Preparing Activity: USACE Superseding without Revision
UFGS-40 95 00 (November 2019)

UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated July 2023
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DIVISION 40 - PROCESS INTERCONNECTIONS

SECTION 40 60 00

PROCESS CONTROL

05/20

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USACE / NAVFAC / AFCEC / NASA **UFGS-40 60 00 (May 2020)**

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UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated July 2023

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SECTION 40 60 00

PROCESS CONTROL
05/20

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NOTE: This guide specification covers the requirements for process instrumentation and control systems.

Adhere to UFC 1-300-02 Unified Facilities Guide Specifications (UFGS) Format Standard when editing this guide specification or preparing new project specification sections. Edit this guide specification for project specific requirements by adding, deleting, or revising text. For bracketed items, choose applicable item(s) or insert appropriate information.

Remove information and requirements not required in respective project, whether or not brackets are present.

Comments, suggestions and recommended changes for this guide specification are welcome and should be submitted as a Criteria Change Request (CCR).

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PART 1 GENERAL

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NOTE: Use Section 43 21 29 FLOW MEASURING EQUIPMENT [POTABLE WATER] [SEWAGE TREATMENT PLANT] for simple liquid flow applications.

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1.1 REFERENCES

****

NOTE: This paragraph is used to list the publications cited in the text of the guide specification. The publications are referred to in the text by basic designation only and listed in this paragraph by organization, designation, date, and title.

Use the Reference Wizard's Check Reference feature when you add a Reference Identifier (RID) outside of the Section's Reference Article to automatically place the reference in the Reference Article. Also use the Reference Wizard's Check Reference feature to update the issue dates.

References not used in the text will automatically be deleted from this section of the project specification when you choose to reconcile references in the publish print process.

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The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

ANSI C12.1	(2014; Errata 2016) Electric Meters - Code for Electricity Metering
ANSI INCITS 154	(1988; R 2004) Office Machines and Supplies - Alphanumeric Machines - Keyboard Arrangement

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)

ASME B31.8	(2022; Supplement 2022) Gas Transmission and Distribution Piping Systems
ASME BPVC SEC VIII	(2010) Boiler and Pressure Vessel Codes: Section VIII Rules for Construction of Pressure Vessel

AMERICAN WATER WORKS ASSOCIATION (AWWA)

AWWA C606	(2022) Grooved and Shouldered Joints

ASTM INTERNATIONAL (ASTM)

ASTM B88	(2022) Standard Specification for Seamless Copper Water Tube
ASTM B88M	(2020) Standard Specification for Seamless Copper Water Tube (Metric)
ASTM D635	(2018) Standard Test Method for Rate of Burning and/or Extent and Time of Burning of Plastics in a Horizontal Position
ASTM D638	(2014) Standard Test Method for Tensile Properties of Plastics
ASTM D792	(2013) Density and Specific Gravity (Relative Density) of Plastics by Displacement
ASTM D1238	(2013) Melt Flow Rates of Thermoplastics

	by Extrusion Plastometer
ASTM D1693	(2015) Standard Test Method for Environmental Stress-Cracking of Ethylene Plastics
ASTM D2000	(2018) Standard Classification System for Rubber Products in Automotive Applications

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE 142	(2007; Errata 2014) Recommended Practice for Grounding of Industrial and Commercial Power Systems - IEEE Green Book
IEEE C37.90.1	(2013) Standard for Surge Withstand Capability (SWC) Tests for Relays and Relay Systems Associated with Electric Power Apparatus
IEEE C62.41.1	(2002; R 2008) Guide on the Surges Environment in Low-Voltage (1000 V and Less) AC Power Circuits
IEEE C62.41.2	(2002) Recommended Practice on Characterization of Surges in Low-Voltage (1000 V and Less) AC Power Circuits

INTERNATIONAL ELECTROTECHNICAL COMMISSION (IEC)

IEC 60584-1	(2013) Thermocouples - Part 1: EMF Specifications and Tolerances
IEC 61131-3	(2013) Programmable Controllers - Part 3: Programming Languages

INTERNATIONAL SOCIETY OF AUTOMATION (ISA)

ISA 7.0.01	(1996) Quality Standard for Instrument Air
ISA 92.00.01	(2010; R 2015) Performance Requirements for Toxic Gas Detectors
ISA 101.01	(2015) Human Machine Interfaces for Process Automation Systems

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

NEMA 250	(2020) Enclosures for Electrical Equipment (1000 Volts Maximum)
NEMA ICS 1	(2022) Standard for Industrial Control and Systems: General Requirements
NEMA ICS 2	(2000; R 2020) Industrial Control and Systems Controllers, Contactors, and Overload Relays Rated 600 V
NEMA ICS 3	(2005; R 2010) Medium-Voltage Controllers

	Rated 2001 to 7200 V AC
NEMA ICS 4	(2015) Application Guideline for Terminal Blocks
NEMA ICS 5	(2017) Industrial Control and Systems: Control Circuit and Pilot Devices

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70	(2023) National Electrical Code
NFPA 79	(2015) Electrical Standard for Industrial Machinery

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY (NIST)

NIST SP 250	(1991) Calibration Services Users Guide

U.S. NATIONAL ARCHIVES AND RECORDS ADMINISTRATION (NARA)

40 CFR 60	Standards of Performance for New Stationary Sources
47 CFR 15	Radio Frequency Devices

UNDERWRITERS LABORATORIES (UL)

UL 94	(2023; Reprint May 2023) UL Standard for Safety Tests for Flammability of Plastic Materials for Parts in Devices and Appliances
UL 508A	(2018; Reprint Jul 2022) UL Standard for Safety Industrial Control Panels
UL 1059	(2019; Reprint Jul 2022) UL Standard for Safety Terminal Blocks

1.2 SUBMITTALS

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NOTE: Review submittal description (SD) definitions in Section 01 33 00 SUBMITTAL PROCEDURES and edit the following list, and corresponding submittal items in the text, to reflect only the submittals required for the project. The Guide Specification technical editors have classified those items that require Government approval, due to their complexity or criticality, with a "G." Generally, other submittal items can be reviewed by the Contractor's Quality Control System. Only add a “G” to an item, if the submittal is sufficiently important or complex in context of the project.

For Army projects, fill in the empty brackets following the "G" classification, with a code of up to three characters to indicate the approving authority. Codes for Army projects using the

Resident Management System (RMS) are: "AE" for Architect-Engineer; "DO" for District Office (Engineering Division or other organization in the District Office); "AO" for Area Office; "RO" for Resident Office; and "PO" for Project Office. Codes following the "G" typically are not used for Navy, Air Force, and NASA projects.

The "S" classification indicates submittals required as proof of compliance for sustainability Guiding Principles Validation or Third Party Certification and as described in Section 01 33 00 SUBMITTAL PROCEDURES.

Choose the first bracketed item for Navy, Air Force and NASA projects, or choose the second bracketed item for Army projects.
****

Government approval is required for submittals with a "G" or "S" classification. Submittals not having a "G" or "S" classification are [for Contractor Quality Control approval.][for information only. When used, a code following the "G" classification identifies the office that will review the submittal for the Government.] Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-02 Shop Drawings

Contractor Design Drawings; G[, [_____]]

Draft As-Built Drawings; G[, [_____]]

SD-03 Product Data

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NOTE: Delete the requirement for compressed air station on systems that do not utilize pneumatic devices.
****

Control Drawings

Sensors and Meters

Performance Verification Test (PVT)

Factory Test Procedure

Compressed Air Stations

SD-06 Test Reports

Factory Test Report

Testing, Adjusting and Commissioning

Performance Verification Test(PVT)

Endurance Test

Turbine Flowmeter

SD-07 Certificates

Control and Sensor Wiring

Ground Rods

Wiring

Installation

SD-10 Operation and Maintenance Data

Training Manual; G[, [_____]]

Control System; G[, [_____]]

SD-11 Closeout Submittals

Final As-Built Drawings; G

1.3 SITE ENVIRONMENTAL CONDITIONS

The expected site environmental conditions are a minimum of [_____] degrees C [_____] degrees F and a maximum of [_____] degrees C [_____] degrees F.

1.4 SEQUENCING

****

NOTE: Provide Table I provides bracketed text in which the following site number of days between items may be specified. In many cases this information will be specified elsewhere. When project schedule is specified elsewhere remove bracketed text and Table I will provide sequencing but not specific intervals. If time intervals are to be specified here keep the bracketed text and enter the number of days in the space provided.

****

TABLE I: PROJECT SEQUENCING specifies the sequencing of submittals as specified in paragraph SUBMITTALS (denoted by an 'S' in the 'TYPE' column) and activities as specified in PART 3 EXECUTION (denoted by an 'E' in the 'TYPE' column).

1.5.1 Sequencing for Submittals

The sequencing specified for submittals is the deadline by which the submittal must be initially submitted to the Government. Following submission there will be a Government review period as specified in Section 01 33 00 SUBMITTAL PROCEDURES. If the submittal is not accepted by the Government, revise the submittal and resubmit it to the Government within [14] [_____] days of notification that the submittal has been rejected. Upon re-submittal there will be an additional Government review period. If the submittal is not accepted the process repeats until the submittal is accepted by the Government.

1.5.2 Sequencing for Activities

The sequencing specified for activities indicates the earliest the activity may begin.

1.5.3 Abbreviations

In TABLE I the abbreviation AAO is used for 'after approval of' and 'ACO' is used for 'after completion of'.

PART 2 PRODUCTS

2.1 SYSTEM DESCRIPTION

****
NOTE: Add site specific requirements. Supplement this specification with drawings which include a piping and instrumentation diagram (P&ID) and a comprehensive control diagram showing devices, a sequence of operations, and a points schedule.
****

The process control system must be used to monitor and control the operation of process equipment as specified and in accordance with the sequence of operation and control schematics shown on the drawings. The process control system must provide for operator interaction, overall process control system supervision, and process equipment control and monitoring. The system must adhere to Section 25 05 11 CYBERSECUIRITY OF FACILITY-RELATED CONTROL SYSTEMS. Provide hardware configured and sized to support expansion as specified and shown on the drawings.

The process control system must be comlete including sensors, field preamplifiers, signal conditioners, offest and span adjustments, amplifiers, transducers, transmitters, control devices, engineering units conversions and algorithms for the applications; and must maintain the specified end-to-end process control loop accuracy from the sensor to display and final control element. Connecting conductors must be suitable for installed controls. Enclosers must be rated for NEMA [1] [4] [_____].

2.1.1 Operation

****
NOTE: Show the number of control panels to be provided on the drawings. Provide setpoint ranges, alarm settings and other parameters not addressed in the sequence of control in a points schedule on the drawings.
****

The process control system provided under this specification must operate using a combination of sequential function charts, function block diagrams, structured text, instruction, and ladder logic type as defined in IEC 61131-3 and supervisory control to provide the required sequences of operation. Input data to the controller must be obtained by using instruments and controls interfaced to mechanical, electrical, utility systems and other systems as shown and specified. All required setpoints, settings, alarm limits, and sequences of operation must be as identified [in the database/ settings tables] [and] [or] [sequences of operation indicated].

2.1.2 Points

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NOTE: Provide an input/output (I/O) summary table on the drawings. List all inputs to and outputs from the process control system. Identify each point type, analog, binary, pulse accumulator; input, output, control, monitoring, etc. Identify alarms, trends, software and failure mode setting associated with each point in the table. Label each point so that it can be easily referenced to the process control system schematic drawings or process and instrumentation drawings.

****

Provide inputs to and outputs from the process control system in accordance with the Input/Output (I/O) Summary Table indicated. Each connected analog output (AO), analog input (AI), binary output (BO), binary input (BI), pulse accumulator (PA) input and other input or output device connected to the control system must represent a "point" where referred to in this specification.

2.1.3 Building Telecommunications Cabling (BTC)

****

NOTE: Include in the project specification any of the following UFGS for the appropriate BTC: Section 27 10 00 BUILDING TELECOMMUNICATIONS CABLING SYSTEM, Section 33 82 00 TELECOMMUNICATIONS OUTSIDE PLANT (OSP).

****

Provide data transmission systems for communication [between PLCs] [and] [between PLCs and the central station] [and] [server] as specified in [Section 27 10 00 BUILDING TELECOMMUNICATIONS CABLING SYSTEM][Section 33 82 00 TELECOMMUNICATIONS OUTSIDE PLANT (OSP)] and as indicated.

2.1.4 System Reliabilty

The system must be designed for maximum reliability, safety and integrity while maintaining an availability of [99.99%] or better.

2.2 MATERIALS AND EQUIPMENT

2.2.1 Product Certifications

****

NOTE: Note: FCC part 15 does not apply to many of the computing devices used for industrial applications. Title 47 Part 15 provides for exqamption of unintentional radiators considered "digital devices used exclusively as an electronic control" or power system utilized by a public utility or in and industrial plant.

****

Computing devices, as defined in FCC Part 15, supplied as part of the process control system must be certified to comply with the requirements

of Class B computing devices.

2.2.2 Standard Products

Materials and equipment must be standard unmodified products of a manufacturer regularly engaged in the manufacturing of such products. Units of the same type of equipment must be products of a single manufacturer. Items of the same type and purpose must be identical and supplied by the same manufacturer, unless replaced by a new version approved by the Government.

2.2.3 Nameplates

Each major component of equipment must have the manufacturer's name and address, and the model and serial number in a conspicuous place. Laminated plastic nameplates must be provided for equipment devices and panels furnished. Each nameplate must identify the device, such as pump "P-1" or valve "VLV-402". Labels must be coordinated with the schedules and the process and instrumentation drawings. Laminated plastic must be 3 mm 1/8 inch thick, white with black center core. Nameplates must be a minimum of 25 by 75 mm 1 by 3 inches with minimum 6 mm 1/4 inch high engraved block lettering. Nameplates for devices smaller than 25 by 75 mm 1 by 3 inches must be attached by a nonferrous metal chain. All other nameplates must be attached to the device.

2.3 GENERAL REQUIREMENTS

****
Show hazardous area classification on the drawings.
****

Equipment located outdoors, not provided with climate controlled enclosure, must be capable of operating in the ambient temperature range. Electrical equipment will conform to Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM. Equipment and wiring must be in accordance with NFPA 70, with proper consideration given to environmental conditions such as moisture, dirt, corrosive agents, and hazardous area classification.

2.4 SENSORS

****
NOTE: Provide a schedule on the drawings that includes all required instrumentation. Provide device information such as: Alpha-Numeric designator, the operating range (pressure, temperature, flow) of construction material, media to be monitored or controlled, control signal, valve type (2-way, 3-way, normally open, normally closed, etc.). Include automatic control valves and manually operated control valves.

It may be appropriate to defer the enclosure requirements to the electrical section or to provide different enclosures for different areas: indoor, outdoor, areas with hazard classification indicated on the drawings, etc. Within an area, the requirements should be consistent.
****

2.4.1 Transmitter

****
NOTE: Show all panels on the drawings. Distance between transmitter and sensor is critical. Specifying the digital communication of sensors opens up the possibility of proprietary sensors.
****

Unless indicated otherwise, each sensor must be provided with a transmitter, selected to match the sensor. Except where specifically indicated otherwise on the drawings, the transmitter must be provided with a [four] [_____] digit or analog visual display of the measured parameter and with a [4 to 20 mAdc] [binary] [0-10 vdc] [_____] output signal proportional to the level of the measured parameter. Accuracy must be plus or minus [0.5] [1] [2] [5] [_____] percent of full scale reading with output error not exceeding plus or minus [0.25] [0.5] [_____] percent of [the calibrated measurement] [full scale]. Transmitter must be located where indicated, mounted integrally with the sensor, pipe mounted, wall mounted or installed in the control panel. The distance between the sensor and transmitter must not exceed the manufacturer's recommendation. Field preamplifiers and signal conditioners must be included when necessary to maintain the accuracy from sensor to the programmable logic controller or recorder.

2.4.2 Off-Gas or Vapor Service

****
NOTE: If there are substantial temperature or pressure changes across a blower or unit process, it may be cost effective to specify differing requirements upstream and downstream of the process.
****

Sensors and meters in [off-gas] [or] [vapor] service must be rated for continuous duty service at fluid approach velocities from 2.5 to 25 m/s 500 to 5000 fpm with correspondingly higher constriction velocities over a fluid temperature range from minus [18] [25] [_____] degrees C to [40] [50] [66] [_____] degrees C minus [0] [15] [_____] degrees F to [105] [120] [150] [_____] degrees F at pressures from minus [50] [_____] kPa gage up to [100] [700] [_____] kPa gage minus [7.2] [_____] psi gage up to [15] [100] [_____] psi gage.

2.4.3 Liquid Service

****
NOTE: If there are substantial temperature or pressure changes across a pump or unit process, it may be cost effective to specify differing requirements upstream and downstream of the process.
****

Sensors and meters in liquid service must be rated for continuous duty service at fluid approach velocities from [0.1] [0.75] [_____] m/s to [2] [3] [_____] m/s [0.327] [2.5] [_____] ft/s to [7] [10] [_____] ft/s with correspondingly higher constriction velocities over a fluid temperature range from [0] [-50] [_____] degrees C to [40] [50] [250] [_____] degrees C [32] [-58] [_____] degrees F to [105] [120] [482] [_____] degrees F at pressures up to [70] [350] [700] [1000] [_____] kPa [10] [50] [100]

[150][_____] psi gage.

2.4.4 Flow Rate Sensors and Meters

****

NOTE: Most flow meters need straight unobstructed piping of 10 pipe diameters upstream and 5 pipe diameters downstream. Verify that the location will allow installation meeting the criteria or that the accuracy of type of flow meter selected is not affected by the location. Design includes attendant elements such as mounting devices, differential pressure transmitter and interpretive ancillary components in this and other sections and on the drawings to complete the system.

****

Liquid flow indication must be provided in [L/s] [gpm]. [Off-gas] [or] [Vapor] flow indication must be provided in [cubic m/second] [cubic feet per minute]. Pressure taps must incorporate appropriate snubbers. Unless indicated otherwise, the flow transmitter must produce a signal that is proportional to the volumetric flow rate, compensated for fluid temperature, and must have an accuracy of plus or minus [1] [3] [_____] percent of [full flow] [the actual flow]. Flow transmitter must be located within [5 m] [15 feet] of the flow element. The flow transmitter must include a [digital] [_____] readout of the volumetric flow rate to [3] [_____] significant figures. [The controller must be provided with a minimum of three alarm lights. The first alarm light must indicate when the lower (warning) detection level has been exceeded. The second alarm light must indicate when the upper (alarm) detection level has been exceeded. The third alarm light must indicate a controller malfunction, including loss of power or loss of sensor input.] [The controller must be provided with a minimum of three sets of dry contacts rated in accordance with NEMA ICS 1. The first set of contacts must close when the lower (warning) detection level has been exceeded. The second set of contacts must close when the upper (alarm) detection level has been exceeded. The third set of contacts must close when a controller malfunction has occurred, including loss of power or loss of sensor input.] The alarm levels must be individually adjustable. The controller must be provided with an audible warning horn that sounds when the upper detection level has been exceeded, and a warning horn silence button. The controller must provide a [4-20 mAdc] [_____] output signal to the programmable logic controller, proportional to the measured parameter. The controller must be provided with an internal battery to maintain operation for a minimum of 12 hours if power is lost. Flow rate must be controlled to within plus or minus [5] [_____] percent of the design flow.

2.4.4.1 Flow Nozzle

Flow nozzle must be made of austenitic stainless steel. The inlet nozzle form must be elliptical and the nozzle throat must be the quadrant of an ellipse. The thickness of the nozzle wall and flange must be such that the accuracy will not be degraded by distortion of the nozzle throat from strains caused by the pipeline temperature and pressure, flange bolting, or other methods of installing the nozzle in the pipeline. The outside diameter of the nozzle flange or the design of the flange facing must be such that the nozzle throat is centered accurately in the pipe.

2.4.4.2 Flow Switch

Flow switch must have a repetitive accuracy of plus or minus [10] [_____] percent of actual flow setting. Switch actuation must be adjustable over the operating flow range. Flow switch for use in [water] [contaminated groundwater] [sewage] [air] [vapor] [gas] [hot gas] [corrosive vapor] [_____] system must be rated for use and constructed of suitable materials for installation in the environment encountered. The flow switch must have non flexible [paddle] [shuttle/piston] [thermal] [pezio] with Form C snap action contacts, rated in accordance with NEMA ICS 1.

****

NOTE: Magnetic flowmeters are to be used only for conductive fluids.

****

2.4.4.3 Magnetic Flowmeter

Magnetic flowmeter must be [non-intrusive,] DC pulse type and must measure fluid flow through the use of a self generated magnetic field. The meter must have automatic zeroing circuitry. The magnetic flow element must be encapsulated in [type 300 stainless steel] [or] [anodized aluminum]. Flowmeter must be capable of measuring up to a maximum flow velocity of [3] [_____] m/s [10] [_____] fps. The metering tube must be constructed of [316 stainless steel] [anodized aluminum] [_____]. The meter must be rated for a process temperature range of [32 to 212 F] [0 to 100C] and [0 to 149F] [-18 to 65C] ambient. The maximum pressure drop across the meter and appurtenances must be 34 kPa 5 psi at the maximum flow rate.

2.4.4.4 Natural Gas or Propane Flow Meter

Flowmeter for natural gas or propane flows, corrected to standard conditions, of up to 19.7 L/sec 2500 SCFH must be of the positive displacement diaphragm or bellows type and for flows above 0.02 cu. m/sec 2500 cfh, must be of the axial flow turbine type. Meters must be designed specifically for natural gas or propane supply metering and rated for the pressure, temperature and flow rates of the installation. Permanent meters must be suitable for operation in conjunction with an energy monitoring and process control system. Meter body must be constructed of [316 stainless steel] [_____]. Meter must have a minimum turndown ratio of [10] [_____] to [1] [_____] with an accuracy of plus or minus [1] [_____] percent of actual flow rate. The meter index must include a direct reading mechanical totalizing register and electrical impulse dry contact output for remote monitoring. The electrical impulse dry contact output must provide not less than 1 pulse per 2.8 cubic meters 100 cubic feet of gas and must require no field adjustment or calibration. The highest electrical impulse rate available from the manufacturer, not exceeding [15] [_____] pulses per second, for the installed application must be provided.

2.4.4.5 Orifice Plate

****

NOTE: Show the operating ranges and ratings on the drawings for operating pressures and flow. Differential pressure output ranges for flow conditions are to be coordinated. Accuracy of computed flow will be improved with inclusion of temperature and pressure of upstream conditions.

****

Orifice plate must be made of [304] [316] series stainless steel sheet. The outlet side of the bore must be beveled at a 45 degree angle. The thickness of the cylindrical face of the orifice must [not exceed one-fiftieth of the pipe inside diameter or one-eighth of the orifice bore, whichever is smaller] [be 3.3 mm 0.125 inch nominal]. The orifice plate must be flat within 0.10 mm 20 mils. The orifice surface roughness must not exceed 0.5 micron 0.02 mils. Orifice plates must be concentric plates with a square and sharp upstream edge of the orifice. Orifice bore must be designed to match the operating parameters stated in the drawings. Plate must be permanently identified with line size, flange rating, orifice bore diameter, plate thickness and material. The accuracy must be plus or minus [1] [_____] percent of full flow.

2.4.4.6 Paddle Type Flowmeter

Sensor accuracy must be plus or minus [1] [_____] percent of rate of flow, minimum operating flow velocity must be [0.3] [_____] m/s [1.0] [_____] fps. Sensor repeatability and linearity must be plus or minus [1] [_____] percent. Sensor must be non-magnetic, with forward curved impeller blades designed for water containing debris. Wetted materials must be made from non-corrosive materials and must not contaminate water. The sensor must be provided with isolation valves. The transmitter housing must be a NEMA 250 Type 4 enclosure. The sensor must be rated for installation in pipes of 76 mm to 1 m 3 to 40 inch diameters.

2.4.4.7 Pitot Tube Air Flow Measurement Array (AFMA)

Each Pitot Tube AFMA must contain an array of velocity sensing elements. The velocity sensing elements must be of the multiple pitot tube type with averaging manifolds. The sensing elements must be distributed across the duct cross section in the quantity and pattern specified or recommended by the published installation instructions of the AFMA manufacturer.

a. Pitot Tube AFMAs for use in airflows over 3.0 m/s 600 fpm must have an accuracy of plus or minus [5] percent over a range of 2.5 to 12.5 m/s 500 to 2500 fpm.

b. Pitot Tube AFMAs for use in airflows under 3.0 m/s 600 fpm must have an accuracy of plus or minus [5] percent over a range of 0.6 to 12.5 m/s 125 to 2500 fpm.

2.4.4.8 Annular Pitot Tube

****

NOTE: Annular pitot tubes should not be used where the flow is pulsating or where pipe vibration is allowed. Pulse flow is characteristic of positive displacement pumps and blowers.

****

Sensor must have an accuracy of plus or minus [2] [_____] percent of full flow and a repeatability of plus or minus [0.5] [_____] percent of measured value. Annular pitot tube must be averaging type differential pressure sensors with no less than four total head pressure ports with an averaging manifold and at least one static port made of austenitic stainless steel. The total head pressure ports must extend diametrically across the entire pipe.

2.4.4.9 Electronic AFMA

Each electronic AFMA must consist of an array of velocity sensing elements of the resistance temperature detector (RTD) or thermistor type. The sensing elements must be distributed across the duct cross section in the quantity and pattern specified or recommended by the published application data of the AFMA manufacturer. Electronic AFMAs must have an accuracy of plus or minus [5] percent over a range of [.6] [_____] m/s to [25][50] m/s [120] [_____] fpm to [5,000] [10,000] fpm and the output must be temperature compensated over a range of 0 to 100 degrees C 32 to 212 degrees F.

2.4.4.10 Positive Displacement Flowmeter

Output accuracy must be plus or minus [2] percent of the flow range. The flow meter must be a direct reading, gerotor, nutating disc or vane type displacement device rated for liquid service. A counter must be mounted on top of the meter, and must consist of a non-resettable mechanical totalizer for local reading, and a pulse transmitter for remote reading. The totalizer must have a six digit register to indicate the volume passed through the meter in L gallons. A sweep-hand dial will indicate down to 5 L 1 gallon. The pulse transmitter must have a hermetically sealed reed switch which is activated by magnets fixed on gears of the counter. The meter must have a bronze body with threaded or flanged connections as required for the application. The maximum pressure drop at full flow must be 35 kPa 5 psi gage.

2.4.4.11 Turbine Meters

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NOTE: Verify that the location will allow installation with the minimum straight unobstructed piping of 10 pipe diameters upstream and 5 pipe diameters downstream.

****

Turbine meters wetted metal components must be [nickel plated brass][series 300 stainless steel] [series 316 stainless steel][bronze] with an accuracy of plus or minus [1] [_____] percent from [30] [_____] percent to 100 percent of actual flow.

2.4.4.12 Turbine Flowmeter

****

NOTE: Verify that the location will allow installation with the minimum straight unobstructed piping of 10 pipe diameters upstream and 5 pipe diameters downstream. Placement downstream of the blower or pump is preferable for head loss considerations.

****

Design of the flowmeter probe assembly must incorporate integral flow, temperature, and pressure monitoring. The meter flow sensing element must be [single][double] turbine and operate over the temperature range with a pressure loss limited to [1] [_____] percent of operating pressure at maximum flow rate. The internal temperature transmitter must monitor the full temperature range of the fluid. The integral pressure

transmitter must monitor the pressure range with end limits of [0] [_____] MPa [0] [_____] psi to [2] MPa [300] psi gage. The flowmeter electronics must be scaled and rescaled in the field when application data changes. The flowmeter must be designed for installation in pipe sizes of 75 mm 3 inches and larger to accommodate maximum probe insertion depths up to 1.1 m 44 inches. The retractor assembly must have a rotor depth gage having graduations of 2.5 mm 0.1 inches to determine exact position of turbine rotor in the pipe. The meter retractor assembly and the turbine rotor assembly must be constructed of [Series 300 stainless steel] [_____] with [polytetrafluoroethylene (PTFE)] [_____] seals. The meter retractor assembly must be designed to protect the turbine rotor during insertion into the pipeline. Retraction of the turbine rotor must be accomplished by using a hand wheel and must enable insertion and removal of the meter without system shutdown. The retractor assembly must include an isolation valve providing a means of removal of the meter from service to allow for field maintenance and field replacement of the rotor assembly or parts. The turbine rotor must have an over range operating capacity of 150 percent of maximum flow for up to 5 seconds. The rotor must be calibrated at the factory in an actual flow of similar fluid over the flow range performed on test equipment with accuracy traceable to the National Institute of Standards and Technology (NIST). A copy of the calibration test data, including all of the physical parameters under which the calibration tests were performed, must be submitted with each turbine rotor. Calibration test data must be analyzed to determine the rotor's arithmetic average "K" factor, the best line fit and the plus or minus deviation from these figures. Turbine flowmeter accuracy must be plus or minus 1 percent of reading for a minimum turndown ratio of 1:1 through a maximum turndown ratio of 50:1. Repeatability must be plus or minus 0.25 percent of reading. Accuracy of the transmitter must be plus or minus 0.25 percent over the calibrated span. The turbine rotor response time from minimum to maximum flow must be less than 10 milliseconds. The flowmeter must include one of the following: dry contact pulse outputs, 4-20mA, 0-10Vdc or 0-5Vdc outputs.

2.4.4.13 Ultrasonic Flowmeter

****

NOTE: Doppler meters rely on reflectors in the flowing liquid. To obtain reliable measurements attention must be given to the lower limits for concentrations and sizes of solids or bubbles. The flow must also be rapid enough to keep these materials in suspension. One manufacturer gives values of 1.8 m/s 6 ft/s for solids and 0.75 m/s 2.5 ft/s for small bubbles. To perform within their stated specifications, some Doppler meters require a minimum Reynolds number of 4,000.

Transit-time meters rely on an ultrasonic signal's completely traversing the pipe, so the path must be relatively free of solids and air or gas bubbles. To perform within stated specifications, one type of transit-time meter requires a minimum Reynolds number of 10,000.

****

Ultrasonic flowmeter must utilize high frequency [Doppler shift] [transit-time] transducer. Flowmeter must be capable of measuring flow up to a maximum flow rate of [5] [_____] m/s [15] [ ] fps. Provide

Ultrasonic Flow Meters complete with matched transducers, self aligning installation hardware and transducer cables. Ultrasonic transducers must be optimized for the specific pipe and process conditions for the application. The flow meter accuracy must plus or minus 1 percent of rate from 0.3 to 12 meters/sec 0 to 40 ft/sec. The flowmeter must include one of the following: dry contact pulse outputs, 4-20mA, 0-10Vdc or 0-5Vdc output.

2.4.4.14 Variable Area Flow Indicator

Indicator must have an accuracy of plus or minus [5] [ ] percent of full scale. The body must be clear acrylic plastic with [brass] [stainless steel] end fittings. The float must be [glass] [or] [stainless steel]. The metering tube must be tapered and must be provided with a direct reading flow scale engraved on the meter body.

2.4.4.15 Venturi Tube

Venturi tube must be made of cast iron or cast steel and must have an accuracy of plus or minus [1] percent of full flow. The throat section must be lined with austenitic stainless steel. Thermal expansion characteristics of the lining must be the same as that of the throat casting material. The surface of the throat lining must be machined to a plus or minus 1.2 micron 50 mils finish, including the short curvature leading from the converging entrance section into the throat. The metering tube must be rated for continuous duty service at minimum pressure of [700] [_____] kPa [100] [_____] psi gage.

2.4.4.16 Vortex Shedding Flowmeter

The accuracy must be within plus or minus [0.8] [_____] percent of the actual volumetric flow. Steam meters must contain density compensation by direct measurement of temperature. Mass flow inferred from specified steam pressure are not acceptable. The flow meter body must be made of austenitic stainless steel and include a weather tight NEMA 4X electronics enclosure. Flowmeter must be rated for continuous duty service at minimum pressure of [700] [_____] kPa [100] [_____] psi gage. The vortex shedding flowmeter body must not require removal from the piping in order to replace the shedding sensor.

2.4.5 Level Instrumentation

****

NOTE: Indicate the location and the NFPA hazard classification on the drawings. Hazard classification of sumps and tank interiors frequently differ from the general area hazard classification. Include a schedule of level sensing elements with operating range requirements. Tabulation of devices is to be included on the drawings. Component identifiers are to be coordinated with the drawings. Use the Instrument Society of America (ISA) suggested alphanumeric system for development of discrete device numbering.

****

Pressure taps must incorporate appropriate snubbers. Relays and housing must be intrinsically safe or explosion proof as required by the NFPA

hazard rating for compatibility with the contents of the tank or sump. [The controller must be provided with a minimum of three alarm lights. The first alarm light must indicate when the lower (warning) detection level has been exceeded. The second alarm light must indicate when the upper (alarm) detection level has been exceeded. The third alarm light must indicate a controller malfunction, including loss of power or loss of sensor input.][The controller must be provided with a minimum of three sets of dry contacts rated in accordance with NEMA ICS 1. The first set of contacts must close when the lower (warning) detection level has been exceeded. The second set of contacts must close when the upper (alarm) detection level has been exceeded. The third set of contacts must close when a controller malfunction has occurred, including loss of power or loss of sensor input.] The alarm levels must be individually adjustable. The controller must be provided with an audible warning horn that sounds when the upper detection level has been exceeded, and a warning horn silence button. The controller must provide a [4-20 mAdc] [_____] output signal to the programmable logic controller, proportional to the measured parameter. The controller must be provided with an internal battery to maintain operation for a minimum of 12 hours if power is lost.

2.4.5.1 Bubble Type Level Sensor

Bubble type liquid level sensor must be of the hydrostatic balance type, operating from compressed air. Each gauging system must contain the following: an air set including [compressor] [or] [connection to plant air], compressed air pressure regulating valve, air filter and moisture trap; a sight feed bubbler with built-in adjusting needle valve; a tank entry gland with air supply and equalized pilot signal connections; a [13 mm 1/2 inch] [standard weight 316 stainless steel] [schedule 80 carbon steel] dip tube; a direct reading circular gauge 300 mm 12 inch in diameter calibrated for the connected tank and tank liquid; connections to the circular gauge and to the pressure transducer for zero setting and calibration check; a connecting bubbler supply and equalized pilot signal [copper] [aluminum] [stainless] tubing with minimum field made joints; and a pressure transmitter mounted at the top of the dip tube, selected to correspond to the range required to gauge the connected tank. Instrument air lines must be trace heated if there is a frost risk with an air flowrate of [28 L/H][1.0SCFH].

2.4.5.2 Capacitance Type Level Sensor

Liquid level sensor must produce a signal that is proportional to the measured level. Sensor must be capacitance type. Sensor must [work with conductive material] [work with non-conductive material] [be proximity or non-contact type]. The transmitter must have non-interacting zero and span adjustments, and must have an accuracy of plus or minus [0.1] [_____] percent of calibrated span. Assemblies must include wall bracket or mounting plate, austenitic stainless steel rods, stainless steel bolts and corrosion resistant housing.

2.4.5.3 Conductivity Switch

The switch must detect the presence of a fluid by measuring the electrical resistance between a sensor and a ground electrode. Electrodes must be constructed of [316 stainless steel] [Hastelloy] [titanium]. Electrodes must be fully clad using [polyolefin] [polytetrafluoroethylene (PTFE)]. The conductivity switch must be capable of [1] [2] [3] [4] separate level set points. The switch must [be provided with] [use the container as] a ground electrode. Electrode lengths must be as necessary, based on the

application and to meet the requirements of the control sequence. A relay switching point must be provided for each sensor. Contacts must be rated for a maximum of 240 VAC, 5 A. Switch must have a maximum response time of 2 seconds. Assembly must be [flange mounted] [NPT thread (male)] [including surface mounting bracket] and suitable for the indicated environment.

2.4.5.4 Displacement Type Level Switch

Liquid level switch must be displacement type, having a minimum of two tandem floats with each float independently activating a set of Form C contacts at two different level settings. Each switch must have an adjustable differential band. The mounting connections must be threaded, flanged or surface mounted to suit the application. All surfaces in contact with the tank contents must be austenitic stainless steel. The switch enclosure must be explosion proof for use in a hazardous environment, complete with a sealed water tight junction box, terminal block, and mounting plate. Each set of contacts must be snap action, dry contact type with one normally open and one normally closed, contact rated in accordance with NEMA ICS 1. The switch must be actuated by a magnetically equipped stainless steel displacer. Repetitive accuracy must be plus or minus 6 mm 1/4 inch of actual displacer setting.

2.4.5.5 Mercury Float Switch

Float switch assemblies for use in liquid systems must consist of wall bracket or mounting plate, galvanized steel rods, stainless steel bolts, explosion proof and corrosion resistant housing, and intrinsically safe relays. Each switch must consist of two normally open mercury switches, encapsulated in epoxy resin. The float casing must be polypropylene. The switch cable must be oil resistant neoprene or PVC cable with 4 No. 18 gauge stranded copper conductors, rated for 600 Volt application.

2.4.5.6 Reed Switch

Switch must consist of a transmitter tube with a reed strip located inside. The tube length must [be of sufficient length to permit adjustment of switch actuation within process parameters] [extend the full height of the tank]. A float containing a permanent magnet must fit over the transmitter tube and must move up and down with the liquid level. The transmitter tube and sliding float assembly must be as required for the application as shown on the drawings. Wetted parts must be [_____], [316 stainless steel,] [PVC,] [polypropylene,] or [polytetrafluoroethylene (PTFE)] suitable for the installed service indicated. Assembly must be [flange mounted] [NPT thread (male)] [include surface mounting bracket]. Maximum switching power must be [15 Watts], maximum switching current [1 amp], maximum carrying current [200Vdc], breakdown voltage [300Vdc], and initial contact resistance [0.10 ohms]. Maximum operating time must be [0.50 msec].

2.4.5.7 Non-Contact Ultrasonic Level Sensor

The sensor must be microprocessor based and must provide continuous, non-contact level measurement of liquids and solids utilizing microwave pulsed time of flight measurement method. [Sensor must have pushbutton calibration and LCD display.] The sensor must operate in a frequency band approved for industrial use. The sensor must be capable of measuring in a range of 0 to [7] [1] [_____] m 0 to [20] [3] [_____] feet with an accuracy of plus or minus [.25] [_____] percent of full scale and

repeatability [±0.125" 3mm]. The sensor must be capable of distinguishing between real echoes, reflections and background noise. The sensor must automatically compensate for temperature changes. The sensor must be capable of operating in a temperature range from minus [25] [_____] degrees C to [40] [50] [_____] degrees C minus [15] [_____] degrees F to [105] [120] [_____] degrees F. Assembly must be [flange mounted] [NPT thread (male)] [include surface mounting bracket] of sufficient size to eliminate echoing and suitable for the installed environment indicated. Mounting assembly must be suitable for service without requiring entry or drainage of the [vessel] [sump] where level is being measured.

2.4.5.8 Leak Detection

Double walled containment system leak detectors must use electrodes mounted in the interstices of double walled containment systems with a minimum time delay of [0.5] [_____] seconds. Leak detectors for open systems must be mounted at slab or floor level with either a minimum time delay of [0.5] [_____] seconds or a minimum built-in-vertical adjustment of [3] [_____] mm [1/8] [_____] inch to prevent activation due to high humidity. Detector must have a contact rating of 1.0 amps resistive or 200 mA inductive at 28 VDC. Leak detector panel must indicate the location and detector causing the alarmed state. The indicator must be manual reset type. A framed, non-fading half-size as-built location map in laminated plastic must be provided for the cable leak detection system in double containment piping systems indicating the as installed system configuration; sensing string layout must be furnished. Marks in meters feet along the length of pipeline interstitial cable must be provided as references to locate leaks.

2.4.6 Pressure Instrumentation

****

NOTE: Indicate on the drawings where visual indication of the measured pressure is required. Include a schedule of pressure sensing elements with operating range requirements. Include a tabulation of devices drawings. Component identifiers are to be coordinated with the drawings using the Instrument Society of America (ISA) suggested alphanumeric system for development of discrete device numbering.

****

Pressure taps must incorporate appropriate snubbers.

2.4.6.1 Pressure Controller

The controller must be provided with a minimum of three [alarm lights. The first alarm light must indicate when the lower (warning) detection level has been exceeded. The second alarm light must indicate when the upper (alarm) detection level has been exceeded. The third alarm light must indicate a controller malfunction, including loss of power or loss of sensor input] [sets of dry contacts rated in accordance with NEMA ICS 1. The first set of contacts must close when the lower (warning) detection level has been exceeded. The second set of contacts must close when the upper (alarm) detection level has been exceeded. The third set of contacts must close when a controller malfunction has occurred, including loss of power or loss of sensor input]. The alarm levels must be individually adjustable. The controller must be provided with an audible

warning horn that sounds when the upper detection level has been exceeded, and a warning horn silence button. The controller must provide a [4-20 mAdc] [_____] output signal to the programmable logic controller, proportional to the measured parameter. The controller must be provided with an internal battery to maintain operation for a minimum of 12 hours if power is lost. Pressures must be controlled to within plus or minus [5] [_____] percent of design pressures.

2.4.6.2 Pressure Sensor and Transducer

The sensing element must be either [capsule] [diaphragm] [bellows] [Bourdon tube] [solid state] type. The pressure transducer must withstand up to 150 percent of rated pressure, with an accuracy of plus or minus [1.0] [_____] percent of full scale selected to put the design range of the measured pressure in the middle third of the transducer's range. Pressure must be measured in [kPa psi] gage with a range, plus or minus [10] [_____] percent of design range and must be furnished with [display] [display and printout] to the nearest [1.0] [_____] kPa [0.145] [_____] psi. The transmitter output error must not exceed [0.1] [_____] percent of calibrated span.

2.4.6.3 Pressure Switch

Sensors must be [diaphragm] [Bourdon tube] [solid state] and must be constructed of [brass] [316 stainless steel] [_____]. Pressure switch must have a repetitive accuracy of plus or minus [5.0] [_____] percent of the operating range and must withstand up to [150] [_____] percent of rated pressure.

Switch actuation set point must be adjustable over the operating pressure range with a differential adjustment span of [20] [_____] to [40] [_____] percent of the range of the switch. The switch must have Form C snap-action contacts rated in accordance with NEMA ICS 1.

2.4.6.4 Differential Pressure

The sensor/transmitter assembly accuracy must be plus or minus [1] [_____] percent of full scale. The over pressure rating must be a minimum of [150] [_____] percent of the operating pressure. Transmitter must be suitable for installation with the low pressure connection removed.

2.4.6.5 Differential Pressure Switch

Provide differential pressure switches with a user-adjustable setpoint that are sized for the application such that the setpoint is between 25 percent and 75 percent of the full range. The over pressure rating must be a minimum of 150 percent of the highest design pressure of either input to the sensor. The switch must have two sets of contacts and each contact must have a rating greater than it's connected load. Contacts must open or close upon rise of pressure above the setpoint or drop of pressure below the setpoint as indicated. Each switch must have taps for sensing lines for connection of pressure fittings designed to sense fluid pressure. [For measuring air, gas or vapor stream differential pressure, these fittings must be of the angled-tip type with tips pointing into the air stream.] The adjustable differential range must be a maximum of [0.037] [0.125] [_____] kPa [0.15] [0.5] [_____] inches water at the low end to a minimum of [0.087] [1.49] [_____] kPa [0.35] [6.0] [_____] inches water at the high end. Two Form C contacts rated in accordance with NEMA ICS 1 must be provided.

2.4.6.6 Pneumatic to Electric (PE) Switch

Provide each switch with an adjustable set point range of [20] [_____] to [137] [_____] kPa [3.0] [_____] to [20] [_____] psi gage and an adjustable differential from [13] [_____] to [41] [_____] kPa [2.0] [_____] to [6.0] [_____] psi. Contacts must be Form C rated in accordance with NEMA ICS 1.

2.4.7 Temperature Instrumentation

****

NOTE: Component identifiers are to be coordinated with the drawings using the Instrument Society of America (ISA) suggested alphanumeric system for development of discrete devise numbering.

****

Temperature sensors may be provided without transmitters. Where transmitters are used, the range must be the smallest available from the manufacturer and suitable for the application such that the range encompasses the expected range of temperatures to be measured. The end to end accuracy includes the combined effect of sensitivity, hysteresis, linearity and repeatability between the measured variable and the end user interface (graphic presentation) including transmitters if used.

2.4.7.1 Temperature Controller

The controller must be provided with a minimum of [three] alarm lights. [The first alarm light must indicate when the lower (warning) detection level has been exceeded. The second alarm light must indicate when the upper (alarm) detection level has been exceeded. The third alarm light must indicate a controller malfunction, including loss of power or loss of sensor input]. Also [3] sets of dry contacts rated in accordance with NEMA ICS 1. [The first set of contacts must close when the lower (warning) detection level has been exceeded. The second set of contacts must close when the upper (alarm) detection level has been exceeded. The third set of contacts must close when a controller malfunction has occurred, including loss of power or loss of sensor input]. The alarm levels must be individually adjustable. The controller must be provided with an audible warning horn that sounds when the upper detection level has been exceeded, and a warning horn silence button. The controller must provide a [4-20 mAdc] [_____] output signal to the programmable logic controller, proportional to the measured parameter. The controller must be provided with an internal battery to maintain operation for a minimum of 12 hours if power is lost.

2.4.7.2 Fluid Temperature Range

****

NOTE: Include a schedule of temperature sensing elements with operating range requirements. The following includes sample tables to assist in defining the exposure and service requirements. Alternatively, tabulation of devices may be included on the drawings. Include a table on the drawings with the following headings:

ID No.	Description	Minimum, C	Maximum, C	Type

****

All devices must be suitable for process temperatures, which define the exposure of the element, and are described in the table on the drawings. Mercury must not be used in thermometers.

2.4.7.2.1 Type A Bimetal Thermometer

Direct reading, hermetically sealed, suitable for external adjustment. Accurate within 1 percent of full range. Stainless steel construction. Complete with thermowell. Thermometers must have either 230 mm 9 inch long scales or 90 mm 3.5 inch diameter dials, with insertion, immersion, or averaging elements.

2.4.7.2.2 Type B Remote Reading Gas/Vapor Thermometer

Direct reading, [stainless steel] [aluminum] [phenolic] case designed for panel mounting, complete with armor cable, bulb and ancillary components for complete system. Motionless design, resistant to shock and vibration and free from error created by elevation. Provided with gas operated molecular sieve. Accurate within 1 percent over full range.

2.4.7.2.3 Type C Resistance Temperature Detector (RTD)

RTD must be [platinum] [copper] [_____], with an accuracy of plus or minus [0.1] [_____] percent at 0 degrees C 32 degrees F. RTD must be encapsulated in [epoxy,] [stainless steel Series 300,] [anodized aluminum,] [copper].

2.4.7.3 Continuous Averaging RTD

****

NOTE: Indicate on the drawings where averaging temperature probes are required.

****

Continuous averaging RTD must have an accuracy of plus or minus [0.5] [2] [_____] degrees C [0.9] [3.6] [_____] degrees F at the reference temperature, and must be of sufficient length to ensure that the resistance represents an average over the cross-section in which it is installed. The sensor must have a bendable copper sheath.

2.4.7.4 Infrared Temperature Sensor

Infrared temperature sensor must be encapsulated in series 300 stainless steel or anodized aluminum. Sensor must have an accuracy of plus or minus 1 percent of temperature measured or 1.4 degrees C 2.5 degrees F, whichever is less.

2.4.7.5 Temperature Switch

****

NOTE: Include a table on the drawings with the following headings:

ID No.	Description	Minimum, C	Maximum, C

****

All devices must be suitable for process temperatures, which define the exposure of the element, and as described in the table shown on the drawings. Temperature switch must have a repetitive accuracy of plus or minus [1] [_____] percent of the operating ranges shown. Switch actuation must be adjustable over the operating temperature range. The switch must have Form C snap action contacts, rated in accordance with NEMA ICS 1.

2.4.7.6 Thermocouple

****

NOTE: Thermocouples should not be used for measuring temperatures below 260 degrees C 500 degrees F.

****

Thermocouple must be factory assembled with Series 300 stainless steel sheathing. Wiring insulation must be magnesium oxide. Minimum insulation resistance wire to wire or wire to sheath must be 1.5 megohm at 500 V dc. Thermocouple must be [Type E,] [Type K,] [Type J,] [or] [Type R]. Thermocouple error must not exceed that specified in IEC 60584-1. All wire/cable from thermocouple to transmitter must be of the type necessary to match the thermocouple used. Transmitter selected must match the type of thermocouple provided. The transmitter must include automatic cold junction reference compensation with span and offset adjustments, and upscale open thermocouple detection.

2.4.7.7 Thermowell

Thermowell must be monel, brass, or copper for use in water lines; wrought iron for measuring flue gases; and austenitic stainless steel for other applications. Calibrated thermowells must be provided with threaded plug and chain, 50 mm 2 inch lagging neck and inside diameter insertion neck as required for the application. The thermowell must include a connection box, sized to accommodate the temperature sensing devise.

2.4.8 Process Analytical Instrumentation

****

NOTE: Add requirements for additional site specific measurements, including span and accuracy for any application not included in this specification.

****

Probes must be easily removable without interrupting service. Sampling pumps must be included where necessary or applicable to the sensing device. For sensors integral to the electronic controller the sample may be drawn directly into the sensor or may be drawn through a sample tube. For sensors remotely located the sample may be drawn through a sample tube. Outdoor sample tubes must be heat traced. Sensor and controller construction must be suitable for operation in the monitored medium. Systems requiring automated zero and calibration gas or reagents must be provided with [_____] days supply of calibration gas or reagent. The controller must be provided with a minimum of three [alarm lights. The

first alarm light must indicate when the lower (warning) detection level has been exceeded. The second alarm light hall indicate when the upper (alarm) detection level has been exceeded. The third alarm light must indicate a controller malfunction, including loss of power or loss of sensor input] [sets of dry contacts rated in accordance with NEMA ICS 1. The first set of contacts must close when the lower (warning) detection level has been exceeded. The second set of contacts must close when the upper (alarm) detection level has been exceeded. The third set of contacts must close when a controller malfunction has occurred, including loss of power or loss of sensor input]. The alarm levels must be individually adjustable. The controller must be provided with an audible warning horn that sounds when the upper detection level has been exceeded, and a warning horn silence button. The controller must provide a [4-20 mAdc] [_____] output signal to the programmable logic controller, proportional to the measured parameter. The controller must be provided with an internal battery to maintain operation for a minimum of 12 hours if power is lost.

2.4.8.1 Ammonia Gas

The sensor must be capable of monitoring ammonia in the range of [0] [_____] to [100] [_____] mg/L with an accuracy of plus or minus [1] [_____] percent of full scale reading. The sensor response time must be [90] [_____] percent in a maximum of [20] [_____] seconds.

2.4.8.2 Calorimeter (Heat Capacity/Fuel Value)

Calorimeter must be a self-contained device capable of measuring the heat capacity of a sample. The colorimeter must measure the heat released from the sample by igniting the sample reading use of multiple temperature sensors. The sensor must be capable of detecting methane in the range of [0] [_____] to [100] [_____] ppmv with an accuracy of plus or minus [1] [_____] percent of full scale reading.

2.4.8.3 Carbon Dioxide

Continuous emissions monitoring systems (CEMS) for measuring CO2 must be provided with installed back-up devices. The CEMS must comply with 40 CFR 60, Appendix B, Performance Specification 2 and the QA/QC requirements of 40 CFR 60, Appendix F. Calculation of emission rates must be in conformance with 40 CFR 60, Appendix A, Reference Method 19. Provide photometric type CO2 sensors with integral transducers and linear output. Carbon dioxide (CO2) sensors must measure CO2 concentrations between [0 to 2000] parts per million (ppm) using non-dispersive infrared (NDIR) technology with an accuracy of plus or minus [50 ppm] and a maximum response time of 1 minute. The sensor must be rated for operation at ambient air temperatures within the range of 0 to 50 degrees C 32 to 122 degrees F and relative humidity within the range of 20 to 95 percent (non-condensing). The sensor must not exceed a maximum drift of 2 percent by volume a year. The sensor chamber must be manufactured with a non-corrosive material that does not affect carbon dioxide sample concentration. Sensors must be designed to protect the sensing element from dust accumulation and mechanical damage. The sensor must have a calibration interval no less than 5 years.

2.4.8.4 Carbon Monoxide - CO

Continuous emissions monitoring systems (CEMS) for measuring CO must be provided with installed back-up devices. The CEMS must comply with

40 CFR 60, Appendix B, Performance Specification 4 and the QA/QC requirements of 40 CFR 60, Appendix F. Calculation of emission rates must be in conformance with 40 CFR 60, Appendix A, Reference Method 19. Carbon monoxide analyzer must consist of an infrared light source in a weather proof steel enclosure for duct or stack mounting. An optical detector/analyzer in a similar enclosure, suitable for duct or stack mounting must be provided. Both assemblies must include internal blower systems to keep optical windows free of dust and ash at all times. The third component of the analyzer must be the electronics cabinet. Automatic flue gas temperature compensation and manual/automatic zeroing devices must be provided. Unit must read parts per million (ppm) of carbon monoxide in the range of [0] [ ] to [100][ ] ppm and the response time must be less than 3 seconds to 90 percent value. Unit measurement range must not exceed specified range by more that 50 percent. Repeatability must be plus or minus 1 percent of full scale with an accuracy of plus or minus 1 percent of full scale.

2.4.8.5 Chlorine Gas

****
NOTE: Follow Chlorine Institute Recommendations.
****

All parts of the chlorine measurement system, including the sensors, transmitters, controllers and peripheral devices, that may come in contact with chlorine or a chlorine-filled environment must be constructed of materials suitable for this application. The chlorine sensor must provide continuous monitoring of the chlorine concentration. The detector must measure concentrations of chlorine in air with a range of [0 to 10 ppm] [with a repeatability of plus or minus [1] percent of full scale] and an accuracy of plus or minus 2 percent of full scale. The Chlorine Detector transmitter must be housed in a non-corrosive NEMA 250 Type 4X enclosure. Detector must include a local panel with adjustable alarm trip level, local audio and visual alarm with silence function. The sensor response time must be [90] [_____] percent in a maximum of [30] [_____] seconds.

2.4.8.6 Chlorine in Liquid

****
NOTE: Follow Chlorine Institute recommendations.
****

All parts of the chlorine measurement system, including the sensors, transmitters, controllers and peripheral devices, that may come in contact with chlorine or a chlorine-filled environment must be constructed of materials suitable for this application. Residual chlorine sensor must continuously monitor the chlorine residual. The sensor must be capable of detecting chlorine in the range of [0] [_____] to [1] [5] [10] [20] [_____] mg/L with an accuracy of plus or minus [1] [_____] percent of full scale reading. The sensor response time must be [90] [_____] percent in a maximum of [60] [_____] seconds.

2.4.8.7 Combustible Gas

Combustible gas sensor must be provided with a means to collect representative continuous samples and measure for the presence of explosive vapors. Measuring range must be from [0] [_____] percent of the lower explosive limit (LEL) to 100 [_____] percent of the [lower explosive limit (LEL)] [upper explosive limit (UEL)]. Response time must be less

than [10] [_____] seconds to indicate [50] [_____] percent LEL when exposed to [100] [_____] percent LEL. Drift must be less than [3] [_____] percent per year. The sensor must have a minimum operational life of [1] [_____] year. The system must be provided with [_____] days of zero and calibration gas.

2.4.8.8 Calorimetric Analyzer

****

NOTE: Limit the range to improve the sensitivity. Substitute the appropriate analyzer name and range in the first sentence. The remainder of the paragraph applies to any of the following:

Phenolphthalein Alkalinity Analyzer	**0 to [50] [100] mg/L**
Total Alkalinity Analyzer	**0 to [50] [100] [500] mg/L**
Free Chlorine Analyzer	**0 to [0.5] [1.0] [2.0] [5.0] mg/L**
Total Chlorine Analyzer	**0 to [0.5] [1.0] [2.0] mg/L**
Hexavalent Chromium Analyzer	**0 to [0.2] [1.0] mg/L**
Copper Analyzer	**0 to [5.0] [10.0] mg/L**
Hardness Analyzer	**0 to [0.5] [1.0] [2.0] [5.0] [10] [20] [50] [100] mg/L**
Silica Analyzer	**0 to [25] [50] mg/L**

****

[Hardness] [_____] analyzer must be suitable for range of [0] [_____] to [_____] mg/L as [Calcium Carbonate ($CaCO_3$) equivalent] [_____]. Calorimetric analyzer must be an on-line continuous reading process instrument using a colorimeter that compensates for moderate changes in the light source, the sample cell condition, sample turbidity and background color. Analyzer must include sampling pumps, reagent storage and dispenser as well as colorimeter and colorimeter cell. System must be self-cleaning. Analyzer must require no more than weekly instrument standardization. Repeatability and reproducibility must be plus or minus [10] percent of the alarm trip value on 1 and 2 mg/L range and plus or minus 4 percent of alarm trip value on the remaining ranges. Reagent requirements must be no greater than 1 L each of indicator and buffer every two months for continuous operation.

2.4.8.9 Flame Ionization Detector (FID)

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NOTE: A version with non-methane (NMOC) measurement capability is available when regulations require it.

****

A continuous flame ionization detector (FID) must be installed on a pumped sampling line to measure the total hydrocarbon (THC) content. The analyzer must have been configured at the factory for either H_2, H_2/He, or

H2 and nitrogen fuel and calibrated for propane or methane equivalence. Total accuracy (includes calibration gas, response factor, and sample mix accuracies) must be not less than [_____] [4 ppmv] [± 3 percent of full scale] as methane. Repeatability must be [± 1%] maximum. Range and span must be continuously variable. Zero stability must be [± 1% in 30 days], span stability must be [±5% in 1 year]. Linearity must be within 1% of full scale. Outputs must include one 4-20mA and [6] relays for [warning, danger, fault, horn, calibration-in-progress, and service needed]. Detector response time must be [1.2 seconds] or less.

2.4.8.10 Hydrogen Sulfide Gas

****

NOTE: OSHA has established a permissible exposure limit (PEL) of 10 ppm. 10-20 ppm is the borderline concentration for eye irritation. 20 ppm is the acceptable ceiling concentration established by OSHA. 50 ppm is the acceptable maximum peak above the ceiling concentration for an 8 hour shift, with a maximum duration of 10 minutes.

****

The hydrogen sulfide sensor must be rated for continuous monitoring of the hydrogen sulfide level in the range from [0] [_____] to [20] [50] [100] [_____] ppmv with an accuracy of plus or minus [1] [_____] percent of full scale reading. The sensor response time must be a maximum of [30] [_____] seconds with full scale gas applied according to ISA 92.00.01. Repeatability must be ± 2ppm or 10% of the applied gas, whichever is greater. The sensor must have a calibration, calibration check, and setup modes.

2.4.8.11 Oxides of Nitrogen (NOx) Gas

Continuous emissions monitoring systems (CEMS) for measuring NOx must be provided with installed back-up devices. The CEMS must comply with 40 CFR 60, Appendix B, Performance Specification 3 and the QA/QC requirements of 40 CFR 60, Appendix F. Calculation of emission rates must be in conformance with 40 CFR 60, Appendix A, Reference Method 19. Monitor must be designed to verify compliance with standards for NOx normalized to a 3 percent oxygen basis and must have a range of from [0] [_____] to [100] [_____] ppmv. Sensor must be accurate to plus or minus [5] [_____] ppmv. Sensor must be complete with automatic zero and span calibration using a timed calibration gas system, and must require no periodic calibration.

2.4.8.12 Oxygen Gas

Continuous emissions monitoring systems (CEMS) for measuring O2 must be provided with installed back-up devices. The CEMS must comply with 40 CFR 60, Appendix B, Performance Specification 2 and the QA/QC requirements of 40 CFR 60, Appendix F. Calculation of emission rates must be in conformance with 40 CFR 60, Appendix A, Reference Method 19. Oxygen in air must be monitored by an oxygen sensor and electronic controller. The oxygen sensor must be rated for continuous monitoring of the oxygen level in air in the range of [0] [_____] to [20] [25] [30] [_____] percent with an accuracy of plus or minus [1] [_____] percent of full scale reading at constant temperature and pressure and plus or minus [5] percent of full scale reading over operating temperature range. The sensor response time must be [90] [_____] percent in a maximum of [5] [_____]

seconds. The controller must have automatic zeroing and must require no normal maintenance or periodic recalibration.

2.4.8.13 Oxygen Dissolved

The dissolved oxygen sensor must provide continuous measure of dissolved oxygen. Wetted materials must be [stainless steel,] [PVC] or glass. Sensor must be rated for continuous use to a depth of [15] [_____] m [50] [_____] feet and must be automatically temperature compensating over the temperature range. Sensor must be capable of measuring dissolved oxygen level of from [0] [_____] to [15] [_____] ppmv. The sensor must have an accuracy of plus or minus [1] [_____] percent of full scale reading, repeatability of [±0.05] and response time of [25 sec to 63%] of final reading at 25°C 77F.

2.4.8.14 Oxygen Reduction Potential (ORP)

The sensor must be [submersible] [flow-through] type. Sensor must have a redox potential range of plus or minus [500] [_____] mV and must have an accuracy of plus or minus [1] percent of sensor span. The sensor must automatically compensate for temperature over the temperature range. The sensor body must be [PVC, CPVC, Liquid Crystal Polymer (LCP) or epoxy] and suitable for installation in the environment.

2.4.8.15 Ozone (O3) Gas

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NOTE: The standard instrument provides the range 0-1,000 ppmv (parts per million by volume) an alternate display of ozone concentration is in millipascals.

****

Ozone in air must be monitored by an ozone gas sensor and electronic controller. The sensor must be capable of detecting ozone in the range of [0] [_____] to [1,000] [_____] ppmv with an accuracy of plus or minus [1] [_____] percent of the full scale reading. The sensor response time must be [90] [_____] percent in a maximum of [60] [_____] seconds.

2.4.8.16 Ozone (O3) in Water

The dissolved ozone sensor must provide continuous measurement of dissolved ozone level from [0] [_____] to [5] [_____] mg/L. The sensor must automatically compensate for temperature over the temperature range. The sensor must have an accuracy of plus or minus [1] [_____] percent of the full scale reading. [System must include variable area flow meter and needle valve to regulate rate of sample flow through sensor unit.] [Sensor must be suitable for direct submersion.]

2.4.8.17 pH Monitoring

****

NOTE: Limit the range to improve the sensitivity.

****

The sensor must be [submersible] [or] [flow-through] type. [Sensor must be a differential type]. Sensor must have a range of [1] [4] [5] [5.5] [_____]. pH units to [8.5] [9] [11] [14] [_____]. pH units and must have an accuracy of plus or minus [0.1] [0.01] [_____]. pH unit. The sensor

must automatically compensate for temperature over the temperature range. The sensor body must be PVC, CPVC or epoxy.

2.4.8.18 VOC Detector

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NOTE: Show sampling points on the drawings.
****

Detector must be either photoionization or Gas Sensitive Semiconductor type. Contaminant and background concentrations are [as follows:] [_____]. Detector must be provided with a means to collect representative continuous samples and measure for the presence of volatile organic compounds (VOCs). Sampling points are as indicated on the drawings. The system must be provided with automated zero and calibration gas system as well as a [4-20ma] [relay controller] output.

2.4.8.19 Total Dissolved Solids (TDS)

The TDS sensor must measure the specific conductance using a conductivity sensor, displaying the total dissolved solids value in [milligrams per liter (mg/L) of dissolved NaCl equivalent] [microohms (microSiemens) per centimeter (uS/cm)] and transmitting an analog signal for remote processing. System must be industrial grade, [contacting][torodial] and suitable for measurement of conductivity in a solution [by insertion of the sensing element into the pipeline, using a hot tap assembly] [including a variable area flow meter and needle valve to regulate rate of sample flow through sensor unit]. Sensor assembly must be suitable for periodic removal for adjustment and cleaning without requiring shut down of the process. Sensor must be suitable for range of [0] [_____] to [10,000] [_____] [milligrams per liter (mg/L) of dissolved NaCl equivalent] [microohms per centimeter (uS/cm)]. Range must be field verified for the application and adjusted as required. Sensing element must be constructed of [316 stainless steel] [_____] and glass, including temperature element, and be capable of continuous operation. Sensing element must be unaffected by color in the fluid, pressure, and rate of flow. Sensor must have automatic temperature compensation and must require no normal maintenance or periodic recalibration.

2.4.8.20 Water Turbidity

System must be complete and include indicating meter, sensing element and a transmitter. System must be industrial grade and suitable for measurement of turbidity by [insertion of the sensing element into the pipeline, using a hot tap assembly] [direct submersion of the sensing element into the vessel or flow channel]. Sensor assembly must be suitable for periodic removal for adjustment and cleaning without requiring shutdown of the process. Sensor must be suitable for range from [0] [_____] to [2] [20] [200] Nephelometric turbidity units (NTU). The accuracy must be plus or minus [2] [_____] percent of full scale reading. Range must be field verified for the application and adjusted as required. Sensing element must be constructed of [316 stainless steel] [_____] and glass. Sensing element must be unaffected by color in the fluid, pressure, temperature and rate of flow. Sensor must have automatic zeroing and must require no normal maintenance or periodic recalibration. Sensor must have [active and] passive anti-fouling mechanisms.

2.4.9 Electrical Instrumentation

Electrical power measurements with a range for the specific application, plus or minus [1.0] [_____] percent of range (display and print to nearest kWh and kW). Electrical measurements with a range for the specific application plus or minus [1.0] [_____] percent of range (display and print to nearest [0.1] [_____] for volts and amperes, and to the nearest [0.01]

2.4.9.1 Hour Meter

Hour meter must provide a totalized readout of the number of hours of operation for the equipment monitored. Meter must provide readout with a minimum of [5] [6] [7] digits including [1] [_____] decimal places. The display must be non-resettable. The meter must be driven by a [24] [120] [240] VAC synchronous motor.

2.4.9.2 Watt-Hour Meter

Watt-hour meters must be in accordance with Section 23 09 13 INSTRUMENTATION AND CONTROL DEVICES FOR HVAC.

2.4.10 Limit Switch

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NOTE: See NEMA ICS 5 Part 9 for application guidelines. To increase the number of operations during the life of the contact, select contacts with make and break values much higher than those applied

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Limit switch must be [rotary/lever] [induction/proximity] type, contacts must be heavy duty and rated A600 or N600. Enclosure must be metal. The actuating head must vary based upon the application.

2.4.11 Absolute Rotary Encoder

The absolute rotary encoder must retain the count upon loss of power without use of battery or alternate power source. The encoder must increase the count when turning in the direction which causes [the gate to raise] [_____] and must decrease the count in the opposite direction. The encoder must be capable of counting at least [4,096] data points per revolution and [counting [4096] revolutions.][tracking the full range of operation.] The output signal must be [synchronous serial interface (SSI)][Common Industrial Protocol (CIP)] [_____]. Draw wire string encoder type of absolute rotary enconder must not be used in outdoor settings.

2.4.12 Linear Displacement Position Sensor

The linear displacement position sensor must be a magnetostrictive position sensor capable of 0.02% accuracy or better along the entire hydraulic cylinder stroke length. The sensor mmust measure the full stroke of the hydraulic cylinder. The sensor must be capable of 4-20mA analog output with an update cycle of at most 10ms. The sensor module and rod must meet IP 67 standards. The sensor must mount to the hydraulic cylinder by threaded flange and be constructed to integrate with the hydraulic cylinder.

2.4.13 Emergency Stop

Emergency stop pushbutton must have red mushroom actuator and yellow background. Actuator must be self-latching and manually reset. Provide contacts that are NEMA ICS A600 and directly opened. Pushbutton must meet NFPA 79 SECTION 10.7.

2.5 COMPRESSED AIR STATIONS

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NOTE: If the process control system does not utilize pneumatic devices, the air compressor and accessories should be deleted.

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Submit instrumentation compressed-air station schematic diagram showing equipment utilized, including compressor with motor output and voltage; starter; isolators; manual bypasses; tubing sizes; drain piping and drain traps; reducing valves; air-dryer; and data on manufacturer's names and model numbers, mounting, access, and clearance requirements. Include in the air-compressor and air-dryer data calculations of the air consumption of pneumatic control valves and of other process control system devices to be connected to the compressed-air station; the number of starts per hour, the running time for the unit selected; and the compressed air-supply dewpoint temperature at 552 kPa 80 psig.

2.5.1 Air Compressor Assembly

The air compressor must be a high-pressure compressing unit with electric motor. The compressor must be equipped with a motor with totally enclosed belt guard, an operating-pressure switch, safety relief valves, gauges, intake filter and intake silencer and combination type magnetic starter with under voltage protection and thermal overload protection for each phase, and must be supported by a steel base mounted on an air storage tank. The air compressor must provide the compressed air required for control operation while operating not more than one-third of the time. The tank must be of sufficient volume so that no more than six compressor starts per hour are required with the starting pressure switch differential set at 140 kPa 20 psi gage. The air storage tank must be fabricated for a working pressure of not less than 1380 kPa 200 psi gage and constructed and certified in accordance with ASME BPVC SEC VIII D1. The tank must be provided with an automatic condensate drain trap with manual override feature. [A second (duplex arrangement) compressor of capacity equal to the primary compressor must be provided, with interlocked control to provide automatic changeover upon malfunction or failure of either compressor. A manual selector switch must be provided to index the lead compressor including the automatic changeover.]

2.5.2 Compressed Air Station Specialties

2.5.2.1 Refrigerated Dryer, Filters and Pressure Regulator

A refrigerated dryer must be provided in the air outlet line of the air storage tank. The dryer must be of the size required for the full delivery capacity of the compressor. The air must be dried at a pressure of not less than 483 kPa 70 psi gage to a temperature not greater than 2 degrees C 35 degrees F. The dryer must be provided with an automatic condensate drain trap with manual override feature. The refrigerant used in the dryer must be one of the fluorocarbon gases. A 5 micron prefilter

and coalescing-type oil removal filter with shut-off valves must be provided in the dryer discharge. Each filter bowl must be rated for 1034 kPa 150 psi gage maximum working pressure. A pressure regulator with high side and low side pressure gauges and a safety valve must be provided downstream of the filter. Pressure regulators of the relieving type must not be used.

2.5.2.2 Coalescing Filter

A coalescing prefilter, together with an automatic drain valve, must be provided for removal of liquids. The flow through the prefilter must be from inside to outside and reduce an entrained quantity of 50 ppmv oil to 0.0013 ppmv effluent liquid oil and water and remove all particulates greater than 0.6 micron absolute. The prefilter housing (bowl) must be fitted with a drain port to eliminate collected liquids and provide sufficient sump volume to prevent liquid re-entrainment, and an automatic drain valve with adjustable cycle and drain times. Prefilter pressure drop must be less than 21 kPa 3 psi saturated. A particulate after filter, outside to inside flow, designed to remove desiccant fines must be provided. The after filter cartridge must have a particulate removal rating of 0.5 micron absolute. Both prefilter and after filter housings must allow for service of elements without removing the entire assembly from the system. Filter life must be stated and guaranteed by the vendor.

2.5.2.3 Flexible Pipe Connections

The flexible pipe connectors must be designed for 1034 kPa 150 psi gage and 121 degrees C 250 degrees F service and must be constructed of rubber, polytetrafluoroethylene (PTFE) resin or braided corrosion-resistant steel, bronze, monel or galvanized steel. The connectors must be suitable for the service intended and may have threaded or soldered ends. The length of the connectors must be as recommended by the manufacturer for the service intended.

2.5.2.4 Vibration Isolation Units

The vibration isolation units must be standard products with published loading ratings and must be single rubber-in-shear, double rubber-in-shear or spring type.

2.5.2.5 Compressed Air Piping

Control air delivered to the system must conform to ISA 7.0.01. Air lines for pneumatic controls must be seamless copper tubing or nonmetallic tubing. Nonmetallic tubing must be compounded from polyethylene. Air lines concealed in walls must be hard-drawn copper tubing or nonmetallic tubing in rigid conduit. Terminal single lines must be hard-drawn copper tubing except when the run is less than 300 mm 12 inches in length, flexible polyethylene may be used. Nonmetallic tubing will not be used for applications where the tubing could be subjected to a temperature exceeding 55 degrees C 130 degrees F. Fittings for nonmetallic tubing must be for instrument service and may be brass or acetyl resin of the compression or barbed push-on type. Tubing must be as follows:

a. Copper tubing must conform to ASTM B88M ASTM B88 and must have sweat fittings and valves.Exposed tubing must be hard drawn in exposed areas and hard-drawn or annealed in concealed areas. Only tool made bends must be used. Fittings for copper tubing must be brass or copper solder joint type except at connections to the apparatus, where

fittings must be brass compression type. Grooved mechanical joints and fittings must be designed for not less than 862 kPa 125 psig service and must be the product of the same manufacturer. Grooved fittings and mechanical coupling housing must be ductile conforming to ASTM A536. Gaskets for use in grooved joints must be molded synthetic polymer of pressure responsive design and must conform to ASTM D2000 for circulating medium up to 110 degrees C 230 degrees F. Grooved joints must conform to AWWA C606. Tubing must be rack mounted where multiple tubes run in parallel. Multiple tubes may be bundled when concealed.

b. Tubing must be flame resistant, multiple polyethylene tubing in an extruded PVC protective sheath, or unsheathed polyethylene tubing in rigid metal, intermediate metal, or electrical metallic tubing conduit for areas where tubing is exposed. Tubing must have barbed fittings and valves, and must conform to the following: Burst pressure must be 3.8 MPa 550 psi gage at 24 degrees C 75 degrees F to 1.2 MPa 175 psi gage at 66 degrees C 150 degrees F, minimum. Stress crack resistance in accordance with ASTM D1693 must be 200 hours, minimum. Tensile strength in accordance with ASTM D638 must be 14 MPa 2000 psi, minimum. Average density in accordance with ASTM D792 must be 920 kg/m3. Average flow rate in accordance with ASTM D1238 must be 0.30 decigram per minute.

c. Plastic tubing must have the burning characteristics of linear low density polyethylene tubing, must be self extinguishing when tested in accordance with ASTM D635, must have UL 94 V-2 flammability classification, and must withstand stress cracking when tested in accordance with ASTM D1693. Polyethylene tubing must not be used for smoke removal systems.

2.5.3 Barrier Jacket

Provide plastic tubing bundles mylar barrier and flame retardant polyethylene jacket. Each tube must be numbered.

2.6 PROGRAMMABLE LOGIC CONTROLLER (PLC)

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NOTE: Typically, either modular or loop type PLCs will be used throughout the process control system. The designer must determine which is best suited for the application and delete the paragraph pertaining to the type that will not be used. If it is determined that the use of both types is necessary, the drawings will indicate where each type will be used and both types will be included in the edited specification.

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2.6.1 PLC General Requirements

PLCs must be micro-processor based, capable of receiving binary and analog inputs and, through programming, must be able to control binary and analog output functions, perform data handling operations and communicate with external devices. PLCs must meet the requirements of Class A computing devices, and must be labeled as set forth in 47 CFR 15 and must be able to withstand conducted susceptibility test as outlined in NEMA ICS 1, NEMA ICS 2, NEMA ICS 3, [and] [or] IEEE C37.90.1. PLCs must

function properly at temperatures between 0 and 50 degrees C 32 and 122 degrees F at 5 to 95 percent relative humidity non-condensing and must tolerate storage temperatures between minus 40 and plus 60 degrees C 40 and plus 140 degrees F at 5 to 95 percent relative humidity non-condensing.

2.6.2 Modular PLC

PLCs must be based on a modular, field expandable design allowing the system to be tailored to the process control application. The system must be expandable through the use of additional hardware and/or user software. As a minimum, the PLC must include a mounting backplane, power supply module, central processing unit (CPU) module, communications module, and input/output (I/O) module. The modules must be grouped together in a mounting rack or cabinet. The mounting rack backplane must provide the communications mechanism to fully integrate the individual modules located within the rack. Modules other than I/O modules must plug directly into the backplane. The use of wire connectors between modules will not be allowed except for expansion of the system to include multiple backplanes. The rack size must be as needed to hold the equipment necessary while performing the required control functions. [The system configuration must allow for the removal and/or installation of modules under power.]

2.6.2.1 Central Processing Unit (CPU) Module

The CPU module must be a self contained, microprocessor based unit that provides time of day, scanning, application program execution, storage of application programs, storage of numerical values related to the application process and logic, I/O bus traffic control, peripheral and external device communications and self diagnostics. The scan time must be [250 milliseconds] or better including spare I/O channels.

2.6.2.2 Communications Module

The communications module must allow peer-to-peer communication with other PLCs and must allow the PLC to communicate with the central station, or workstation. The communication module must utilize the manufacturer's standard communication architecture and protocol, ethernet architecture and protocol or a combination of these. The communication module must allow programming of the PLC to be done locally through the use of a laptop computer[or from the central station or remote workstation].

2.6.2.3 Power Supply Module

One or more power supply modules must be provided as necessary to power other modules installed in the same cabinet. Power supply modules must plug directly into the backplane. Auxiliary power supplies may be used to supply power to remote cabinets or modules.

a. Power supply modules must use [AC] [DC] power with a nominal voltage of [120 VAC] [220 VAC] [24 VDC] [48 VDC] [125VDC] plus or minus 5 percent. The power supply module must monitor the incoming line voltage level and must provide over current and over voltage protection. If the voltage level is detected as being out of range the power supply module must continue to provide power for an adequate amount of time to allow for a safe and orderly shutdown. Power supply modules must be capable of withstanding a power loss for a minimum of 20 milliseconds while still remaining in operation and providing adequate power to all connected modules.

b. Each power supply module must be provided with an on-off switch integral to the module. If the manufacturer's standard power supply module is not provided with an on-off switch, a miniature toggle type switch must be installed near the PLC and must be clearly labeled as to its function..

c. Provide power supply modules with an indicating light which must be lit when the module is operating properly.

2.6.2.4 Input/Output (I/O) Modules

Modules must be self contained, microprocessor based units that provide an interface to field devices.[The modules must be located in the same cabinet as the other PLC components.] Each module must contain visual indication to display the on-off status of individual inputs or outputs. Each I/O must be protected against reversal of polarity of the signal. Analog inputs and analog outputs must have 'open, short and out of range circuit' detection. It must be configurable per channel.

2.6.3 Loop PLC

PLCs must be single or multiple loop controllers depending on the process control system requirements. Controllers must be self contained and must include a central processing unit (CPU), program memory, power supply, input/output capability, [network communications capability] and display/keyboard. The controller must have a scaleable process variable for each loop. Controller must have proportional, integral and derivative (PID) control logic. Analog outputs must be configured as direct acting or reverse acting. The controller must have keyboard, display, auto/manual selection for control of each loop output, remote setpoint, adjustment/local setpoint adjustment selection with adjustable high-end and low-end limits, ratio and bias adjustment on remote setpoint input, [operator-initiated self-tune/manual-tune selection] [and anti-reset wind-up feature]. Controller must power analog output loops to 20 mAdc when connected to a load of 600 ohms.

2.6.3.1 Central Processing Unit (CPU)

The central processing unit must be microprocessor based and must provide time of day, scanning, application program (ladder rung logic) execution, storage of application programs, storage of numerical values related to the applications process and logic, I/O bus traffic control, peripheral and external device communications and self diagnostics.

2.6.3.2 Power Requirements

Each controller must be powered by [AC] [DC] power with a nominal voltage of [120 VAC] [220 VAC] [24 VDC] [48 VDC] [125VDC]. Power consumption must not exceed 25 watts. Controller must provide electrical noise isolation between the AC power line and the process variable inputs, remote setpoint inputs and output signals of not less than 100 dB at 60 Hertz common mode rejection ration and not less than 60 dB at 60 hertz normal-mode rejection ration.

2.6.3.3 On-Off Switch

Each controller must be provided with an integral on-off switch. If the controller is not provided with a manufacturers standard on-off switch, a

miniature toggle type switch must be installed near the controller and must be clearly labeled as to its function.

2.6.3.4 Parameter Input and Display

Enter and display control parameters directly, in the correct engineering units, through a series of keystrokes on a front panel display with decimal point and polarity indication. Provide display [in metric English units] [in metric or English units as selected by the operator].

[2.6.3.5 Self Tuning

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NOTE: If the process control system does not utilizeAnalog control, or if self tuning is not needed delete this bracketed section as it limits the number of vendors.

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Provide controllers with self-tuning operation which applies to proportional, integral and derivative modes of control and modify the mode constants as required. Self-tuning must only be in operation when selected from the front panel.

]2.6.3.6 Manual Tuning

Controllers must be provided with manual tuning operation which must apply to proportional, integral and derivative modes of control, by means of individually adjustable mode constants. These adjustments must be set for the appropriate value if a particular control mode action is required or to zero if that particular mode is not desired. The proportional mode constant must be adjustable from 0 to 200 percent of the input signal range. The integral mode constant must be adjustable from 0 to 20 repeats per minute. The derivative mode constant must be adjustable from 0 to [5] [____] minutes.

2.6.4 Program Storage/Memory Requirements

The CPU must utilize the manufacturer's standard non-volatile memory for the operating system. The controller must have electronically [readable and writeable non volatile memory (EPROM, EEPROM, or Flash PROM)] [battery backup volatile memory. Must be possible to change battery with power on] for storage of user programs. The user programs must be loaded through the controller keypad, central station or through the use of a laptop computer. The CPU memory capacity must be based on the system's control requirements. The memory capacity must be sized such that, when the system is completely programmed and functional, no more than 50 percent of the memory allocated for these purposes is used.

2.6.5 Input/Output Characteristics

Each controller must allow for analog input, analog output, binary input and binary output. The number and type of inputs and outputs for the system must be as shown on the drawings and must comply with the sequence of control. The system capacity must include a minimum of 20 percent spare input and output points (no less than two points) for each point type provided. During normal operation, a malfunction in any input/output channel must affect the operation of that channel only and must not affect the operation of the CPU or any other channel. All input circuits must

have a minimum optical isolation of 1500 VRMS and must be filtered to guard against high voltage transients from the externally connected devices. All output circuits must have a minimum optical isolation of 1500 VRMS and must be filtered to guard against high voltage transients from the externally connected devices.

2.6.5.1 Analong Inputs

Analog input circuits must be available in [+/-10V] [+/-5V] [0-10V] [0-5V] [4-20 mA].

2.6.5.2 Binary Inputs

Binary input circuits must be available in [5 volt TTL] [10-30 VDC] [18-26 VDC] [79-132VDC] [79-132 VAC].

2.6.5.3 Analog Outputs

Analog output circuits must be available in [+/-10V] [4-20 mA].

2.6.5.4 Binary Outputs

Binary output circuits must be available in [5 volt TTL] [10-30 VDC] [18-26 VDC] [79-132 VAC].

2.6.5.5 Pulse Inputs

Pulse inputs must be able to detect a pulse of [x milliseconds] or less.

2.6.6 Wiring Connections

Wiring connections must be heavy duty, self lifting, pressure type screw terminals to provide easy wire insertion and secure connections. The terminals must accept two #14 AWG wires. A hinged protective cover must be provided over the wiring connections. The cover must have write-on areas for identification of the external circuits.

2.6.7 On-Off Switch

Each controller must be provided with an integral on-off power switch. If the controller is not provided with a manufacturer's standard on-off switch, a miniature toggle type switch must be installed in the control panel near the controller and must be clearly labeled as to its function.

2.6.8 Diagnostics

Each PLC must have diagnostic routines implemented in firmware. The CPU must continuously perform self-diagnostic routines that will provide information on the configuration and status of the CPU, memory, communications and input/output. The diagnostic routines must be regularly performed during normal system operation. A portion of the scan time of the controller must be dedicated to performing these housekeeping functions. In addition, a more extensive diagnostic routine must be performed at power up and during normal system shutdown. The CPU must log input/output and system faults in fault tables which must be accessible for display. When a fault affects input/output or communications modules the CPU must shut down only the hardware affected and continue operation by utilizing the healthy system components. All faults must be annunciated at [the PLC] [and] [the central station]. Diagnostic software

must be useable in conjunction with the portable tester. The following diagnostics must be performed:

a. Analong Inputs: Sensor out of range, open or shorted loop, analog-to-digital converter check

b. Analog Outputs: Open or shorted loop

c. Configuration: Check compatibility and availability of selected I/O hardware and software

d. Memory: Checksum, parity check End-to End CPU memory

2.6.9 Accuracy

Provide controllers with an accuracy of plus or minus [0.25] percent of input span.

[2.6.10 Primary/Secondary PLC

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NOTE: Determine if the system is critical enough to require a Primary/Secondary PLC arrangement. This is a significant cost addition and makes the system more complex.

****

The Primary/Secondary PLCs must have redundancy built into the process control system by having two systems (power supply and CPU) either of which is capable of controlling the system. Data must be transferred from the primary processor to the secondary processor each logic cycle. [The I/O scan must be transferred from the PLC currently in charge to the other at the end of each logic execution and the logic must be executed.] [The data must be transferred via asynchronous transfer where the primary processor haws two separate microprocessors embedded in its circuitry and at the end of logic execution all data must be passed to the second microprocessor and the second microprocessor must handle all transfer tasks while the first executes the next program scan.] The Primary must perform the execution of the outputs unless a fault is detected in which case execution of the outputs is performed by the Secondary. Switchover must be automatic and indication of the switchover must be displayed on the Central Operator Workstation.

]2.7 PLC SOFTWARE

Furnish all PLC software described in this specification as part of the complete control system.

2.7.1 Operating System

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NOTE: If loading of control logic is allowed from the central station this presents a security risk.

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Each PLC must be provided with the manufacturer's standard operating system software package. The PLC must maintain a point database in its memory that includes all parameters, constraints and the latest value or status of all points connected to the PLC. Execution of the PLC

application programs must use the data in memory resident files. The operating system must support a full compliment of process control functions. It must be possible to define these functions using a mix of ladder logic diagrams, function blocks, sequential function charts and text programming. Programming methods and interactions must be based on IEC 61131-3. A combination of the programming methods must be possible within a single controller. The operating system must allow loading of control logic locally [or from the central station in which case it must require a password to do so] and data files from the portable tester. It must also support data entry and diagnostics using an operator interface panel attached directly to the PLC. Each PLC must be capable of operating in stand alone mode.

2.7.1.1 Startup

The PLC must have startup software that causes automatic commencement of operation without human intervention, including startup of all connected I/O functions. A PLC restart program based on detection of power failure at the PLC must be included in the PLC software. The restart program must include start time delays between successive commands to prevent demand surges or overload trips.

2.7.1.2 Failure Mode

Upon failure for any reason, each PLC must perform an orderly shutdown. Systems which are not Primary/Secondary must force all PLC outputs to a predetermined (failure mode) state, consistent with the failure modes shown and the associated control device. Primary/Secondary systems must transfer I/O scan and control to the PLC not currently failed.

2.7.2 Functions

The controller operating system must be able to scan inputs, control outputs, and read and write to its internal memory in order to perform the required control as indicated in the sequence of control on the drawings. The controller must periodically perform self diagnostics to verify that it is functioning properly. [If the system is set up as a Primary/Secondary system the system must attempt to switch to the other PLC upon sensing a fault in the currently controlling PLC.]

2.7.2.1 Analog Monitoring

Measure and transmit all analog values including calculated analog points.

2.7.2.2 Logic (Virtual)

Logic (virtual) points must be software points entered in the point database which are not directly associated with a physical I/O function. Logic (virtual) points must be analog or binary points created by calculation from any combination of binary and analog points, or other data having all the properties of real points, including alarms, without the associated hardware. Logic (virtual) points must be defined or calculated and entered into the database. The calculated analog point must have point identification in the same format as any other analog point.

2.7.2.3 State Variables

If an analog point represents more than two (up to 8) specific states,

each state must be nameable. For example, a level sensor must be displayed at its measured engineering units plus a state variable with named states usable in programs or for display such as low alarm/low/normal/high/high alarm.

2.7.2.4 Analog Totalization

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NOTE: If the analog totalization is to be performed at the central station and is not to be done at the PLC, this requirement will be deleted.

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Any analog point must be operator assignable to the totalization program. Up to eight analog values must be totalized within a selectable time period.

2.7.3 Alarm Processing

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NOTE: If the alarm processing function is to be performed at the central station and is not to be done at the PLC, this requirement will be deleted.

****

Each PLC must have alarm processing software for AI, DI, and PA alarms for all real and virtual points connected to that PLC.

2.7.3.1 Binary Alarms

Binary alarms are those abnormal conditions indicated by BIs as specified and shown. The system must automatically suppress analog alarm reporting associated with a binary point when that point is turned off.

2.7.3.2 Analog Alarms

Analog alarms are those conditions higher or lower than a defined value, as measured by an AI. Analog readings must be compared to predefined high and low limits, and alarmed each time a value enters or returns from a limit condition. Unique high and low limits must be assigned to each analog point in the system. In control point adjustment (CPA) applications, key the limit to a finite deviation traveling with the setpoint. The system must automatically suppress analog alarm reporting associated with an analog point when that analog point is turned off.

2.7.3.3 Pulse Accumulator (PA) Alarms

Pulse accumulator alarms are those conditions calculated from totalized values of accumulator inputs or PA input rates that are outside defined limits as specified and shown. PA totalized values must be compared to predefined limits and alarmed each time a value enters a limit condition. Unique limits must be assigned to each PA point in the system.

2.7.4 Constraints

2.7.4.1 Equipment Constraints Definitions

Each control point in the database must have PLC resident constraints

defined and entered by the Contractor, including as applicable: maximum starts (cycles) per hour; minimum off time; minimum on time; high limit (value in engineering units); and low limit (value in engineering units).

2.7.4.2 Constraints Checks

All control devices connected to the system must have the PLC constraints checked and passed before each command is issued. Each command point must have unique constraints assigned. High and low "reasonableness" values or one differential "rate-of-change" value must be assigned to each AI. Each individual point must be capable of being selectively disabled by the operator from the central station.

2.7.5 Control Sequences and Control Loops

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NOTE: Sequences to be implemented will be developed by the designer to meet site requirements. The designer will define allowable process control loop accuracies as a part of the sequences. Control sequences and database tables will be shown on the drawings.

****

Specific functions to be implemented are defined in individual system control sequences and database tables shown on the drawings, and must include, as applicable, the following functions: PI control must provide proportional control and proportional plus integral control; two position control must provide control for a two state device by comparing a set point against a process variable and an established dead band; floating point control must exercise control when an error signal exceeds a selected dead band, and must maintain control until the error is within the dead band limits; signal selection must allow the selection of the highest or lowest analog value from a group of analog values as the basis of control and must include the ability to cascade analog values so that large numbers of inputs can be reduced to one or two outputs; signal averaging must allow the mathematical calculation of the average analog value from a group of analog values as the basis of control and must include the ability to "weight" the individual analog values so that the function output can be biased as necessary to achieve proper control; reset function must develop an AO based on up to two AIs and one operator specified reset schedule.

2.7.6 Command Priorities

A scheme of priority levels must be provided to prevent interaction of a command of low priority with a command of higher priority. Override commands entered by the operator must have higher priority than those emanating from applications programs.

2.7.7 Resident Application Software

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NOTE: The data base and settings tables will be incorporated into the contract package. Specify only those applications programs to be implemented at time of acceptance. Do not specify a program unless sensors and controls required to implement it are included in the design package.

****

Provide resident applications programs developed in accordance with paragraph GRAPHICAL PROGRAMMING to achieve the sequences of operation, parameters, constraints, and interlocks necessary to provide control of the process systems connected to the process control system. All application programs must be resident in the PLC and must execute in the PLC, and must coordinate with each other, to ensure that no conflicts or contentions remain unresolved.

2.7.7.1 Program Inputs and Outputs

Use program inputs listed for each application program to calculate the required program outputs. Where specific program inputs are not available, a "default" value or virtual point appropriate for the equipment being controlled and the proposed sequence of operation must be provided to replace the missing input, thus allowing the application program to operate.

2.7.7.2 Failure Mode

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NOTE: Assure that the appropriate failure modes are identified on the drawings.

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In the event of a PLC failure, the controlled equipment must continue to function in the failure mode shown on the drawings. Systems that are Primary/Secondary must transfer control to the non-failed system.

2.8 CONTROL PANELS

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NOTE: For locations or equipment that will be powered by an uninterruptible power supply (UPS) during a commercial power outage, the control panel must be included on the UPS.

Include in the design package requirements for sufficient ventilation, heating or air conditioning to ensure that the control panel internal temperature and humidity will be maintained within the PLCs operational parameters when exposed to the temperature and humidity indicated in paragraph SITE ENVIRONMENTAL CONDITIONS. Include allowance for any solar gain. If the requirements for ventilation, heating and air conditioning are not necessary, they will be deleted.

****

2.8.1 Components

2.8.1.1 Enclosures

The enclosure for each control panel must conform to the requirements of NEMA 250 for the types specified. Finish color must be the manufacturer's standard, unless otherwise indicated. Enclosures for installation in mechanical equipment rooms must be Type [1] [4] [12]; those for installation in clean, dry indoor occupied space may be Type 1; other

locations must be as otherwise specified or shown. Enclosures for equipment installed outdoors must be Type 4 or as shown. Enclosures for installation in a corrosive environment must be Type 4X and must be constructed of [stainless steel] [fiberglass] [polymer plastic]. Painted steel must not be allowed for use in a corrosive environment. Enclosure must be provided with a single, continuously hinged exterior door with print pocket, 3-point latching mechanism and key lock and a single, continuously hinged interior door.

2.8.1.2 Controllers

Provide controllers in accordance with paragraph Programmable Logic Controller (PLC).

2.8.1.3 Standard Indicator Light

Indicator lights showing on, off, stand-by, automatic, manual depending on the application must comply with NEMA ICS 1, NEMA ICS 2 and UL 508A. Lights must be heavy duty, round and must mount in a 22.5 mm 0.875 inch mounting hole. Indicator lights must be LED type and must operate at 120 VAC or 24 VDC. Long life bulbs must be used. Indicator light must be provided with a legend plate labeled as shown on the drawings. Lens color must be as indicated on the drawings. Lights must be push to test (lamp) type.

2.8.1.4 Selector Switches

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NOTE: Indicate on the drawings where key operated switches are required.

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Selector switches must comply with NEMA ICS 1, NEMA ICS 2 and UL 508A. Selector switches must be heavy duty, round and must mount in a 22.5 mm 0.875 inch mounting hole. The number of positions must be as indicated on the drawings. Switches must be [illuminated] [non-illuminated] [as indicted of the drawings]. Switches must be rated for 600 volts, 10 amperes continuous. Selector switches must be provided with a legend plate labeled as shown on the drawings. Where indicated or required, dual auxiliary contacts must be provided for the automatic position to provide position sensing at the central station or workstation. Auxiliary contacts must be rated for 120 VAC, 1A as a minimum. Where indicated on the drawings, switches must be key operated. All keys must be identical.

2.8.1.5 Push Buttons

Push buttons must comply with NEMA ICS 1, NEMA ICS 2 and UL 508A. Push buttons must be heavy duty, round and must mount in a 22.5 mm 0.875 inch mounting hole. The number and type of contacts must be as indicated on the drawings or required by the Sequence of Control. Push buttons must be rated for 600 volts, 10 amperes continuous. Push buttons must be provided with a legend plate labeled as shown on the drawings.

2.8.1.6 Relays

Relays must comply with NEMA ICS 5 and derated for altitude above 1,500 m. Relays must be [single-pole, single-throw (SPST)] [single-pole, double-throw (SPDT)] [double-pole, single throw (DPST)] [double-pole,

double-throw (DPDT)] [as required by the Sequence of Control]. Relay coil must be [120 VAC] [24 VDC] and must be provided with matching mounting socket. Power consumption must not be greater than 3 watts. Coils must have a minimum current rating of [___] amps and minimum voltage rating of [___] volts. Contacts must have a minimum current rating of [ ] amps and minimum voltage rating of [___] volts.

2.8.1.7 Terminal Blocks

Terminal blocks must comply with NEMA ICS 4 and UL 1059. Terminal blocks for conductors exiting control panels must be two-way type with double terminals, one for internal wiring connections and the other for external wiring connections. Terminal blocks must be made of bakelite or other suitable insulating material with full deep barriers between each pair of terminals. A terminal identification strip must form part of the terminal block and each terminal must be identified by a number in accordance with the numbering scheme on the approved wiring diagrams.

2.8.1.8 Alarm Horns

Alarm horns must be provided where indicated on the drawings. Horns must be vibrating type and must comply with UL 508A. Horns must provide 100 dB at 10 feet. Exterior mounted horns must be weather proof by design or must be mounted in a weather proof enclosure that does not reduce the effectiveness of the horn.

2.8.2 Panel Assembly

Control panels must be factory assembled and shipped to the jobsite as a single unit. Panels must be fabricated as indicated and devices must be mounted as shown or required. Each panel must be fabricated as a bottom-entry connection point for process control system electrical power, [process control system main air source,] process control system wiring, [control air pneumatic tubing,] [communications system wiring to [other control panels] [operators workstation]].

2.8.3 Electrical Requirements

Each panel must be powered by a dedicated [120 volts ac] [208 volts ac] [125VDC] circuit, with a fuse, [10 amp] [____] [sized as recommended by the equipment manufacturer], and a disconnect switch located inside the panel. Wiring must terminate inside the panel on terminal blocks. Electrical work must be as specified in Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM and as shown on the drawings.

2.8.4 Power Line Conditioner

Each control panel must be provided with a power line conditioner to provide both voltage regulation and noise rejection. The power line conditioner must be of the ferro-resonant design, with no moving parts and no tap switching, while electrically isolating the secondary from the power line side. The power line conditioner must be sized for 125 percent of the actual connected kva load. Characteristics of the power line conditioner must be as follows:

2.8.4.1 85 Percent Load

At 85 percent load, the output voltage must not deviate by more than plus or minus 1 percent of nominal voltage when the input voltage fluctuates

between minus 20 percent to plus 10 percent of nominal voltage.

2.8.4.2 Load Changes

During load changes of zero to full load, the output voltage must not deviate by more than plus or minus 3 percent of nominal voltage. Full correction of load switching disturbances must be accomplished within 5 cycles, and 95 percent correction must be accomplished within 2 cycles of the onset of the disturbance.

2.8.5 Grounding

Control panel enclosures must be equipped with a solid copper ground bus or equivalent. The ground bus must be securely anchored to the enclosure so as to effectively ground the entire structure. Clamp-type terminals sized large enough to carry the maximum expected current must be provided on the ground bus for grounding cables. Where a definite circuit ground is required, a single wire not less than #10 AWG must run independently to the panel ground bus and must be fastened to the ground bus with a bolted terminal lug. Cases of instruments, relays and other devices must be effectively grounded through the enclosures steel structure unless otherwise indicated. Insulated wiring having a continuous rated current of not less than the circuit fuse rating must be used for grounding. Grounding terminals of power receptacles must be solidly grounded to the panel enclosure.

2.8.6 Convenience Outlet

****
NOTE: Coordinate with electrical drawings to provide power for control panel convenience outlet and other required accessories.
****

A 120 volt ac, 20 amp, ground fault interruption (GFI) type duplex convenience outlet must be provided inside the panel. The outlet circuit must be separate from the panel power circuit.

2.8.7 Panel Interior Light

[Where indicated,] [Each] control panel[s] must be provided with a [60 watt incandescent] [40 watt fluorescent] [15 watt LED] light. The light must be operated by a manual on-off switch mounted on the interior door of the enclosure. The light must be powered by the same circuit as the convenience outlet.

2.8.8 Ventilation System

[Where indicated,] [Each] control panel[s] must be provided with two single phase, 120 volt ac ventilation fans. Each fan must supply a minimum of 50 L/s 100 cfm of ventilation air through the enclosure. Each fan must be provided with a line voltage thermostat. Thermostat setpoints must be adjustable in a range of 21 to 60 degrees C 70 to 140 degrees F as a minimum. Each supply and exhaust grille must contain a filter that is easily removed for cleaning or replacement.

2.8.9 Heating System

[Where indicated,] [Each] control panel(s) must be provided with a

thermostatically controlled electric heater capable of maintaining an enclosure temperature of [2] [_____] degrees C [35] [_____] degrees F when continuously exposed to an ambient temperature of [_____] degrees C degrees F.

2.8.10 Air Conditioning System

[Where indicated,] [Each] control panel[s] must be provided with a mechanical refrigeration air conditioning system. The system must be capable of maintaining a temperature of [38] [_____] degrees C [100] [_____] degrees F inside the enclosure with all equipment in the panel operating and while continuously exposed to [full sunlight and] an ambient air temperature of [_____] degrees C degrees F. The compressor and condenser must be located outside the control panel enclosure. Provisions must be made to remove condensate from the control panel and to protect all devices within the enclosure from condensate.

2.9 COMPUTER HARDWARE

****

NOTE: The designer must edit the following paragraph to require only the computer equipment that is necessary based on the requirements and complexity of the process control system. Must Verify that the location for the equipment will be provided with climate controls to provide a suitable environment for the equipment.

****

For computer hardware furnished under this specification provide standard products of a single manufacturer which advertises service in all 48 contiguous states, and provide only model currently in production. Except for PCI-E cards installed into expansion slots provided in a desktop or server computer in order to meet the requirements of this specification, do not modify computer hardware from the manufacturer configuration.

[2.9.1 Server Hardware

****

NOTE: Coordinate with the project site to determine if the server(s) will be contractor supplied or Government Furnished. If contractor supplied, coordinate with the Project Site's NEC (IT group) and include the sites 'standard' server redundancy requirements. Note that computer technology changes quickly and these requirements should be edited to reflect current products. Default requirements (current as of 2012) have been provided in brackets.

****

Computer Server Hardware (server) [will be furnished by the Government] [must be a desktop or server computer meeting the following minimum requirements:]

2.9.1.1 Processor

[____][Quad-core processor designed for server applications. Processor speed must be at least 50 percent of the speed of the fastest Intel server

processor commercially available].

2.9.1.2 Random Access Memory (RAM)

[____][300 percent of the recommended requirements of the software to be installed on the server[and no less than 24GB].]

2.9.1.3 Communications Ports

[____][Four USB 3 3.0 3.1 ports.]

2.9.1.4 Hard Drives

2.9.1.4.1 Internal Hard Drives

[____][Solid State Hard drives with SATA-3 Controller providing at least [2TB][____] usable disk space. Hard drives must use RAID (Redundant Array of Inexpensive Disks) at levels 1 or 5 (RAID-1 or RAID-5).]

2.9.1.5 Optical Drive

[____][Blue-Ray burner drive.]

2.9.1.6 Video Output

[____][32-bit color at a minimum resolution of 1920 by 1080 at a minimum refresh rate of 70 Hz and a DVI or display port output.]

2.9.1.7 Network Interface

[[____][[Two] integrated 1000Base-T Ethernet with RJ45 connector.]]

2.9.1.8 Monitor

[____][Widescreen flat panel LCD monitor sized as indicated but no less than 24 inch nominal with a minimum resolution of 1920 by 1080 pixels and a minimum refresh rate of 70Hz.]

2.9.1.9 Keyboard

[____][101 key wired USB keyboard having a minimum 64 character standard ASCII character set based on ANSI INCITS 154.]

2.9.1.10 Mouse

[____][2-button wired USB optical scroll mouse with a minimum resolution of 400 dots per inch.]

2.9.1.11 Power Supplies

[____][Hot-swappable redundant power supplies.]
]
2.9.2 Workstation Hardware (Desktop and Laptop)

****

NOTE: Coordinate with the project site to determine if the workstation(s) will be contractor supplied or Government Furnished, or a mix where some workstations are Gov't furnished and others are

contractor supplied:

"Replace Brackets" instructions

1) Government furnished only : Keep first bracketed text and remove the [as indicated].

2) Contractor supplied only: Keep the second bracketed text.

3) Combination of Government furnished and Contractor supplied: Keep all bracketed text. When keeping bracketed text (Contractor supplied or combination of Government and Contactor supplied) note that computer technology changes quickly and these requirements should be edited to reflect current products. Default requirements (current as of 2012) have been provided in brackets.

****

[The Government will provide the] [Provide a standard desktop computer or a laptop meeting the following minimum requirements for the] Computer Workstation Hardware (workstation) [as indicated].

2.9.2.1 Processor

2.9.2.1.1 Desktop

Quad-core processor designed for desktop applications. Processor speed must be at least 75 percent of the speed of the fastest Intel desktop processor commercially available.

2.9.2.1.2 Laptop

Quad-core processor designed for laptop applications. Processor speed must be at least 50 percent of the speed of the fastest Intel laptop processor commercially available.

2.9.2.2 Random Access Memory (RAM)

[____][300 percent of the recommended requirements of the software to be installed on the server[and no less than 16GB].]

2.9.2.3 Communications Ports

2.9.2.3.1 Desktop

[____][Six USB ports.]

2.9.2.3.2 Laptop

[____][Two USB ports, plus a PCMCIA card slot or an additional USB port, plus an integral RS-232 serial port or an additional USB port and a USB to RS-232 serial adapter.]

2.9.2.4 Hard Drive and Controller

2.9.2.4.1 Desktop

[____][[1.5TB][____] or larger with a SATA-3 controller.]

2.9.2.4.2 Laptop

[____][[250GB][____] or larger solid state drive.]

2.9.2.5 Optical Drive

[____][Blue-Ray drive]

2.9.2.6 Video Output

2.9.2.6.1 Desktop

[____][32-bit color with dual monitor support minimum resolutions of 3840 by 2160 at minimum refresh rates of 70 Hz and dual DVI or display port outputs.]

2.9.2.6.2 Laptop

[____][32-bit color with a minimum resolution of 3840 by 2160 at minimum refresh rates of 70 Hz and VGA or HDMI output.]

2.9.2.7 Network Interface

2.9.2.7.1 Desktop

[____][Integrated 1000Base-T Ethernet with RJ45 connector.]

2.9.2.7.2 Laptop

[____][Integrated 1000Base-T Ethernet with RJ45 connector.]

2.9.2.8 Monitor

2.9.2.8.1 Desktop

[____][Dual widescreen flat panel LCD monitors sized as indicated but no less than 600 mm 24 inch nominal with minimum resolutions of 3840 by 2160 pixels and a minimum refresh rate of 70Hz.]

2.9.2.8.2 Laptop

[____][LCD Screen sized as indicated but no less than 325 mm 13 inch nominal with a maximum supported resolution of no less than 3840 by 2160 pixels.]

2.9.2.9 Keyboard

2.9.2.9.1 Desktop

[____][101 key wired USB keyboard having a minimum 64 character standard ASCII character set based on ANSI INCITS 154]

2.9.2.9.2 Laptop

[____][Standard laptop keyboard.]

2.9.2.10 Mouse

2.9.2.10.1 Desktop

[____][2-button wired USB optical scroll mouse with a minimum resolution of 400 dots per inch.]

2.9.2.10.2 Laptop

[____][Integrated touch-pad plus a 2-button wired USB optical scroll mouse with a minimum resolution of 400 dots per inch.]

2.9.2.11 Printers

Provide [local or network] printers as indicated. Provide local printers which have a USB interface. Provide network printers which have a 100Base-T or faster interface with an RJ45 connection.

2.9.2.11.1 Alarm Printer

Provide alarm printers which use sprocket-fed fanfold paper with adjustable sprockets for paper width up to 280 mm 11 inches. Alarm printers must have programmable control of top-of-form. [Provide floor stands with paper racks for alarm printers.]

2.9.2.11.2 Laser Printer

Provide laser printers as indicated meeting the following minimum requirements:

Resolution 600 by 600 dots per inch
Printing Time 10 pages per minute
Data Buffer Size 16 Megabytes
Media Type Paper and transparency film
Media Size ANSI A(216 by 279 mm 8.5 by 11 inches) or 11 by 17 inches [Color] and other sizes as indicated
Paper Cassette 250 sheet capacity

2.9.3 Uninterruptible Power Supply (UPS)

A self contained UPS suitable for installation and operation at the Server and Workstation must be provided. The unit[s] must be sized to provide a minimum of 10 minutes of operation of the central station [and operator's workstation] computer. The UPS must incorporate surge suppression, noise filtering (normal and common mode) short circuit protection and voltage regulation (brownout and overvoltage protection). UPS must be complete with all necessary power supplies, transformers, batteries, and accessories and must include visual indication of normal power operation, UPS operation, abnormal operation and visual and audible indication of low battery power. The UPS must comply with the Federal Communications Commission Standard 15J part A for radio noise emissions.

2.9.4 Communication and Programming Device

A hand-held communication [and programming]device must be provided. The

communication [and programming]device must connect to the PLC directly for readout of variables, override, control, servicing, troubleshooting and adjustment of control parameters. The device must be provided with all necessary cables, connectors and adapters to allow connection to the PLC. The device must communicate in English language for inquiry, reporting [and programming] purposes.

2.10 TOUCHSCREEN HMI

Human Machine Interface (HMI) display screens must be supplied to provide an interface to the PLC. The touch screens must be compatible with the specific PLC being furnished. Locate touch screens in the cabinets as shown in the Contract Drawings. The touch screens must provide maintenance information and indication of the systems. The touch screens must be [15"] [ ] panel mount with a minimum resolution of 1024x768. Provide operator interface as shown on the Contract Drawings or approved equal.

2.10.1 TOUCHSCREEN HMI Display Layout

Develop HMI control and supervision display layouts complying with the minimum requirements of the Control Narrative in the Contract Drawings. Submit for approval prior to implementation.

2.11 MONITORING AND CONTROL SOFTWARE

****

NOTE: The designer should edit this paragraph, as needed, to require only the central station software that is necessary based on the requirements and complexity of the process control system. Where no information is available on future expansion, require a minimum expansion capability of 50 percent. Where specific expansion requirement information is available, it must be used to determine the expansion capability requirements.

****

Provide a single software package which implements the Scheduling, Alarming, Trending, Graphical System Display, and System Display Editor functionality. Other specified M&C functionality may be implemented in the same software package or in additional software packages. The monitoring and control software must provide the communication, programming and control capabilities necessary to support all specified points and functions, plus a minimum expansion of [50] [____] percent of the current number of points, complete with their point database. The monitoring and control station must be online at all times and must perform all required functions as specified. Where multiple modules are used the modules must be capable of sharing data and operating together seamlessly. [Software must be a client-server software package with a graphical user interface (GUI) using web-browser based clients.]The system must support multiple user operation with multiple tasks for each user and must support operation and management of all peripheral devices.

2.11.1 M&C Software Update Licensing

****

NOTE: The installation may procure its own software update licensing or contract and thus need less than 5 years. Alternatively the installation may

require longer than five years (although this will likely increase the costs significantly). Coordinate with the installation to determine if they have any specific requirement; if they don't then keep the 5 year requirement.
****

In addition to all other licensing requirements, provide M&C Software licensing which includes licensing of the following software updates for a period [of no less than 5 years][____]:

a. Security and bug-fix patches issued by the M&C Software manufacturer.

b. Security patches to address any vulnerability identified in the National Vulnerability Database at http://nvd.nist.gov with a Common Vulnerability Scoring System (CVSS) severity rating of MEDIUM or higher.

2.11.2 Graphical Operations

2.11.2.1 Graphical User Interface

****
NOTE: Standalone or web based are designer options.
****

The central station must be provided with a mouse driven, graphical user interface.

2.11.2.2 Display Information

The central station must display information necessary to support all requirements specified, including: operator commands; alarm notification; reports; system graphics as specified and as shown, incorporating dynamic data; and curve plotting.

2.11.2.3 System Graphics Implementation

System graphics displays must be hierarchical displays which integrate dynamic data into the display. System graphics must reflect actual system configuration. Each system schematic must be included as a separate display. Different colors, textures, and use of inverted video must be used for various components and dynamic data. The displays must include standard and/or custom symbols. A library of callable display symbols containing symbols for all necessary equipment and control devices must be furnished. Symbols must conform to ISA 101.01 where applicable. Data associated with a display must be updated within 5 seconds of the binary status change or the analog change in excess of the analog change differential. Any dynamic data which is not current, due to PLC communications failure, PLC failure, or point out of service, must be highlighted or flagged.

2.11.2.4 Display Editor

The display editor must enable the user to create, modify, save and delete displays and symbols. Within the display there must by dynamic fields with the function of linking the dynamic fields with the database and must be executed automatically as the last step of the database generation and modification procedure.

2.11.2.5 Graphical Programming

The system must include a graphical programming function which must be used to create all control sequences utilized in the control panels. This function must reside in the central station to create, modify, and test software for control panel resident programs. The graphical programming function must provide programming elements to be connected together to create a logic diagram. The diagram must be compiliable to produce executable code for the control panel. The graphical programming function must include elements necessary to create logic diagrams that represent sequences of operation. Program elements must be able to be combined into a custom template which can then be used as a standard function. Program checkout and debug facilities must include display of dynamic and/or simulated system variables and points on the programming screens. The user must be able to fix or force values of variables to enable program checkout during debugging. The programming must allow for the use of the portable tester for loading files directly into the control panel, uploading of existing control panel programming and database information and downloading of control panel programming and database information.

2.11.2.6 System Menus and Displays

The user must be able to call up the following displays by dedicated function key, pull down menu or by icon and must be able to page forward and backward on linked multiple page displays. The system menu and index displays must also contain icons which can be used to call up subsequent displays.

a. System Menu (list of all graphics and menus).

b. Index (list of all PLCs).

c. Alarm Summary (list of all uncleared alarms).

d. Abnormal Summary (list of all devices not in normal state; keeps track of alarm conditions which have been cleared).

e. Data Communications Summary (listing of availability for each communication channel, by statistically processing the number of transmission errors, outages, and other abnormal conditions for each channel).

2.11.2.7 Hard-Copy Screen Request

The central station must be able to obtain a hard copy of the monitor display being viewed. This must be an exact "snapshot" of the data and device symbols shown on the selected monitor.

2.11.3 Command Software

The software must provide for defining and selecting points, parameters, graphics, report generation, and all other functions associated with operation. The operator commands must be usable from central station computer and workstation keyboards with individual operator passwords as specified.

2.11.3.1 Command Input

Command menus must utilize full words and acronyms selected to allow operators to use the system without extensive training or data processing backgrounds. The system must prompt the operator.

2.11.3.2 Command Input Errors

The system must supervise operator inputs to ensure they are correct for proper execution. Provide operator input assistance whenever a command cannot be executed because of operator input errors.

2.11.3.3 Special Functions

The system must support the following special functions by using a mouse, in addition to all other commands specified:

2.11.3.3.1 Help

Produce a display of all commands available to the operator. The help command, followed by a specific command, must produce context sensitive listing with a short explanation of the purpose, use, and system reaction to that command.

2.11.3.3.2 Start/Enable

Manually start equipment and enable monitoring and control of points.

2.11.3.3.3 Stop/Disable

Manually stop equipment and disable monitoring and control components.

2.11.3.3.4 Display Diagram

Display diagrams of specific utility systems or other systems.

2.11.3.3.5 Diagram Development

Facilitate development of diagrams of specific utility systems or other systems.

2.11.3.3.6 Auto/Override

Override automatic operation of a point or return a point to automatic operation.

2.11.3.3.7 Print Report

Allow the operator to print reports.

2.11.3.3.8 Confirm Action

Allow the operator to confirm that the desired command sequence has been correctly entered and is to be executed.

2.11.3.3.9 Cancel Action

Perform the opposite function of the confirm action, at any time prior to executing confirm action.

2.11.3.3.10 Memo Pad

Allow the operator to create, store and retrieve pop-up notes.

2.11.3.4 Operator's Commands

The operator's commands must provide the means for entry of control and monitoring commands, and for retrieval of information. The operator's commands must perform such tasks as requesting a display of any binary, analog, or accumulator point, or any group of related points, startup and shutdown selected systems or devices, modifying

2.11.3.5 Level of Addressing

****

NOTE: When specifying level of addressing for identification, delete Area or Facility where not required.

****

Provide four levels of addressing for identification as follows:

2.11.3.5.1 Point

The individual sensor or control device within a unit.

2.11.3.5.2 Unit

The unit that a point is associated with, such as a blower.

2.11.3.5.3 Sub-System

The sub-system that a point is located in or near.

2.11.3.5.4 System

The system that a sub-system is located in or near.

2.11.3.6 System Access Control

A minimum of [_____] passwords must be usable with the process control system software. The system must maintain an ASCII disk file logging all operators logged onto the system, alarm acknowledgments, commands issued and all database modifications for each password. Each password must be definable as to the functions that the operator can perform.

2.11.4 Alarms

Provide M&C Software meeting the following minimum requirements for alarms:

a. The M&C software must be capable of generating alarms by comparing the value of any point from any connected system to user-configurable limits and must notify an operator of the occurrence of an alarm condition. The process control system alarm history must be stored and must be recallable by the operator using the report generator. Alarm messages must take precedence over other functions. A minimum of the most recent [25] [_____] system alarms must be directly available at the central station computer. Operator acknowledgment of

one alarm must not be considered as acknowledgment of any other alarm nor must it inhibit reporting of subsequent alarms. Alarm data to be displayed and stored must include: identification of the alarm; date and time to the nearest second of occurrence; device or sensor type; limit exceeded (if analog); engineering units; current value or status; alarm class; and alarm messages.

b. The M&C software must support at least two alarm priority levels: critical and informational. Critical alarms must remain in alarm until acknowledged by an operator and the alarm condition no longer exists; informational alarms must remain in alarm until the alarm condition no longer exists or until the alarm is acknowledged.

c. The creation, modification, and handling (routing) of alarms must be fully accessible and fully adjustable from the graphical user interface.

d. Alarm Data. Alarm data to be displayed and stored must include:

1) Identification of alarm including building, system (or sub-system), and device name.

2) Date and time to the nearest second of occurrence.

3) Alarm type:

4) Unreliable: Indicates that the source device has failed due to the sensing device or alarm parameter being out-of-range or bad data.

5) High Alarm.

6) Low Alarm.

7) Current value or status of the alarm point, including engineering units

8) Alarm limits, including engineering units.

9) Alarm priority.

10) Alarm Message: A unique message with a field of at least 60 characters. Assignment of messages to an alarm must be an operator editable function.

11) Acknowledgement status of the alarm including the time, date and user of acknowledgement.

2.11.4.1 Binary Alarms

Binary alarms must be subject to immediate reporting, within the alarm response time, at the central station.

2.11.4.2 Analog Alarms

These alarms must be subject to immediate reporting, within the alarm response time, at the central station. The control panel analog readings must be compared to predefined high and low limits, and alarmed to the central station each time a value enters or returns from a limit condition. The program must automatically change the high or low limits, or both, of any analog point, based on time scheduled operations as

specified, allowing for a time interval before the new alarm limit becomes effective. For those applications where setpoint adjustments are made, the alarm limit must be keyed to a finite deviation traveling with the setpoint.

2.11.4.3 Alarm Messages

A unique message with a field of 60 characters must be provided for each alarm. Assignment of messages to a point must be an operator editable function. Secondary messages must be assignable by the operator for printing to provide further information, such as telephone lists or maintenance functions, and must be editable by the operator.

2.11.4.4 Alarm Classes

Classes of alarms, which will be identified for each item, include class 1 and class 2 alarm conditions. Class 1 (Critical) must include display, print, and audible alarm at occurrence and at return-to-normal. Acknowledgment of class 1 alarms by the operator must be required at occurrence and at return-to-normal. Class 2 (Informational) must include display, print, and audible alarm at occurrence and at return-to-normal. No acknowledgment of class 2 alarms is required unless otherwise shown.

2.11.5 Pop-up Note Function

A pop-up note function must be included with the workstation, providing the operator a capability of noting any data which may be associated with alarms or with any other event. A note created by an operator must be automatically called up when any other workstation calls up the associated point, alarm, or alarm summary. The pop-up note function must also support free form entry of data which can be used by any workstation operators as general reminders or instructions.

2.11.6 Real Time Clock Synchronization

****
NOTE: If real time clock synchronization is not required, this paragraph will be deleted.
****

The system must synchronize each central station computer, real time clock, within one second and at least once per day automatically, without operator intervention and without requiring system shutdown. The central station computer must automatically initiate a call once per day to the NIST clock to obtain the correct time and date and update the real time clock. The central station computer must generate a report showing the time difference.

2.11.7 System Reaction

Under system normal heavy load, no more than [10] [_____] seconds must lapse from the time a binary status alarm or analog alarm occurs at a PLC until the change is displayed at the central station [and operator's workstation]. The total system response time from initiation of a control action command to display of the resulting status change must not exceed [20] [_____] seconds under system normal heavy load conditions, assuming a zero response time for operation of the PLC's control device. The alarm printer must continue to print out all occurrences, including time of occurrence, to the nearest second. All system normal heavy load

conditions must be introduced to the system via AIs and DIs.

2.11.7.1 Occurrence

System normal heavy load conditions are defined as the occurrence throughout the system of a total of three status changes, three binary alarms, three analog high or low limit alarms, and three analog quantity changes within the high and low limits during a single 1-second interval. This number of similar occurrences must repeat on a continuous basis during successive 1-second intervals for a period of 2 minutes.

2.11.7.2 Location

System normal heavy load conditions, as specified, must have 50 percent of the changes and alarms, including no less than one of each type, occurring at a single PLC with the remaining changes and alarms distributed among the remaining PLCs.

2.11.8 Report Generator

Software must be provided to generate and format standard and custom reports for displaying, printing, and storing on disk. Reports must use database values and parameters, values calculated using the real time static database or historical data base; with the reports subsequently stored on hard disk or zip drive. Dynamic operation of the system must not be interrupted to generate a report. The report must contain the time and date when the sample was taken, and the time and date when the report was printed. The software must allow for automatic and manual generation of reports. For automatic reports an operator must be able to specify the time the initial report is to be generated, the time interval between reports, end of period, and the output format for the report. Manual report generation must allow for the operator to request at any time the output of any report.

2.11.8.1 Periodic Automatic Report

The system must allow for specifying, modifying, or inhibiting the report to be generated, the time the initial report is to be generated, the time interval between reports, end of period, and the output peripheral.

2.11.8.2 Request Report Mode

The system must allow for the operator to request, at any time, an immediate printout of any report.

2.11.9 Data Interchange

Software must be provided to format and store on a government approved removable hard drive the data, trends, profiles, reports and logs as specified in a defined, standard format such as ASCII text or DIF for export and further processing by other software and/or computer systems.

2.11.10 Control Panel and DTS Circuit Alarms

The system must supervise each control panel, I/O function and DTS circuit for alarm reporting, including: control panel not responding; control panel responding (return to normal); control panel to central station DTS circuit high error rate; control panel to control panel DTS circuit high error rate; control panel/central station real time clock error more than

15 seconds (adjustable); control panel intrusion alarm; control panel offline; control panel online (return to normal); control panel failure (self-diagnostics); point not responding to command; and point change of state without command.

2.11.11 Central Station Database

The central station database must be stored on disk and in memory. The static database must be downloadable as required to control panels in the system.

2.11.11.1 Database Definition Process

Software must be provided to define and modify each point in the database using operator commands. The definition must include all physical parameters and constraints associated with each point. Each database item must be callable for display or printing, including EEPROM, ROM and RAM resident data. Each point must be defined and entered into central station database.

2.11.11.2 Dynamic Database

The dynamic database includes those variables which change with time or conditions including all DIs, AIs, PAs, and virtual (logic) points.

2.11.11.3 Dynamic Database Update

Update the dynamic database from the field, allowing the operator to select update times from 0.1 seconds to 2.0 seconds.

2.11.11.4 Static Database

The static database includes those fixed parameters and constraints from all PLCs which define the characteristics of the system and I/O functions such as alarm limits, start/stop times, point names, PLC channel addresses, and sensor spans.

2.11.11.5 Central Station Static Database Update

A copy of each control panels static database must be updated automatically once per day, each time an authorized change is submitted or upon demand from the central station database.

2.11.11.6 Workstation Access to Dynamic Data

Any workstation with proper access password and connected to the central station via the BTS must have access to the central station's dynamic data. Display of data must commence within 5 seconds.

2.11.12 Historical Data Storage and Retrieval

A historical data storage and retrieval function must be provided at the central station to collect and store dynamic data. This function must be in addition to other data storage requirements. The function must have the capability to collect and store alarm status changes, point values, events and operator commands, and system responses. The storage function must also have the capability to collect and store multiple sets of analog data at pre-specified sampling rates. This function must have the capability to retain historical data on hard disk for pre-specified time

periods, up to forty five days using last day roll over, for short-term analysis, and then output the data to a solid state drive in a SQL database for long-term retention. The operator must also be able to selectively recall short-term data stored on hard disk. Retrieval and printing of the contents of any selected historical data file must be available using the data retrieval and report generation program. The output of the report generation program must be capable of being viewed on the screen, printed in a report, or stored.

2.11.13 Trending

Provide M&C software capable of creating, modifying, uploading and archiving Point properties and performing real-time display of point properties with a minimum trending rate of 100 points per second.

a. The M&C Software must include a graphical display for trend configuration, creation and deletion accessible through the graphical user interface. Each trend must be user-configurable for:

   (1) Point to trend.

   (2) Sampling interval: adjustable between 1 second and 1 hour.

   (3) Start and Stop Time of Trend: Start and stop times determined by one or more of the following methods:

      (a) Start time and stop time

      (b) Start time and duration

      (c) Start time and number of samples

b. The M&C software must be capable of displaying and printing a graphical representation of each trend, and of multiple trended points on the same graph. The software must be capable of saving trend logs to a file. If the file format is not plain ASCII text in a Comma-Separated-Value (CSV) format, provide a means to export or convert the file to plain ASCII text in a CSV format.

2.11.14 Analog Monitoring

The system must measure, transmit, and display analog values, including calculated analog points. Differential measurements must be displayed as positive or negative values with respect to their reference points shown. An analog change in value is defined as a change exceeding a preset differential value as specified. Each analog change in value must be operator selectable and settable to provide for a minimum reporting change in value of one-half the specified end-to-end accuracy of the measured variable. Displays and reports must express analog values in proper engineering units with sign. Provide [128] [____] different sets of engineering unit conversions. Each engineering conversion unit must include range, span, and conversion equation.

2.11.15 Analog Totalization

Any analog or calculated point must be operator assignable to the totalization program. The analog totalization time period must be defined uniquely for each point. At the end of the period, totals must be stored on disk for future reference. Totalization must then restart from zero

for the next time period. The program must keep track of the peak and total value measured during the current period and for the previous period. The operator must be able to initiate a summary of totalization information on a point, unit, sub-system or system. The operator must be able to set or reset each totalized value individually. The operator must be able to define, modify, or delete the time period online.

2.11.16 LAN Software

A network operating system must be supplied as part of the LAN software. The network operating system must support network device access to the central station. The system must provide workstation access to the central station as a virtual terminal. The network must provide network access to shared peripherals. The LAN software must provide for transparent communication with any node on the system. The LAN software must support the following:

2.11.16.1 Access Control

Access control to the central station computer and workstations. Operators must be able to perform all specified functions, given the proper passwords, including database definition/modification, graphic creation/modification, and trending.

2.11.16.2 Other Functions and Configurations

2.11.17 Virus Protection Software

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NOTE: Coordinate with the project site to determineif the Virus Protection Software will be contractor supplied or Government Furnished.

****

[Provide Virus Protection Software consisting of the project site's standard virus protection software complete with a virus definition update subscription] [Virus Protection Software will be furnished by the Government].

2.11.18 Disk Imaging (Backup) Software

****

NOTE: Coordinate with the project site to determineif the Disk Imaging (Backup) Software will be contractor supplied or Government Furnished.

****

[Provide Disk imaging (backup) software capable of performing a bare-metal restore (imaging and restoring to a new blank hard drive such that restoration of the image is sufficient to restore system operation to the imaged state without the need for re-installation of software).] [Provide Disk imaging (backup) software consisting of the project site's standard disk imaging software.] [Disk imaging (backup) software will be furnished by the Government.]

2.12 DATA COMMUNICATION REQUIREMENTS

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NOTE: The designer will edit the following

paragraph as needed to require only the data communications requirements that are necessary based on the requirements and complexity of the control system. A communications system layout or block diagram must be provided on the drawings to clearly show the communications system configuration requirements.
****

Process control system data communications must support the specified functions and process control system configuration shown on the drawings.

2.12.1 Central Station/Workstation

Each workstation must be able to communicate with the central station as a virtual terminal. The workstation must be able to initiate uploads or downloads of programs and resident data, including parameters of connected systems PLCs and devices, constraints and programs in the central station.

2.12.2 Central Station/PLC

The central station must be able to initiate an upload or download of PLC data programs.

2.12.3 Communication

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NOTE: Indicate on the communications system layout diagram, on the drawings, where modem communication is required. Coordinate this with the central station/workstation computer requirements.
****

Communication with other computer systems must be accomplished using an Ethernet communications port. The central station or workstation must be able to initiate upload or download of data files.

2.12.4 Error Detection and Retransmission

Error detection and retransmission must comply with current Ethernet standards.

2.13 FACTORY TEST

****
NOTE: Evaluate the need for factory tests. Take into account the size of the system, the complexity of the system, the devices that comprise the system as well as other pertinent information. If a factory test is deemed necessary, the factory test requirements below must be tailored to the process control system to be tested. If any factory test is deemed unnecessary, delete it from the following paragraphs.
****

The process control system must be tested at the factory prior to shipment. Written notification of planned testing must be given to the Government at least 21 days prior to testing, and in no case must notice

be given until after the Contractor has received written Government approval of the test procedures.

2.13.1 Factory Test Setup

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NOTE: Items not applicable to the factory test should be deleted.

****

Assemble and integrate the factory test setup as specified to prove that performance of the system satisfies all requirements of this project, including system communications requirements in accordance with the approved test procedures. The factory test must take place during regular daytime working hours on weekdays. Equipment used must be the same equipment that is to be delivered to the site. The factory test setup must include the following:

Factory Test	
central station equipment	one each of the components
workstation	one of each type
control panel	not less than two control panels: at least one of each type used in the system plus at least one per DTS type
test set	one of each type
portable tester	one of each type
communications circuits	one of each type and speed to be utilized in the proposed system including bridges, modems, encoder/decoders, transceivers and repeaters
surge protection equipment	for power, communications, I/O functions and networks
I/O functions	sufficient to demonstrate the I/O capability and system normal operation
software	software required for proper operation of the proposed system including application programs and sequences of operation

2.13.2 Factory Test Procedure

Test procedures must define the tests required to ensure that the system meets technical, operational, and performance requirements. The test procedures must define location of tests, milestones for the tests, and identify simulation programs, equipment, personnel, facilities, and supplies required. Provide for testing all process control system capabilities and functions specified and shown. Cover actual equipment

and sequences to be used for the specified project and include detailed instructions for test setup, execution, and evaluation of test results. The test reports must document results of the tests. Surge testing need not be conducted acceptable documented proof can be provided that such testing has been satisfactorily demonstrated to the Government with identical surge protection applied. The procedures must include the following:

	Test Procedure
equipment	block diagram
hardware and software	descriptions
commands	operator commands
I/O functions	test database points with failure modes
passwords	required for each operator access level
each type of digital and analog point in the test database	description
test equipment	list
surge protection	circuit diagrams
inputs required (I/O point values and status) and corresponding expected results of each set of input values	for each application program
default values	for the application program inputs not implemented or provided for in the contract documents for the application programs to be tested

2.13.3 Factory Test Report

Submit original copies of data produced during the factory test, including results of each demonstration procedure within 7 days after completion of each test. Arrange the report so that commands, responses, and data acquired are correlated to allow logical interpretation of the data.

PART 3 EXECUTION

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NOTE: Determine the applicability and need for a Factory Test and remove the Factory Test requirements if a Factory Test is not needed.

****

3.1 FACTORY TEST

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NOTE: Include the reference to section 25 08 10 UTILITY MONITORING AND CONTROL SYSTEM TESTING if

appropriate. Otherwise indicate another basis for the Factory Test Procedures.
****

Perform factory testing of the System as specified. The Contractor is responsible for providing personnel, equipment, instrumentation, and supplies necessary to perform required testing. Provide written notification of planned testing to the Government at least 21 days prior to testing, and do not give this notice until after receiving written Government approval of the specific Factory Test Procedures. Provide Factory Test Procedures which define the tests required to ensure that the system meets technical, operational, and performance specifications. Within the Procedures define location of tests, milestones for the tests, and identify simulation programs, equipment, personnel, facilities, and supplies required. Provide procedures which test all capabilities and functions specified and indicated. Perform the Factory Test using equipment and software of the same manufacturer, model and revision as will be used for the specified project. Include detailed instructions for test setup, execution, and evaluation of test results in the Procedures. Upon completion of the test, prepare a Factory Test Report, documenting the results of the Test, and submit it as specified. This report must be approved before any equipment is shipped.

Perform the Factory Test and provide Factory Test Submittals as shown in TABLE II. FACTORY TEST SEQUENCING.

TABLE II FACTORY TEST SEQUENCING

ITEM #	DESCRIPTION	SEQUENCING (START of ACTIVITY or DEADLINE FOR SUBMITTAL)
1	Submit Factory Test Procedure	[[_____] days after notice to Proceed] [_____]
2	Perform Factory Test	After Approval of #1
3	Submit Factory Test Report	[____] days After Completion of #2

3.2 EQUIPMENT INSTALLATION REQUIREMENTS

3.2.1 Installation

Install system components and appurtenances in accordance with the manufacturer's instructions and provide necessary interconnections, services, and adjustments required for a complete and operable system. Adjust or replace devices not conforming to the required accuracies. Replace factory sealed devices, rather than adjusting. Installation, adjustment, and operation of the equipment specified must be supervised by a manufacturer's representative experienced in the installing, adjusting, and testing of the equipment.

a. Install instrumentation and communication equipment and cable grounding as necessary to preclude ground loops, noise, and surges from adversely affecting system operation.

b. Install wiring in exposed areas, including low voltage wiring, in

[metallic raceways] [EMT conduit] [rigid conduit] as specified in Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM. Wiring in air plenum areas installed without conduit must be plenum-rated in accordance with NFPA 70.

c. Submit detail drawings containing complete piping, wiring, schematic, flow diagrams and any other details required to demonstrate that the system has been coordinated and will properly function as a unit. Piping and Instrumentation (P&ID) drawings (prepared using industry recognized device symbols, clearly defined and describing piping designations to define the service and materials of individual pipe segments and instrument tags employing Instrument Society of America suggested identifiers). Include in the Drawings, as appropriate: product specific catalog cuts; a drawing index; a list of symbols; a series of drawings for each process control system using abbreviations, symbols, nomenclature and identifiers as shown; valve schedules; compressed instrument air station schematics and ASME air storage tank certificates for each type and make of compressed instrument air station.

3.2.1.1 Isolation, Penetrations and Clearance from Equipment

Dielectric isolation must be provided where dissimilar metals are used for connection and support. Penetrations through and mounting holes in the building exteriors must be made watertight. Holes in concrete, brick, steel and wood walls must be drilled or core drilled with proper equipment; conduits installed through openings must be sealed with materials which are compatible with existing materials. Openings must be sealed with materials which meet the requirements of NFPA 70 and Section 07 84 00 FIRESTOPPING. Installation must provide clearance for control-system maintenance. Process control system installation must not interfere with the clearance requirements for mechanical and electrical system maintenance.

3.2.1.2 Device Mounting

Devices must be installed in accordance with manufacturers' recommendations and as shown. Control devices to be installed in piping must be provided with required gaskets, flanges, thermal compounds, insulation, piping, fittings, and manual valves for shutoff, equalization, purging, and calibration. Any deviations must be documented and submitted to the Government for approval prior to mounting. Damaged insulation must be replaced or repaired after devices are installed to match existing work. Damaged galvanized surfaces must be repaired by touching up with zinc paint.

3.2.1.3 Pneumatic Tubing

Tubing must be concealed in finished areas. Tubing may be run exposed in unfinished areas, such as mechanical equipment rooms. For tubing to be enclosed in concrete, rigid metal or intermediate metal conduit must be provided. Tubing must be installed parallel or perpendicular to building walls throughout. Maximum spacing between tubing supports must be 1.5 m 5 feet. Each tubing system must be tested pneumatically at 1.5 times the working pressure for 24 hours, with a maximum pressure drop of [0.15] [___] kPa [1.0] [___] psig with compressed air supply turned off. Joint leaks must be corrected by remaking the joint. Caulking of joints will not be permitted. Tubing and two insulated copper phone wires for installation checkout may be run in the same conduit. Tubing and

electrical power conductors must not be run in the same conduit; however, control circuit conductors may be run in the same conduit as polyethylene tubing.

3.2.1.4 Grooved Mechanical Joints

Grooves must be prepared according to the coupling manufacturer's instructions. Grooved fittings, couplings, and grooving tools must be the products of the same manufacturer. Pipe and groove dimensions must comply with the tolerances specified by the coupling manufacturer. The diameter of grooves made in the field must be measured using a "go/no-go" gauge, vernier or dial caliper, narrow-land micrometer, or other method specifically approved by the coupling manufacturer for the intended application. Groove width and dimension of groove from end of pipe must be measured and recorded.

3.2.2 Sequences of Operation

Study the operation and sequence of local equipment controls, as a part of the conditions report, and note any deviations from the described sequences of operation on the contract drawings. Perform necessary adjustments to make the equipment operate in an optimum manner and must fully document changes made.

3.3 INSTALLATION OF EQUIPMENT

Install equipment as specified, as shown and as required in the manufacturer's instructions for a complete and fully operational control system.

3.3.1 Control Panels

Control panels must be located as indicated on the drawings. Devices located in the control panels must be as shown on the drawings or as needed to provide the indicated control sequences.

3.3.2 Flow Measuring Device

Fluid flow instruments must be installed in accordance with manufacturer's recommendations, unless otherwise indicated in the specification. The minimum straight unobstructed piping for the flowmeter installation must be 10.0 pipe diameters upstream and 5.0 pipe diameters downstream. Meters for gases and vapors must be installed in vertical piping, and meters for liquids must be installed in horizontal piping, unless otherwise recommended by the manufacturer or indicated in the specifications.

3.3.2.1 Flow Nozzle

Flow nozzles flanges must be installed so that the pressure taps are in a horizontal plane with the centerline of the pipe. Flow nozzles must be installed for ease of accessibility for periodic maintenance. Differential pressure sensors must be installed as close to the flow nozzle as possible.

3.3.2.2 Flow Switch

Flow switches must be installed in such a manner as to minimize disturbance of the flow of fluid while maintaining reliable operation of the switch.

3.3.2.3 Magnetic Flowmeter

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NOTE: Locating magnetic flowmeters near large electric motors or transformers should be avoided.

****

Meter must be installed in vertical piping so that the flow tube remains full of the process fluid under all operating conditions. A minimum of ten pipe diameters straight run upstream of the flowmeter and five pipe diameters straight run downstream of the flowmeter must be provided. The flowmeter and piping system must be grounded to earth ground.

3.3.2.4 Natural Gas or Propane Flowmeter

Install meters in accordance with ASME B31.8. Permanent gas meters must be installed with provisions for isolation and removal for calibration and maintenance, and must be suitable for operation in conjunction with an energy monitoring and control system.

3.3.2.5 Orifice Plates

Orifice plates must be installed for ease of accessibility for periodic maintenance. Differential pressure sensors must be as close to the orifice plates as possible. Orifice plates for liquid measurement must be located in horizontal pipe runs with the orifice plate flanges installed so that the pressure taps are in the horizontal plane with the centerline of the pipe. For liquid, the differential pressure transmitter must be installed below the orifice taps. For gas measurement, the orifice plate flanges must be installed so that the pressure taps are 45 degrees or more above the horizontal plane with the centerline of the pipe. For gas measurement the required differential pressure transmitter must be physically installed above the orifice taps.

3.3.2.6 Paddle Flowmeter

Meter must be installed using manufacturer's published procedures. Installers must be trained for such installations in the pipes encountered. Provide certificates demonstrating installer's qualifications.

3.3.2.7 Annular Pitot Tubes

Annular pitot tubes must be installed so that the total head pressure ports are set-in-line with the pipe axis upstream and the static port facing downstream. The total head pressure ports must extend diametrically across the entire pipe. Annular pitot tubes must not be used where the flow is pulsating or where pipe vibration is allowed.

3.3.2.8 Positive Displacement Flow Meters

Flow meters must be installed horizontally, and aligned correctly in the direction of flow.

3.3.2.9 Turbine Meters

Turbine meters must be installed so that the sensor is located in the center of the fluid flow pipe on the main axis. Turbine meters must be

installed without interruption to service. Install a welded flanged riser of appropriate pipe line rating, with a full opening valve bolted to it. Sensor must be located in accordance with the manufacturer's instructions for the specified flow rates and installation conditions. Reduced diameter pipe sections must be provided as necessary to achieve required flow velocities. Meters must be installed using the hot-tap method with tools recommended by the manufacturer. The minimum straight unobstructed piping for the flow meter installation must be 10 pipe diameters upstream and 5 pipe diameters downstream. The meter must be installed in a horizontal section unless manufacturer specifically allows otherwise.

3.3.2.10 Ultrasonic Flowmeter

Meter must be installed using manufacturer's published procedures for installation. Installers must be trained for such installations in the pipes encountered. Provide certificates demonstrating installer's qualifications.

3.3.2.11 Variable Area Flowmeter

Meters must be installed in a vertical piping section with full flow through the meter.

3.3.2.12 Venturi Flowmeter

The flowmeter must be installed with its top above the pipeline in horizontal pipe run installations. The direction of flow must be upward in vertical pipe run installations. The flowmeter must be aligned to the direction of the flow and must be rigidly mounted and vibration free. The minimum straight unobstructed piping for the flow meter installation must be 10 pipe diameters upstream and 5 pipe diameters downstream.

3.3.2.13 Vortex Shedding Flowmeters

The flowmeter must be installed with its top above the pipeline in horizontal pipe run installations. The direction of flow must be upward in vertical pipe run installations. The flowmeter must be aligned to the direction of the flow and must be rigidly mounted and vibration free. The minimum straight unobstructed piping for the flow meter installation must be 10 pipe diameters upstream and 5 pipe diameters downstream.

3.3.3 Level Instruments

3.3.3.1 Liquid Level Sensor (Bubble Type)

The air pressure regulating valve, air filter, moisture trap, air flow adjustment valve, level gauge, air isolation valve and pressure transducer must be mounted on a panel where indicated on the drawings. The level gauge must be labeled to identify the tank being measured. The isolation valve must be located in the air supply line upstream of the moisture trap, air filter and pressure regulator. The air inlet line to the dip tube and the dip tube must be mounted to a flange at the top of the tank. The dip tube must extend to the bottom of the tank, leaving the manufacturer's recommended clearance between the dip tube and tank bottom. The dip tube material must be compatible with the tank contents. The pressure regulating valve must be adjusted to the outlet pressure recommended by the manufacturer. Where exposed, the air supply line to the tank and from the tank to the level gauge and pressure transducer must be protected from damage.

3.3.3.2 Capacitance Liquid Level Sensors

The sensing probes must be located close to, and parallel with, the tank or sump wall.

3.3.3.3 Conductivity Level Switch

Level switches must be installed vertically and in accordance with the manufacturer's instructions. Switches must be accessible for maintenance and calibration. In applications where switches cannot be directly mounted to a tank by the threaded or flanged connection, a mounting bracket must be provided for connection to the inside tank wall, maintaining the minimum recommended distance from the tank fill opening.

3.3.3.4 Displacement Type Liquid Level Switch

Level switches must be installed in accordance with the manufacturer's instructions. Switches must be accessible for maintenance and calibration. In applications where switches cannot be directly mounted to a tank by the threaded or flanged connection, a mounting bracket must be provided for connection to the inside tank wall.

3.3.3.5 Mercury Float Switches

Switches must be mounted in accordance with manufacturer's published instructions. Procedures must be those used for equipment in hazardous locations.

3.3.3.6 Ultrasonic Level Sensor

Sensor must be installed vertically in the top of the tank and in accordance with the manufacturer's instructions. Switches must be accessible for maintenance and calibration. In applications where switches cannot be directly mounted to a tank by the threaded or flanged connection, a mounting bracket must be provided for connection to the inside tank wall. Sensor must be positioned to maximize the return echo signal and minimize vessel obstructions in the sensors line of sight. The minimum recommended distance from the tank fill opening and from the side of the tank must be maintained.

3.3.4 Pressure Instruments

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NOTE: Do not use differential pressure switches on liquid pumps. Gage pressure switches are better suited for liquid application. Indicate by appropriate icon on the drawings where the switches are to be located and which type is to be used.

****

Pressure sensors and pressure transducers must be verified by calibration. All pressure taps must incorporate appropriate snubbers. Pressure sensors and pressure switches must have valves for isolation, venting, and taps for calibration. Pressure switches and pressure transducers installed on liquid or steam lines must have drains. Pressure transducers, differential pressure sensors and differential pressure switches must have nulling valves. Pressure switches must be adjusted to the proper setpoint and must be verified by calibration. Switch contact

ratings and duty must be selected for the application.

3.3.5 Temperature Instrument Installation

3.3.5.1 RTD

[When the RTD is installed in pipe or is susceptible to corrosion or vibration, the] [Each] RTD must be installed in a thermowell. Thermowells must be filled with conductive heat transfer fluid prior to installation of the RTD in the thermowell. RTDs used for space temperature sensing must include a housing suitable for wall mounting. RTDs used for outside air sensing must have an instrument shelter or sun shield as shown to minimize solar effects, and must be mounted to minimize building effects. RTD assemblies must be readily accessible and installed to allow easy replacement.

3.3.5.2 Temperature Switches

Temperature switches must be installed as specified for RTDs. Temperature switches must be adjusted to the proper setpoint and must be verified by calibration. Switch contact ratings and duty must be selected for the application.

3.3.5.3 Thermometers and Temperature Sensing Elements

Thermometers and temperature sensing elements installed in liquid systems must be installed in thermowells.

3.3.5.4 Thermocouples

Each thermocouple must be installed in a protective tube or in a thermowell. Thermocouples must be insulated from ambient temperature effects. Thermocouple wires must not be installed in the same conduits as power wiring. Thermocouples must not be used for measuring temperatures below 260 degrees C 500 degrees F. Type E thermocouples may be used when the atmosphere is chemically reducing environment. Type K thermocouples may be used when the atmosphere is a chemically oxidizing environment.

3.3.6 Process Analytical Instrumentation

3.3.6.1 Ammonia Monitor

The controller must be located as shown on the drawings. The ammonia sensor must be mounted as recommended by the manufacturer. The location of the sensor must be representative of the area to be monitored and must allow access to the sensor for periodic calibration. The sensor must be located in a dry area or must be protected from moisture without restricting the flow of ammonia gas to the sensor.

3.3.6.2 Carbon Dioxide Measurement

The controller must be located in the control panel or other location as shown on the drawings. Where a sample tube is used, the size and maximum length of sample tubing must be as recommended by the manufacturer. Sample tubing must be not crimped or kinked.

3.3.6.3 Carbon Monoxide Measurement

Carbon monoxide controller and sensor must be located as shown on the

drawings or as recommended by the manufacturer. The location must be representative of the area to be monitored. Installation must be in accordance with the manufacturer's instructions.

3.3.6.4 Chlorine in Air

The controller must be located in the control panel or other location as shown on the drawings. Where a sample tube is used, the size and maximum length must be a recommended by the manufacturer. The sample tube must not be crimped or kinked. The location of the [controller] [sample tube inlet] must be near the bottom of the area to be monitored.

3.3.6.5 Chlorine in Water

The controller must be located in the control panel or other location as shown on the drawings. The chlorine sensor must be immersed in the fluid being monitored using an assembly that will allow removal of the sensor from the water. The sensors must be located in an area of continuous flow.

3.3.6.6 Combustible Gas Sensor

The sensor and transmitter must be located as shown or the drawings or as recommended by the manufacturer. The location of the sensor must be representative of the area to be monitored and must allow access to the sensor for periodic replacement.

3.3.6.7 Hydrogen Sulfide

The controller must be located as shown on the drawings or as recommended by the manufacturer. Where a sample tube is used, the tube size and maximum length must be a recommended by the manufacturer. The sample tube must not be crimped or kinked. The location of the [controller] [sample tube inlet] must be representative of the area to be monitored.

3.3.6.8 NOx Monitor

The controller must be mounted in the control panel or as otherwise shown. Sensor must be located in the flue as shown and in accordance with the manufacturer's recommendation. Installation must prevent all leakage of flue gases at the sensor.

3.3.6.9 Oxygen and Ozone in Air Monitor

The controller must be mounted in the control panel or as otherwise shown on the drawings. The oxygen sensor must be located in accordance with the manufacturer's recommendations and as shown on the drawings. High and low alarm settings must be set as required by the sequence of control. Settings must be verified through the use of a manufacturer's standard calibration kit.

3.3.6.10 Dissolved Oxygen

The dissolved oxygen sensor must be immersed in the fluid to be monitored using manufacturer's mounting assembly. The sensor must be located in an area of continuous fluid flow. [The transmitter must be located remote from the sensor.] The transmitter and wiring connections must be in a weathertight enclosure. [The transmitter must be mounted to allow the digital readout to be easily viewed.]

3.3.6.11 PH and ORP Sensor

Pipe mounted flow sensor must be located in a threaded tee or fitting to allow removal from the pipe. Submersible sensor must be completely immersed in the fluid being monitored using an ensemble that will allow for removal of the sensor from the fluid for replacement. The sensor must be located in an area of continuous flow. The transmitter must be located [at the sensor] [remote from the sensor]. [The transmitter must be mounted to allow the digital readout to be easily viewed].

3.3.6.12 Total Dissolved Solids

The sensor must be [pipe] [tank] [submersible] type as indicated on the drawings. [Pipe mounted sensor must be mounted in a threaded tee or fitting to allow removal of the sensor.] [Tank mounted sensor must be mounted in a threaded fitting to allow removal of the sensor.] [Submersible sensor must be mounted in an assembly that will allow removal of the sensor from the fluid for replacement.] The transmitter must be located [at the sensor] [remote from the sensor]. The transmitter and wiring connections must be located in a weathertight enclosure.

3.3.7 Instrument Shelters

Instrument shelters must be installed in the location shown with the bottom 1.2 meter 4.0 feet above the supporting surface using legs and secured rigidly to minimize vibrations from winds. Instrument shelters must be oriented with door facing North. Instruments located in shelters must be mounted in the 3-dimensional center of the open space of the shelter.

3.3.8 Electric Power Devices

3.3.8.1 Potential and Current Transformers

Install potential and current transformers in enclosures unless otherwise shown. Current transformer leads must be shorted when they are not connected to the measurement circuits.

3.3.8.2 Hour Meters

Meters must be located in the control panel or as otherwise shown. Power to the meter must be connected to the motor starter auxiliary contacts for pumps, blowers and other motor driven devices. For devices without motor starters, the meter must be connected in parallel with the load. Where the meter voltage differs from the metered devices voltage, transformer must be provided as necessary.

3.3.8.3 Watt-hour Meters

Install watt-hour meters and transducers in enclosures unless otherwise shown.

3.3.8.4 Transducers

Transducers must be wired in accordance with the manufacturer's instructions, and installed in enclosures.

3.3.8.5 Current Sensing Relays and Current Transducers for Motors

When used to sense meter/fan/pump status, current sensing relays must be used for applications under 4 kW 5 hp. Applications over 4 kW 5 hp must use a current transducer.

3.3.9 Output Devices

Output devices (transducers, relays, contactors, or other devices) which are not an integral part of the control panel, must be mounted in an enclosure mounted adjacent to the control panel, unless otherwise shown. Where H-O-A and/or override switches on the drawings or required by the control sequence, the switches must be installed so that the process control system controls the function through the automatic position and other controls work through the hand position.

3.3.10 Enclosures

All enclosure penetrations must be from the bottom of the enclosure, and must be sealed to preclude entry of water using a silicone rubber sealant.

3.3.11 Transformers

Transformers for control voltages below 120 VAC must be fed from the nearest power panel or motor control center, using circuits provided for the purpose. Provide a disconnect switch on the primary side and a fuse on the secondary side. Transformers must be enclosed in a steel cabinet with conduit connections.

3.4 WIRE, CABLE AND CONNECTING HARDWARE

3.4.1 LAN Cables and Connecting Hardware

LAN cables and connecting hardware must be installed in accordance with Section 27 10 00 BUILDING TELECOMMUNICATIONS CABLING SYSTEM and Section 33 82 00 TELECOMMUNICATIONS OUTSIDE PLANT (OSP).

3.4.2 Metering and Sensor Wiring

Metering and sensor wiring must be installed in accordance with the requirements of ANSI C12.1, NFPA 70, Section 33 71 02 UNDERGROUND ELECTRICAL DISTRIBUTION and Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM.

3.4.2.1 Power Line Surge Protection

Control panels must be protected from power line surges. Protection must meet the requirements of IEEE C62.41.1 and IEEE C62.41.2. Fuses must not be used for surge protection.

3.4.2.2 Sensor and Control Wiring Surge Protection

Digital and analog inputs must be protected against surges induced on control and sensor wiring. Protect binary and analog outputs against surges induced on control and sensor wiring installed outdoors and as shown. Fuses must not be used for surge protection. Test the inputs and outputs in both the normal and common mode using the following two waveforms: The first waveform must be 10 microseconds by 1000 microseconds with a peak voltage of 1500 volts and a peak current of 60 amperes. The second waveform must be 8 microseconds by 20 microseconds

with a peak voltage of 1000 volts and a peak current of 500 amperes. Submit certified test results for surge protection.

3.5 SOFTWARE INSTALLATION

Load software required for an operational process control system, including databases (for points specified and shown), operational parameters, and system, command, and application programs. Adjust, tune, debug, and commission all software and parameters for controlled systems to assure proper operation in accordance with the sequences of operation and database tables.

3.6 CONTROL DRAWINGS

3.6.1 Control

Control drawings, [framed, non-fading half-size in laminated plastic] [reproducible, with corresponding CADD files] [____], must be provided for equipment furnished and for interfaces to equipment at each respective equipment location. Condensed operating instructions explaining preventive maintenance procedures, methods of checking the system for normal safe operation and procedures for safely starting and stopping the system manually must be prepared in typed form, [framed as specified for the instrumentation and control diagrams] [reproducible, with corresponding word processor files] [____] and posted beside the diagrams. Diagrams and instructions must be submitted prior to posting. The framed instructions must be posted before acceptance testing of the system.

3.6.2 Contractor Design Drawings

Contractor Design Drawings as a single complete package: [_____] hard copies and [_____] copies in electronic form. As a minimum they must include wiring, logic, and layout. Submit hardcopy drawings on [ISO A1 841 by 594 mm 34 by 22 inches][or][A3 420 by 297 mm 17 by 11 inches] sheets, and electronic drawings in PDF and in [AutoCAD][Microstation][Bentley BIM V8][Autodesk Revit 2013] format. In addition, submit electronic drawings in editable Excel format for all drawings that are tabular, including but not limited to the Point Schedule and Equipment Schedule. Contractor Design Drawings must be approved prior to any fabrication.

3.6.2.1 Draft As-Built

Draft As-Built Drawings as a single complete package: [_____] hard copies and [_____] copies in electronic form. Submit hardcopy drawings on [ISO A1 841 by 594 mm 34 by 22 inches][or][A3 420 by 297 mm 17 by 11 inches] sheets, and electronic drawings in PDF and in [AutoCAD][Microstation][Bentley BIM V8][Autodesk Revit 2013] format. In addition, submit electronic drawings in editable Excel format for all drawings that are tabular, including but not limited to the Point Schedule and Equipment Schedule.

3.6.2.2 Final As-Built

Final As-Built Drawings as a single complete package: [_____] hard copies and [_____] copies in electronic form. Submit hardcopy drawings on [ISO A1 841 by 594 mm 34 by 22 inches][or][A3 420 by 297 mm 17 by 11 inches] sheets, and electronic drawings in PDF and in

[AutoCAD][Microstation][Bentley BIM V8][Autodesk Revit 2013] format. In addition, submit electronic drawings in editable Excel format for all drawings that are tabular, including but not limited to the Point Schedule and Equipment Schedule.

3.6.3 Points Schedule

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NOTE: Template Points Schedules in electronic format for use with this section are available in online at: http://www.wbdg.org/ccb/NAVGRAPH/graphtoc.pdf
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Provide a Points Schedule in tabular form for each system, with the indicated columns and with each row representing a hardware point, network point or configuration point in the system.

a. When a Points Schedule was included in the Contract Drawing package, use the same fields as the Contract Drawing with updated information in addition to the indicated fields.

b. When Point Schedules are included in the contract package, items requiring contractor verification or input have been shown in angle brackets ("<" and ">"), such as <___> for a required entry or <value> for a value requiring confirmation. Complete all items in brackets as well as any blank cells. Do not modify values which are not in brackets without approval. Points Schedule Columns must include:

3.6.3.1 Point Name

The abbreviated name for the point using the indicated naming convention.

3.6.3.2 Description

A brief functional description of the point such as "Supply Air Temperature".

3.6.3.3 DDC Hardware Identifier

The Unique DDC Hardware Identifier shown on the DDC Hardware Schedule and used across all drawings for the DDC Hardware containing the point.

3.6.3.4 Settings

The value and units of any setpoints, configured setpoints, configuration parameters, and settings related to each point.

3.6.3.5 Range

The range of values, including units, associated with the point, including but not limited to setpoint adjustment range, a sensor measurement range, or the status of a safety.

3.6.3.6 Input or Output (I/O) Type

The type of input or output signal associated with the point. Use the following abbreviations for entires in this column:

a. AI: The value comes from a hardware (physical) Analog Input

b. AO: The value is output as a hardware (physical) Analog Output

c. BI: The value comes from a hardware (physical) Binary Input

d. BO: The value is output as a hardware (physical) Binary Output

e. PULSE: The value comes from a hardware (physical) Pulse Accumulator Input

f. NET-IN: The value is provided from the network (generally from another
device). Use this entry only when the value is received from another device as part of scheduling or as part of a sequence of operation, not when the value is received on the network for supervisory functions such as trending, alarming, override or display at a user interface.

g. NET-OUT: The value is provided to another controller over the network.
Use this entry only when the value is transmitted to another device as part of scheduling or as part of a sequence of operation, not when the value is transmitted on the network for supervisory functions such as trending, alarming, override or display at a user interface.

3.6.3.7 Network Data Exchange Information

(Gets Data From, Sends Data To) Provide the DDC Hardware Identifier of other DDC Hardware the point is shared with.

3.6.3.8 Override Information

For each point requiring an Override, indicate if the Object for the point is Commandable.

3.6.3.9 Trend Object Information

For each point requiring a trend, indicate if the trend is Local or Remote. For remote trends provide the DDC Hardware Identifier for the device performing the trend.

3.6.3.10 Alarm Information

Indicate the Alarm Generation Type.

3.7 FIELD TESTING AND ADJUSTING EQUIPMENT

Provide personnel, equipment, instrumentation, and supplies necessary to perform site testing. The Government will witness the PVT, and written permission must be obtained from the Government before proceeding with the testing. Original copies of data produced, including results of each test procedure, during PVT must be turned over to the Government at the conclusion of each phase of testing prior to Government approval of the test. The test procedures must cover actual equipment and functions specified for the project.

3.7.1 Testing, Adjusting and Commissioning

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NOTE: Delete reference to a factory test if no factory test is to be required.
****

After successful completion of the factory test as specified, the Contractor will be authorized to proceed with the installation of the system equipment, hardware, and software. Once the installation has been completed, tested, adjusted, and commissioned each control loop and system in accordance with NIST SP 250 and must verify proper operation of each item in the sequences of operation, including hardware and software. Calibrate field equipment, including control devices, adjust control parameters and logic (virtual) points including control loop setpoints, gain constants, constraints, and verify data communications before the system is placed online. Test installed ground rods as specified in IEEE 142 and submit certification stating that the test was performed in accordance with IEEE 142. Calibrate each instrumentation device connected to the process control system control network by making a comparison between the reading at the device and the display at the workstation, using a standard at least twice as accurate as the device to be calibrated. Check each control point within the process control system control network by making a comparison between the control command at the central station and field-controlled device. Deliver trend logs/graphs of all points showing to the Government that stable control has been achieved. Points on common systems must be trended simultaneously. One log must be provided showing concurrent samples taken once a minute for a total of [4] [___] hours. One log must be provided showing concurrent samples taken once every 30 minutes, for a total of [24] [___] hours. Verify operation of systems in the specified failure modes upon Process control system network failure or loss of power, and verify that systems return to process control system control automatically upon a resumption of process control system network operation or return of power. Deliver a report describing results of functional tests, diagnostics, calibrations and commissioning procedures including written certification to the Government that the installed complete system has been calibrated, tested, adjusted and commissioned and is ready to begin the PVT. The report must also include a copy of the approved PVT procedure.

3.7.2 Performance Verification Test (PVT)

Submit test procedures for the PVT. The test procedure must describe all tests to be performed and other pertinent information such as specialized test equipment required and the length of the PVT. The test procedures must explain, in detail, step-by-step actions and the expected results, to demonstrate compliance with all the requirements of the drawings and this specification. The test procedure must be site specific and based on the inputs and outputs, required calculated points and the sequence of control. Refer to the actions and expected results to demonstrate that the process control system performs in accordance with the sequence of control. Include a list of the equipment to be used during the testing plus manufacturer's name, model number, equipment function, the date of the latest calibration and the results of the latest calibration.

Demonstrate that the completed Process control system complies with the contract requirements. All physical and functional requirements of the project including communication requirements must be demonstrated and shown. Demonstrate that each system operates as required in the sequence of operation. The PVT as specified must not be started until after receipt of written permission by the Government, based on the written report including certification of successful completion of testing,

adjusting and commissioning as specified, and upon successful completion of training as specified. Upon successful completion of the PVT, furnish test reports and other documentation.

3.7.3 Endurance Test

Use the endurance test to demonstrate the overall system reliability of the completed system. The endurance test must be conducted in phases. The endurance test must not be started until the Government notifies the Contractor in writing that the PVT is satisfactorily completed, training as specified has been completed, outstanding deficiencies have been satisfactorily corrected, and that the Contractor has permission to start the endurance test. Provide an operator to man the system [8 hours per day during daytime operations, including weekends and holidays,] [during Phase I endurance testing, in addition to any Government personnel that may be made available.] The Government may terminate testing at any time when the system fails to perform as specified. Upon termination of testing by the Government or by the Contractor, commence an assessment period as described for Phase II. Upon successful completion of the endurance test, deliver test reports and other documentation, as specified, to the Government prior to acceptance of the system.

3.7.3.1 Phase I (Testing)

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NOTE: The designer will determine the required Phase I testing period. The testing period should be based on the system size and complexity.

****

The test must be conducted 24 hours per day, 7 days per week, for [_____] consecutive calendar days, including holidays, and the system must operate as specified. Make no repairs during this phase of testing unless authorized by the Government in writing.

3.7.3.2 Phase II (Assessment)

After the conclusion of Phase I, identify failures, determine causes of failures, repair failures, and deliver a written report to the Government. The report must explain in detail the nature of each failure, corrective action taken, results of tests performed, and must recommend the point at which testing should be resumed. After delivering the written report, convene a test review meeting at the job site to present the results and recommendations to the Government. The meeting must not be scheduled earlier than 5 business days after receipt of the report by the Government. As a part of this test review meeting, demonstrate that failures have been corrected by performing appropriate portions of the performance verification test. [The Government reserves the right to cancel the test review meeting if no failures or deficiencies occur during the Phase I testing. If the Government chooses to do so, the Contractor will be notified in writing.] Based on the Contractor's report and the test review meeting, the Government will determine if retesting is necessary and the restart point. The Government reserves the right to require that the Phase I test be totally or partially rerun. Do not commence any required retesting until after receipt of written notification by the Government. After the conclusion of any retesting which the Government may require, the Phase II assessment must be repeated as if Phase I had just been completed.

3.7.3.3 Exclusions

The Contractor will not be held responsible for failures resulting from the following: Outage of the main power supply in excess of the capability of any backup power source, provided that the automatic initiation of all backup sources was accomplished and that automatic shutdown and restart of the process control system performed as specified. Failure of a Government furnished communications link, provided that the PLC automatically and correctly operates in the stand-alone mode as specified, and that the failure was not due to Contractor furnished equipment, installation, or software. Failure of existing Government owned equipment, provided that the failure was not due to Contractor furnished equipment, installation, or software.

3.8 FIELD TRAINING

****

NOTE: The number of hours required to instruct a Government representative in operation and maintenance of the system will depend on the complexity of the system specified. Designer is to establish the number of hours of each type (preliminary, additional maintenance, specialized, flow meter, and specialized sensor) of training based on equipment manufacturer recommendations, system complexity and consultation with the installation..

****

Field training oriented to the specific system must be provided for designated personnel. Furnish a copy of the training manual for each trainee plus [two] [_____] additional copies. Manuals must include an agenda, the defined objectives for each lesson, and a detailed description of the subject matter for each lesson. Furnish audiovisual equipment and other training supplies and materials. Copies of the audiovisuals must be delivered with the printed training manuals. The Government reserves the right to videotape training sessions for later use. A training day is defined as 8 hours of classroom instruction, excluding lunchtime, Monday through Friday, during the daytime shift in effect at the training facility. Submit the training manual and schedule to receive approval from the Government at least 30 days before the training.

3.8.1 Preliminary Operator Training

Prior to the start of field testing, preliminary operator training must be taught at the project site for [___] consecutive training [days] [hours]. Upon completion of this course, each student, using appropriate documentation, should be able to perform elementary operations with guidance and describe the general hardware architecture and functionality of the system. This course must include: general system architecture; functional operation of the system, including workstations; operator commands; application programs, control sequences, and control loops; database entry and modification; reports generation; alarm reporting; diagnostics; and historical files.

3.8.2 Additional Operator Training

Following the field testing, additional classroom training for operators must be taught for [___] consecutive training days; individual instruction

sessions of [4] [___] -hour periods in the morning (or afternoon) of the same weekday for [___] consecutive weeks and an additional [___] day classroom session for answering operator questions. Individual instruction must consist of "hands-on" training under the constant monitoring of the instructor. Classroom training must include instruction on the specific hardware configuration of the installed process control system and specific instructions for operating the installed system. Schedule activities during this period so that the specified amount of time on the equipment will be available for each student. The final session will address specific topics that the students need to discuss and to answer questions concerning the operation of the system. Upon completion of the course, the students should be fully proficient in system operation and have no unanswered questions regarding operation of the installed process control system. Each student should be able to start the system, operate the system, recover the system after a failure and describe the specific hardware architecture and operation of the system and be fully proficient in all system operations. Report the skill level of each student at the end of this course.

3.8.3 Maintenance Training

****
NOTE: Edit training requirements to the systems.
****

Following the [endurance test] [_____] a minimum period of [one] [_____] training [days][hours] must be provided by a factory representative or a qualified Contractor trainer for [five] [_____] designated personnel on maintenance of the equipment. The training must include: physical layout of each piece of hardware, calibration procedures, preventive maintenance procedures, schedules, troubleshooting, diagnostic procedures and repair instructions.

3.8.4 Specialized Training

****
NOTE: Coordinate with specifications for the unit processes, adding or deleting parts.
****

Following the maintenance training, a minimum period of [five] [_____], total training day(s) mustbe provided by a factory representative or a qualified Contractor trainer for [ten] [_____] people on the input devices.

3.8.4.1 Flow Meter Training

Each type of flow meter, to include calibration, maintenance and testing of flow elements and transducers.

3.8.4.2 Specialized Sensor Training

Provide training on each type of specialized sensor such as [chlorine,] [turbidity,] [pH,] [NOx,] [_____] to include calibration, maintenance and testing of sensing elements and transducers for [five] people.

3.9 OPERATION AND MAINTENANCE DATA REQUIREMENTS

Outline the step-by-step procedures required for system startup, operation and shutdown. Include in the instructions layout, wiring and control

diagrams of the system as installed, the manufacturer's name, model number, service manual, parts list and a brief description of all equipment and their basic operating features. List routine maintenance procedures, possible breakdowns and repairs and troubleshooting guides.

-- End of Section --