally in a vertically upright part of the pipe or on the side of a horizontal pipe; and
- f) The instrument shall not be installed in a down pipe.

41.1.9.5 Performance Characteristics

- Maximum measured error - <5% of measured value; and
- Repeatability - <1% of measured value.

41.1.10 Analysis – Multi-Parameter Controller

41.1.10.1 General

The multi-parameter controller shall be able to work with pH sensors, conductivity sensors and turbidity sensors. The multi-parameter controller shall be able to accept the inputs from two analytical sensors as minimum.

41.1.10.2 Construction

The multi-parameter controller shall be modular in design, so as to easily facilitate the addition of another analytical quantity by simply adding an applicable extension module.

The multi-parameter controller shall have a graphical display with a backlight. The unit shall have soft key functionality.

41.1.10.3 Installation

The multi-parameter controller shall be wall mounted using a mounting plate, brackets, wall plugs and screws. A weather protection cover shall also be supplied as part of the installation.

41.1.10.4 Environment

- Ambient temperature range - Between -20°C to 60°C;
- Storage temperature - Between -40°C to 80°C;
- Electromagnetic compatibility - As per EN 61326 -1:2006; and
- Degree of protection - IP 67.

41.1.10.5 Communication

The multi-parameter controller shall be able to accept digital and analogue inputs from sensors and the output of the controller shall be a 4 – 20 mA signal. The controller shall have a minimum of two 4 – 20 mA outputs.

The controller shall have a memory storage area with sufficient data storage capacity. The data format of the memory module shall be off the shelf type like flash drives, SD cards, etc. No proprietary memory modules shall be accepted.

The typical data that shall be recorded on these memory modules shall be similar to the following:

- Total operational hours of the sensor;
- Maximum and minimum recorded values from sensors; and
- Condition of sensor (maintenance).

41.2 CABLES AND CABLING

41.2.1 Cable Types

- a) The instrument cable type shall be of the 300 Volt copper, XLPE, overall aluminium Mylar, PVC, Lonspeare Type 2A28.
- b) The sizes of the instrument copper cabling shall be the following:
 - 2 pair, 1.5 mm²;
 - 4 pair, 1.5 mm²;
 - 8 pair, 1.5 mm²;
 - 12 pair, 1.5 mm²;
 - 16 pair, 1.5 mm²;
 - 20 pair, 1.5 mm²;
 - 24 pair, 1.5 mm²;
 - 2 triad, 1.5 mm²;
 - 4 triad, 1.5 mm²; and
 - 8 triad, 1.5 mm².

- c) The Fibre Optic Cabling shall be of the 24-fibre optic Single mode – 9/125 micro metre Polyethylene outer sheath, Galvanized steel wire armour, PVC bedding sheath cabling. This cabling shall be used for the primary Ethernet network.
- d) Switches, routers, Ethernet hubs and all other Plant items using optical interface Plant shall use 50/125 micro metre Multi-mode Fibre Optic under the following conditions:
 - Where distances between Plant items are less than 2 kilometres;
 - Where there are instances of electro-magnetic interferences;
 - Where recommended by suppliers / vendors / manufacturers;
 - Where high bandwidth is required; and
 - Where high transmission speeds are required up to 1 Gigabyte.
- e) The PROFIBUS-DP purple cabling shall be of the PROFIBUS-DP Belden type of cable conforming to the following electrical properties:
 - Impedance between 135 – 165 Ohm;
 - Capacitance ≤ 30 pF/m;
 - Wire diameter ≥ 0.64 mm; and
 - Conductive area ≥ 0.34 mm².
- f) Refer to Clauses 39.2.8 to 39.2.14 for the identification of cables, competencies, cable trenching, routing of cables, installation of cables and termination and joining of cables.
- g) Refer to Clause 41.2.1.1 below on PROFIBUS-DP standards to follow on installation, termination, cable laying, network lengths to adhere to and other specifications to follow when working with the PROFIBUS-DP standard.

41.2.1.1 PROFIBUS-DP Standards Requirements

The installation guidelines concerning the PROFIBUS-DP network and Plant shall conform to the following PI (PROFIBUS International) guidelines:

- a) The PROFIBUS cables shall be purple cable for DP and blue or black for PA;
- b) The PROFIBUS cables shall always be issued from the supplier with complete data sheets and the PROFIBUS cables shall also have the correct markings on the cables;
- c) The PROFIBUS cables shall always be the correct type used for a particular application;
- d) The PROFIBUS cables shall be of the solid core type when using Fast Connect (FC) connectors;
- e) The PROFIBUS cables shall only be terminated using recognized and high quality PROFIBUS connectors;
- f) The PROFIBUS-DP cables shall adhere to the following table for the maximum segment lengths, maximum network lengths and total stub cable lengths when using the following Baud rates:

**TABLE 41/1
PROFIBUS-DP CABLES**

| BAUD RATE | MAX SEGMENT LENGTH | MAX NETWORK LENGTH (ASSUMING 9 REPEATERS) | TOTAL DP STUB CABLE LENGTH |
|------------------|---------------------------|--|-----------------------------------|
| 9.6 Kb/s | 1000 m | 10 000 m | Not prescribed |
| 19.2 Kb/s | 1000 m | 10 000 m | 500 m |
| 45.45 Kb/s | 1000 m | 10 000 m | 200 m |
| 93.75 Kb/s | 1000 m | 10 000 m | 100 m |
| 187.5 Kb/s | 1000 m | 10 000 m | 33 m |
| 500.0 Kb/s | 400 m | 4 000 m | 20 m |
| 1.5 Mb/s | 200 m | 2 000 m | 6.7 m |
| 3.0 Mb/s | 100 m | 1 000 m | None Allowed |
| 6.0 Mb/s | 100 m | 1 000 m | None Allowed |
| 12.0 Mb/s | 100 m | 1 000 m | None Allowed |

- g) The PROFIBUS-DP cabling shall be 1 metre in length or longer between connectors. This rule applies to all PROFIBUS installations including Motor Control Units, IEDs and other intelligent Plant items placed in close proximity in Motor Control Centres and Substations;
- h) The PROFIBUS-DP cabling, when installed in a cabinet shall be installed in the following manner:
 - Always remove the outer cable insulation and clamp the exposed shield to the cabinet earth bar or back plate where cables enter and leave the cabinet.
- i) The PROFIBUS-DP cable network shall not include spur lines;
- j) The PROFIBUS-DP network shall never exceed 32 devices per segment;
- k) The PROFIBUS-DP network shall never exceed more than 9 repeaters between any master and a slave;
- l) To prevent ground loop problems, the PROFIBUS-DP network shall be installed using any of the following two techniques:
 - Potential Equalization – Ground both ends of the segment to the exact same earth cable; or
 - Electrical Isolation – Only ground the screen at one end only and ensure that the continuity is kept throughout the segment and at the other end the screen is cut back and insulated to prevent it from touching anything.
- m) PROFIBUS-DP cabling shall be installed according to the following guidelines when being installed in channels or trunking next to other cables:
 - 10 centimetres away from the following ($25V < AC \leq 400 V$, $60V < DC \leq 400 V$);
 - 20 centimetres away from the following ($AC, DC > 400 V$); and
 - 50 centimetres away from the following (Any cable that is at risk from a lightning strike).
- n) The power provided to all the PROFIBUS-DP network components shall be of a good quality and no power spikes or surges shall be present on the power network;
- o) Under no circumstances shall general purpose RS485 cabling be used;

- p) The installation of the PROFIBUS-DP network shall only be done by an installer listed on the PI website and registered with PROFIBUS International having completed the installer's course and having written and passed the exam;
- q) A certified PROFIBUS-DP Engineer listed and registered with PROFIBUS International having completed the PROFIBUS-DP engineer's course and having passed the exam, shall audit the complete installation and give his findings in a detailed report to the Engineer;
- r) The bend radius shall never exceed the minimum specified bend radius on the data sheets on any of the PROFIBUS-DP cables used for the installation;
- s) PROFIBUS-DP cable segments shall have piggy-back plugs installed at the beginning and at the end of each segment for diagnostics by a Class 2 master;
- t) PROFIBUS-DP terminations shall only be done at the beginning and at the end of a segment;
- u) All PROFIBUS-DP terminations shall always be active (5 Volt power supplied to the terminator);
- v) PROFIBUS-DP cables shall be installed separately from other cables or divided by a steel partition if running together in a conduit. Please refer to (m) above;
- w) Earthing shall be done strictly in accordance with the PROFIBUS-DP network design and PI guidelines; and
- x) The PROFIBUS-DP cabling shall have the screens of the cables between each device on the PROFIBUS-DP segment connected through. The end point shall then be connected to a reliable instrument earth. This shall ensure that there are no ground loops in each of the segments. This shall be done in accordance with best practice and PI guidelines.

41.2.2 Cable Trenching

Refer to Clause 39.2.9 for the installation of underground cables. Trenching is covered under Section 9 and Backfilling under Section 15.

Where the Contractor identify ground conditions that allows the use of narrow trench technology or cable plough train technology for the installation of armored fibre optic cables, the requirements of Clause 9.5.6 shall be taken into account. In the case where the cable plough train is used the method statement shall clearly indicate the impact on the use of the bedding and backfill payment items.

41.3 PROGRAMMABLE LOGIC CONTROLLER (PLC)

41.3.1 Scope

Clause 41.2 covers the design, supply, and delivery, installation, testing and commissioning of a distributed programmable logic controller (PLC) system. This is a performance specification focusing on PLCs. These controllers form part of a larger pump control system designed by the Contractor. This section also defines the Employer's Requirements with regard to these controllers. The Contractor is responsible for the design of the PLCs and the integration of the signals from these with the SCADA System.

41.3.2 Standards

The Plant shall conform to the latest edition at the time of tender closing of the following national and international specification, publications and codes of practice which shall be read in conjunction with this Clause.

IEC 61131 for PLCs

- a) Part 1: General information;
- b) Part 2: Equipment requirements and tests;
- c) Part 3: Programming languages;
- d) Part 4: User guidelines;
- e) Part 5: Messaging service specification;
- f) Part 6: Communications via Fieldbus;
- g) Part 7: Fuzzy control; and
- h) Part 8: Guidelines for the applications and implementation of programming languages.

41.3.3 Process Automation Protocols

The Plant shall be compatible with some of the Protocols mentioned below:

- a) Foundation Fieldbus;
- b) PROFIBUS – By PROFIBUS International;
- c) PROFINET;
- d) ControlNet - Originally created by Allen Bradley;
- e) DeviceNet - Originally created by Allen Bradley;
- f) Ethernet/IP – Originally created by Rockwell Automation;
- g) Ethernet Powerlink – An open protocol managed by the Ethernet POWERLINK Standardization Group;
- h) Interbus – Phoenix Contact's protocol for communication over serial links;
- i) Hart – Open protocol;
- j) Modbus RTU or ASCII;
- k) Modbus-NET – Modbus for Networks;
- l) Modbus/TCP;
- m) Modbus Plus;
- n) Modbus PEMEX;
- o) EGD – Ethernet Global Data – By GE Fanuc PLCs;
- p) FINS – Omron protocol for communication over several networks including Ethernet;
- q) Host Link – Omron protocol for communication over serial links;
- r) MelsecNet/10 – Supported by Mitsubishi Electric;
- s) SERCOS interface;
- t) SERCOS III;
- u) GE SRTP;

- v) Sinec H1 – Siemens; and
- w) PieP – An open Fieldbus Protocol.

41.3.4 Introduction

Flexible open system design is a fundamental requirement.

Both the hardware and software shall incorporate open system architectures, providing a system that fulfils both current and future requirements.

The system provided shall be capable of interfacing with existing architectures where specified, performing as a stand - alone system or as an integrated part in a distributed control system.

41.3.5 Functional Requirements

- a) The PLCs shall perform the following main process tasks:
 - Analogue value processing;
 - Binary value processing;
 - Closed-loop control;
 - Open-loop control;
 - Logic and arithmetic processing; and
 - Trend acquisition.
- b) The PLCs shall have an I&C library that has standardised function blocks for typical devices and instruments.
- c) The I&C library shall have most of the following pre-configured blocks, faceplates and symbols:
 - Mathematical logic blocks;
 - Interlocking blocks;
 - Process control blocks;
 - Motor and valve blocks;
 - Signalling and diagnostic blocks; and
 - Field devices blocks.
- d) The PLCs shall have access control functions to allow only authorized access to a certain user group. When accessed by someone with the necessary authority, there shall be a trail record left.
- e) This I&C library will speed up the software program completion due to already having pre-configured software blocks of program and will make the programming easier and more understandable.
- f) The PLCs shall be able to support several communication protocols like the following:
 - PROFIBUS DP/PA interface;
 - MODBUS interface; and
 - Conventional I/O interface.
- g) The process signal acquisition and output shall be by means of suitable signal formation modules for both digital and analogue values.

- h) The process signal acquisition function shall include the measurement of operational variables such as dissolved oxygen levels, flows and temperatures etc. as analogue values. Primary signals such as contacts, limits, disturbances and Plant statuses and counter values such as counter contents, impulse counts, and time integrals of operational process variables.
- i) The process signal output function shall include the setting of analogue control values and limit selection and the issuing of binary commands such as the actual starting and stopping of drives.
- j) The Contractor shall write, adjust, tune, debug and commission all software and hardware to ensure a proper and fully functional installation.

41.3.6 Technical Requirements

41.3.6.1 General

- a) All hardware shall be purpose-designed for industrial use.
- b) The hardware modules shall be hot-swappable.
- c) The entire control system architecture shall be designed for redundancy. This shall include network redundancy, controller redundancy and operator interfaces redundancy.
- d) The control system architecture shall allow for an OPC gateway to allow direct access to process data and alarms from the process controllers.
- e) The system provided shall consist of, at least the following Plant items and functionality:
 - Control system hardware including I/O and field devices;
 - Communication networks;
 - HMI operator stations;
 - Integrated Safety applications for Automation;
 - Diagnostic and asset management functionality;
 - Batch processes functionality; and
 - Configuration tools functionality.
- f) The Engineer will accept or reject any part of the Plant depending on compliance or otherwise of the quality of workmanship and materials and Plant provided.

41.3.6.2 PLC Detail Requirements

(a) Architecture

- i) The PLCs shall not be a stand-alone system and shall form part of an integrated control process solution;
- ii) This PLC specification shall be read in conjunction with the SCADA specification in this Section as they each form part of an integrated solution; and
- iii) The PLC control system shall be based on a modular structure. The PLCs shall have plug-in input / output modules.

(b) Mechanical Features

- i) The PLCs shall be installed in standard electrical cabinets with adequate dimensions to the approval of the Engineer;
- ii) The controller shall be modular in form. Each processor or I/O module shall not occupy more than one slot;
- iii) The design shall be such that the minimum number of function cards is required to support binary input / output and analogue input / output; and
- iv) The I/O modules shall have a removable termination faceplate.

(c) Environmental Conditions

PLCs shall perform reliably and shall be suitable for the environment in which they will be installed.

The PLCs shall have the following electromagnetic compatibility:

- i) Radio interference suppression according to EN 55022 and EN 55014;
- ii) Interference immunity according to IEC 801, EN 60801 and VDE 0843; and
- iii) Security level 3 and NAMUR industrial standard.

(d) Power Supply

The power supply shall:

- i) Be suitable for connection to the mains supply voltage;
- ii) Contain isolated, internal power sources suitable for I/O modules requiring external power;
- iii) Be compatible with main CPU racks as well as expansion racks; and
- iv) Contain integral thermal overload and short circuit protection. Once activated, this condition shall be manually resettable only.

(e) Central Processing Unit Requirements and Specifications

- i) The supply voltage shall be:
 - DC 24 V.
- ii) The memory shall be:
 - RAM – At least 128 Kbyte; and
 - Pluggable RAM – At least 4 Meg.
- iii) The backup functionality shall be:
 - Required for program and data without battery.
- iv) The CPU processing time shall be:
 - At least <0.2 micro seconds for bit operations;
 - At least <0.4 micro seconds for word operations;
 - At least <4 micro seconds for fixed point arithmetic operations; and
 - At least <5 micro seconds for floating point arithmetic operations.

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- v) The amount of special counters shall be:
- At least 128.
- vi) The amount of Address areas for I/O shall be at least:
- 2 Kbyte for Inputs; and
 - 2 Kbyte for Outputs.
- vii) The amount of digital channels that can be handled shall be at least:
- 1024 for inputs; and
 - 1024 for outputs.
- viii) The amount of analogue channels that can be handled shall be at least:
- 256 for inputs; and
 - 256 for outputs.
- ix) The hardware configuration for CPU shall be:
- The maximum amount of modules per rack to be at least 8.
- x) The time synchronization specifications:
- The CPU shall have a real-time hardware clock;
 - The CPU shall be buffered and synchronizable; and
 - The CPU shall be able to synchronize to slave devices.
- xi) The CPU shall have a diagnostic buffer.
- xii) The CPU shall have a communication port for an engineering programmable device.
- xiii) The CPU shall have a function to automatically search for the fastest applicable Baud rate between itself and another device.
- xiv) The CPU shall be able to handle transmission speeds of 12 Mbits/second.
- xv) The CPU shall be able to work with most of the IEC 61131-3 programming languages, namely:
- FBD – Function Block Diagram;
 - LD – Ladder Diagram;
 - ST – Structured Text;
 - IL – Instruction List; and
 - SFC – Sequential Flow Chart.
- xvi) The CPU shall have password protection for program access.

(f) Digital I/O

- i) Input specifications. The DI modules shall:
- Be either 16, 32 or 64 input cards;
 - Work with either 24 V – AC/DC or 48 V – AC/DC unless otherwise specified;
 - Have an operating distance of at least 800 metres for shielded cables and 400 metres for unshielded cables;

- Have galvanic isolation between the channels; and
- Have isolation via an opto-coupler device between the channels and the backplane bus.

ii) Output specifications. The DO modules shall:

- Be either 16, 32 or 64 output cards;
- Work with either 24 V – AC/DC or 48 V – AC/DC unless otherwise specified;
- Have an operating distance of at least 800 metres for shielded cables and 400 metres for unshielded cables;
- Have short circuit protection;
- Have galvanic isolation between the channels; and
- Have isolation via an opto-coupler device between the channels and the backplane bus.

(g) Analogue I/O

i) Analogue input. The AI modules shall:

- Be rated for 24 V DC;
- Have reverse polarity protection;
- Have 8 inputs at least;
- Work with most of the following input voltage ranges:
 - 0 V to +10 V;
 - 1 V to +5 V;
 - 1 V to +10 V;
 - -1 V to +1 V;
 - -10 V to +10 V;
 - -5 V to +5 V; and
 - -2.5 V to +2.5 V.
- Work with most of the following input current ranges:
 - 0 to +20 mA;
 - -20 mA to +20 mA; and
 - 4 mA to 20 mA.
- Work with most of the following input thermo elements ranges:
 - Type E;
 - Type J;
 - Type K; and
 - Type N.
- Work with most of the following input resistor ranges:
 - 0 – 150 Ohm;
 - 0 – 300 Ohm;
 - 0 – 600 Ohm; and
 - 0 – 6000 Ohm.

- Work with most of the following input resistance thermo elements ranges:
 - Ni 100;
 - Ni 1000;
 - Pt 100; and
 - Pt 1000.
- Have isolation via an opto-coupler device between the channels and the backplane bus.

ii) Analogue output. The AO modules shall:

- Have at least 8 outputs;
- Have a voltage rating of 24 V DC;
- Have a maximum working distance of at least 150 metres;
- Have short circuit voltage protection;
- Work with most of the following output voltage ranges:
 - 0 V to +10 V;
 - 1 V to +5 V;
 - 1 V to +10 V;
 - -1 V to +1 V;
 - -10 V to +10 V;
 - -5 V to +5 V; and
 - -2.5 V to +2.5 V.
- Work with most of the following output current ranges:
 - 0 to +20 mA;
 - -20 mA to +20 mA; and
 - 4 mA to 20 mA.
- Have an alarm for diagnostics;
- Have readable diagnostic information; and
- Have isolation via an opto-coupler device between the channels and the backplane bus.

(h) Communications Network

i) General

- The backbone of the network shall be industrial Ethernet. The backbone network shall be designed for redundancy;
- The PLCs connect to the Ethernet backbone via an Ethernet communications card module on the PLC; and
- The transmission media that is used shall be 100 BaseT and 10 BaseFL.

41.3.7 Testing and Commissioning

The Contractor shall provide all personnel, equipment, instrumentation and supplies necessary to perform site testing and commissioning.

Original copies of all data produced, including results of each test procedure shall be submitted to the Engineer at the conclusion of each phase of testing.

Once the installation has been completed, the Contractor shall test, adjust and commission each control loop and system and shall verify proper operation of each item in the sequences of operation, including hardware and software and all communication links before the system is placed on-line.

During the testing and commissioning period, the Contractor shall identify failures, determine causes of failures and correct them and deliver a written report to the Engineer detailing the nature of each failure, the corrective action taken and the results of tests performed and shall recommend when testing should be resumed.

41.3.8 Documentation

Written software, control logic diagrams and functional specification showing the proposed control shall be submitted to the Engineer for review and approval prior to system start-up.

The Contractor shall provide schematics showing system architecture including network, software layout diagrams and I/O layouts referred to in the I/O list etc. as part of the O&M manuals.

41.4 SUPERVISORY CONTROL AND DATA ACQUISITIONING SYSTEMS (SCADA)

41.4.1 Scope

This performance specification covers the Employer's requirements for a supervisory control and data acquisition (SCADA) system. The Contractor is responsible for the design of the data communication systems and the integration of the signals from this system with the SCADA System.

The work consists of the development, supply, delivery, installation, testing and commissioning of the required software and hardware constituting a complete and fully operational SCADA System including, but not limited to, the system functions as specified herein.

41.4.2 Standards and Protocols

The Plant shall conform to the latest edition at the time of tender closing of the following national and international specifications publications and codes of practice which shall be read in conjunction with this Clause:

- SANS 171 surge arrestors for low voltage distribution systems.

41.4.3 System Overview

The SCADA package shall not be a stand-alone system and shall form part of an integrated control process solution.

The SCADA / Integrated DCS system design shall be based on the key principles of total integrated Automation given below.

The system shall be efficient, upgradable, configurable, user definable (very important) and easy to use.

41.4.3.1 Communication

The system shall have communication protocols that are based on international standards and are inter-connectable with many different vendor types of Plant that conform to the same well known international standards.

41.4.3.2 Diagnostics

The system shall feature integrated diagnostic functionality that shall be able to identify and, in some instances eliminate faults to ensure increased system availability.

41.4.3.3 Safety

The system shall adhere to sound safety engineering principles which are based on leading international safety standards like IEC 620621, EN ISO 13849-1 and BS EN ISO 13849-1. These standards shall not be the only safety standards that the system adheres to.

41.4.3.4 Security

The system shall be protected from attacks on the integrity of its data through the use of security options such as firewalls, access protection, encryption and virtual private networks. The C&I Contractor shall be responsible for this.

The system shall have different levels of access control which shall grant certain users access privileges while denying other users. This feature shall also be able to assign groups with special access privileges whilst denying other groups access.

41.4.3.5 Robustness

The SCADA system Plant shall be of the highest quality and be certified for industrial environments according to international standards. They shall be certified compliant with the requirements in such standards for Ingress Protection, Vibration resistance, electromagnetic compatibility and temperature resistance.

The system shall be able to work as a single-user system as well as a multi-user system complete with redundant servers and web clients if so, required in Clause 40.9.

The system shall be able to view archived trend and log files. The representation of the format of the data shall be either in graphic or tabular form.

The licensing required for all software including tags and logs shall be scalable. Only the amount of licensing required for the current system as installed shall be provided in the Contract with the option of extending the licensing for future expansion.

The SCADA system shall be able to still use the initial licenses when expanding the network I/O and shall only have to acquire the additional licenses required to maintain functionality of an expanded system.

41.4.4 Summary of Functional Requirements

The SCADA system shall have the following main functionality:

- a) Plant-specific graphics;
- b) Single displays with mini trend display;
- c) Standardized displays;
- d) Overview display;
- e) SFC display;
- f) Trend display;
- g) Time scheduler display;
- h) System display;
- i) Faceplates;
- j) Archiving;
- k) Logging; and
- l) System diagnosis.

41.4.4.1 Capacity per HMI Station

Each operator station shall have the following minimum capability:

- a) At least one main overview graphical display of the entire operation;
- b) At least 60 group displays of the operation; and
- c) At least 30 trend displays of the operation.

41.4.5 General Requirements

- a) The Engineer will accept or reject any part of the Plant depending on compliance or otherwise of the quality of workmanship and materials and Plant provided;
- b) The SCADA system shall have process operation features like a faceplate library, standardized displays like group, trend, SFC and system displays, quick and direct access to tags for operation, system diagnostics and overall message management and logging capabilities; and
- c) The system shall have a display update time of approximately 1 second. The display build-up time shall be between 1 and 2 seconds.

41.4.6 SCADA System Hardware

The SCADA system shall have the minimum specifications listed below, or better:

41.4.6.1 Operator / Engineering Station

(a) Processor and Memory

- Intel C622 Chipset;

- DDR4-DIMM GB RAM 16/32/64;
- 24 slots for memory expansion; and
- Memory speed 2133MT/s, 2400MT/s, 2666MT/s and 2933MT/s.

(b) Communication

- Ethernet card with support – Interface BNC/AUI/TP.

(c) Similar to Graphics Cards Below or Better

- NVIDIA® Quadro® P400 Graphics Card;
- GP107 GPU;
- 256 NVIDIA® CUDA® cores; and
- Max Power: 30 Watts.

(d) Minimum Operating System

- Microsoft Windows 10 Professional with latest service pack or newer that is compatible with the SCADA Software.

(e) Viewing Screens

- LED Size (Widescreen) – 22" – 24";
- Dynamic Contrast Ratio - $\geq 10\,000:1$;
- Response Time - ≤ 5 ms;
- Colour – Black;
- Resolution – 1680 x 1050;
- Energy Star compliant – Yes;
- USB 2.0 Connectors - ≥ 2 ; and
- Inputs – VGA, DVI, HDMI.

41.4.6.2 OPC Server / Trend Server

(a) Processor and Memory

- Intel C622 Chipset;
- DDR4-DIMM GB RAM 16/32/64; and
- 24 slots for memory expansion.

(b) Memory speed 2133MT/s, 2400MT/s, 2666MT/s and 2933MT/s Communication

- Ethernet card with support – Interface BNC/AUI/TP.

(c) Similar to Graphics Cards Below or Better

- NVIDIA® Quadro® P400 Graphics Card;
- GP107 GPU;
- 256 NVIDIA® CUDA® cores; and
- Max Power: 30 Watts.

(d) Operating System

- Microsoft Windows 10 Professional with latest service pack or newer that is compatible with the SCADA Software.

(e) Viewing Screen

- LED Size (Widescreen) – 22" – 24";
- Dynamic Contrast Ratio - $\geq 10\,000:1$;
- Response Time - ≤ 5 ms;
- Colour – Black;
- Resolution – 1680 x 1050;
- Energy Star compliant – Yes;
- USB 2.0 Connectors - ≥ 2 ; and
- Inputs – VGA, DVI, HDMI.

41.5 MICROWAVE SYSTEM PLANT**41.5.1 Microwave System Layout**

The Telemetry System shall consist of Ethernet Radios and other wireless transmission Plant items.

Communication between the Ethernet Radios shall be in the Licensed Band - UHF frequency range (440 MHz – 446 MHz @ 12.5 kHz intervals).

A voice communication channel shall be provided for communication between the different Ethernet Radios situated at the different sites as well.

Mentioned below is a breakdown of the technical specifications required for the Ethernet Radios, as per each specific site.

41.5.2 Abstraction Works and Low-Lift Pumping Station**(a) General**

- Frequency Programmability – Configurable;

- Operational Modes – Simplex and Half-duplex;
- Modulation – Digital/CPFSK;
- RF data rate and Bandwidth – 9600 bps @12.5 kHz; and
- Frequency Bands – 400 – 450 MHz.

(b) Transmitter

- Frequency Stability - +/- 0.5 ppm;
- Carrier Power – 0.1 to 0.5 Watts Programmable;
- Accuracy – Normal +/- 1.5 dB;
- Duty Cycle – Continuous; and
- Output Impedance – 50 Ohms.

(c) Receiver

- Type – Double Conversion Super heterodyne;
- Bit error rate – 1×10^{-6} @ -112 dBm typical;
- Frequency Stability - +/- 0.5 ppm;
- Selectivity - >70 dB; and
- Adjacent Channel Rejection – 40 dB nominal.

(d) Interfaces

- Serial COM1 – RS-232, DB-9;
- Serial COM2 – RS-232, RS-485, DB-9;
- Ethernet – 10/100 BaseT, RJ45; and
- Antenna – TNC Female.

(e) Management Software

- Radio Configuration Software;
- View Software; and
- Additional Software required.

(f) Environmental

- Temperature Rating – (-40°C) to +70°C; and
- Humidity – 95% at 40°C non-condensing.

(g) Electrical

- Primary Power – 10.5 to 16 VDC (13.8 VDC nominal);
- Tx Current – 2 A Typical at 5 Watts;
- Rx Current - <125 mA; and
- Sleep Mode – 9 mA nominal.

(h) Mechanical

- Enclosure – Die Cast Aluminium.

(i) Agency Approvals

- CSA Class 1 Div 2 for Hz Loc;
- IEEE 1613 Substation Environment;
- FCC Part 90;
- CE Mark;
- ETSI;
- EMC; and
- EN 300 279.

41.5.3 Sedimentation Works and Balancing Reservoir**(a) General**

- Frequency Programmability – Configurable;
- Operational Modes – Simplex and Half-duplex;
- Modulation – Digital/CPFSK;
- RF data rate and Bandwidth – 9600 bps@12.5 kHz; and
- Frequency Bands – 400 – 450 MHz.

(b) Transmitter

- Frequency Stability - +/- 0.5 ppm;
- Carrier Power – 0.1 to 0.5 Watts Programmable;
- Accuracy – Normal +/- 1.5 dB;
- Duty Cycle – Continuous; and
- Output Impedance – 50 Ohms.

(c) Receiver

- Type – Double Conversion Super heterodyne;
- Bit error rate – 1×10^{-6} @ -112 dBm typical;
- Frequency Stability - +/- 0.5 ppm;
- Selectivity - >70 dB; and
- Adjacent Channel Rejection – 40 dB nominal.

(d) Interfaces

- Serial COM1 – RS-232, DB-9;
- Serial COM2 – RS-232, RS-485, DB-9;
- Ethernet – 10/100 BaseT, RJ45; and
- Antenna – TNC Female.

(e) Management Software

- Radio Configuration Software;
- View Software; and
- Additional Software required.

(f) Environmental

- Temperature Rating – (-40°C) to +70°C; and
- Humidity – 95% at 40°C non-condensing.

(g) Electrical

- Primary Power – 10.5 to 16 VDC (13.8 VDC nominal);
- Tx Current – 2 A Typical at 5 Watts;
- Rx Current - <125 mA; and
- Sleep Mode – 9 mA nominal.

(h) Mechanical

- Enclosure – Die Cast Aluminium.

(i) Agency Approvals

- CSA Class 1 Div 2 for Hz Loc;
- IEEE 1613 Substation Environment;

- FCC Part 90;
- CE Mark;
- ETSI;
- EMC; and
- EN 300 279.

41.5.4 High-Lift Pumping Station

(a) General

- Frequency Programmability – Configurable;
- Operational Modes – Simplex and Half-duplex;
- Modulation – Digital/CPFSK;
- RF data rate and Bandwidth – 9600 bps@12.5 kHz; and
- Frequency Bands – 400 – 450 MHz.

(b) Transmitter

- Frequency Stability - +/- 0.5 ppm;
- Carrier Power – 0.1 to 0.5 Watts Programmable;
- Accuracy – Normal +/- 1.5 dB;
- Duty Cycle – Continuous; and
- Output Impedance – 50 Ohms.

(c) Receiver

- Type – Double Conversion Super heterodyne;
- Bit error rate – 1×10^{-6} @ -112 dBm typical;
- Frequency Stability - +/- 0.5 ppm;
- Selectivity - >70 dB; and
- Adjacent Channel Rejection – 40 dB nominal.

(d) Interfaces

- Serial COM1 – RS-232, DB-9;
- Serial COM2 – RS-232, RS-485, DB-9;
- Ethernet – 10/100 BaseT, RJ45; and
- Antenna – TNC Female.

(e) Management Software

- Radio Configuration Software;
- View Software; and
- Additional Software required.

(f) Environmental

- Temperature Rating – (-40°C) to +70°C; and
- Humidity – 95% at 40°C non-condensing.

(g) Electrical

- Primary Power – 10.5 to 16 VDC (13.8 VDC nominal);
- Tx Current – 2 A Typical at 5 Watts;
- Rx Current - <125 mA; and
- Sleep Mode – 9 mA nominal.

(h) Mechanical

- Enclosure – Die Cast Aluminium.

(i) Agency Approvals

- CSA Class 1 Div 2 for Hz Loc;
- IEEE 1613 Substation Environment;
- FCC Part 90;
- CE Mark;
- ETSI;
- EMC; and
- EN 300 279.

41.5.5 Break Pressure Tank**(a) General**

- Frequency Programmability – Configurable;
- Operational Modes – Simplex and Half-duplex;
- Modulation – Digital/CPFSK;
- RF data rate and Bandwidth – 9600 bps @12.5 kHz; and
- Frequency Bands – 400 – 450 MHz.

(b) Transmitter

- Frequency Stability - +/- 0.5 ppm;
- Carrier Power – 0.1 to 0.5 Watts Programmable;
- Accuracy – Normal +/- 1.5 dB;
- Duty Cycle – Continuous; and
- Output Impedance – 50 Ohms.

(c) Receiver

- Type – Double Conversion Super heterodyne;
- Bit error rate – 1×10^{-6} @ -112 dBm typical;
- Frequency Stability - +/- 0.5 ppm;
- Selectivity - >70 dB; and
- Adjacent Channel Rejection – 40 dB nominal.

(d) Interfaces

- Serial COM1 – RS-232, DB-9;
- Serial COM2 – RS-232, RS-485, DB-9;
- Ethernet – 10/100 BaseT, RJ45; and
- Antenna – TNC Female.

(e) Management Software

- Radio Configuration Software;
- View Software; and
- Additional Software required.

(f) Environmental

- Temperature Rating – (-40°C) to +70°C; and
- Humidity – 95% at 40°C non-condensing.

(g) Electrical

- Primary Power – 10.5 to 16 VDC (13.8 VDC nominal);
- Tx Current – 2 A Typical at 5 Watts;
- Rx Current - <125 mA; and
- Sleep Mode – 9 mA nominal.

(h) Mechanical

- Enclosure – Die Cast Aluminium.

(i) Agency Approvals

- CSA Class 1 Div 2 for Hz Loc;
- IEEE 1613 Substation Environment;
- FCC Part 90;
- CE Mark;
- ETSI;
- EMC; and
- EN 300 279.

41.5.6 Break Pressure Reservoir**(a) General**

- Frequency Programmability – Configurable;
- Operational Modes – Simplex and Half-duplex;
- Modulation – Digital/CPFSK;
- RF data rate and Bandwidth – 9600 bps@12.5 kHz; and
- Frequency Bands – 400 – 450 MHz.

(b) Transmitter

- Frequency Stability - +/- 0.5 ppm;
- Carrier Power – 0.1 to 0.5 Watts Programmable;
- Accuracy – Normal +/- 1.5 dB;
- Duty Cycle – Continuous; and
- Output Impedance – 50 Ohms.

(c) Receiver

- Type – Double Conversion Super heterodyne;
- Bit error rate – 1×10^{-6} @ -112 dBm typical;
- Frequency Stability - +/- 0.5 ppm;
- Selectivity - >70 dB; and
- Adjacent Channel Rejection – 40 dB nominal.

(d) Interfaces

- Serial COM1 – RS-232, DB-9;
- Serial COM2 – RS-232, RS-485, DB-9;
- Ethernet – 10/100 BaseT, RJ45; and
- Antenna – TNC Female.

(e) Management Software

- Radio Configuration Software;
- View Software; and
- Additional Software required.

(f) Environmental

- Temperature Rating – (-40°C) to +70°C; and
- Humidity – 95% at 40°C non-condensing.

(g) Electrical

- Primary Power – 10.5 to 16 VDC (13.8 VDC nominal);
- Tx Current – 2 A Typical at 5 Watts;
- Rx Current - <125 mA; and
- Sleep Mode – 9 mA nominal.

(h) Mechanical

- Enclosure – Die Cast Aluminium.

(i) Agency Approvals

- CSA Class 1 Div 2 for Hz Loc;
- IEEE 1613 Substation Environment;
- FCC Part 90;
- CE Mark;
- ETSI;
- EMC; and
- EN 300 279.

41.5.7 Surge Protection

The Contractor shall include for the installation of surge protection Plant on all system input / output circuits, power supply input (dc, mains) circuits, and for the installation of the necessary earth mats and earth connections.

The following Plant items shall be included as an absolute minimum required:

- a) On all analogue / digital input and output circuits - DEHN BLITZDUCTORS TYPE LZ or equivalent with appropriate voltage ratings;
- b) On all mains power supply circuits - DEHN type VA-280 surge arrestors or equivalent; and
- c) On all telephone lines - Telkom approved protection network, containing gas arrestors, inductances, transorb type arrestors and 600 ohm/600 ohm isolating transformers. Loop and ringing current circuits shall be optically isolated.

The Engineer may allow use of alternative types of surge arrestors, provided that equivalent or superior protection levels will be achieved. SABS and/or CSIR test reports to substantiate claims shall be provided for the alternative offers.

It is not anticipated that the stated Plant items will, when used on their own, necessarily provide the required level of protection and the Contractor shall implement additional measures deemed necessary to achieve the required protection level.

41.6 SPARE PARTS REQUIREMENTS

Spare parts requirements are defined by a combination of that defined by the Employer and that defined by the Contractor based on the recommendations made by the manufacturers and suppliers of specific Plant items.

A Spare Part Schedule by the Employer is available in Section 48 – Test on Completion as well as the BoQ. Payment for spares identified by the Contractor and approved by the Engineer, shall be made from the provisional sums allowed for this in the Bill of Quantities. The rates provided for these spares shall provide for the manufacture, supply, delivery to Site and handing over of the spares ordered and shall include permanent packing for long term storage. The spares shall be manufactured at the same time as the installed items.

Over and above the Employers defined requirements for spares, the Contractor shall list the spare parts considered to be necessary as required for the continued operation of all mechanical, electrical and electronic Plant based not only on a reliability analysis of the Plant, but also on the reliability and availability of local suppliers of spare parts. The lists shall also include all long lead maintenance items and special maintenance tools that will be required during the maintenance of the Plant. The additional critical spare parts must be provided prior to achieving RFTO.

41.7 MEASUREMENT AND PAYMENT

The rates tendered under this Section shall not include for the general obligations, Contractor's Equipment and work deemed to be covered by the items provided in Section 1 – General.

41.001 Design and documentation**Unit : lump sum (Sum)**

The rates tendered shall include for full compensation of all costs incurred in the preparation of the design and calculations, detail working drawings for all items, specifications, schematic diagrams, loop diagrams and wiring diagrams, Control System layout diagrams, Control Network layout diagrams, SCADA graphic layouts, engineering software code, engineering design philosophy, control philosophy, operation and maintenance instructions, programmes of work (manufacture and on-site) and any other work as specified for the design of the complete installation. Payment will only be effected after the design and associated documentation has been approved by the Engineer.

Measurement and Payment for the preparation and submission of O&M Manuals shall be covered under Clause 48.11 of Section 48 – Tests on Completion and paid elsewhere.

41.002 Supply and Deliver to Site**Unit : number (No)
or : sets (Sets)
or: pairs (Pairs)
or : lump sum (Sum)**

The rates tendered shall include full compensation for the supply and delivery of the Plant to Site including supply of raw materials and bought-out items and associated operating Plant items; fabrication, manufacture and assembly; quality assurance and quality control; inspection and Factory Acceptance Testing (including attendance on inspections and tests witnessed by the Engineer); type and routine tests; application of finishes (painting and corrosion protection); trial erection and dismantling; preparation and packing for transport; transport from place of manufacture to the Site; insurance, harbour dues etc., during transport; loading and unloading; storage under appropriate conditions from date of delivery until commencement of erection; and any other work as specified. Payment will be made per unit. Payment will only be effected after full compliance of the Plant items with this Section and associated documentation has been approved by the Engineer.

a) Temperature sensor and transmitter**Unit: number (No)**

The rate shall include the temperature sensors and transmitters as per the Technical Schedules, complete with control units, brackets and pedestals, enclosures, interconnecting cables, surge protection and all other sundry requirements.

b) Pressure sensor and transmitter**Unit: number (No)**

The rate shall include the specified pressure sensors and transmitters as per the Technical Schedules including all required material including surge protection.

c) Level sensor and transmitter**Unit: number (No)**

The rate shall include the specified level sensors and transmitters as per the Technical Schedules including all required material and process connections including surge protection.

d) Flow Switch**Unit: number (No)**

The rate shall include the flow switch as per the Technical Schedules, complete with flow sensor and flow transmitter, reverse flow indication, communication module, all process piping (stainless steel), reducers and fittings, process connection isolation valves, three-way bleed-off valves, instrumentation cable, metallic compression glands, terminal box, surge protection and all other sundry requirements.

e) 19 inch racks**Unit: number (No)**

The rate shall include corrosion protection complete with back plate, wiring harnesses as specified and any other items necessary for mounting the rack in the enclosures or any items necessary for the mounting of modules within the rack.

f) Turbidity sensors**Unit: number (No)**

The rate shall include the turbidity sensors as per the Technical Schedules, complete with PVC / PPS sensor, sapphire optical window, rubber wiper, brackets and pedestals, enclosures, instrumentation cables and surge protection.

g) pH electrodes**Unit: number (No)**

The rate shall include the pH electrodes as per the Technical Schedules, complete with graphite sensor, PES sensor shaft, titanium thermal sensor, graphite electrodes, brackets and pedestals, enclosures, instrumentation cables and surge protection.

h) Multi-parameter Controller**Unit: number (No)**

The rate shall include the multi-parameter controller, complete with communication output modules, power supply, HMI, weather protection cover, brackets and pedestals, enclosures, instrumentation cables and surge protection.

i) Conductivity sensors**Unit: number (No)**

The rate shall include the conductivity sensors, complete with graphite sensor, titanium thermal sensor, PES shaft sensor, brackets and pedestals, enclosures, instrumentation cables and surge protection.

j) 24 fibre optic Single mode – 9/125 micro metre Polyethylene outer sheath, Galvanized steel wire armour, PVC bedding sheath cabling**Unit: metre (m)**

Cable lengths are approximate lengths. Installed cable will be measured on site.

The rate shall include all clamping, strapping and cable tag marking. Trenching is priced separately.

- k) 2 pair, 1,5 mm² XLPE, OAM, PVC, 300 Volt rated instrumentation cabling Unit: metre (m)**

Cable lengths are approximate lengths. Installed cable will be measured on site.

The rate shall include all clamping, strapping and cable tag marking. Trenching is priced separately.

- l) 4 pair, 1,5 mm² XLPE, OAM, PVC, 300 Volt rated instrumentation cabling Unit: metre (m)**

Cable lengths are approximate lengths. Installed cable will be measured on site.

The rate shall include all clamping, strapping and cable tag marking. Trenching is priced separately.

- m) 8 pair, 1,5 mm² XLPE, OAM, PVC, 300 Volt rated instrumentation cabling Unit: metre (m)**

Cable lengths are approximate lengths. Installed cable will be measured on site.

The rate shall include all clamping, strapping and cable tag marking. Trenching is priced separately.

- n) 12 pair, 1,5 mm² XLPE, OAM, PVC, 300 Volt rated instrumentation cabling Unit: metre (m)**

Cable lengths are approximate lengths. Installed cable will be measured on site.

The rate shall include all clamping, strapping and cable tag marking. Trenching is priced separately.

- o) 16 pair, 1,5 mm² XLPE, OAM, PVC, 300 Volt rated instrumentation cabling Unit: metre (m)**

Cable lengths are approximate lengths. Installed cable will be measured on site.

The rate shall include all clamping, strapping and cable tag marking. Trenching is priced separately.

- p) 20 pair, 1,5 mm² XLPE, OAM, PVC, 300 Volt rated instrumentation cabling Unit: metre (m)**

Cable lengths are approximate lengths. Installed cable will be measured on site.

The rate shall include all clamping, strapping and cable tag marking. Trenching is priced separately.

- q) 24 pair, 1,5 mm² XLPE, OAM, PVC, 300 Volt rated instrumentation cabling Unit: metre (m)**

Cable lengths are approximate lengths. Installed cable will be measured on site.

The rate shall include all clamping, strapping and cable tag marking. Trenching is priced separately.

- r) 2 Triad, 1,5 mm² XLPE, OAM, PVC, 300 Volt rated instrumentation cabling Unit: metre (m)**

Cable lengths are approximate lengths. Installed cable will be measured on site.

The rate shall include all clamping, strapping and cable tag marking. Trenching is priced separately.

- s) 4 Triad, 1,5 mm² XLPE, OAM, PVC, 300 Volt rated instrumentation cabling Unit: metre (m)**

Cable lengths are approximate lengths. Installed cable will be measured on site.

The rate shall include all clamping, strapping and cable tag marking. Trenching is priced separately.

- t) 8 Triad, 1,5 mm² XLPE, OAM, PVC, 300 Volt rated instrumentation cabling Unit: metre (m)**

Cable lengths are approximate lengths. Installed cable will be measured on site.

The rate shall include all clamping, strapping and cable tag marking. Trenching is priced separately.

- u) 12 Triad, 1,5 mm² XLPE, OAM, PVC, 300 Volt rated instrumentation cabling Unit: metre (m)**

Cable lengths are approximate lengths. Installed cable will be measured on site.

The rate shall include all clamping, strapping and cable tag marking. Trenching is priced separately.

- v) Battery Operated Electromagnetic flow sensor and signal convertor Unit: number (No)**

The rate shall include the Battery Operated Electromagnetic flow sensors and flow convertors as per the Technical Schedules, complete with both flow sensor and flow convertor, lithium type battery, data logger, stainless steel flanges, stainless steel electrodes, Rilsan or hard rubber liner, LCD high contrast display, communication module with pulse and status outputs, die-cast aluminium polyurethane coated flow convertor housing, brackets and pedestals, enclosures, instrumentation cables and surge protection.

- w) PROFIBUS-DP, impedance between 135 – 165 Ohm, Capacitance <=30 pF/m, wire diameter >= 0.64 mm, conductive area >=0.34 mm² Belden purple cabling Unit: metre (m)**

Cable lengths are approximate lengths. Installed cable will be measured on site.

The rate shall include all clamping, strapping and cable tag marking. Trenching is priced separately.

x) CPU Processor unit **Unit: number (No)**

The rate shall include the specified CPU Processor unit as per the Technical Schedules, including base plate, CEX-bus terminator, module bus terminator and battery for memory backup.

y) PROFIBUS-DP-V1 Communication Interface unit **Unit: number (No)**

The rate shall include the specified PROFIBUS-DP-V1 units as per the Technical Schedules, including communication interface and base plate.

z) Analogue Input Module **Unit: number (No)**

The rate shall include the specified Analogue Input Module as per the Technical Schedules.

aa) Analogue Output Module **Unit: number (No)**

The rate shall include the specified Analogue Output Module as per the Technical Schedules.

ab) Digital Input Module **Unit: number (No)**

The rate shall include the specified Digital Input Module as per the Technical Schedules.

ac) Digital Output Module **Unit: number (No)**

The rate shall include the specified Digital output Module as per the Technical Schedules.

ad) Power Supply Module – PLC/DCS **Unit: number (No)**

The rate shall include the specified Power supply Module as per the Technical Schedules.

ae) Voting Unit for Power Supply units **Unit: number (No)**

The rate shall include the specified Voting units for the Power supply Modules as per the Technical Schedules.

af) Software for the SCADA and PLC systems **Unit: number (No)**

The rate shall include all license tag fees applicable, application software, operating system software, drivers, graphics packages, network licences, anti-virus software, read and write software, office suite software, diagnostic software and any other software required for the engineering work stations, operator work stations, servers, historian, PLCs, etc.

The rate shall be all inclusive and shall include for all latest service pack upgrades.

ag) SCADA and PLC Engineering Workstations **Unit: number (No)**

The rate shall include the specified DCS/PLC Engineering Work Stations as per the Technical Schedules, including LCD screens and all hardware accessories.

ah) SCADA and PLC Operator Workstations **Unit: number (No)**

The rate shall include the specified DCS/PLC Operator Work Stations as per the Technical Schedules, including LED screens and all hardware accessories.

ai) Aspect Server **Unit: number (No)**

The rate shall include the specified Aspect Server as per the Technical Schedules, including LED screens and all hardware accessories.

aj) Connectivity Server **Unit: number (No)**

The rate shall include the specified Connectivity Server as per the Technical Schedules, including LED screens and all hardware accessories.

ak) Historian **Unit: number (No)**

The rate shall include the specified Historian as per the Technical Schedules, including LED screens and all hardware accessories.

al) Data Server **Unit: number (No)**

The rate shall include the specified Data Server as per Technical Schedules, including LED screens and all hardware accessories.

am) Web Portal **Unit: number (No)**

The rate shall include the specified Web Portal, including all hardware accessories.

an) Industrial Ethernet Switch **Unit: number (No)**

The rate shall include the specified Industrial Switch as per the Technical Schedules, including fibre (1000BaseX) and copper ports (10/100BaseTX), LC/SC/SFP/Pluggable Optics connector types, password protection, encryption, port security, galvanized steel enclosure, mounting rails and surge protection.

ao) Converters **Unit: number (No)**

The rate shall include the specified Converters.

ap) Repeaters **Unit: number (No)**

The rate shall include the specified Repeaters.

aq) Colour Laser Printer **Unit: number (No)**

The rate shall include the specified Colour Laser Printer.

ar) Laser Printer **Unit: number (No)**

The rate shall include the specified Laser Printer.

as) RTD Input Module **Unit: number (No)**

The rate shall include specified RTD Input Modules.

at) HMI 12-inch colour touch screen for indication (High-Lift Pumps and Low-Lift Pumps) **Unit: number (No)**

The rate shall include the specified HMI 12-inch colour touch screens.

au) Valve open and close confirmation proximity switches **Unit: number (No)**

The rate shall include the specified valve open and close confirmation proximity switches including surge protection.

av) Power Supplies for Instruments **Unit: number (No)**

The rate shall include the specified power supplies Input - 230 V/Output - 24.-28 VDC, output current +/-5 Amps with a fusible link, surge protection, parallel connection option, status relay/change over contact, overload protection including mounting rail, clamps and all other material and sundries required.

aw) Marshalling Cabinet / Enclosure IP 65 rated **Unit: number (No)**

The rate shall include the specified marshalling cabinet / enclosure, stainless steel, IP65 rated of sufficient size to cater for two redundantly connected power supplies, terminals, wiring, trunking, mounting rails, surge protection and all other required material for a fully functional and complete installation.

41.003 Installation of Plant

The rates tendered shall include for full compensation for the installation of the Plant on Site including the provision of all labour, transport, materials and Temporary Works necessary to install

the complete Works; on-site quality assurance and quality control, inspection, testing (including attendance at tests witnessed by the Engineer); the installation of all auxiliary Plant items; necessary for the operation of the installation until taken over by the Employer; the putting into service of the complete installation of the Plant; and any other work as specified.

The rate shall also include for all pre-commissioning testing and the provision of equipment therefore including all disruptions to installation caused by such testing. Payment will be made per unit. Payment will only be effected after full compliance of the Plant items with this Section and associated documentation has been approved by the Engineer.

Measurement and Payment for Test on Completion shall be covered under Clause 48.11 of Section 48 – Tests on Completion and paid elsewhere.

a) Temperature sensor and transmitter

Unit: number (No)

The rate shall include full compensation for the installation, testing and pre-commissioning of the temperature sensors and transmitters, inclusive of all connected exterior indicating and control loops, all labour, installation materials and sundries for a fully operational and serviceable installation.

b) Pressure sensor and transmitter

Unit: number (No)

The rate shall include full compensation for the installation, testing and pre-commissioning of the specified pressure sensors and transmitters for a complete and operational installation as specified including surge protection.

c) Level sensor and transmitter

Unit: number (No)

The rate shall include full compensation for the installation, testing and pre-commissioning of the specified level sensors and transmitters to render a complete and operational installation as specified, including surge protection.

d) Flow Switch

Unit: number (No)

The rate shall include full compensation for the installation, testing and pre-commissioning of the specified flow switch complete with flow sensor and flow transmitter, reverse flow indication, communication module, all process piping (stainless steel), reducers and fittings, process connection isolation valves, three-way bleed-off valves, instrumentation cable, metallic compression glands, terminal box, mounting equipment, labour, testing equipment and material for a complete operational flow switch installation.

e) 19 inch racks

Unit: number (No)

The rate for each type shall include full compensation for the installation of the specified 19 inch racks complete with back plate, wiring harnesses as specified and any other items necessary for mounting the rack in the enclosures or any items necessary for the mounting of modules within the rack.

f) Turbidity sensors**Unit: number (No)**

The rate shall include full compensation for the installation, testing and pre-commissioning of the turbidity sensors, inclusive of all connected exterior indicating and control loops, all labour, installation materials and sundries for a fully operational and serviceable installation.

g) pH electrodes**Unit: number (No)**

The rate shall include full compensation for the installation, testing and pre-commissioning of the pH electrodes, inclusive of all connected exterior indicating and control loops, all labour, installation materials and sundries for a fully operational and serviceable installation.

h) Multi-Parameter Controller**Unit: number (No)**

The rate shall include full compensation for the installation, testing and pre-commissioning of the multi-parameter controllers, inclusive of all connected exterior indicating and control loops, all labour, installation materials and sundries for a fully operational and serviceable installation.

i) Conductivity sensors**Unit: number (No)**

The rate shall include full compensation for the installation, testing and pre-commissioning of the conductivity sensors, inclusive of all connected exterior indicating and control loops, all labour, installation materials and sundries for a fully operational and serviceable installation.

j) 24 fibre optic Single mode – 9/125 micro metre Polyethylene outer sheath, Galvanized steel wire armour, PVC bedding sheath cabling**Unit: metre (m)**

The rate shall include full compensation for the installation of the required 24 fibre optic Single mode – 9/125 micro metre Polyethylene outer sheath, Galvanized steel wire armour, PVC bedding sheath cabling including all peripherals to ensure a complete and functional installation.

k) 2 pair, 1,5 mm² XLPE, OAM, PVC, 300 Volt rated instrumentation cabling**Unit: metre (m)**

The rate shall include full compensation for the installation of the required 2 pair, 1,5mm² XLPE, OAM, PVC, 300 Volt rated instrumentation cabling including all peripherals to ensure a complete and functional installation.

l) 4 pair, 1,5 mm² XLPE, OAM, PVC, 300 Volt rated instrumentation cabling**Unit: metre (m)**

The rate shall include full compensation for the installation of the required 4 pair, 1,5 mm² XLPE, OAM, PVC, 300 Volt rated instrumentation cabling including all peripherals to ensure a complete and functional installation.

- m) 8 pair, 1,5 mm² XLPE, OAM, PVC, 300 Volt rated instrumentation cabling** **Unit: metre (m)**

The rate shall include full compensation for the installation of the required 8 pair, 1,5 mm² XLPE, OAM, PVC, 300 Volt rated instrumentation cabling including all peripherals to ensure a complete and functional installation.

- n) 12 pair, 1,5 mm² XLPE, OAM, PVC, 300 Volt rated instrumentation cabling** **Unit: metre (m)**

The rate shall include full compensation for the installation of the required 12 pair, 1,5 mm² XLPE, OAM, PVC, 300 Volt rated instrumentation cabling including all peripherals to ensure a complete and functional installation.

- o) 16 pair, 1,5 mm² XLPE, OAM, PVC, 300 Volt rated instrumentation cabling** **Unit: metre (m)**

The rate shall include full compensation for the installation of the required 16 pair, 1,5 mm² XLPE, OAM, PVC, 300 Volt rated instrumentation cabling including all peripherals to ensure a complete and functional installation.

- p) 20 pair, 1,5 mm² XLPE, OAM, PVC, 300 Volt rated instrumentation cabling** **Unit: metre (m)**

The rate shall include full compensation for the installation of the required 20 pair, 1,5 mm² XLPE, OAM, PVC, 300 Volt rated instrumentation cabling including all peripherals to ensure a complete and functional installation.

- q) 24 pair, 1,5 mm² XLPE, OAM, PVC, 300 Volt rated instrumentation cabling** **Unit: metre (m)**

The rate shall include full compensation for the installation of the required 24 pair, 1,5 mm² XLPE, OAM, PVC, 300 Volt rated instrumentation cabling including all peripherals to ensure a complete and functional installation.

- r) 2 Triad, 1,5 mm² XLPE, OAM, PVC, 300 Volt rated instrumentation cabling** **Unit: metre (m)**

The rate shall include full compensation for the installation of the required 2 Triad, 1,5 mm² XLPE, OAM, PVC, 300 Volt rated instrumentation cabling including all peripherals to ensure a complete and functional installation.

- s) 4 Triad, 1,5 mm² XLPE, OAM, PVC, 300 Volt rated instrumentation cabling** **Unit: metre (m)**

The rate shall include full compensation for the installation of the required 4 Triad, 1,5 mm² XLPE, OAM, PVC, 300 Volt rated instrumentation cabling including all peripherals to ensure a complete and functional installation.

- t) 8 Triad, 1,5 mm² XLPE, OAM, PVC, 300 Volt rated instrumentation cabling** **Unit: metre (m)**

The rate shall include full compensation for the installation of the required 8 Triad, 1,5 mm² XLPE, OAM, PVC, 300 Volt rated instrumentation cabling including all peripherals to ensure a complete and functional installation.

- u) 12 Triad, 1,5 mm² XLPE, OAM, PVC, 300 Volt rated instrumentation cabling** **Unit: metre (m)**

The rate shall include full compensation for the installation of the required 12 Triad, 1,5 mm² XLPE, OAM, PVC, 300 Volt rated instrumentation cabling including all peripherals to ensure a complete and functional installation.

- v) Terminate 2 pair, 1,5 mm² XLPE, OAM, PVC, 300 Volt rated instrumentation cabling** **Unit: number (No)**

The rate shall include full compensation for the termination of the required 2 pair, 1,5 mm² XLPE, OAM, PVC, 300 Volt rated instrumentation cabling including all peripherals to ensure a complete and functional installation.

- w) Terminate 4 pair, 1,5 mm² XLPE, OAM, PVC, 300 Volt rated instrumentation cabling** **Unit: number (No)**

The rate shall include full compensation for the termination of the required 4 pair, 1,5 mm² XLPE, OAM, PVC, 300 Volt rated instrumentation cabling including all peripherals to ensure a complete and functional installation.

- x) Terminate 8 pair, 1,5 mm² XLPE, OAM, PVC, 300 Volt rated instrumentation cabling** **Unit: number (No)**

The rate shall include full compensation for the termination of the required 8 pair, 1,5 mm² XLPE, OAM, PVC, 300 Volt rated instrumentation cabling including all peripherals to ensure a complete and functional installation.

- y) Terminate 12 pair, 1,5 mm² XLPE, OAM, PVC, 300 Volt rated instrumentation cabling** **Unit: number (No)**

The rate shall include full compensation for the termination of the required 12 pair, 1,5 mm² XLPE, OAM, PVC, 300 Volt rated instrumentation cabling including all peripherals to ensure a complete and functional installation.

- z) Terminate 16 pair, 1,5 mm² XLPE, OAM, PVC, 300 Volt rated instrumentation cabling** **Unit: number (No)**

The rate shall include full compensation for the termination of the required 16 pair, 1,5 mm² XLPE, OAM, PVC, 300 Volt rated instrumentation cabling including all peripherals to ensure a complete and functional installation.

- aa) Terminate 20 pair, 1,5 mm² XLPE, OAM, PVC, 300 Volt rated instrumentation cabling** **Unit: number (No)**

The rate shall include full compensation for the termination of the required 20 pair, 1,5 mm² XLPE, OAM, PVC, 300 Volt rated instrumentation cabling including all peripherals to ensure a complete and functional installation.

- ab) Terminate 24 pair, 1,5 mm² XLPE, OAM, PVC, 300 Volt rated instrumentation cabling** **Unit: number (No)**

The rate shall include full compensation for the termination of the required 24 pair, 1,5 mm² XLPE, OAM, PVC, 300 Volt rated instrumentation cabling including all peripherals to ensure a complete and functional installation.

- ac) Terminate 2 Triad, 1,5 mm² XLPE, OAM, PVC, 300 Volt rated instrumentation cabling** **Unit: number (No)**

The rate shall include full compensation for the termination of the required 2 Triad, 1,5 mm² XLPE, OAM, PVC, 300 Volt rated instrumentation cabling including all peripherals to ensure a complete and functional installation.

- ad) Terminate 4 Triad, 1,5 mm² XLPE, OAM, PVC, 300 Volt rated instrumentation cabling** **Unit: number (No)**

The rate shall include full compensation for the termination of the required 4 Triad, 1,5 mm² XLPE, OAM, PVC, 300 Volt rated instrumentation cabling including all peripherals to ensure a complete and functional installation.

- ae) Terminate 8 Triad, 1,5 mm² XLPE, OAM, PVC, 300 Volt rated instrumentation cabling** **Unit: number (No)**

The rate shall include full compensation for the termination of the required 8 Triad, 1,5 mm² XLPE, OAM, PVC, 300 Volt rated instrumentation cabling including all peripherals to ensure a complete and functional installation.

- af) Terminate 12 Triad, 1,5 mm² XLPE, OAM, PVC, 300 Volt rated instrumentation cabling** **Unit: number (No)**

The rate shall include full compensation for the termination of the required 12 Triad, 1,5 mm² XLPE, OAM, PVC, 300 Volt rated instrumentation cabling including all peripherals to ensure a complete and functional installation.

- ag) Battery Operated Electromagnetic flow sensor and signal convertor** **Unit: number (No)**

The rate shall include full compensation for the installation, testing and pre-commissioning of the Battery Operated Electromagnetic flow sensors and flow convertors including both flow sensor and flow convertor, lithium type battery, data logger, stainless steel flanges, stainless steel electrodes, Rilsan or hard rubber liner, LCD high contrast display, communication module with pulse and status outputs, die-cast aluminium polyurethane coated flow convertor housing, brackets and pedestals, enclosures, instrumentation cables and surge protection, inclusive of all labour, installation materials and sundries for a fully operational and serviceable installation.

- ah) PROFIBUS-DP, impedance between 135 – 165 Ohm, Capacitance \leq 30 pF/m, wire diameter \geq 0.64 mm, conductive area \geq 0.34 mm² Belden purple cabling** **Unit: metre (m)**

The rate shall include full compensation for the installation, testing and pre-commissioning of the required PROFIBUS-DP, impedance between 135 – 165 Ohm, Capacitance \leq 30 pF/m, wire diameter \geq 0.64 mm, conductive area \geq 0.34 mm² Belden purple cabling including all peripherals to ensure a complete and functional installation.

- ai) Installation, Testing and Pre-commissioning of PLC and SCADA systems** **Unit: lump sum (Sum)**

The rate shall include full compensation for the installation, testing and pre-commissioning of the PLC and SCADA systems in the designated areas, inclusive of complete I/O marshalling IP65 rated stainless steel cabinets / enclosures with terminal strips, labelling, cable glands and dual connected power supplies to instruments, wiring, terminals, trunking, numbering systems, circuit breakers, installation of software packages, power supplies for PLC, expansion racks, mounting brackets, interface modules required for coupling to the network and all other material and Plant items required to give a fully operational PLC and SCADA system after loading of software and installation. The rate shall be all inclusive of all required material and labour but excluding the provision of unique software for the PLC and SCADA which will be measured separately.

- aj) Terminate 24 fibre optic Single mode – 9/125 micro metre Polyethylene outer sheath, Galvanized steel wire armour, PVC bedding sheath cabling** **Unit: metre (m)**

The rate shall include full compensation for the terminations of the required 24 fibre optic Single mode – 9/125 micro metre Polyethylene outer sheath, Galvanized steel wire armour, PVC bedding sheath cabling including all peripherals to ensure a complete and functional installation.

- ak) Terminate PROFIBUS-DP, impedance between 135 – 165 Ohm, Capacitance ≤ 30 pF/m, wire diameter ≥ 0.64 mm, conductive area ≥ 0.34 mm² Belden purple cabling** **Unit: metre (m)**

The rate shall include full compensation for the terminations of the required PROFIBUS-DP, impedance between 135 – 165 Ohm, Capacitance ≤ 30 pF/m, wire diameter ≥ 0.64 mm, conductive area ≥ 0.34 mm² Belden purple cabling including all peripherals to ensure a complete and functional installation.

- al) Valve open and close confirmation proximity switches** **Unit: number (No)**

The rate shall include full compensation for the installation, testing and pre-commissioning of the specified Valve open and close confirmation proximity switches for a complete and operational installation as specified including surge protection.

41.004 Spares

Unit : Provisional sum

The payment for specific spare items required by the Employer shall be made per item listed in the Commissioning and Trial Operation parts of the Bill of Quantities. Payment Item 48.007 is relevant in this regard.

Payment for spares identified by the Contractor as per 41.6 and approved by the Engineer, shall be made from the provisional sums allowed for this in the Bill of Quantities. The rates provided for these spares shall provide for the manufacture, supply, delivery to Site and handing over of the spares ordered and shall include permanent packing for long term storage. The spares shall be manufactured at the same time as the installed items.