SECTION 13300 - INSTRUMENTATION AND CONTROL

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SECTION 13300 - INSTRUMENTATION AND CONTROL

PART 1 -- GENERAL

1.1 WORK OF THIS SECTION

A. The WORK of this Section includes the general specification and requirements for the instrumentation and control WORK under this and other applicable Specifications. The WORK also includes providing instrumentation and all related wiring as shown in these Contract Documents.

NTS: The following paragraph should be edited to reflect the scope of work for this project. If no new DCS equipment is being provided, edit accordingly.

B. The CONTRACTOR shall be responsible for the design, procurement, installation, testing, training, and documentation for instrumentation and control systems provided under this Contract. A distributed control system (DCS) shall be provided by the CONTRACTOR who shall contact Emerson to provide control systems integration. The CONTRACTOR shall be responsible for interfacing with the DCS components, including installing and terminating DCS inputs and outputs (I/O), providing power, and for installing and testing all equipment.

C. Per Section 01300 the CONTRACTOR shall be responsible for providing instrument submittals to be used in the generation of panel wiring diagrams and loop drawings which depict the interconnection between instruments, panels, valve actuators, MCCs, and the DCS.

NTS: The responsibility for developing loop drawings differs between projects. Ordinarily, the Contractor develops the drawings and forwards them to the I&C Subcontractor or Emerson for completion of the DCS-related data. On larger projects, the Construction Manager has done this. Alternately, the Design Consultant could do this. Include the following paragraph for CM-provided loops. Modify for Contractor or consultant-provided loop drawings.

D. These drawings shall be forwarded to the Design Engineer. The Design Engineer will incorporate the CONTRACTOR's data and generate a complete loop drawing for each measuring or control loop. The loop drawing shall include a minimum of 3 sheets as required in paragraph 1.5 B.2.

E. All control system field tests including loop tests, plant commissioning, and plant startup, shall be the responsibility of the CONTRACTOR. The CONTRACTOR shall provide competent personnel including electrical engineer, I&C engineer, and process engineer during all field tests. The CONTRACTOR shall be responsible for providing field and control room personnel to witness the simulation of field inputs associated with the DCS I/O. The CONTRACTOR shall be responsible for providing all competent personnel and NIST certified, current within a year, equipment (current

drivers, jumpers, read out devices, oscilloscopes, voltage-resistance meters, etc.) required to perform the loop test simulations. All devices used shall be traceable to the National Institute of Standards and Technology (NIST).

F. The CONTRACTOR shall perform field engineering design as required for mounting and supporting all field mounted components. The CONTRACTOR shall develop any additional schematic and interconnection diagrams which may be required for complete and operable instrumentation.

G. [The CONTRACTOR shall secure the services of an I&C Subcontractor who acting through the CONTRACTOR shall provide all components, system installation services, as well as all required and specified ancillary services in connection with the I&C system. The system includes all materials, labor, tools and documentation required to furnish, install, test and place in operation a complete and operable I&C system as shown and/or specified in the contract drawings. The I&C Subcontractor shall employ the services of Emerson to provide a complete, integrated and operable DCS system. The Subcontractor's role shall include, but is not limited to, witnessing the functional testing of all control loops ensuring instruments and wiring for each loop have been correctly installed. The I&C Subcontractor shall also ensure, amongst other tasks that, all wires are correctly numbered, drawings are correctly updated and within the required time frame and that all parties concerned work to the project time line to meet project milestones. During commissioning the Subcontractor shall coordinate between the relevant subcontractors to ensure that the necessary stage of completion is reached by all involved parties and all functional tests have been performed by all involved parties and all functional tests have been performed satisfactorily before that particular phase of the project is scheduled for commissioning. This shall include polarity and functional tests of all field devices, all data communication links are functional and all devices being controlled and monitored are adequately represented on the graphic display including any associated functions, which may be required.] [ ]

1.2 RELATED SECTIONS

A. The WORK of the following Sections applies to the WORK of this Section. Other Sections of the Specifications, not referenced below, shall also apply to the extent required for proper performance of this WORK.

1. Section 09800 Protective Coating

2. Division 11 Equipment, as applicable

3. Division 15 Mechanical, as applicable

4. Division 16 Electrical, as applicable

5. [Section 13400, Distributed Control System (DCS)] [ ]

1.3 CODES

A. WORK of this Section shall comply with the current editions of the following codes as adopted by the City of San Diego Municipal Code:

1. Uniform Fire Code

2. National Electrical Code

1.4 SPECIFICATIONS AND STANDARDS

A. Except as otherwise indicated, the current editions of the following apply to the WORK of this Section:

1.	ANSI/ASME B 16.5	Pipe Flanges and Flanged Fittings
2.	API RP-550	Manual on Installation of Refinery Instruments and Control Systems, Part 1 - Process Instrumentation and Control Sections 1 Through 13
3.	ASTM A 105	Specification for Forgings, Carbon Steel for Piping Components
4.	ASTM A 193	Specification for Alloy Steel and Stainless Steel Bolting Materials for High Temperature Service
5.	ASTM A 194	Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure and High Temperature Service
6.	ASTM A 283	Specification for Low and Intermediate Tensile Strength Carbon Steel Plates, Shapes, and Bars
7.	ASTM A 312	Stainless Steel Piping
8.	ISA-RP60.6	Nameplates, Labels, and Tags for Control Centers
9.	ISA-RP7.1	Pneumatic Control Circuit Pressure Test
10.	ISA-RP12.6	Installation of Intrinsically Safe Systems for Hazardous (Classified) Locations
11.	ISA-S5.1	Instrument Symbols and Identification
12.	ISA-S5.4	Instrument Loop Diagrams
13.	ISA-S12.4	Instrument Purging for Reduction of Hazardous Area Classification

14.	ISA-S20	Specification Forms for Process Measurement and Control Instrumentation; Primary Elements and Control Valves
15.	ANSI - B16.1	Cast Iron Pipe Flanges and Flanged Fittings, Class 25, 125, 250, and 800
16.	ANSI/AWWA C207	Steel Pipe Flanges for Waterworks Service - Sizes 4 In Through 144 In.
17.	ANSI/AWWA C701	Cold-Water Meters - Turbine Type for Customer Service
18.	ANSI/AWWA C702	Cold-Water Meters - Compound Type
19.	AWWA C704	Cold-Water Meters - Propeller Type for Main Line Applications
20.	ASTM A 126	Specification for Gray Iron Castings for Valves, Flanges and Pipe Fittings
21.	ASTM B 61	Specification for Steam or Valve Bronze Castings
22.	ANSI/AWWA	Ductile-Iron and Gray-Iron Fittings, 3-In Through C110/A21.10 48-In for Water and Other Liquids
23.	ASME REPORT	Fluid Meters, Sixth Edition, 1971

1.5 SHOP DRAWINGS AND SAMPLES

A. **Presubmittal Conference**:

1. The CONTRACTOR shall arrange and conduct a Presubmittal Conference within [60][ ] days after award of the Contract. The purpose of the Presubmittal Conference is to review and approve the manner in which the CONTRACTOR intends to carry out his responsibilities for shop drawing submittal on the WORK to be provided under this Section. The CONTRACTOR and the CONSTRUCTION MANAGER shall attend. Both the CONTRACTOR and the CONSTRUCTION MANAGER may invite additional parties at their discretion.

2. The CONTRACTOR shall allot two, [1] [8-hour] [4-hour] days for the Conference.

3. The CONTRACTOR shall prepare the following for discussion at the Conference:

   a. List of equipment and materials for the instrumentation systems, including proposed manufacturer names and model numbers.

b. List of proposed clarifications to the indicated requirements plus a brief written explanation of each exception. Review and acceptance of proposed clarifications will be according to Section 01600.

c. One complete example of each type of submittal proposed.

d. A flow chart showing the steps the CONTRACTOR will take in preparing and coordinating each submittal to the CONSTRUCTION MANAGER.

e. A bar chart type schedule for the WORK provided under this Section, covering the time period beginning with the conference and ending after startup and training. Dates for the beginning and ending of submittal preparation, submittal review, design, fabrication, programming, factory testing, delivery to the site, installation, field testing, and training shall be scheduled. The schedule shall be subdivided into major items or groups of items which are on the same schedule.

4. The CONTRACTOR shall furnish [3] [ ] copies of all the items above to the CONSTRUCTION MANAGER.

5. The CONTRACTOR shall take formal minutes of the Conference, including all events, questions, and resolutions. Prior to adjournment, all parties must concur with the accuracy of the minutes and sign accordingly.

B. **Shop Drawings:**

1. General:

a. Preparation of shop drawings shall not commence until adjournment of the Presubmittal Conference.

b. Preliminary Shop Drawings shall be submitted as a single package at one time within [90] [ ] days of the commencement data stated in the Notice to Proceed.

c. Both paper (hard copy) and electronic copies are required for both Preliminary and Final Shop Drawing submittals.

d. In the Contract Documents, all systems, meters, instruments, and other elements are represented by symbology derived from the latest version of ANSI/ISA S5.1. The nomenclature and numbers indicated herein shall be used exclusively in all shop drawings. No manufacturer's standard symbology or nomenclature shall replace those indicated in the Contract Documents.

e. During the period of shop drawing preparation, the CONTRACTOR shall

maintain a direct, informal liaison with the CONSTRUCTION MANAGER for exchange of technical information. As a result of the exchange, certain minor refinements and revisions to the indicated systems may be authorized informally by the CONSTRUCTION MANAGER but these shall not alter the WORK or cause increase or decrease in the Contract Price. During informal exchanges, no statement by the CONSTRUCTION MANAGER shall be construed as approval of any component or method or exception to or variation from these Contract Documents.

2. Submittals:

   a. Preliminary Submittal: Four copies of the preliminary submittal shall be provided for the City's review. Documents shall be in PDF format.

   b. Final Submittal: All documents, including design and O&M documents, shall be provided on CD-ROM. One set of CD-ROMS shall contain the native file formats (Microstation, MS Word, MS Excel, etc), and the other in PDF format, using the same file name with "PDF" or "TIF" as the file extension. Four copies of the final submittal shall be provided.

   c. Each document shall be indexed, and a database table in Excel shall be provided which includes the following data for each document

      (1) Document file name

      (2) Document description

      (3) Hard Copy Catalog No. (used by facility document coordinator)

      (4) Document Type:

         (a) Shop drawings
            i) P&IDs
            ii) Loop Drawings
            iii) Instrument Data Sheets
            iv) Other

         (b) Manufacturer's data

         (c) Maintenance instructions

         (d) Training

      (5) Facility Name

      (6) Specification Number

      (7) Process Name

(8) Unit Process Number

d. Electronic Document Submittal Requirements:

(1) All documents shall be submitted in electronic format, including shop drawings manufacturer's data and O&M manuals.

(2) Documents shall be in Adobe Acrobat PDF format, version as specified by the Contract Manager. Vendor and Contractor shop drawings developed under the Contract shall be in Bentley Microstation (.DGN) format. Documents in electronic format (WordPerfect, Microsoft Word, Excel, Lotus, etc.) shall be electronically converted to standard PDF format. In order to minimize file size, drawing conversion from Microstation files to Acrobat PDF shall be in monochrome.

(3) Deviation from this standard will be accepted only if advance approval is given by the Owner

(4) Documents not available in electronic format shall be scanned at 300 dpi, bitonal (black and white) for documents without graphics, or 150 dpi color for documents with graphics where color is required for legibility, and converted into Adobe Acrobat (PDF). Scanned image enhancement software shall be used. PDF sub-format shall be full Image Hidden Text PDF file format.

(5) All PDF documents shall be reviewed, and corrected if necessary, for orientation and legibility.

(6) Individual document files shall not exceed 3 megabytes in size.

e. Paper Document Submittal Requirements

(1) All shop drawings shall include the letterhead or title block of the CONTRACTOR. The title block shall include, as a minimum, the CONTRACTOR registered business name and address, project name, drawing name, revision level, and personnel responsible for the content of the drawing.

(2) Shop drawing copies shall be submitted as standard size 3-ring, loose-leaf, vinyl plastic binders suitable for bookshelf storage. Maximum binder size shall be 2 inches.

(3) A complete index shall be placed at the front of each binder.

(4) A separate technical brochure or bulletin shall be included for each instrument, meter system, and other element. The brochures shall be

indexed by systems or loops. If, within a single system or loop, a single item is employed more than once, one brochure may cover all identical uses of that item in the system. Each brochure shall include a list of tag numbers to which it applies. System groups shall be separated by labeled tags.

(5) All shop drawings shall be produced in using Microstation CAD formats. Each shop drawing submittal shall include the requisite number of hard copies and one (1) Microstation electronic copy. Upon completion of this project, the Contractor shall submit four (4) electronic copies of all current shop drawings.

NTS: Include the following paragraph for Contractor-provided loops. Delete for CM or consultant-provided loop drawings.

3. Loop Diagrams: loop diagrams shall be provided in accordance with Section 01300 conforming to ISA 5.4 to verify the DCS interfaces with all instrumentation and devices being provided or installed under the project. The loop diagrams shall also define all interfaces with equipment provided by area Contractors. The following three-sheet format is required:

a. Sheet 1: A device schedule developed from an electronic spreadsheet or database file, which will be submitted with the loop diagrams. The table will show the following:

(1) Device tag number, with Prefix, Unit Process, ISA Tag Prefix, Tag No. (a three or four-digit number based on the loop number) and Tag suffix

(2) Equipment Service

(3) Device Type

(4) Location

(5) Device Manufacturer

(6) Model No.

(7) Spec. No.

(8) Area Contractor (if applicable

(9) Submittal No.

(10) Calibrated Range/Remarks

(11) Data Sheet No.

(12) I/O Signal type (AI, AO, DI, or DO)

(13) Signal Level

(14) Device Range (full available instrument range)

(15) Engineering Units

(16) Process Set Point

(17) Loop Diagram No., reflecting the field instrument tag number.

(18) Loop Drawing File Name

(19) Interconnect Drawing File Name

b. Sheet 2: Loop drawing meeting the Requirements of ANSI/ISA S5.4, except that intermediate terminal junction boxes may omitted and be shown on Page 3 for clarity. Butt splices and wire nuts shall be shown on as-builts, with the corresponding termination housing (JB, LB, etc. shown on Sheet 3.

c. Sheet 3: (Expansion sheet - required if the number of intermediate devices or terminal junction boxes exceeds what can be legibly shown on Sheet 2). Abbreviated diagram showing instrument, wire and cable numbers, intermediate terminal junction boxes, and PCM terminations. Wire identification numbers will reflect the field instrument tag number, and not the DCS I/O number.

d. DCS I/O tag numbers will generally reflect the device tag number. Each I/O tag number will be unique. The tag prefix will be based on ISA-5.4, with the following additional special acronyms:

Acronym	**Signal Use**
YL	Ready Signals/ Status
ZL	In Computer status
ZSO	Device Open
ZSC	Device Closed
YL	Motor Run
HS	Equipment Start/Stop

4. Technical brochures, bulletins and data sheets containing:

a. Fully completed ISA S20 data sheets

b. Component functional descriptions

c. Locations or assembly at which component is to be installed

d. Materials of a component's parts which will be in contact with process fluids or gases

5. Shop Drawings of differential pressure producing flow tubes and elements, showing the device's proportions and performance. The CONTRACTOR shall furnish a certified curve from the manufacturer showing flow versus differential pressure for each flow metering device furnished. Where applicable, the following data shall be furnished for each device:

a. Coefficient values and tolerances

b. Effects of upstream configuration

c. Headloss as a function of the velocity head expended

d. Test results from a recognized hydraulic laboratory showing that the discharge coefficient is within 0.75 percent of standard for each meter. Documentation tabulating tests of at least 30 different meters of the same type which show compliance with the two standard deviation tests in ASME "Fluid Meters," Sixth Edition, will be an acceptable alternative.

6. Schematic and wiring diagrams for control circuits shall be submitted in two stages. Initially, schematic control diagrams shall show complete details on the circuit interrelationships of all devices within and outside each Control Panel. Subsequent to acceptance of all schematic control diagrams, by the CONSTRUCTION MANAGER, piping and wiring diagrams shall be submitted. The diagrams shall consist of component layout drawings to scale, showing numbered terminals on components together with the unique number of the wire to be connected to each terminal. Piping and wiring diagrams shall show terminal assignments from all primary measurement devices, such as flow meters, and to all final control devices, such as pumps, valves, chemical feeders and local control panels. Wiring diagrams shall include MCC Panel, circuit, and breaker number for each power feed

7. Assembly and construction drawings for each alarm annunciator, local indicating panel and for other special enclosed assemblies for field installation. These drawings shall include dimensions, identification of all components, surface preparation and finish data, and nameplates. These drawings also shall include enough other details, including prototype photographs, to define exactly the style and overall appearance of the assembly; a finish treatment sample shall be

included.

8. Installation, mounting, and anchoring details for all components and assemblies to be field-mounted, including conduit connection or entry details.

9. Complete control panel layouts, all drawn to a 1-1/2 inch=1 foot scale showing:

   a. Physical arrangements which define and quantify the physical groupings of annunciators, handstations, recorders, indicators, pilot lights and all other instrumentation devices associated with control panel sections, auxiliary panels, subpanels and racks.

   b. All cutout locations fully dimensioned. All outside panel dimensions shall be shown.

   c. Locations of back-of-panel stiffeners.

   d. Terminal point locations for all panel and back-of-panel piping and wiring connections. Terminations shall be coded with identifiers for wiring and piping connections for all electric, hydraulic and pneumatic terminations.

   e. Nameplate engraving list.

   f. A complete and detailed bill of material list shall be submitted for each field mounted device or assembly as well as cabinet assemblies and subassemblies. Bills of material shall include all items within an enclosure. An incomplete submittal shall be rejected and no further evaluation performed until a complete and detailed bill of material is submitted

1.6 OWNER'S MANUAL

A. The Owner’s Manual shall be submitted in both paper and electronic format. Electronic format shall conform to the Electronic Document Submittal Requirements for Shop Drawings.

B. Information included in the OWNER'S MANUAL shall comply with the requirements of Section 01300 with the following exceptions:

   1. Two copies of the OWNER'S MANUAL shall be submitted after acceptance of all submittals under Paragraph 1.5. One set will be returned to the CONTRACTOR with comments.

   2. Final copies of the OWNER'S MANUAL, after revision, shall be submitted to the CONSTRUCTION MANAGER 15 days prior to startup.

C. The following shall be included in the OWNER'S MANUAL in accordance with

Section 01300:

1. Installation, connection, operating, troubleshooting, maintenance, and overhaul instructions from the manufacturer.

2. Exploded or details views of all instruments, assemblies, and accessory components.

3. Parts lists and ordering instructions.

4. Wiring diagrams.

5. A list of spare parts for 1 year operation recommended by the manufacturers of all analog equipment.

1.7 AS-BUILT DRAWINGS

A. As-built drawings shall be prepared in accordance with Section 01300 with the following exceptions and changes:

1. The CONTRACTOR shall keep current an approved set of complete loop diagrams and schematic diagrams which shall include all field and panel wiring, all piping and tubing runs, all routing, all mounting details, all point-to-point diagrams with cable, wire, tube and termination numbers. These drawings shall include all instruments and all instrument elements for the complete instrument loop as provided under Divisions 11, 13, 14, 15, and 16 of this Contract.

2. One set of original drawings and two copies of each as-built drawing under this Section shall be submitted to the CONSTRUCTION MANAGER after completion of field checkout but before placing the systems in service for the OWNER'S use.

3. Drawings shall also be submitted in electronic format (Microstation)

1.8 SERVICES OF MANUFACTURER

A. **Calibration, Testing and Startup**: A technical service representative of the manufacturer shall visit the site and perform the following on all flow meters and analyzers.

1. Inspection, checking and calibrating the equipment.

2. Startup and field testing for proper operation.

3. Performing field adjustments to ensure that installation and operation comply with the Specifications.

B. **Instruction of OWNER'S Personnel**: The manufacturer's technical service representative shall instruct the OWNER'S personnel as indicated in Paragraph 3.4.

1.9 SPECIAL GUARANTEE

A. The CONTRACTOR shall guarantee the WORK of this section for two years following final acceptance of the WORK. In making any warranty repairs, the CONTRACTOR shall utilize technical service personnel designated by the manufacturer of the failed device. Repairs shall be completed within 5 days after written notification by the OWNER.

1.10 PRODUCT DELIVERY, STORAGE, AND HANDLING

A. **Delivery of Materials**: Products delivered to the site for incorporation into the WORK of this Section shall be delivered in original, unbroken packages, containers, or bundles bearing the name of the manufacturer.

B. **Storage**: Products shall be carefully stored in a manner that will prevent damage and in an area that is protected from the elements.

1.11 ENVIRONMENTAL CONDITIONS

A. **General**: All instrumentation and control system components and associated wiring shall be suitable for use in a treatment facility environment where there may be high energy AC fields, DC control pulses, and varying ground potentials between transducers and system components. The system design shall be adequate to provide proper protection against interferences from all such possible situations.

B. **Field Situated Equipment**: The instrumentation and control system shall be installed on a wastewater treatment plant site. All devices shall be designed to exist in environments rated (G2)(G3)(GX) per ISA S71.04. The system design shall be adequate to provide proper protection the environment typically associated with these facilities. As a minimum, the instrumentation and control systems shall be designed and constructed for satisfactory operation and low maintenance requirements under the following environmental conditions:

1. Temperature Range: 0 through 50 degrees C (32 through 122 degrees F)

2. Thermal Shock: 0.55 degrees C per minute (1.0 degrees F per minute)

3. Relative Humidity: 20 through 95 percent (non-condensing)

C. **Control Room Situated Equipment**: Control rooms shall be air conditioned to achieve the environmental noted in item B herein. (No positive control of relative humidity is provided.) In the event of a failure of the air conditioning system, all

components of the instrumentation and control system shall be rated to operate in an environment where the ambient temperature is 15 through 35 degrees C (59 through 95 degrees F) and the relative humidity is 20 to 95 percent (non-condensing).

D. **Noise Tolerance**: The instrumentation and control system components shall not exceed a db level of 55 when monitored 3-feet away from the devices. If upon testing it is found that this limit is exceeded at the option of the CONSTRUCTION MANAGER and at no additional cost to the OWNER, devices shall be replaced in order to achieve a maximum level of 55 db or sound absorption materials shall be added.

1.12 CABLE NUMBERING

A. The first two characters denote the facility or area number.

B. The second group of characters identifies the device being served (field device, not

C. The third section uses one of the four suffixes in the table below. Where multiple circuits of the same type are routed to the same endpoint, the suffix will be P1, P2, as required.

D. At each device or termination point, the circuit identification number is appended with the individual wire number. For Direct-Current (DC) circuits only, wire polarity is shown in parentheses as (+) or (-).

E. Spaces are not allowed, and letters are not case-sensitive, and written in upper case.

SUFFIX	CIRCUIT TYPE	EXAMPLE
(A)	24 v dc analog (4-20 mA)	01FIT022(A)-1(+)
(C)	120 volt AC control	05P320(C)-2
(D)	24v dc digital status or control	55LSH201(D)-1(+)
(P)	Power (120 volt, 480 v, 5 kv, 15 kv, etc.)	01MCC6101(P)-2

PART 2 -- PRODUCTS

2.1 GENERAL

A. All meters, all instruments, and all other components shall be of the most recent field-proven models marketed by their manufacturers at the time of submittal of the shop drawings unless otherwise indicated.

B. Panel mounted instruments shall have matching style and general appearance. Instruments performing similar functions shall be of the same type, model, or class, and shall be of one manufacturer.

C. Outdoor instrumentation shall be suitable for operation in the ambient conditions at the equipment installation locations. Heating, cooling, and dehumidifying devices shall be incorporated with the outdoor instrumentation in order to maintain it within its rated environmental operating ranges. The CONTRACTOR shall provide all power wiring for these devices. Outdoor enclosures suitable for the environment shall be provided.

D. All instrumentation in hazardous areas shall be intrinsically safe or be approved for use in the particular hazardous classification in which it is to be installed.

E. Mercury switches and components containing liquid mercury shall not be used.

F. Analog measurements and control signals shall be electrical and shall vary in direct linear proportion to the measured variable, except as indicated. Electrical signals outside control board(s) shall be 4 to 20 milliamperes DC except as noted. Signals within enclosures shall be 1-5 volts DC unless otherwise specified. Dropping resistors shall be installed at all field side terminations in the control panels to ensure loop integrity.

G. The accuracy of each instrumentation system or loop shall be expressed as a probable maximum error; this shall be the square-root of the sum of the squares of certified "accuracies" of the designated components in each system, expressed as a percentage of the actual span or value of the measured variable. Each individual instrument shall have a minimum accuracy of ± 0.5 percent of full scale and a minimum repeatability of ± 0.25 percent of full scale unless otherwise indicated. Instruments which do not conform to or improve upon these criteria are not acceptable.

H. Control panels shall be provided with redundant power supplies which are configured in a fault-tolerant manner to prevent interruption of service upon failure and interruption of service necessitated by the replacement of a power supply. All power supplies shall have an excess rated capacity of 40 percent. The failure of a power supply shall be annunciated locally and shall generate an alarm to the DCS.

I. Each control loop shall be individually fused.

2.2 CONTROL PANELS

NTS: It is PUD's intent to minimize the use of local and vendor control panels. The DCS shall be used as the primary control system. Small PLCs may be used as relay replacements if the number of relays exceeds 10 to 15. See Design Guidelines, Chapter D6 for guidance on use of PLCs. Generally, PLCs are used only in pumping stations and when supplied by a vendor as a part of a packaged system. The designer should be cautious about using redundant PLCs: generally, using the DCS for control is more reliable and easier to manage than a redundant PLC configuration. Communication between control panel PLCs and the DCS shall be via Ethernet for Allen-Bradley PLCs

or RS-232 MODBUS RTU protocol (with the PLC acting as a MODBUS slave) for all other devices. See Design Guidelines for additional data link requirements.

A. **General**: Control panels, including those furnished by equipment manufacturers, and shall be provided according to the following requirements.

1. Where indicated, control panels shall be provided with all required taps, fittings, rotameters, regulation and alarm interlocks to enable the implementation of a purge system which is in conformance with ISA-S12.4 Type Z requirements. Dimensions shall be in accordance with manufacturer's requirements. Elevations and horizontal spacing shall be subject to CONSTRUCTION MANAGER'S approval.

2. All control panels which require NEMA 3 or 4 ratings will be provided with window kits to preserve the panel's integrity and enable operations ready access to information.

3. Panels shall be fabricated, piped and wired by fully qualified workmen who are properly trained, experienced and supervised.

4. See Appendix C for control panels to be provided under this Contract.

B. **Materials**:

1. Panel section faces shall be #10 gage minimum thickness steel for free standing panels and #14 gage minimum thickness steel for smaller panels. All materials shall be selected for levelness and smoothness.

2. Relay rack high density type panels shall utilize standard relay racks with 14 gage steel frame and supports.

3. Structural Shapes and Strap Steel: ASTM A 283.

4. Bolting Material: Commercial quality carbon steel bolts, nuts and washers, all ½-inch diameter with UNC threads. Carriage bolts shall be used for attaching end plates. All other bolts shall be hex head machine bolts. All nuts shall be hot pressed hex, American Standard, heavy. Standard wrought washers shall be used for foundation bolts and attachments to building structures. All other bolted joints shall have S.A.E. standard lock washers.

C. **Fabrication**:

1. End plates, top plates and top closure panels shall be furnished when required. End plates, top plates and top closure panels shall be removable with countersunk bolts to match panels. Top closure panels shall be furnished in lengths which match the widths of standard panels, except that one top closure panel may extend across two 4-feet 6-inches wide or five 2-feet 0-inches wide standard panels. The

vertical joints of these panels shall align with the vertical joints of the standard panels.

2. End closure or rear closure doors shall be provided. Such doors shall be flush fitting and gasketed and be of the hinged lift-off type with lockable door handles. A common key shall be provided for all doors on one panel assembly. Where removable access panels are indicated, they shall be furnished with dished handle fasteners. Screw driver 1/4 turn type fasteners are not acceptable.

    a. The flanged edges of all panels shall be straight and smooth. Corners shall be welded and ground smooth.

    b. The face of the panel shall be true and level after flanging.

    c. All panel cut-outs and holes may be cut or drilled by any standard method that will not cause deformation. Burrs shall be ground smooth.

    d. Adjacent panels shall be assembled with faces flush. Gaps or cracks shall not be visible from the front of the assembled instrument board.

    e. Stiffeners shall be welded to the back of panels, as required to prevent panel deformation due to the weight of front of panel mounted instruments.

    f. Panels shall be self-supporting as defined below.

D. **Framework and Supports**:

1. The rear of each panel section shall have a steel framework for supporting conduit, tubing, wireways, switches, air piping and all instrument accessory items such as relay or terminal enclosures, transducers, pressure switches, valves and air relays. The main frame work shall be constructed of standard structural shapes. Special shapes such as "Unistrut" may be used for secondary supports. Framework must not interfere with instrument connections or access needed for maintenance or adjustments.

2. Steel framework shall extend 2-feet 8-inches back of the panel face unless otherwise required. Where indicated, individual adjustable leg supports shall be provided at the back of the framework so that the entire panel shall be self-supporting.

E. **Finish**:

1. Preparation: The front and rear face of the panel, both sides and the edges of all flanges, and the periphery of all openings shall be prepared as follows.

    a. All high spots, burrs, and rough spots shall be ground smooth.

    b. The surfaces shall be sanded or sandblasted to a smooth, clean bright finish.

c. All traces of oil shall be removed with a solvent.

2. Finishing:

a. A 3-mils dry coat of Amercoat 185 or equal primer shall be applied over the entire panel surface immediately after solvent cleaning.

b. Wet sand, dry, then quick glaze spot putty on the front of the panel only. Dry, then wet sand again and dry.

c. Apply a second 3-mils dry coat of alkyd enamel primer to the front of the panel.

d. Wet sand to smooth clear finish, then dry.

e. At least two 3-mil dry coats of air-dry, satin finish, alkyd enamel shall be applied over the entire surface. Color to be as selected by CONSTRUCTION MANAGER.

f. The CONTRACTOR shall furnish two 1-pint containers of the enamel to the CONSTRUCTION MANAGER.

3. Instrument Finishing:

a. The final coats applied to painted surface of instrument cases, doors, or bezels which are visible from the front of panels shall be manufacturer's standard unless otherwise indicated. Black japan or "crinkle" finishes on instrument cases are not acceptable

F. **Mounting of Instruments**:

1. The CONTRACTOR shall provide cut-outs, and shall mount all instrument items indicated to be panel mounted, including any instruments indicated to be furnished by other manufacturers.

2. The CONTRACTOR shall also mount, behind the panels, other instrument accessory items as indicated.

3. Rear of panel mounted equipment shall be installed with due regard to commissioning adjustments, servicing requirements and cover removal.

4. Wiring shall be kept clear of spare space to give maximum space for future additions.

G. **Piping Requirements for Control Panels**:

1. General:

   a. The CONTRACTOR shall provide terminal connections near the top, rear of the panel for all tubing and piping which connect to instruments, valves, air supply and other pressure leads external to the panel. Terminal connections for tubing shall be bulkhead tube unions. Those for pipe shall be threaded couplings, plugged for shipping purposes.

   b. Each terminal connection shall have an engraved metal or plastic plate with a terminal and instrument tag number affixed nearby.

   c. The CONTRACTOR shall provide the air supply pressure reducing station, all instrument and supply piping and all pneumatic tubing or piping to terminal connections and between instruments located within the confines of the panel and supporting framework.

2. Air Supply Piping:

   a. The CONTRACTOR shall provide air supply piping from a point near the top of the panel framework to the inlet side of the pressure reducing station, or alternately to the inlet side of individual filter regulators.

   b. Piping, fittings and valves downstream of the filters at the air supply reducing station shall be brass or copper. Headers may be extruded aluminum if the tube wall section is thick enough to accept threaded connections.

   c. The low pressure instrument air supply header shall extend from the down stream side of the main pressure reducing valves across the length of panel which includes air users. Where the header must be broken for shipping purposes, brass unions shall be provided at the panel section junctions.

   d. A separate air supply take-off consisting of a 1/4-inch brass connection braced into the air header (if brass or copper) shall be furnished for each instrument requiring an air supply. An additional 10 percent of the take-offs shall also be provided. Take-offs for 3/4-inch size headers may be made by using 3/4-inch by 3/4-inch by 1/4-inch reducing tees.

   e. Each take-off shall be fitted with a 1/4-inch brass diaphragm of needle type shut-off valve. Provide circular type handle with tag number shown thereon.

   f. The dead end of the air header opposite the supply end shall be fitted with a plugged ½-inch brass gate valve.

g. The connection from the shut-off valves air head to the instruments shall be by means of 1/4-inch or 3/8-inch O.D. tubing as required

H. **Electrical Requirements for Control Panels**:

1. The CONTRACTOR shall provide all wiring, conduit, wireways, and switches required to make instruments and other panel electrical devices operational.

2. Conduit, wireways, junction boxes and fittings shall be installed for all signal wire, all thermocouple and resistance thermometer lead wire including those between temperature sensors and temperature indicators.

3. Each terminal connection shall have a plastic plate with a terminal and instrument tag number. All wiring shall be identified with stamped tubular wire markers.

4. Freestanding panels shall be provided with switched 100-watt incandescent back-of-panel lights which are powered from a source independent from that which powers the panel devices. One light shall be provided for every 4 feet of panel width and shall be mounted inside in the top of the back-of-panel area.

5. Freestanding panels shall be provided with a 15-amp, 120 volt service outlet circuit within the back-of-panel area which are powered from a source independent from that which powers the panel devices. The circuit shall be provided with one 3-wire, 120-volt, 15-ampere, duplex receptacle for every 4 feet of panel width spaced evenly along the back-of-panel area. As a minimum, 2 duplex outlets shall be provided for each panel.

6. Smaller panels shall be sized to adequately dissipate heat generated by equipment mounted in or on the panel.

7. Where smaller panels are mounted outside or in unshaded areas, they shall be provided with thermostatically controlled heaters capable of maintaining inside temperatures above 40 degrees F.

8. Smaller panels shall be provided with a hand-switch controlled 100-watt incandescent light and a breaker protected 120-volt, 15-amp duplex receptacle.

9. Wiring Methods: Wiring methods and materials for all panels shall be in accordance with the NEC requirements for General Purpose unless otherwise indicated. Opening wiring in close cabinet type panels is allowed when indicated.

10. Construction:

    a. Wire for 115-volt circuits shall be No. 14 AWG stranded with Type THWN or THHN insulation. All terminals for external wiring connections shall be suitable for No. 12 AWG wire.

    b. Flexible conduit is not acceptable.

c. Conduit fittings shall be cast fittings.

d. Soldered or pressure crimped wire splicing in conduits shall be acceptable.

e. For case grounding, panels shall be provided with a 1/4-inch by 1-inch copper ground buss completed with solderless connector for one No. 4 AWG bare stranded copper cable. The CONTRACTOR shall connect the copper cable to a system ground loop.

f. Single case annunciator units with no remote logic which are installed at the top of a panel may be considered as being a terminal box when top of panel wire entry is indicated. If bottom of panel entry is indicated, terminal box shall be provided at the bottom of the panel and wired to the annunciator. Terminals shall be identified with plastic marker strips.

g. Terminal boxes for incoming and outgoing signal leads shall be located at the top or bottom of the panel as indicated or as otherwise required.

11. Power Supply Wiring:

a. Unless otherwise indicated, all instruments, all alarm systems, and all motor controls shall operate on 24 VDC circuits.

b. The CONTRACTOR shall furnish terminal box connections for the main power supply entry as indicated.

c. Power supply switches for alarm units shall be three pole type, arranged to open both the power and alarm circuits. Each annunciator shall be equipped with a separate switch.

d. Instruments located on a single panel section which serve one process unit may be connected to a common branch power circuit. The number of branch circuits shall be such that no circuit load exceeds 10 amps. Different panel sections and instruments serving different process units shall not use common branch circuits. A 15-amp, two-pole circuit breaker shall be provided in each branch circuit. When instruments do not come equipped with integral fuses, the panel fabricator shall furnish and install fuses as required for the protection of individual instrument against fault currents. Fuses shall be mounted on the back of the panel, in a fuseholder, with each fuse identified by a service name tag.

e. Each potentiometer type instrument, electronic transducer, controller or analyzer shall have an individual disconnect switch. Disconnect switches shall have metal or plastic tags listing the associated instrument tag numbers. Individual plug and cord set power supply connections may be used without switches when indicated.

f. Where alarm units are single unit types, one switch may be used to disconnect not more than six alarm units located on the same or adjacent panels.

12. Alarm Wiring: The CONTRACTOR shall provide all alarms including light cabinets, audible signal units, test and acknowledge switches and remote logic units as indicated. Interconnecting wiring to panel mounted initiating devices shall also be provided. Wiring from external initiating devices shall be provided by the CONTRACTOR. Where plug and cord sets are provided for component interconnection, the CONTRACTOR shall harness and support the cables in a neat and orderly fashion. Where separate wire is required, the CONTRACTOR shall install 16 AWG with THWN or THHN insulation between all components.

13. Signal Wiring:

a. Computer and Non-Computer Use:
Signal wire shall be twisted shielded pair or triads in conduit or troughs. Cable shall be constructed of No. 16 AWG copper signal wires with THWN or THHN insulation. Color code for instrument signal wiring shall be:

(1) Positive - Black (+)

(2) Signal Ground Negative - White (-)

(3) Equipment Ground - Green

(4) Ungrounded - Red

(5) Energized by voltage sound external to panel - Yellow

(6) DC circuit - Blue

b. Multiconductor cables where indicated shall consist of No. 16 AWG copper signal wires twisted in pairs, with 600 volt fault insulation. A copper drain wire shall be provided for the bundle with a wrap of aluminum polyester shield. The overall bundle jacket shall be PVC.

c. Multi-conductor cables, wireways and conduit shall provide for 10 percent allocation of spare, unused signal wires in addition to the indicated requirements.

14. Thermocouple Wiring:

a. The CONTRACTOR shall provide metal wire troughs, pullboxes, and thin walled conduit for duplex thermocouple lead wire in a manner which will facilitate field installation of lead wire without splices or terminal connections. The CONTRACTOR shall also provide the lead wire connections between multipoint temperature sensors and temperature

indicators when indicated. When a thermocouple junction box is indicated, it shall be located with the approval of the CONSTRUCTION MANAGER. The panel manufacturer shall install conduit and troughs and lead wires between the junction box and the instruments. Terminal material shall be compatible with extension wire used.

b. Thermocouple lead wire shall be No. 16 AWG with high temperature PVC insulation on each wire and PVC jacket overall, and shall conform to the latest ISA Specification for standard grade.

c. Conduit for thermocouple lead wire shall be in accordance with the following:

CONDUIT SIZE	½"	3/4"	1"	1½"	2"
NO. OF DUPLEX LEADS	1	4	6	16	26

d. Where the number of duplex lead wires exceeds 26, the wires shall be installed in rectangular ducts filled to not more than 40 percent capacity.

e. All thermocouple wireways and main conduits shall be sized to allow for 10% spare thermocouple leads.

f. Each signal, control, alarm, and indicating circuit conductor shall be designated by a single unique number which shall be shown on shop drawings. These numbers shall be marked on all conductors at every terminal using white numbered wire markers which shall be plastic-coated cloth, or shall be permanently marked heat-shrink plastic.

15. Terminal Blocks: Terminal blocks shall be molded plastic with barriers and box lug terminals, and shall be rated 15 amperes at 600-volts. White marking strips, fastened securely to the molded sections, shall be provided and wire numbers or circuit identifications shall be marked thereon with permanent marking fluid.

I. **Color Conventions:** Lens covers for indicating lights on all panels will be colored as follows:

1. Red-ON when;

- Motor not running (STOPPED)
- Valve CLOSED (not fully opened)
- Device not energized.
- Circuit breaker OPENED

2. Green-ON when;

- Motor running in forward direction (fast speed for multi-speed motors).
- Valve OPEN (not fully closed)

- Device energized.
- Circuit breaker CLOSED

3. White-ON when;

   - Power available
   - System in AUTOMATIC mode.
   - Monitoring taking place.

4. Amber-ON when;

   - Malfunction trip.
   - Equipment locked out.
   - Alarm condition

J. **Nameplates:** Nameplates shall be provided for instruments, function titles for each group of instruments, and other components mounted on the front panel(s) as indicated. A nameplate shall be provided for each signal transducer, signal converter, signal isolator, and electronic trip mounted inside the panel(s). Nameplates shall be descriptive to define the function and system of such element. These nameplates shall be of the same material as those on the front of the panel(s). Adhesives shall be used for attaching nameplates. Nameplates shall be fabricated from black face white-center laminated engraving plastic. Painted surfaces shall be prepared to allow permanent bonding of adhesives. Colors, lettering, styles, abbreviations and sizes shall be in conformance with ISA-RP60.6 with an intended viewing distance of 3 feet to 6 feet.

K. **Factory Inspection:**

1. Panels shall be inspected for compliance with requirements at the factory before shipment to the site. The CONTRACTOR shall notify the CONSTRUCTION MANAGER 2 weeks in advance of the testing date. A representative of the CONSTRUCTION MANAGER will visit the factory to make the inspection.

2. CONTRACTOR shall perform the following tests prior to arrival of the CONSTRUCTION MANAGER:

   a. All air lines adequately tested for leaks.

   b. All alarm circuits rung out to determine their operability.

   c. Electrical circuits checked for continuity and where applicable, operability.

   d. Nameplates checked for correct spelling and correct size of letters.

   e. Other test required to place the panel in an operating condition.

3. It shall be the responsibility of the CONTRACTOR to furnish all necessary testing devices and sufficient manpower to perform the tests required by the

CONSTRUCTION MANAGER to determine conformance to the requirement of the Contract documents.

4. If the above tests have not been performed prior to the arrival of the CONSTRUCTION MANAGER, the CONTRACTOR shall reimburse the OWNER for the cost of the extra time required for the inspector's services and travel expenses

L. **Shipment:**

1. Panels shall be crated for shipment using a heavy framework and skids. Panel sections shall be cushioned to protect the finish of the instruments and panel during shipment. Instruments which are shipped with the panel shall have suitable shipping stops and cushioning material installed to protect instrument parts from mechanical shock damage during shipment. Each panel crate shall be provided with removable lifting lugs to facilitate handling

2.3 GENERAL INSTRUMENTATION ENCLOSURE COMPONENTS

A. **Signal Isolators, Converters, and Power Supplies:** Signal isolators shall be provided in each measurement and control loop, wherever required, to match adjacent component impedances, or where feedback paths may be generated or to maintain loop integrity when the removal of a component of a loop is required. Signal converters shall be provided where required to resolve any signal incompatibilities. Signal power supplies shall be provided to supply sufficient power to each loop component.

B. **General Purpose Relays:** General purpose relays in the Control Panels shall be plug-in type with contacts rated 10 amperes at 120 volts ac; quantity and type of contacts shall be as indicated. Each relay shall be enclosed in a clear plastic heat and shock resistant dust cover. Sockets for relays shall have screw type terminals.

C. **Time Delay Relays:** Time delay relays shall be electronic on-delay or off-delay type with contacts rated [10],[ ]-amperes at 120-volts AC. Units shall include adjustable dials with graduated scales covering the indicated time range.

D. **Slave Relays:** Slave relays shall be provided when the number or type of contacts indicated exceed the contact capacity of the indicated relays and timers.

E. **Circuit Breakers:** Circuit breakers shall be single pole, 120-volt, 15 ampere rating or as required to protect wiring and equipment. Circuit breakers shall be mounted inside the panels as shown.

NTS: Specific nameplates should be defined in a schedule on the drawings.

NTS: The following technical specifications define the <u>minimum</u> criteria for

various field instrumentation devices. The designer shall require the use of "smart" transmitter when those devices are available and are intended to communicate with the DCS.

2.4 FLOW MEASURING SYSTEMS

A. **Magnetic Flow Measuring Systems:** Magnetic flowmeter systems shall be of the low frequency electromagnetic induction type and produce a 4 - 20 mA DC signal directly proportional to and linear with the liquid flowrate. Complete zero stability shall be an inherent characteristic of the flowmeter system. Each magnetic flow metering system shall include a metering tube, signal cable, transmitter and flowmeter grounding rings.

1. The metering tube shall have the following attributes:

   a. constructed of 304 or 316 stainless steel with flanged connections

   b. utilize a minimum of 2 bullet-nosed, self-cleaning electrodes

   c. liner in conformance with the manufacturer's recommendation for the meters intended service

   d. electrodes constructed of materials which are in conformance with the manufacturer's recommendation for the meters intended service

   e. meter housing rated for NEMA 6 submergence conditions

   f. meter coating consisting of epoxy painted finish

   g. two grounding rings which are in conformance with the manufacturer's bore and material recommendation for the meters intended service. Grounding rings shall be designed to protect and shield from process abrasion the liners edge interface at the meters end:

2. The microprocessor-based signal converter/transmitter shall have the following attributes:

   a. utilize DC pulse technique to drive flux-producing coils

   b. convert DC pulse signal from the tube to a standardized 4-20 mA signal into a minimum of 700 ohms

   c. 6 digit LCD display for flow rate, percent of span, and totalizer

   d. an operator interface consisting of keypads which respond to English text entry

   e. integral zero return to provide a consistent zero output signal in response to an external dry contact closure

f. integral low flow cutoff and zero return

g. automatic range change

h. capable of measuring flow in both directions

i. programmable parameters including meter size, full scale Q, magnetic field frequency, primarily constant, time constant

j. data retention for a minimum of 5 years without auxiliary power (main or battery)

k. self diagnostics and automatic data checking

l. protected terminals and fuses in a separate compartment which isolates field connection from electronics

m. utilize "Smart" technology which employs a hand-held configuration terminal and outputs a digital flow signal superimposed on 4-20 mA signal and complies to protocol which is ungradable to SP 50.

n. produces a scalable frequency output, 0 to 100 Hz, transistor switch closure up to 5.75 W externally powered, 5, to 24 VDC

o. can tolerate ambient temperature operating limits of -20 to 140 degrees F (-29 to 60 degrees C)

3. Each flow metering system shall be hydraulically calibrated at a facility which is traceable to the National Institute of Standards and Technology. The calibrations procedure shall conform to the requirements of MIL-STD-45662A. A real-time computer generated printout of the actual calibration data indicating apparent and actual flows at 20%, 40%, 60%, 80% and 100% of the calibrated range shall be submitted to the Construction Manager at least thirty (30) days prior to shipment of the meters to the project site. The flow metering system shall conform to the following technical specifications: Time constant = 0.5 to 1000 seconds; galvanic or optic isolation: Accuracy: 0.25 of flow rate from 10 to 100% full scale for velocities over 3 FPS: Repeatability: 0.25% full Scale: Power consumption: 30 watts or less: Power Requirements: 120 VAC, ± 10% (24 VDC).

4. See Appendix C for a schedule of required devices for this Contract.

5. Magmeters shall be Krohne America to match existing.

B. **Propeller Flow Measuring Systems:** The flowmeter shall be designed to operate continuously at any flow rate within the rated range. Meter accuracy shall be ± 2 percent of rate at any flow from the minimum rating to 150 percent of maximum rating.

The meter shall be wet flow calibrated against a primary standard accurate to ± 0.25 percent. Two copies of the calibrations taken at or near minimum flow rating, at mid-range and at the highest flow rate within the range attainable by the test facility shall be furnished to the Construction Manager. Meter-mounted indicators, totalizer, and transmitters, or any combination thereof, shall be of the same manufacture as the propeller meters. The meterhead shall be mounted on a flanged connection for ease of removal from the pipe, for inspection or service. The meterhead shall consist of a cast iron or steel cover plate bronze or cast iron gear box, stainless steel, Delrin, hard rubber or ceramic wetted working parts and acceptable injection molded engineered grade thermoplastic propeller. The drive mechanism shall be by means of stainless steel worm, worm gear shafting with O-ring packing or a ring angle or ceramic radial sleeve magnetic drive, as shown in Schedule. The meter shall be equipped with [a 6-digit straight reading totalizer with center sweep test hand, protected by an all metal or sealed, injection molded plastic register box and cover assembly, with locking hasp.] [a 6-digit straight reading totalizer, test hand, and instantaneous rate of flow indicator, protected by an all metal, or sealed, injection molded plastic register box and cover assembly, with locking hasp.] [a 6-digit straight reading totalizer-transmitter with center sweep test hand,] and a 4-20 mA dc protected by an all metal, or sealed, injection molded plastic register box and cover assembly, with locking hasp. Use of external converters shall not be acceptable. Zero and span shall be field adjustable and shall not cause loss of local totalization while in operation. Meters, 2-inch to 4-inch in size, shall be furnished with straightening vanes in cast iron tubes lined with stainless steel, or fusion epoxy coating. The ends shall be flanged to ANSI standards. Meters 6-inch through 36-inch in size, shall be furnished with either saddles and straightening vanes, or with flanged tubes with integral vanes. Vanes shall be fabricated of carbon steel with AWWA Class D flanges. The tubes and straightening vanes shall be lined and coated with a 7-mil minimum coating of epoxy polyamide or equal with the outside of the tube further protected by the manufacturer's standard protective coating. Meters, 42-inch to 72-inch in size, shall be furnished with saddles and straightening vanes. Propeller flow measuring systems shall be McCrometer to match existing.

See Appendix C for a schedule of required devices for this Contract.

C. **Ultrasonic Flow Measuring System (Factory Mounted):** Two sensors shall be factory welded to a straight pipe on opposite sides of the pipe, installed to ensure that acoustic pulses are transmitted diagonally upstream and downstream across the centerline of the pipe. Probes shall be wetted, removable under pressure and flow conditions and shall be rated for 250 psig working line pressure. Meter shall be designed to operate on 120V ac supply with a power consumption of not more than 30 watts for indoor mounting and 250 watts for outdoor mounting with heater. The probes shall be fabricated of non-corrosive material and shall be equipped with an armored triaxial cable. The equipment manufacturer shall recommend and select the signal and frequency to be utilized for the measurement to ensure process pipeline and shall comply to Section 02650 for welded steel cement mortar-lined installation requirements. The electronic unit recommended by the manufacturer to measure the flow of water in the pipe shall be housed in a NEMA 4X housing designed for wall-mounting. The electronic unit shall utilize the output of the velocity sensing probes to measure fluid velocity in each pipe and shall be factory wired, solid state. The

electronic unit shall include an integral totalizer display and a rate display. An attached programming unit shall include a signal strength indication display for use during calibration of the meter unit. The transmitter unit shall produce an isolated 4 to 20 mAdc output signal capable of driving a load impedance of 600 ohms at 24 VDC. Ultrasonic flow measuring systems shall be Nusonics to match existing.

See Appendix C for a schedule of required devices for this Contract.

D. **Ultrasonic Flow Measuring System (Field Mounted):** Meters shall be directional and utilize ultrasonic velocity measurement principles. Field-mounted ultrasonic flow meters shall consist of transducers mounted in bosses welded directly to metal pipes, or transducers mounted to gasketed saddles strapped to concrete or plastic pipe. The meters shall be suitable for measuring [raw sewage] [treated sewage effluent] [RAS/WAS] [raw water] [drinking water] with an accuracy of ±2 percent at flows above one foot per second, and a range of 10 to 1, or 25 to 1 at higher velocities. Two sensors shall be permanently mounted to a straight pipe provided by the CONTRACTOR, with weldments or Type 316 stainless steel straps on opposite sides of the pipe, such that the acoustic pulses pass diagonally upstream and downstream across the centerline of the pipe. The probes shall be wetted and removable under pressure and flow conditions. The meter shall be designed to operate on 120 VAC supply with a power consumption of not more than 30 watts indoor and 250 watts outdoor with heater. The probes shall be fabricated of non-corrosive material and shall be equipped with an armored triaxial cable for electric transmission. The equipment manufacturer shall select the signal and frequency to be utilized for the measurement to assure proper ultrasonic transmission. The electronic unit shall utilize information from the velocity sensing probes to accurately measure fluid velocity in each pipe. All wiring within the electronic unit shall be factory pre-wired. The transmitter unit shall produce a 4 to 20 mA-dc signal, and a scaled pulse output signal, if totalization is required, proportional to the flow rate. A local flow indicator, scaled in the specified flow range, shall be provided and installed in an accessible location for easy reading. Ultrasonic flow measuring systems shall be Polysonics to match existing.

See Appendix C for a schedule of required devices for this Contract.

E. **Wafer Type Magnetic Flow Measuring Systems:** Magnetic flowmeter systems shall be of the low frequency electromagnetic induction type and produce a DC pulsed signal directly proportional to and linear with the liquid flow rate. Compete zero stability shall be an inherent characteristic of the flowmeter system. Each magnetic flow metering system shall include a metering tube, signal cable, transmitter and flowmeter grounding rings. The metering tube shall be constructed of 304 or 316 stainless steel wafer type, have at least two (2) diametrically opposed bullet-nosed self cleaning electrodes, a liner material recommended by the manufacturer for the meters intended service as described in these documents, a meter housing rated for NEMA 6 submergence conditions, and a meter coating consisting of epoxy painted finish. The system shall utilize two (2) grounding rings for a system ground. All grounding shall conform to the manufacturer's requirements. The signal converter/transmitter shall use a DC pulse technique to drive flux-producing coils and convert the DC pulse signal form the tube to a standardized 4-20 mA signal. The signal converter/transmitter shall

have a six (6) digit back lit indicator, be housed in a remotely mounted NEMA 4X enclosure, have integral zero return to provide a constant zero output signal in response to an external dry contact closure, an integral calibration self-test feature to verify proper operation of the electronics, high and low alarms and an automatic zero adjustment. Each flow metering system shall be hydraulically calibrated at the facility which is traceable to the National Bureau of Standards. The calibration procedure shall conform to the requirements of MIL-STD-45662A. A real-time computer generated printout of the actual calibration data indicating apparent and actual flows at 20%, 40%, 60%, 80%, and 100% of the calibrated range shall be submitted to the CONSTRUCTION MANAGER at least thirty (30) days prior to shipment of the meters to the project site. The flow metering system shall conform to the following technical specifications: **Output:** 4-20 mA into 600 ohms minimum; Time Constant = 0.5 to 100 seconds; galvanic or optic isolation: Accuracy: 0.25% of flow rate from 10 to 100% full scale for velocities over 3 FPS: Repeatability: 0.25% Full Scale: Environmental Limits: T = - 25 to + 160F: Power Consumption: 30 watts or less. Wafer type magnetic flow measuring systems shall be Krohne America to match existing.

See Appendix C for a schedule of required devices for this Contract.

F. **Paddle Wheel Flow Measuring Systems:** Paddle wheel insertion meters shall be devices that can be built into pipelines of any material and up to 96 inches in diameter. They shall be designed for easy insertion and withdrawal under pressure, of materials suitable for the intended service. The meter stem shall contain an electronic pickup, sensing the passage of each rotor blade. A pulsed output shall produce a repetition rate directly related to flow velocity. The meter shall be capable of registering flow with an accuracy of ±2 percent over a 10 to 1 range, with a negligible pressure loss. The meter inserts shall be made of Type 316 stainless steel or of plastic material suitable for the intended service. The shaft material shall be stainless steel, titanium, or Hastelloy. The paddle wheels shall be of Type 316 stainless steel or suitable plastic. The meter inserts shall be mounted securely through a screwed, flanged, welded, or socket-welded tee connection or fitting, for precise positioning in the pipeline. The fittings shall be of the same material as the pipeline and, unless otherwise called out, the inserts shall be easily retractable and replaceable under line pressure through a gate or ball valve with a gland and retaining cable or chain. The mounting hardware or probe shall include a clear indicating device to correctly position the meter insert in the pipeline. The meter shall be furnished with a local flow indicator for mounting on the pipeline, the insert, or the wall, with all necessary connections and supports. The indicator shall read in [cubic feet per minute] [cubic feet per hour] [gallons per minute], and it shall be enclosed in a corrosion-resistant and weatherproof housing. [The meter shall generate a 4-20 mA output into 600 ohms.] Paddle wheel flow measuring systems shall be Signet, or equal.

See Appendix C for a schedule of required devices for this Contract.

G. **Vortex-Shedding Flow Measuring Systems:** The meters shall be of the enhanced vortex-shedding type, utilizing the Karmon Vortex-shedding phenomenon, with either thermal, pressure, or ultrasonic sensing. The sensor shall not be wetted by the liquid. The meters shall be suitable for indoor or outdoor installation and they shall have an

accuracy of ± 1 percent over a range of 10 to 1. The meter body shall be of Type 316 stainless steel with a Type 316 stainless steel flow element. The body shall fit between a pair of standard pipe flanges and it shall be of weather-proof construction. The direct-mounted flow indicator/transmitter shall be encased in a rotatable, weather- [and explosion-proof] aluminum housing and it shall produce a 4 to 20 mA-dc signal output proportional to the flow rate. The transmitter shall be suitable for operation on 120-volt, ac, single-phase, 60 Hz supply. Vortex-Shedding flow measuring systems shall be UFM, RFI, or equal.

See Appendix C for a schedule of required devices for this Contract.

H. **Rotameter Flow Measuring Systems:** Unless otherwise shown, all rotameters in chemical solutions lines and where shown shall have vertical bottom inlets and top outlets with ANSI 150-lb flanged ends, for vertical mounting. Meters in air, and pump seal flushing lines shall be of the modified rotameter design with screwed ends, spring-loaded pistons, and union bodies for mounting in any position. All meters shall be rated for a minimum working pressure of 150 psi. All flanged rotameters for chemical solutions and other service, where shown, shall be calibrated in gallons per minute. The meters shall have Hastelloy C floats, 10-inch long scales, and a range of 10:1 with an accuracy of ± 2 percent. The scales shall be suitable for the capacity ranges shown. The following body materials shall be used for the rotameters:

1. Activated carbon solution - all Type 316 stainless steel construction with magnetically actuated float and scale.

2. Other chemicals - Type 316 stainless steel ends with heavy borosilicate glass tubes and packing glands, or other best suitable material.

All rotameters with NPT screwed ends for water, air, and fuel gas service shall be calibrated in gallons per minute or cubic feet per minute. The bodies shall have union ends for ease of maintenance, polysulphone tubes, aluminum or brass end fittings, Type 316 stainless steel internal parts and scales suitable for the capacity range shown in Appendix C. The rotameters shall have an accuracy of not less than ± 5 percent over the capacity range shown. Rotameters for chemical applications shall be Brooks Instruments to match existing. Rotameters for water applications shall be UFM to match existing.

See Appendix C for a schedule of required devices for this Contract.

I. **Mechanical Batch Flow Measuring Systems:** The meters shall be designed to operate intermittently at maximum flow rate within the rated range, and with an accuracy of ± 1 - ½ percent within that range. The meters shall be furnished complete with control registers, shut-off valves, and linkage to measure a pre-set amount of water. The meter shall be of the positive displacement type using discs or pistons, measuring chambers and sealed gears. The body shall be of bronze, with screwed or flanged ends, flanged body for servicing, stainless steel trim, hard rubber or other suitable plastic disc or piston. The flexible spindle between gear and register shall have a stuffing box with minimum friction, or the register shall be hermetically sealed with a

magnetic drive. The meter shall be suitable for a working pressure of not less than 125 psi, unless otherwise specified. The valve shall automatically stop the flow through the meter when a pre-wet quantity of liquid has been delivered. The meter shall have a resettable 5-digit display to measure batches up to [5,000] gallons. The automatic stop shall be performed mechanically by a valve linked to the register. The valve shall have a 2-stage closure, which closes partially as the end of the delivery nears to prevent shock pressure when the valve closes completely. The meter, register, valve, and linkage shall be a completely assembled unit, not requiring any electrical wiring or pneumatic lines. Mechanical batch flow measuring systems shall be Controls Warehouse, Actaris, or equal.

See Appendix C for a schedule of required devices for this Contract.

J. **Electronic Batch Flow Measuring Systems**: The meters shall be designed to operate intermittently at maximum flow rate within the rated range, and with an accuracy of ±1-1/2 percent within that range. The meters shall be furnished complete with control registers, electrically operated valves, and switches to measure a pre-set amount of water into chemical mixing tanks. The meters shall be of the positive displacement type or turbine type, using discs or pistons, or rotors, measuring chambers, and sealed gears. The body shall be of bronze, with screwed or flanged ends, flanged body for servicing, stainless steel trim, hard rubber or plastic disc or piston, or plastic rotor, and oil enclosed gear. The turbine-type meters shall have straightening vanes in the inlet. The drive shall be hermetically sealed, of the magnetic type. Pressure rating shall be 125 psi operating pressure, unless otherwise specified. The automatic reset control unit shall be enclosed in a sturdy cast aluminum, brass, or stainless steel housing, mounted directly on the meter body. It shall have a large, calibrated dial with a 6-digit totalizer and an automatic reset motor, suitable for 115-volt ac power supply. Internal wiring shall terminate at an easily accessible connector strip. The preset quantity shall be adjustable from one percent to 100 percent of total dial capacity. The dial shall be calibrated in gallons. The control unit shall be operated in conjunction with a motor-operated ball valve or a solenoid valve. After a pre-determined quantity of water is measured, a cam shall close an electric circuit and close the valve in the line. Electronic batch flow measuring systems shall be Actaris, or equal.

See Appendix C for a schedule of required devices for this Contract.

K. **Displacement Flow Measuring Systems:** The flowmeters shall be designed to operate continuously at any flow rate within the rated range, and with an accuracy of ±1-1/2 percent within that range. The meters shall be of the positive displacement type using discs or pistons, measuring chambers and sealed gears. The body shall be of bronze, with screwed or flanged ends, flanged body for servicing, stainless steel trim, hard rubber or other suitable plastic disc or piston, and oil enclosed gear. The register shall be hermetically sealed with a magnetic drive and it shall indicate and totalize in gallons or cubic feet. Minimum pressure rating shall be 125 psi operating pressure, unless otherwise specified. Displacement flow measuring systems shall be UFM, or equal.

See Appendix C for a schedule of required devices for this Contract.

L. **Venturi Flow Measuring Systems:** The meter shall be of the pressure differential-producing type utilizing pure static pressures sensed at the inlet and at the throat, without the use of devices which amplify differential through change in direction of flow at the cross-sections where inlet and/or throat static pressure is sensed. The inlet section which incorporates the high pressure tap shall be a cylindrical section of the same diameter as the pipe. The throat section shall be cylindrical for a minimum length of ½ of the throat diameter. The low pressure tap shall be installed in the throat section. The metering element shall be free of debris-collecting cavities or annular chambers and shall have a single pressure connection at the inlet and one at the throat. The venturi body shall be of cast iron per ASTM A 126, Grade B, with bronze throat per ASTM B 61, or of carbon steel with stainless steel trim. All internal, ferrous surfaces shall be coated in accordance with the requirements of Section 09800 - Protective Coating. The tubes shall have plain ends for welding, grooved ends for mechanical type couplings, or flanged ends per ANSI/AWWA C110/A21.10, or AWWA C207.

Where shown, meters shall be of the short pattern Venturi tube, plastic-insert type, with necessary pressure connections and transmitting equipment as specified below. Flow tubes shall have glass fiber polyester plastic outlet, inlet cone, and holding flange. Capacity, size, and location of flow tubes shall be as shown in Appendix C. Venturi flow measuring systems shall be Badger to match existing.

See Appendix C for a schedule of required devices for this Contract.

M. **Orifice Plate Flow Measuring Systems:** Each orifice meter shall consist of an orifice plate, placed between a pair of ANSI 125-lb cast iron, or 150-lb steel flanges as shown. The flanges shall have ½-inch pressure taps and stainless steel tubing to flow indicator or transmitter. Unless otherwise specified, all orifice plates shall be made of annealed Type 316 stainless steel, with a minimum thickness of 1/8-inch, as recommended by the manufacturer. The surface finish shall be within 15-20 micro inches roughness and the concentricity within 3 percent of the inside diameter of the meter tube. Tolerances for the bore shall comply with AGA and ASME specifications. The seals shall be of Teflon with stainless steel retainer rings. Orifice plate flow measuring systems shall be Daniels to match existing.

See Appendix C for a schedule of required devices for this Contract.

N. **Pitot Tube Flow Measuring Systems:** The averaging pitot tube shall consist of a perforated metering tube to be inserted into the main pipe, the necessary mounting and isolating hardware, two connecting tubes, and a wall-or pipe-mounted flow indicator and/or transmitter. The metering tube shall be installed in such a way, that it can be withdrawn from the main pipe under pressure, without interruption of the service. The meter shall be capable of registering the flow with an accuracy of ±2 percent over a range of 4:1, with a pressure loss not to exceed 3 percent of the output differential. The metering tube shall be fabricated of heavy gage Type 316 stainless steel, for insertion through the centerline of the main pipe. It shall have a series of inlet and outlet ports and two passages connecting to the flow readout device. The tube shall terminate at the top in a stainless steel bar stock tee, for connection to the instrument tubes. The metering tube shall be mounted through a flanged or threaded connection, welded to the

main pipe, or through a saddle clamp for non-metallic and cast iron pipe. The mounting hardware shall include a gate or ball valve, a packing gland, a restraining chain, and all required fittings. Where necessary, a vent or settling chamber shall be added for trouble-free operation. The mounting hardware shall be of Type 316 stainless steel, except for the welded connection to the main pipe, which shall be made of a 3000-lb carbon steel half-coupling or a 300-lb carbon steel welding fitting and flange. The entire assembly shall be rigidly constructed. The metering tube shall be connected to its instrumentation by means of 2 Type 316 stainless steel tubes with balancing and isolating valves and union fittings of a size recommended by the manufacturer. The tubes shall be as short as possible and firmly supported. Pitot tube flow measuring systems shall be Dietrich Standard to match existing.

See Appendix C for a schedule of required devices for this Contract.

O. **Differential Pressure Flow Transmitters:** Electronic gauge pressure transmitters shall be of the differential pressure type and consist of a capsule assembly, bottom works, weatherproof and bugproof atmospheric vent assembly, drain plug, cover, flange, process connector and connection, Teflon gaskets, amplifier unit, integral indicator, terminal box with cover, block an bleed valves, and conduit connections. Pressure applied to the transmitter shall be transmitted by a sealed fill fluid to both sides of a sensing diaphragm. The sensing diaphragm and the sensor body shall function as the moving and fixed electrodes of a differential capacitor respectively. As the applied pressure causes the diaphragm to move, the capacitance of the cell shall change. The transmitter enclosure (topworks) shall be rotatable to facilitate access to the electronics with an over-rotation stop to prevent damage to sensor wires. The amplifier unit shall convert the change in capacitance to a 4-20 mA DC signal, 2 wire type, with an allowable loop load of no less than 575 ohms. Transmitter design shall incorporate voltage surge and RFI protection. Static pressure rating shall be a minimum of 500 psig. The maximum over-range pressure limit shall be a minimum of 150 percent of the maximum range. Span shall be adjustable over a minimum of a 5:1 range. External adjustments shall include zero and span. Output signal damping shall be provided as an internal adjustment. Square root extraction circuitry shall be provided which can easily be added or removed from the transmitter. All equipment shall be suitable for an ambient operating range of minus 40 degree F to plus 212 degrees F. All wetted parts shall be constructed of 316 stainless steel. All block and bleed valves shall be constructed of 316 stainless steel. Bolts from process covers and process connectors shall be of the same material as that specified for the process covers. The topworks shall be constructed of low copper die-cast aluminum and finished with epoxy paint. The integral indicator shall have a linear scale and be calibrated in process units. Power supply shall be 24 VDC. Accuracy, including linearity and repeatability, shall be a ± 0.2 percent of span. Hysteresis shall be limited to 0.05 percent of span. Drift, over a six month period shall not exceed 0.1 percent of reference minus 0.5 percent of maximum span per 100 degrees F. Differential flow transmitters shall be SMAR to match existing.

See Appendix C for a schedule of required devices for this Contract.

P. **Differential Pressure Flow Rate Indicators:** Flow rate indicators shall have a six inch, 270 degree dial with two scales, one differential pressure and one flow rate graduated to match the characteristics at the differential producer. The indicator shall be actuated by 316 stainless steel bellows. The housing material shall be 316 stainless steel with a safe working pressure of 500 psi minimum. Accuracy shall be ± ½ percent of full scale. Each indicator shall be furnished with a 316 stainless steel three valve manifold. Differential pressure flow rate indicators shall be Dietrich Standard to match existing.

See Appendix C for a schedule of required devices for this Contract.

Q. **Propeller Flow Measuring Systems (Open-Flow):** Each propeller meter shall have a 4-pole magnetic-type drive preventing the process fluid from contacting any gears, overrun bearings, shafts, etc., within the meter. The rotation of the propeller shall be transmitted from the magnetic drive to the register and transmitter (where required) by means of a flexible connecting shaft. Flowmeters shall be designed to operate continuously at flow rates within the rated range. Meter accuracy shall be ± 2 percent of rate at flow from the minimum rating to 150 percent of maximum rating. The meter shall be wet-flow calibrated against a primary standard accurate to ± 0.25 percent at the following ratings: minimum flow; midrange; and at the maximum. Meter-mounted indicators, totalizers, and transmitters shall be manufactured by the same manufacturer as the propeller meters.

Meters shall be of the open-flow type, designed for headwall mounting and to measure flows in submerged influent conduits. Meter shall consist of: injection molded thermoplastic propellers; bronze or cast iron gear boxes; bronze, epoxy-coated steel or stainless steel drop pipes; and stainless steel, Delrin, hard rubber, or ceramic in contact with fluids. The drive mechanism shall include stainless steel worm gear and shafting or ceramic radial-sleeve magnetic drive with water-lubricated ceramic sleeve bearings and oil-filled sealed gear box. Shafts shall be stainless steel. The meter shall be equipped with [a 6-digit direct reading totalizer with center sweep test hand, protected by an all-metal or injection-molded plastic register box and cover assembly with locking hasp] [a 6-digit direct reading totalizer, test hand and instantaneous flow rate of flow indicator]. The unit shall be protected by an all-metal or injection-molded plastic, register box and cover assembly with locking hasp.] [a 6-digit direct reading totalizer-transmitter (with test hand), with 4-20 mA-dc and scaled-pulse output protected by an all-metal or injection-molded plastic, register box and cover assembly with locking hasp.] External converters are not acceptable. Zero and span shall be field-adjustable and designed not to cause loss of totalization while in operation. Meters shall include straightening vanes designed to be mounted in the influent pipe immediately preceding the propeller and located in accordance with the manufacturer's installation instructions.

Meters 10 inches to 30 inches in size shall include bronze or cast iron rabbit-ear mounting brackets with the lower bracket designed to serve as a guide for positioning the meter on the lower-bracket locking pin when submerged. Meters 36 inches to 72 inches in size shall include bronze or cast iron scabbard mounting brackets or rabbit-ear mounting brackets. Where indicated, meters shall include revolving mounting frame and brackets designed for installation and removal of the meter when submerged in

flowing fluids. Brackets shall permit removal of the meter by lifting the meter 6 inches, rotating it 180 degrees, and then extracting it vertically in guide rails. Mounting frames shall be fabricated from stainless steel, or hot-dipped galvanized carbon steel. Submerged supports and anchor bolts shall comply with Section 05500. Open flow propeller flow measuring systems shall be Marsh-McBirney to match existing.

See Appendix C for a schedule of required devices for this Contract.

R. **Turbine Gas Flow Measuring Systems:** Meters shall be of the turbine type with flanged cast aluminum body, built-in straightening vanes, molded plastic turbine rotors, and magnetic drives, and designed for vertical or horizontal installation. Meters shall be suitable for totalizing the flow of gas in cubic feet units at an accuracy of ± 1 percent over a range of 10 to 1, at 0.25 psig pressure. Meters shall be designed for a differential pressure drop of 4.25 inches W.C., based on 0.6 specific gravity and 0.25 psig inlet pressure. Meters shall be cast aluminum or cast steel bodies with 150-lb flanged ends, a flanged, interchangeable pre-calibrated measuring cartridge, integral plastic straightening vanes, and plastic rotors with magnetic drives. Meters shall include precision bearings fabricated of stainless steel with external fittings designed to permit lubrication while the meter is in operation. Parts exposed to gas shall be fabricated of corrosion-resistant materials. Meters shall include direct mounted totalizers, reading in cubic feet. Meters shall be equipped for direct-mounting of mechanical, electro-mechanical, or electronic read-out and transmitting devices. Turbine gas flow measuring systems shall be Daniel, or equal.

See Appendix C for a schedule of required devices for this Contract.

S. **Rotary Gas Flow Measuring Systems:** The meters shall be of the rotary, positive displacement lobe or vane type, designed for vertical or horizontal installation and with moving parts enclosed in a cast aluminum housing. Meter shall be designed for measuring and totalizing gas flow in cubic feet units at an accuracy of ± 0.5 percent from 10 to 100 percent of capacity, and with a maximum pressure loss of 0.8-inch W.C. at 100 percent of rated capacity. The meters shall include magnetic coupling or sealed stainless steel bearings designed to transmit the rotation of the rotor to the instrument drive mechanism. The drive mechanism shall be isolated from the rotor and the gas flow. The rotor shall be dynamically balanced and fabricated of corrosion-resistant material. The body shall be of cast iron coated in accordance with Section 09800, or cast aluminum, hard-coat anodized internally and shall include 125-lb flanges complying with ANSI B16.1. Bearings and shafts exposed to the gas stream shall be stainless steel. Bearings shall comply with Section 11000. The meters shall be suitable for outdoor installation. The bearings shall be shielded with self-lubricating timing gear or shall be splash-lubricated and monitored by oil level gauge. Rotary gas flow measuring systems shall be Elster Instromet, or equal.

See Appendix C for a schedule of required devices for this Contract.

T. **Diaphragm Gas Flow Measuring Systems:** The meters shall be of the diaphragm displacement type designed with moving parts enclosed in an aluminum housing. The meters shall be suitable for measuring and totalizing the flow of gas in cubic feet units

at an accuracy of ± 1 percent from 10 to 100 percent of capacity. Moving parts of the diaphragm displacement type meter shall be housed in a flanged die-cast aluminum alloy body. Valves, linkages, and the diaphragm assembly shall be mounted on a common plate for easy removal. Bearings shall be of the low-friction type and the design shall include a bolted access cover to permit adjustment. The totalizer assembly shall be mounted outside of the meter body, and shall be protected by a hinged cover. Both inlet and outlet connections shall be threaded. The meters shall be designed for outdoor installation [and for minimum pressure loss]. Diaphragm gas flow measuring systems shall be Elster Instromet, or equal.

See Appendix C for a schedule of required devices for this Contract.

U. **Parshall Flume Flow Measuring Systems:** Fiberglass reinforced plastic liner shall comply with Section 06610. Full-length, molded, fiberglass-reinforced polyester Parshall Flume liners shall be installed in the flume channels for measurement of [raw sewage plant influent] [and/or] [plant effluent] flow. Flumes shall be provided with [integral, molded side cavity and bubbler system] [Type 304 stainless steel mounting bracket and ultrasonic level sensing system] designed to measure the flow [and a factory installed gauge calibrated in tenths of feet mounted on the sidewall]. The flume insert shall be a full-length, molded, fiberglass-reinforced polyester liner fabricated in one piece from polyester resin and reinforced with glass mat. Not less than 30 percent (by weight) of the flume insert shall be reinforcement. The thickness of the walls shall not be less than 1/4-in. There shall be a sufficient number of locking clips or flanges integral with the liner to ensure secure anchorage and proper alignment. Integral stiffeners shall be designed to withstand shipping and installation. Temporary spreaders may be placed across the top of the flume to prevent damage. The flume shall be designed for trouble-free operation to produce metering heads to within 2 percent of its published rating curve. The flume shall include integrally molded stilling wells and stainless steel brackets for mounting of instruments. Parshall flume flow measuring systems shall be Tracom, or equal.

See Appendix C for a schedule of required devices for this Contract.

V. **Mass Flow Gas Measuring Systems:** The mass flow meters shall be designed to operate continuously on the thermal dispersion principle, at flow rates within rated range. The meters shall be suitable for service with digester gas from sewage treatment plants. Digester gas is a moisture-saturated, corrosive gas composed of methane, carbon dioxide, nitrogen, hydrogen sulfide, and particulates. The mass flow meter shall be of the single insertion probe type. The insertion probe shall have flanged or one-inch screwed connections, to be installed through a packing gland and a ball valve. The packing gland shall have a 1-1/4-inch NPT connection, a packing compression collar, and a split ring locking collar. The sensor shall sense mass flow and automatically compensate for all specific changes in temperature and pressure. The sensor shall consist of two matched platinum resistance temperature detector (RTD) elements, (one heated and the other passive), sheathed in a [nickel] [gold] brazed [Type 316 stainless steel] [Hastelloy C-276] insertion assembly. The gas flow shall pass directly over sheathed elements without the need for an indirect. The sensor probe assembly shall be mounted in a [cast iron] [aluminum] enclosure, approved for Class 1, Groups C and D

hazardous areas. The meter shall have the following characteristics:

1.	Accuracy	-	± 1 percent (at 30 degree F)
2.	Repeatability	-	± 1 percent of full scale
3.	Turndown ration	-	100:1 (max)
4.	Signal output	-	4-20 mA, 600 ohms max. load
5.	Power input	-	115 VAC, ± 15 VAC, 16 watts max.
6.	Pressure rating (psi)	-	up to 1000 psig
7.	Probe temperature rating	-	minus 50 - plus 330 deg. F (probe) (deg. F)
8.	Accuracy	-	± one percent of full scale
9.	Gas flow velocities	-	0.5 to 200 feet per second

The electrical components shall be [meter-mounted] [remote mounted] in a NEMA [4X] [Class 1, Groups C and D] [explosion-proof] enclosure, with flow indicator and totalizer, Factory Mutual and CSA approved for hazardous locations. The electronics shall read flow in SCFM with digital display. [8-conductor interconnection cable shall be provided between sensor and remote electronics]. The unit shall be adjustable in the field for span and zero to narrow the output range. All wetted parts of the sensor assembly shall be made of [Type 316 stainless steel with nickel braze] [Hastelloy C with gold braze]. Electronic enclosures shall be fiberglass, Type 316 stainless steel for NEMA 4X, or cast iron or aluminum for explosion-proof designations. The CONTRACTOR shall furnish one calibrator. The calibrator shall plug into the main circuit board in lieu of the sensor probe and shall provide simulation of the differential resistance signal produced by the flowmeter's sensor. Mass flow gas measuring systems shall be FCI to match existing.

See Appendix C for a schedule of required devices for this Contract.

2.5 FLOW DETECTION SWITCHES

A. **Vane Flow Switches:** Vane flow switch shall utilize the motion of the vane to attract a magnet which actuates a micro switch. Switch shall be SPDT snap-action with contacts rated at 10 Amps, 110 Vac. The switch actuating magnet shall reside in a sealed body. Proof-pressure rating of the entire switch shall be 1000 psi. See Appendix C for a schedule of required devices for this Contract. Vane flow switches shall be WE Anderson to match existing.

See Appendix C for a schedule of required devices for this Contract.

B. **Thermal Flow Switches:** Flow switches shall be thermally activated based on heat transfer between probes in the pipe flow stream. The probes, electronic circuits and relay shall all be part of an integral unit with a non-ferrous cast housing. Process wetted parts shall be 316 stainless steel. In horizontal pipe runs the unit shall be side mounted. All switches shall be equipped to function in an environment where the probes are not always immersed. Output relay shall be configurable to energize on increasing decreasing flow and have SPDT contacts rated 2 Amps @ 120 Vac minimum. Contact transfer point shall be field adjustable from .015 to 5 ft/sec in water. Response time shall be adjustable from 1 to 150 seconds. The trip flow point shall not be affected by process fluid changes in the range of 32 to 140 degrees F and shall have a repeatability of ± 5 percent. The contract unit shall operate with the specified repeatability in an ambient temperature range of 25 to 120 degrees F. The power supply shall be [24 VDC] [120 Vac]. See Appendix C for a schedule of required devices for this Contract. Thermal flow switches shall be FCI to match existing.

See Appendix C for a schedule of required devices for this Contract.

C. **Ultrasonic Doppler Flow Switch:** The system shall consist of a flow element, switch control box, and connecting cable. The flow element shall be an ultrasonic Doppler non-invasive type. The flow element shall be attached to the outside of the pipe with a coupling compound furnished with the switch. The control box shall contain set point adjustment (0.5 to 20 fps), an adjustable relay dropout timer used to eliminate false alarms and relay chatter (0 to 60 seconds), and a low flow indicator. Switching differential shall be 0.8% of span. Output contacts shall be DPDT rated at 3 amps, 120 Vac. Contacts shall be hermetically sealed. The control box shall operate on 120 Vac. The control box shall be suitable for operation in an environment of -10 to 140 degrees F, 0-100% relative humidity. The transducer shall be suitable for operation in an environment of -30 to 300 degrees F. The switch response time shall be between 1 to 30 seconds. Connecting cable shall be armored and provided in lengths suitable for each location. Ultrasonic Doppler flow switches shall be Polysonics to match existing.

See Appendix C for a schedule of required devices for this Contract.

2.6 LEVEL MEASURING SYSTEMS

A. **Differential Pressure Level Measuring Systems**: Level transducers shall be flanged, differential pressure sensing units. Transmitters shall be two wire devices with continuously adjustable span, zero and damping adjustments, integral indicator scaled in engineering units, solid state circuitry, and 4-20 mA output. Accuracy shall be ± 0.25 percent of span. Process wetted parts of the transducer shall be 316 SS. Flanges shall be 316 SS, 150 lbs rated. The low pressure connection shall be ½-inch NPT. Differential Pressure level measuring systems shall be SMAR to match existing.

See Appendix C for a schedule of required devices for this Contract.

B. **Ultrasonic Level Measuring Systems:** The meter shall be a non-contact, ultrasonic echo-time measuring device suitable for 120-volt, 60-Hz power supply. It shall consist of an ultrasonic transducer element assembly and a remote transmitter unit

interconnected by manufacturer-supplied coaxial cable. Cable length shall be to accommodate the instrument locations shown on the Drawings. The system shall utilize 1,500-volt peak minimum energy level on the transducer and shall be suitable for measuring liquid surfaces from 1 to 25 feet below the transducer. The meter shall incorporate a reference reflector to provide instantaneous sound velocity compensation and it shall utilize microprocessor circuitry to process echo times for elimination of stray echoes and, where indicated, to provide linearization functions. The ultrasonic level meter shall produce a narrow beam angle of not more than 7 degrees total included angle. The ultrasonic sensor system shall have temperature compensation circuitry operable over the range of -40 degrees C to +50 degrees C, and shall be encapsulated to ensure a Class 1, Division 1 hazard rating. The sensor shall be unaffected by condensation and shall be provided with an integral heater, unless otherwise noted. The transmitter shall have a six digit display for level and "echo-lost" indication, and shall produce a 4 to 20 mA output signal into 750 ohms, maximum. The entire system shall be accurate within ± 0.1 foot of range. Meter shall have five Form C contacts. The meter shall be provided with an 8" flange with Teflon facing unless otherwise noted. Ultrasonic level measuring systems shall be Miltronics to match existing.

See Appendix C for a schedule of required devices for this Contract.

C. **RF Admittance-based Level Measuring Systems:** The level measurement system shall consist of a sensing element (rigid or flexible), a two-wire electronic transmitter, a three terminal inter-connecting cable, and radio frequency filters. The transmitter shall be a solid state unit with 4-20 mA output into 500 ohms (minimum), linear to level. The transmitter shall have non-interacting zero and span controls, a local indicator scalable in the desired process variable. The level measurement shall not be affected by changes in process conductivity or by more than 3" with a 1/32" coating build-up of a 1000 µmho material on the sensing element. The transmitter shall measure the capacitance/admittance generated by the process on the sensing element. The sensing element shall be chemically resistant to the process material. It shall be supplied with a concentric supplemental ground rod when used in non-metallic vessels. The sensing element shall be flange mounted. The flange shall be chemically resistant to the process and, if necessary, contain either the concentric shield or ground rod. Length shall be as specified or shown on the drawings. The inter-connecting cable shall be a temperature stabilized coaxial cable with molded ground. The cable shall be capable of field shortening without affecting the system calibration, and shall be intrinsically safe. RFI filters shall be supplied by the system manufacturer and shall be field mounted on the sensing element input and transmitter output. RF Admittance-based level measuring systems shall be Drexelbrook to match existing.

See Appendix C for a schedule of required devices for this Contract.

D. **Submersible Transducer Level Measuring Systems:** The level measurement system shall consist of a submersible transducer, electronic transmitter, support cable, and interconnecting cable. The submersible transducer shall be the strain gage type suitable for sensing pressure equivalent to the liquid level range indicated. The transducer shall have 316 stainless steel process wetted parts and shall be furnished with a waterproof

interconnecting cable. The transducer shall be suspended by a corrosion resistant cable as recommended by the manufacturer. The installation shall allow easy removal of the transducer and cable assembly for maintenance purposes. The electronic level transmitter shall be remote mounted and shall produce a 4-20 mA DC signal linearly proportional to the level range indicated. The unit shall be complete with enclosure, zero and span adjustments and the measurement system shall be suitable for operation over a temperature range of 32 to 122 degrees Fahrenheit with an accuracy of ± 0.5 percent of span. Submersible transducer level measuring systems shall be Siemans, Dwyer, or equal.

See Appendix C for a schedule of required devices for this Contract.

E. **Float Actuated Level Measuring Systems:** The level transmitters shall utilize a tape or cable suspended float to measure level. The transmitter shall be housed in an enclosure and the float and cable or tape shall be constructed of corrosion resistant materials. The transmitter shall produce a 4-20 mA signal into 700 ohms minimum. The transmitter output signal shall be within ± 1 percent of span from 20 to 100 percent of the indicator. The transmitter shall be furnished with a level indicator. The indicator shall be scaled in engineering units corresponding to the level measurement. Transmitter input power shall be 120 VAC 60 Hz. Float actuated level measuring systems shall be Magnetrol, or equal.

See Appendix C for a schedule of required devices for this Contract.

F. **Motorized Float Level Measuring Systems:** The level sensing unit shall utilize a tape or cable suspended float to measure level. Tension on the float shall be maintained by a motor. Counter weighted systems are not acceptable. The level sensing unit housing shall be constructed of corrosion resistant materials. The float, tape or cable, and process wetted parts shall be 316SS. The sensing unit shall include a mechanically operated level indicator and transmitter. The level sensing unit shall be top of tank mounted or ground level mounted as shown on the drawings. The unit shall be furnished with all sheaves and mounting brackets required for the installation. The tape or cable shall be contained within pipe from the level sensing unit to the top of the tank. The level transmitter shall produce a 4-20 mA signal proportional to level into 600 ohms minimum. Accuracy shall be within ± 0.75 percent of full scale. Input power shall be 120 VAC 60 Hz. Motorized float actuated level measuring systems shall be Nivogauge, or equal.

See Appendix C for a schedule of required devices for this Contract.

2.7 LEVEL DETECTION SWITCHES

A. **Induction Level Switch:** Switches shall be of the induction type. Where probe length is over 6 feet, electrodes shall be stainless steel supported by suspension cables, terminated at vendor-supplied electrode fittings in a watertight housing. Where electrode length is less than 6 feet, electrodes shall be stainless steel rods insulated with a Teflon sheath. Each induction relay shall be a combination of a matched transformer and relay, integrally mounted on a common baseplate and connected to electrodes

indicated. Transformer secondary voltage shall be as required by the liquid material. Induction level switches shall be Drexelbrook to match existing.

See Appendix C for a schedule of required devices for this Contract.

B. **Displacer Level Switches:** Switch shall consist of one or more porcelain displacers supported on Type 316 stainless steel rod or cable suspended on a spring. Switch actuating mechanism shall be a magnetic shunt carried within a nonmagnetic sealing tube. Switch shall be operated by a magnet on the outside of the sealing tube. Switch shall be provided with carbon steel cage and flanged closure and process connections. Process connection shall be 2-inch flange, ANSI B16.5, Class 300, raised face, or as indicated. Displacer level switches shall be Magnetrol to match existing.

See Appendix C for a schedule of required devices for this Contract.

C. **Inverted Column Level Switches:** High level flood switches shall be the type that traps air in an inverted column. Contact transfer is initiated by a pressure switch which is actuated by increasing pressure in the column. The pressure switch shall be isolated from the process with a diaphragm. Switch contacts shall be SPST N.O. with 5 Amps 120 VAC rating minimum. Switch enclosure and compression bell shall be aluminum connected by a one-foot steel pipe. Inverted column level switches shall be AUTOCON to match existing.

See Appendix C for a schedule of required devices for this Contract.

D. **Conductance Level Switch:** Switch shall be of the conductance type with PVC sheath and 0.25-inch stainless steel rod electrodes for lengths up through 6 feet. For lengths greater than 6 feet, wire suspension type with stainless steel shield electrodes shall be provided. Electrode fitting enclosure shall be an epoxy coated and gasketed cast aluminum housing of suitable configuration for the application. Induction relays shall be two winding type. Primary power supply shall be 120 volts, 60 Hz. Secondary potential shall not exceed 300 volts AC and short circuit current shall not exceed 25 milliamperes. Conductance level switches shall be Drexelbrook to match existing.

See Appendix C for a schedule of required devices for this Contract.

E. **Intrusive Ultrasonic Level Switches (Single Point Detection):** Intrusive ultrasonic single point level switches shall consist of a sensor, related electronics, and a control relay. The ultrasonic level switches shall transmit a high frequency signal through the gap of an invasive transducer. When the liquid fills the gap, the signal actuates the control output. As the liquid level falls, the signal attenuates in air and deactivates the control output. An integral signal averaging circuit shall inhibit false signals attributed to effervescence, splashing, or turbulence. All wetted parts shall be constructed of 316 stainless steel. All remote mounted units shall be provided with connecting cable provided by the manufacturer of the switches. The switch shall be SPDT with a minimum rating of 10 Amps at VAC or 5 Amps at 24 VDC. Repeatability shall be 0.1-inch or less with a response time of less than one second.

See Appendix C for a schedule of required devices for this Contract.

F. **Intrusive Ultrasonic Level Switches (Two Point Detection):** Intrusive ultrasonic two point level switches shall consist of a sensor, related electronics, and a control relay. The ultrasonic level switches shall transmit a high frequency signal through the gaps of an invasive transducer. When the liquid fills each gap, the signal actuates the control output. As the liquid level falls, the signal attenuates in air and deactivates the control output. An integral signal averaging circuit shall inhibit false signals attributed to effervescence, splashing, or turbulence. All wetted parts shall be constructed of 316 stainless steel. All remote mounted units shall be provided with connecting cable provided by the manufacturer of the switches. The switch shall be SPDT with a minimum rating of 10 Amps at 120 VAC or 5 Amps at 24 VDC. Repeatability shall be 0.1-inch or less with a response time of less than one second.

See Appendix C for a schedule of required devices for this Contract.

G. **Intrusive Ultrasonic Level Switches (Three Point Detection)**: Intrusive ultrasonic three point level switches shall consist of a sensor, related electronics, and a control relay. The ultrasonic level switches shall transmit a high frequency signal through the gaps of an invasive transducer. When the liquid fills each gap, the signal actuates the control output. As the liquid level falls, the signal attenuates in air and deactivates the control output. An integral signal averaging circuit shall inhibit false signals attributed to effervescence, splashing, or turbulence. All wetted parts shall be constructed of 316 stainless steel. All remote mounted units shall be provided with connecting cable provided by the manufacturer of the switches. The switch shall be SPDT with a minimum rating of 10 Amps at 120 VAC or 5 Amps at 24 VDC. Repeatability shall be 0.1-inch or less with a response time of less than one second.

See Appendix C for a schedule of required devices for this Contract.

H. **Non-Intrusive Sonic Level Switches:** Non intrusive sonic level switches shall consist of a transducer, transmitter/receiver, and control relays. The sonic level switch transmitter shall generate pulses which are directed to the liquid level. The returning echo/signal shall be detected by the receiver. A microprocessor shall amplify and convert the signal into a digital representation of the distance from the reflecting surface. An output is produced when manually inputed trip values are exceeded. The microprocessor-based electronics shall enable user selection of range, span, setpoints, time delay, units of distance, and selectable failsafe mode. Relay setpoints shall be adjustable over the entire span without the use of reference targets. Automatic temperature compensation circuitry shall be incorporated. The transducer housing shall be PVC with corrosion resistant sensor element. All remote mounted units shall be provided with connecting cable provided by the manufacturer of the switches. Input power shall be 120 VAC. Switches shall be SPDT with a minimum rating of 10 Amps at 120 VAC. Repeatability shall be 0.1-inch or less with a response time of less than one second and an accuracy of plus or minus 0.25 percent of full scale.
See Appendix C for a schedule of required devices for this Contract.

I. **Side-Mounted Float level Switches:** Liquid level switches shall be the side mounted

float actuated type. Float switches shall be SPDT and shall consist of a fixed sealed reed switch actuated by a floating magnet. Level switches shall be flange or plug mounted to suit field requirements. Process wetted materials shall be plastic and/or 316 stainless steel.

See Appendix C for a schedule of required devices for this Contract.

J. **Paddle Level Switches:** Paddle level switches shall consist of a rotating paddle that transmits an output when paddle movement has been stopped by the buildup of solid material. The paddle and all wetted parts shall be constructed of 316 stainless steel. The switch shall be snap acting, DPDT, with a minimum rating of 10 Amps at 120 VAC. Paddle level switches shall be Dwyer, or equal.

See Appendix C for a schedule of required devices for this Contract.

2.8 PRESSURE MEASURING SYSTEMS

A. **Electronic Pressure Transmitters:** Electronic pressure transmitters shall be two wire devices with continuously adjustable span, zero ad damping adjustments, integral indicators scaled in engineering units, solid state circuitry and 4-10 mA outputs. Accuracy shall be plus or minus 0.25 percent of calibrated span. Process wetted and body materials shall be 316 SS. Process connections shall be ½-inch NPT. Electronic pressure transmitters shall be SMAR to match existing. Electronic pressure transmitters shall be SMAR to match existing.

See Appendix C for a schedule of required devices for this Contract.

B. **Local Pressure Measuring Systems:** Pressure gauges shall be installed on suction and discharge connections to pumps; on discharge connections from blowers and compressors; at each side of pressure reducing valves; and where otherwise indicated. Vacuum gauges and compound gauges, where indicated, shall be installed on vacuum pumps. Gauges shall have Type 316 stainless steel movement and stainless steel or alloy case. Except as otherwise indicated, gauges shall have a 3-1/2-inch dial, 1/4-inch threaded connection, a Type 316 stainless steel snubber adapter, and a shut-off valve. Gauges shall be calibrated to read with an accuracy of ± 1 percent to 150 percent of the indicated pressure. Gauges shall be vibration and shock resistant. Gauges on liquid service should have cases filled with a suitable liquid. Gauges attached to systems containing chemical solutions, corrosive fluids, sludge, sewage, or other liquids containing solids, shall be equipped with diaphragm seals, or equal protective pressure or vacuum sensing devices, and comply with the following:

1. For: sewage, sludge, liquids containing solids, pulsating flow	Seals shall be fabricated with Type 316 stainless steel, with stainless steel diaphragm for pressures over 15 psi, and elastomer diaphragm for pressures of 15 psi and below with Type 316 stainless steel nuts and bolts, fill connection and valved flush port size ¼-inch N.T.P., capable of disassembly without loss of filler fluid.

2. For: chlorine and sulfur dioxide under pressure	Seals shall be fabricated with carbon steel with silver diaphragm and shall be rated at 800 psi.
3. For: chemical solutions, low pressure sewage and chemical sludge except as otherwise indicated	Seals shall be fabricated with PVC body for removable mounting and rated at 200 psi, with Type 316 stainless steel bolts and nuts, ½-inch inlet, ¼-inch outlet, liquid-filled with Teflon diaphragm for pressure service and proper elastomer diaphragm for vacuum service.

See Appendix C for a schedule of required devices for this Contract.

C. **Diaphragm Seals for Pressure Measuring Systems:** Diaphragm seals shall consist of bottom housing, lower ring, diaphragm capsule, fill screw, flushing connection, and a top housing. The diaphragm seal shall attach to the inlet connection of a pressure instrument to isolate its measuring element from the process fluid. The space between the diaphragm and the instruments pressure element shall be solidly filled with a suitable liquid. Displacement of the liquid fill in the pressure element through the movement of the diaphragm shall transmit process pressure changes directly to a gauge, transmitter, switch or any other pressure instrument. The diaphragm seal shall have a removable bottom housing to permit the servicing of the need to refill. All exposed surfaces, housings, and diaphragm shall be constructed of 316 stainless steel.

See Appendix C for a schedule of required devices for this Contract.

D. **Annular Ring Seals for Pressure Measuring Systems:** Where seal elements are used to isolate pipeline flow media from a gauge the sensor shall be flanged and bolted directly into ANSI flanged pipelines. Face to face shall not be greater than a wafer style of a butterfly valve. The flanges shall have thru bolt holes to enable positive alignment in the pipeline. Flanges shall conform to pipe specifications. Inside diameter of the sensor shall be the same as the mating pipe with a full thru uninterrupted flow. There shall be no dead ends or crevices and flow passage shall make the sensor self-cleaning. Wetted parts (liner) shall be capable for continuous duty handling a slurry containing up to 15% solids. The Pressure Sensing Ring shall measure pressure for 360 degrees F around the full inside circumference of the pipeline. The sensing ring shall also be clamped into the body for the full radial width of the sensor. Pressure shall be transmitted to the gauge by a locked in and sealed fluid such as ethylene glycol or silicone oil. The sensor shall have an auxiliary tapped and plugged port to allow connection or other equipment. Annular ring seals for pressure measuring systems shall be Red Valve to match existing.

See Appendix C for a schedule of required devices for this Contract.

2.9 PRESSURE DETECTION SWITCHES

A. **Diaphragm Piston Pressure Switches:** Pressure switches shall consist of a pressure

transducer and a precision switch. Pressure transducer shall be the diaphragm piston type with wetted materials as recommended by the switch manufacturer. Piston shall be backed by a cylinder disc to permit 10 times over range pressure without affecting calibration. Range spring and piston shall be isolated from process fluids by the diaphragm. Switch shall be provided with two 3/4-inch conduit connections. The pressure transducer shall be selected so that setpoint falls between 30 and 70 percent of maximum range. Approximate setpoint and, if applicable, reset point shall be indicated on calibrated scales. Repeatability and sensitivity shall be 1.0 percent of operating range or better. Unless otherwise specified, switches shall be non-adjustable deadband type. Diaphragm piston pressure switches shall be SOR to match existing.

See Appendix C for a schedule of required devices for this Contract.

B. **Differential Pressure Switch:** Differential pressure sensing switches shall be single-pole, double-throw with an adjustable differential range. Minimum differentials shall be less than 10 percent of range. Differential pressure switches shall be able to withstand surge pressure 1.5 times range or better. Each pressure switch shall have a visible scale contact operation. Pressure switches shall have a contact rating of 10 amperes at 125 volts AC. Pressure switches shall be snap-action switches and shall be in general purpose enclosures. A 316SS three valve manifold shall be supplied with each switch. Differential pressure switches shall be Barksdale to match existing.

See Appendix C for a schedule of required devices for this Contract.

2.10 TEMPERATURE MEASURING SYSTEMS

A. **RTD Temperature Measuring Systems:** Temperature transmitters shall be two wire devices with continuously adjustable span and zero adjustments, integral direct reading indicator, solid state circuitry and 4-20 mA output linearly proportional to the specified temperature span. Accuracy including temperature element shall be ± 0.1 percent of span. The temperature sensor shall be a spring loaded platinum RTD with Type 316 stainless steel Thermowells. The RTD and Thermowells length shall be as required or as indicated. The RTD and Thermowells shall be directly or remotely mounted as indicated. All necessary RTD wire shall be provided in conformance with the instrument manufacturer's recommendations. Temperature transmitters shall be SMAR to match existing.

See Appendix C for a schedule of required devices for this Contract.

B. **Bimetallic Dial Temperature Measuring Systems:** Temperature indicators shall have 5-inch nominal diameter "all single" indicating scales, Type 316 stainless steel stems, and be suitable for stainless steel wells. Accuracy shall be plus or minus 1 percent of full range. Bimetallic dial temperature indicators shall be TEL-TRU to match existing.

See Appendix C for a schedule of required devices for this Contract.

C. **Thermowells:** Unless indicated otherwise, Thermowells shall be provided for the following:

1. As part of a thermocouple or resistance bulb assembly

2. For a filled system

3. For test wells

4. For dial thermometers

All Thermowells shall have a ½-inch NPT female thread for connection of the measuring element. Well mounting connections may be screwed, socket-welded, or flanged. Screwed connections shall be 3/4-inch or 1-inch NPT. flanged connections shall be 1-1/2-inch minimum. Socket-weld connections shall be 1-inch or 1-1/2-inch.

Thermowells shall be bored from solid barstock with a minimum thickness of 3/16-inch. The well material shall be Type 316 stainless steel unless indicated otherwise. Well lengths are based on vessel or pipe size. See Appendix C for a schedule of required devices for this Contract.

See Appendix C for a schedule of required devices for this Contract.

2.11 TEMPERATURE DETECTION SWITCHES

A. **Capillary Temperature Switches:** Temperature sensing shall utilize a SAMA Class II vapor pressure thermal system. The temperature sensor shall be either rigid, direct mounting type or remote mount type utilizing armored stainless steel capillary, as required by the specific application. Setpoint repeatability shall be no more than plus or minus one percent of span and deadband shall be adjustable plus or minus 18 degrees F. The switch mechanism shall be hermetically-sealed, SPDT type, rated 5 amperes at 120 VAC. Terminal blocks shall be provided for external wiring. The complete thermal system shall be 316 stainless steel and the minimum bulb length shall be 3 inches. The temperature switch shall be provided with 316 stainless steel Thermowells and bushing suitable for the thermal sensor. Thermowells shall have a minimum wall thickness between bore and outside of well of 3/16 inch. Materials shall be ANSI Type 304 or 316 stainless steel, unless exception is made due to the particular requirements of the process. Flanged Thermowells, when required, shall meet all requirements of material and size specified for that classification. Thermowells insertion length (U dimension) shall be selected for each application so as not to exceed the manufacturer's published allowable length/line velocity recommendations.

See Appendix C for a schedule of required devices for this Contract.

B. **Bimetallic Temperature Switches:** Temperature switches shall be bimetallic type with 0.750 in. NPT Thermowells process connection per applicable piping code. Switches shall have SPDT contacts and be provided with an adjustable setpoint.

See Appendix C for a schedule of required devices for this Contract.

2.12 PROCESS ANALYSIS MEASURING SYSTEMS

A. **Turbidity Measuring Systems (Integral Unit):** The turbidimeter analyzers shall have the capability of detecting Nephelometric Turbidity Units (NTU). The turbidimeter shall include an integral indicating transmitter with selectable ranges of 0-1, 0-3 and 0-30 NTU. The transmitter shall produce a 4-20 mA DC output signal corresponding to the span of the selected range and proportional to the measured turbidity. Accuracy shall be within plus or minus 2 percent of full scale. The analog indicator shall be scaled in NTUs corresponding to the selected range and shall be visible through a window in the transmitter enclosure. The turbidimeter sensor shall be suitable for on-line analysis. Secondary reference standards shall be included with each turbidity analyzer. Both the transmitter unit and sensor shall be suitable for surface mounting. The interconnecting cable between the transmitter unit and the sensor shall be supplied by the instrument manufacturer and shall be of sufficient length to allow proper installation of the cable. Turbidity measuring systems shall be GREAT LAKES to match existing.

See Appendix C for a schedule of required devices for this Contract.

B. **Turbidity Measuring Systems (Non-Integral):** Turbidimeter shall consist of a turbidimeter body, a separate control unit, interconnecting cable, and unless otherwise specified, a sample pump with flow rate adjustment. All optical and hydraulic components shall be housed in the turbidimeter body which shall incorporate a built-in bubble trap. The turbidimeter body shall be powered from the control unit, shall be suitable for surface mounting, and shall be constructed of corrosion-resistant structural plastic. The control unit shall provide a digital LED display with four digits and automatic decimal positioning and shall provide a 4 to 20 milliampere signal linear with turbidity expressed in Nephelometric Turbidity Units (NTU). The linear output signal shall be programmable to span all or any portion of the 0 to 100 NTU range. The control unit shall contain two setpoint alarm systems fully adjustable over the entire range. A bubble rejection system shall be provided in the control unit and self-test diagnostics shall be provided to automatically indicate malfunctions. Accuracy shall be plus or minus 1.0 percent from 0 to 3 NTU and plus or minus 5.0 percent from 30 to 100 NTU. Resolution shall be 0.001 NTU. A Formazin Calibration Kit shall be furnished consisting of a 1 liter calibration cylinder simulating the turbidimeter body, a Ten Sette Pipet and a pint bottle of 4000 NTU Formazin Primary Standard. Turbidity measuring systems shall be GREAT LAKES to match existing.

See Appendix C for a schedule of required devices for this Contract.

C. **pH Measuring Systems**: pH measuring system shall consist of a preamplifier, measuring electrode, reference electrode, automatic temperature compensator, and solution ground electrode encapsulated in a single PES or vinyl ester housing. The measuring electrode shall be glass unless otherwise indicated. The reference electrode shall have a double junction and be gel-filled or have a salt bridge to isolate the standard solution from the process. Electrode assembly shall contain an integral preamplifier for conversion of the high impedance electrode signal to a low impedance

signal for transmission to the transmitter. The output signal shall be of sufficient strength to allow transmission of up to 3000 feet without further amplification. Sensor shall be suitable for either mounting in a PVC flow-through assembly with a union coupler, or submerged, as indicated. Appropriate mounting hardware shall be provided. The transmitter shall accept the input signal from the sensor assembly and produce a 4-20 mA isolated analog output proportional to pH. Transmitter shall be housed in an enclosure suitable for pipe or wall mounting. Transmitter shall be provided with an analog or an LCD display. Power supply shall be 24 VDC via two-wire signal transmission with a load of 0 to 600 ohms (minimum). Each pH system shall be furnished with any additional maintenance materials that are required for sustaining the system in continuous operation for one year. PH measuring systems shall be ROSEMOUNT to match existing.

See Appendix C for a schedule of required devices for this Contract.

D. **Dissolved Oxygen Measuring Systems**: Dissolved oxygen analyzers shall employ the membrane electrolytic method with gold/silver electrodes and integral temperature compensation elements. Electrode assemblies shall be suitable for immersion and insertion service and shall accept mechanical agitators. Agitators shall be provided when indicated. Submersion assemblies shall be suspended in tanks from Type 304 stainless steel, 3/4-inch, Schedule 40 pipe. Pipe shall be supported as indicated. Transmitters shall be two wire devices with continuously adjustable span, zero and damping adjustments, integral indicators scaled in milligrams per liter, solid state circuitry, and 4-20 mA outputs. Accuracy shall be plus or minus 0.25 percent of span. Power supply shall be 24 volts DC from signal transmission circuit. Transmitter shall support an external load of 0 to 600 ohms or greater without requiring trimming resistors. Analyzer output shall be galvanically isolated from the process and the analyzer case. Analyzers shall connect to the electrode assembly utilizing a 20-foot portable cord and receptacle system. Dissolved oxygen measuring systems shall be ROSEMOUNT to match existing.

See Appendix C for a schedule of required devices for this Contract.

E. **Ultrasonic Density Measuring Systems:** The density meter shall consist of a pair of ultrasonic transducers and an electronic control unit. The control unit shall generate an electrical signal which is converted to an ultrasonic signal at the transducer. The signal is directed across the pipe through the sludge where it is converted by the other transducer to an electrical signal in proportion to the sludge density. The received signal shall be amplified in the control unit and used to actuate a relay. The attenuation of sonic energy transmitted through a liquid shall be in proportion to the amount of entrained solids. The sensor shall consist of a vitreous or enamel-lined carbon steel pipe section, with ANSI B 16.5, class 150, raised face flanged ends, a valved flush connection, and externally mounted, removable ultrasonic transducers. A separate, wall-mounted indicating transmitter shall be provided in a NEMA [4] enclosure. The transmitter shall include an indicator graduated in percent density, a power switch, and a calibration control. The chassis shall contain a clearly-marked gain adjustment for density, with a range over which the gain adjustment is usable. Where four-wire transmitters are permitted, they shall be provided with a loop powered signal current

isolator. The process pipe mounted detector and the indicating transmitter shall be inter-connected by a multiconductor cable in a flexible conduit. The density meters shall conform to the following design characteristics:

1.Power supply	- 120 volts, AC, 60 Hertz
2.Output signal	- 4 to 20 milliamperes into 0 to 600 ohms galvanically isolated
3.Measurement type	- ultrasonic
4.Density range	- one to 5 percent solids
5.Repeatability	- within 0.5 percent solids
6.Response time	- 10 seconds
7.Meter body	- Schedule 40 steel pipe, glass or vitreous-enamel-lined
8.For outdoor location, only	- Analyzer to have surge protection
9.For hazardous location, only	- 2-wire transmitter to be intrinsically safe with active intrinsic safety barrier

Output indicators shall be provided with all analyzers. If the analyzer does not include an integral indicator, a 1-1/2-inch, 90 degree movement milliammeter enclosed in a NEMA 7 or 9 meter case shall be attached to the unit. Output indicators shall be calibrated in percent solids units and provided with tic marks at 8, 12, and 16 milliamperes. Milliammeter shall connect into the transmission circuit by means of banana jacks, and a permanently connected diode shall be provided to bypass the jacks if the meter is removed. Ultrasonic density measuring systems shall be BTG to match existing.

See Appendix C for a schedule of required devices for this Contract.

2.13 SAFETY MONITORING SYSTEMS

A. **Combustible and Toxic Gas (Electronic Type) Monitoring Systems:** The system shall consist of a monitor/readout unit and separate gas sensor units. The sensor units shall be capable of being located remote from the monitor/readout unit by up to 500 feet. Sensor units shall receive power from and send signals corresponding to gas values to the monitor/readout unit. The monitor/readout shall be the enclosed wall mount type. Each monitor/readout shall have the capability of monitoring two sensors of any type or mix. The enclosure shall be suitable for location in Class S1, Division 1, Group B, C and D locations as defined by the National Electric Code. Access to the enclosure shall be through a screw on type cover. Calibration shall be non-intrusive, and a calibration kit shall be provided. The cover shall have a window of sufficient size to allow the viewing of meters and indicating lights. Mounting brackets for the purpose of attaching the unit to a flat surface shall be provided. A sealed switch (switches) accessible from the outside of the enclosure shall be provided for the purpose of alarm relay reset and audible alarm silencing. The sensor units shall be in enclosures suitable for location in class 1, Division 1, Groups C and D classified area. When installed in location not readily accessible, a dual condulet shall be provided. The sensor units shall have provisions for mounting to a wall or similar structure. To eliminate radio frequency interference (RFI) and electromagnetic interference (EMI) the signal from

the sensor to the monitor shall be in digital format or frequency format. The manufacturer shall provide all required cable from sensor to monitor. The combustible gas sensor shall be the catalytic bead type. The sensor must have a demonstrated resistance to degradation by silicones and reduced sulfur gases (hydrogen sulfide). Hydrogen sulfide gas sensors shall be the electrochemical type. The sensor shall not require the periodic addition of reagents. All sensing elements (sensors) shall have a minimum useful life of one year. The supplier shall provide replacement sensor at no charge for any sensor that does not meet the minimum requirement. A 3-digit LED readout shall be provided for the purpose of displaying the value, in concentration, of each sensor. The monitor shall have a separate indicating light for caution, warning, and alarm for each gas sensor. The lights shall be color coded. Two separate alarm setpoint levels shall be provided for each sensor. The setpoints shall be independently adjustable for any value in the readout range. The setpoints shall provide signals to user interface relays. Alarm setpoints shall have the capability of providing the user a selection of latching or non-latching mode. As a minimum, one relay for each setpoint level shall be provided. All relays shall be Form C, single-pole, double-throw. Contacts shall be rated for 5 amps resistive at 120 VAC. The contacts shall be capable of being selected normally open or normally closed and normally energized or normally de-energized. A relay shall be provided to indicate trouble when any of the following conditions exist: system power loss, signal loss from a sensor, or 15 percent or greater under range. The LED display shall display a separate unique character when an over range or greater than 10 percent under range condition exists. An audible horn, buzzer, or tone shall be provided when an alarm condition occurs. The following functions shall be accomplished using pushbutton-type controls readily accessible on the front panel: display or alarm setpoint level, resetting any alarm setpoint, temporarily disabling any specific sensor from affecting the system, silencing of audible alarm, resetting any latching relay if alarm condition is cleared, and lamp test. The system shall operate on 115 or 220 VAC 50 or 60 Hz. Power shall not exceed 100 VA. The system shall require no periodic maintenance other than periodic checking of sensor unit function. Periodic sensor checking or actual adjustment of the sensor units shall be capable of being accomplished by one person at the sensor unit location. Gas monitor shall be UL approved. Combustible and toxic gas (electronic type) monitoring systems shall be MSA to match existing.

See Appendix C for a schedule of required devices for this Contract.

B. **Combustible and Toxic (Pumped Sample Type) Monitoring Systems:** The combustible gas detection system shall consist of an indicating monitor unit and separate gas sensor units. The gas sensor unit shall be capable of being located remote from the indicating monitor unit. The sensor unit shall receive power from and send a gas concentration signal to the indicating monitor unit. The signal shall be in a digital or frequency format to eliminate radio frequency or electromagnetic interference. The indicating monitor and remote sensors shall be designed for easy one man calibration. The indicating monitor shall be housed in a [NEMA 4X] enclosure with a shatterproof window of sufficient size to view the readouts and the lights. Each indicating monitor shall be suitable for simultaneously indicating the combustible gas concentration of [two] remote mounted sensors. Each of the [two] channels shall have a three digit LED display of the actual gas concentration value measured and individual alarm lights for

up to three manually adjustable set points. Each of these [three] alarm points shall have individual contacts rated a 5 amperes at 120 VAC for remote alarming. The indicating monitor shall also have an additional contact output which is a common trouble alarm and is activated by failure of one of the sensors or system power loss. The indicating monitor shall operate, and provide required power to the sensors, on a 120 VAC power source. The gas sensor shall be a pumped, remote sampling system powered from the indicating monitor specified above. The gas sensor and the sample pump shall be housed in a [NEMA 4X] enclosure with integral sample flow rate indication. The enclosure shall provide a 1/4-inch NPT connection for the sample suction line and include a three-way valve and 1/4-inch NPT connection port for calibration gas. All tubing, valves and communication cables required for these systems shall be provided by the manufacturer. The sample pump shall be capable of drawing a process gas sample continuously from a source which is at 5 inches w.c. vacuum. The sensor shall be of the catalytic bead type and be resistant to poisoning by hydrogen sulfide or silicones in the gas sample stream. One set of calibration equipment shall be provided for this project. The equipment shall include all components necessary to test and calibrate the combustible gas sensors and monitors specified. Calibration shall be based on a sample gas of known concentration. 0.6% propane in air shall be the basis of calibration. The calibration kit shall include flow control gas regulator, connection tubing, two cylinders of sample gas, and a universal electronic calibrator module. Combustible and toxic (pumped sample type) monitoring systems shall be MSA to match existing.

See Appendix C for a schedule of required devices for this Contract.

C. **Chlorine Gas Monitoring Systems:** Chlorine gas leak detectors shall be designed for mounting in the monitored space and shall provide localized warning and alarm contact outputs in the presence of chlorine gas concentration at setpoints adjustable between 1 and 10 parts per million (ppm). Detector power supply shall be 120 volts AC, 60 hertz, and detector shall alarm in case of power failure. Each detector shall utilize a non-wet chemistry type, voltametric gas sensor requiring minimum maintenance and shall be sensitive to the pressure of chlorine gas only. The detector shall consist of a sensor and alarm module. The sensor shall not require reagents or require pumps to sample the air. Each sensor shall be supplied with cable as required. Warning and alarm activation shall be indicated with a light locally on the alarm module. The system shall be a "fail safe" in that all failures in the internal electrical circuit shall be annunciated. An alarm reset button and power on light shall be provided. The detectors shall be wall-mounted units. Electrical components shall be within gasketed enclosures with gas tight connections. Contact outputs shall be provided for warning and for alarm. Warning output shall be non-latching. Alarm output shall activate upon detection of gas at alarm setpoint, upon detection of internal failure, or upon detection of sensor failure and shall be field selectable for latching or non-latching. Contact outputs shall be rated 5 amperes at 120 volts AC minimum. The entire installation for each leak detector shall be designed to prevent radio frequency interference (RFI) and electro-magnetic interference (EMI). As a minimum, the alarm module and sensor shall be RFI shielded and the sensor cable shall be installed in rigid metal conduit. The shielding and the metal conduit shall be connected to earth ground. The manufacturer shall verify in writing that the units are properly installed and that the units will not alarm when the

antenna of a 5 watt, 450 MHZ transmitter is activated at three feet from the alarm module or sensor with the alarm setpoint as low as one twentieth of full scale. Each leak detector shall be supplied with battery backup which will maintain normal operation of the leak detector for a minimum of 6 hours in the event of a power failure. The battery backup shall recharge while the unit is operating under normal power. Chlorine gas monitoring systems shall be MSA to match existing.

See Appendix C for a schedule of required devices for this Contract.

D. **Sulfur Dioxide Gas Monitoring Systems:** Sulfur dioxide gas leak detectors shall be designed for mounting in the monitored space and shall provide warning and alarm contact outputs in the presence of sulfur dioxide gas concentrations at setpoints adjustable between 1 and 10 parts per million (ppm). Detector power supply shall be 120 volts AC, 60 hertz, and detector shall alarm in case of power failure. Each detector shall utilize a non-wet chemistry type, voltametric gas sensor requiring minimum maintenance and shall be sensitive to the pressure of sulfur dioxide gas only. The detector shall consist of a sensor and alarm module. The sensor shall not require reagents or require pumps to sample the air. Each sensor shall be supplied with cable as required. Warning and alarm activation shall be indicated with a light locally on the alarm module. The system shall be "fail safe" with failures in the internal electrical circuit. An alarm reset button and power on light shall be provided. The detectors shall be wall-mounted units. Electrical components shall be within gasketed enclosure with gas tight connections. Contact outputs shall be provided for warning and for alarm. Warning output shall be non-latching. Alarm output shall activate upon detection of gas at alarm setpoint, upon detection of internal failure, or upon detection of sensor failure and shall be field selectable for latching or non-latching. Contact outputs shall be rated 5 amperes at 120 volts AC minimum. The entire installation for each leak detector shall be designed to prevent radio frequency interference (RFI) and electro-magnetic interference (EMI). As a minimum, the alarm module and sensor shall be RFI shielded and the sensor cable shall be installed in rigid metal conduit. The shielding and the metal conduit shall be connected to earth ground. The manufacturer shall verify in writing that the units are properly installed and that the units will not alarm when the antenna of a 5 watt, 450 MHZ transmitter is activated at three feet from the alarm module or sensor with the alarm set point as low as one twentieth of full scale. Each leak detector shall be supplied with battery backup which will maintain normal operation of the leak detector for a minimum of 6 hours in the event of a power failure. The battery backup shall recharge while the unit is operating under normal power. Sulfur Dioxide gas monitoring systems shall be MSA to match existing.

See Appendix C for a schedule of required devices for this Contract.

2.14 CONTROL PANEL INSTRUMENTATION

A. **Bar Graph Indicators**: Indicators shall be the electronic gas-discharge type suitable for installation in flush panel mounting shelves. Indicator shall provide for two non-isolated input circuits. Input signal level shall be 4-20 mA DC through a shelf-mounted 250-ohm resistor. The units shall contain an integral power supply suitable to energize

two 4-20 mA DC, 2 wire transmitters. Unit power supply shall be 24 VDC. Indicator accuracy shall be plus or minus 0.5 percent of span with a repeatability of 0.1 percent of span. Indicator scales shall be in engineering units.

B. **Digital Indicators**:

1. Digital indicators shall be self-contained instruments that display process signals directly in engineering units. The unit shall be suitable for panel mounting and shall utilize an LED display where numerals are no less than [0.5-inch] height.

2. The input signal to the digital process indicator shall be 4-20 mA DC or 1-5 VDC. The input sample rate of the unit shall be a minimum of 2 per second. The unit shall have an auto-zeroing feature and shall have provisions for field adjustable scaling and offset. Accuracy shall be plus or minus 1 least significant digit. Input power to the digital indicator shall be 120 VAC, 60 Hz.

C. **Totalizers**: The totalizers shall be solid state C-MOS logic type with minimum 8 non-resettable LCD digits. Totalizers shall be approximately 2 inches high by 2 inches wide by 3 inches deep, suitable for front panel mounting. Character height shall be 0.140 inch minimum. Each totalizer shall have a standby battery capable of maintaining the last totalized value for a minimum of 72 hours after a utility power failure. Power supply shall be from transmission signal which shall be 6 to 250 volts AC or DC or DC switch closure. Maximum count speed shall be 3600 counts per minute.

D. **Current Alarm Trip Switches**: Current alarm trips shall be single or dual type as indicated. Units shall accept voltage or current input signals. Dead bands shall be factory set at 1.0 percent of full span for dual trips and adjustable over 100 percent of span for single trips. Alarm trips shall be equipped with 10 A DPDT contacts. Alarm trips shall include setpoint dials calibrated 0 to 100 percent for each trip point. Single alarm trips shall include a dead band adjustment dial calibrated 0 to 100 percent.

E. **Selector and Pushbutton Switches**: Selector and pushbutton switches shall be rated 10 A at 600 volts, shall be heavy-duty, oil-tight, and shall have the number of positions and poles indicated. Operators shall be corrosion resistant.

F. **Indicating Lights**: Indication lights shall be incandescent push-to-test type and shall be heavy-duty, oil-tight. Each light shall have a screwed-on glass prismatic lens approximately 1-inch in diameter. Each light shall have a factory-engraved legend plate as indicated. Indicating lights shall be 120 VAC type with transformers for use with 6.3 volt lamps.

G. **Alarm Annunciator Systems**:

1. Alarm annunciator systems shall consist of a back lighted window display, alarm modules, flasher-audible modules, power supply, and horn. All annunciators which are installed in NEMA 3, 3R, 4, or 4X enclosures shall be protected by window kits which preserve the panels NEMA rating. Annunciator shall be

furnished with (integral)(remotely mounted) acknowledge, test, reset, and silence, pushbuttons. The alarm sequence shall conform to ISA M-1 as follows:

a. Alarm condition sounds the horn and causes the display to flash.

b. Depression of the Acknowledge Pushbutton causes the horn to go silent and the display goes from flashing to continuously lit and remains illuminated until the alarm condition ceases to exist.

c. Depression of the Reset Pushbutton, subsequent to the process condition returning to a normal condition, returns the sequence to a normal state.

d. Depression of the Test Pushbutton shall simulate simultaneous abnormal process conditions on all related alarm points to reveal lamp or circuit failures.

2. **Alarm Modules:** Alarm point modules shall be solid state electronic devices. Each module's relay contacts shall be configured [normally open] [normally closed] to accept dry inputs. The annunciator shall provide [24 VDC] [48 VDC] [125 VAC] wetting voltage for all inputs. All input and alarm logic shall conform to the surge test immunity requirements of IEEE-472-1974. All solid state logic circuits shall conform to the requirements of SAMA PMC 33.1 "Electromagnetic Susceptibility of Process Control Instrumentation" in their ability to resist Radio Frequency Interference (RFI) with the control panel doors open. The time period between the operation of the field contacts and the annunciation of the alarm state shall not exceed 50 milliseconds. Each alarm module shall be field configurable for normally open or normally closed contact operation. [Time delay circuits, adjustable from [0.7 to 1] [.4 to 6] seconds shall be provided for [each alarm point] [for indicated points] to prevent false operation due to extraneous circuit pulses or electrical transients]. Alarm modules and flasher-audible modules shall be easily removable for ease of inspection and servicing. Alarm logic shall be provided for all currently utilized and spare display points.

3. **Alarm Display:** Annunciator windows shall be translucent white with black letters. Annunciator cells shall be approximately 2"/50mm high and 3"/75mm wide. Each window shall have two high intensity 6 volt, 1 watt lamps rated at 20,000 hours. The lamps shall be wired so that the burnout of a lamp will not affect the other lamp. All lamps shall be replaceable from the front of the annunciator.

4. **Window Engraving:** The window arrangement and associated text shown in the Contract Documents shall be interpreted as a guideline only which is subject to modification at the time of submittal by the Construction Manager. All lines of characters shall be centered in the window. All characters shall be engraved in the same size and line thickness all in conformance with the requirements of ISA-RP60.6 (Nameplates, Labels, and Tags for Control Centers) with a recommended viewing distance of 3'/1m to 6'/2m. All characters shall be in uniformly and symmetrically spaced to give a clear, easy-to-read, informative display. Each

window shall have two high intensity 67 volt, 1 watt lamps rated at 50,000 hours. The lamps shall be wired so that the burnout of a lamp will not affect the other lamp. All lamps shall be replaceable from the front of the annunciator.

5. **Audible Alarm Horn:** Solid state tone generators shall be located in the annunciator or control panel enclosure. The adjustable tone generator shall activate an alarm [horn] [chime] [buzzer] [speaker] located on the front of the annunciator. The sound shall be [continuous] [intermittent] until silenced by manual pushbutton operation. The sound shall be adjustable between steady and fluctuating or warble. [The audible alarm shall silence automatically after an adjustable time.] Audible devices shall conform to the environmental requirements that apply to other panel mounted devices.

6. **Power Supply Systems:** Each annunciator shall be provided with its own dedicated redundant 24 VDC power supplies. The sharing of power supplies with panel power shall not be permitted. Power supplies shall provide electrical isolation between power sources and annunciator circuits. Ground detectors shall annunciate the occurrence of accidental circuit grounds. The power supply system shall enable the offending grounds to be located and removed without affecting the annunciator operation or the power source. The power supplies shall be redundantly configured with diode auctioneering to enable the transition between a failed power supply to the backup without impact to the annunciator and to enable the replacement of a failed supply without impact to the annunciator's operation. Power failure detectors shall be provided to alarm the failure of each power source and each power supply to an independent alarm device.

7. **Retransmit Contacts:** All alarm inputs to the annunciator and audible relays shall have retransmit contact outputs for input to other equipment. Retransmit contacts shall be a field contact follower and utilize gold flashed contacts rated at 5 amps at 24 VDC [or] [125 VAC and 0.1 amp at 125 VDC resistive.]

8. **Pushbuttons:** Annunciator pushbuttons shall be provided for Alarm Acknowledge, [Silence], Reset, and Lamp test functions as shown on the contract drawings. All pushbuttons shall be momentary manual switches that cause a change from one annunciator sequence state to another. Pushbuttons shall be heavy duty and conform to the environmental requirements that apply to other panel mounted devices. Pushbuttons shall be located to facilitate convenient operation and access while minimizing the possibility of accidental operation of other nearby pushbuttons. Interlocks shall be provided to (1) require the operation of the Acknowledge pushbutton prior to alarms being Reset (2) require operation of silence and acknowledge pushbuttons in sequence to avoid accidental loss of alarm indications.

H. **Proportional Plus Manual Reset Process Controllers:** Proportional plus manual reset controllers shall be microprocessor based single loop controllers. Units shall have front panel bar graph or digital indicators with scales in engineering units as indicated. Vertical process and setpoint bar graph indicators shall have accuracies of plus or

minus 0.5 percent of span. Fully adjustable high and low alarm set points shall be provided as indicated. Alarm outputs shall be indicated on the face panel of the controller.

1. Units shall be suitable for operation for temperature variations from 40 to 120 degrees F and over a range of relative humidities from 10 to 90 percent.

2. Controllers shall operate on 120 VAC, 60 Hz. Power supplies, if required, shall be provided. All accessories required for adjustment of control parameters shall be provided. Enclosures shall be nominally 3 inches by 6 inches, suitable for separate or multiple panel mounting.

3. Controllers shall include manual-automatic selection, fully adjustable proportional plus manual reset modes, bumpless transfer switching, setpoint control and indications, high and low output limiters, controlled variable and output signal indicating scales. Controllers shall accept 4-20 mA input signals and output a similar signal. In the event of a power loss with controller in either automatic or manual mode, all controller settings shall return to the last value after power is restored. Proportional band shall be fully adjustable from 3 percent to 500 percent. Manual reset controls shall be continuously adjustable from 0 to 100 percent of scale. Controllers shall include manual increase/decrease pushbuttons. Indicated controllers shall include a remote setpoint feature including a remote/local selector switch. Remote setpoint input signal shall be 4-20 mA.

2.15 PROGRAMMABLE LOGIC CONTROLLER (PLC):

A. Where required, the CONTRACTOR shall furnish, install, program, test, calibrate, fully configure and place into operation Programmable Logic Controllers (PLCs) as specified herein. These requirements also pertain to all PLCs provided under Divisions 11, 15, and 16.

B. **General:** The CONTRACTOR shall furnish all necessary interconnecting cables, all accessories, and all appurtenances as indicated herein or as required for proper operation of the system. All major PLC components of the system shall be of the same manufacturer and PLC family product line. All equipment shall be housed in an enclosure or control panel suitable for the intended operation and location. The PLC system shall be capable of tolerating and capable of riding through a power interruption of 8 milliseconds or less without interruption of normal operation. The PLC system shall be Allen Bradley to match existing.

C. **Construction:** The PLC central processing unit (CPU) shall be of solid-state design. The PLC system shall be provided with a housing or chassis with enough slots to handle all power supplies, CPUs, I/O cards, and communication modules. All CPU operating logic shall be contained on plug-in modules for quick replacement. Chassis wired logic is not acceptable. The controller shall be capable of operating in a hostile industrial environment (i.e., heat, electrical transients, RFI, vibration, etc.) without fans, air conditioning, or electrical filtering (up to 60 degrees C and 95 percent humidity).

D. **Design:** The PLC shall be furnished with I/O (input/output) modules suitable for interfacing with new and existing field devices. The PLC I/O modules shall be 4-20 mA signals for analog inputs and analog outputs and shall be 24 VDC and/or 120 VAC signals for discrete inputs and discrete outputs. The PLC shall provide internal fault analysis with a fail-safe mode and a dry contact output for remote location alarming, and a local indicator on the PLC frame in the event of a fault in the PLC.

E. **Central Processor:** The central processor shall contain all the relays, timers, counters, number storage registers, shift registers, sequencers, arithmetic capability, and comparators necessary to perform the specified control strategy functions. It shall be capable of interfacing sufficient discrete inputs, analog inputs, discrete outputs, and analog outputs to meet the specified requirements plus an additional 25 percent excess capacity. The power supply shall contain capacitors to provide orderly shutdown in the event incoming power does not meet specifications. If this occurs, the processor shall cease operation, forcing all outputs off. The processor shall have a key type memory protect switch to prevent unauthorized program changes. The central processor shall be 32-bit, minimum.

F. **Memory:** The programmable controller memory shall be Complementary Metal Oxide Semi-conductor (CMOS) based memory with battery backup or Erasable Programmable Read-Only Memory (EPROM) based memory. The CMOS memory shall be a minimum of 21K with sufficient battery backup to retain the program during power interruptions of up to 1 year. An indicator shall show the status of the batteries. A reference shall be available through the discrete outputs to alarm the operator that the batteries should be changed.

The PLC shall be supplied with sufficient memory to implement the specified control strategy functions plus a reserve capacity of 25 percent of the total provided. This reserve capacity shall be totally free from any system use. The memory shall be programmed in a multi-node configuration with multiple series or parallel contacts, counters, timers, and arithmetic functions.

G. **Controller:** The controller shall have its control strategies programmed in a "ladder logic" language. It shall be easily reprogrammed with a laptop computer as specified below. The PLC system shall be programmed by the CONTRACTOR to perform the specified control strategies and monitoring functions. Two documented copies, in hardcopy and electronic format, of the operating PLC program(s) shall be furnished to the OWNER which shall allow direct, step-by-step, reloading of the PLC system program(s). The ladder logic shall reflect equipment name designations used in the PLC as well as the Contract Drawing equipment name designations (i.e., timer "Q" in the Contract Drawing may become timer OL in PLC program).

H. **Power Supply:** The PLC shall be provided with all requisite power supplies and shall operate at the following:

1. 120V ac RMS plus or minus 15 percent continuously.

2. 120V ac RMS plus or minus 30 percent maximum 30 seconds.

3. 120V ac RMS plus or minus 100 percent maximum milliseconds.

4. Line spikes at 1000V ac (5000 micro-seconds duration; 0.05 percent maximum duty cycle).

I. **Input/Output Modules:** All I/O housings and I/O modules shall be of rugged construction with modules in place. Sufficient input and sufficient output modules shall be provided with the PLC to implement the specified control functions plus a reserve capacity of 25 percent of the total provided. All PLC I/O shall be arranged in a distributed I/O configuration such that the failure of any I/O card will not affect multiple items of the same equipment.

1. Discrete Input Modules: Defined as contact closure inputs from devices external to the programmable logic controller module. Input modules shall be shielded from short time constant noise and 60-Hz pickup. Individual inputs shall be optically isolated for low energy common mode transients to 1500 volts peak from user's wiring or other I/O Modules. The modules shall have LED lights to indicate a discrete input.

2. Discrete Output Modules: Defined as contact closure outputs for ON/OFF operation of devices external to the programmable logic controller module. The output modules shall be fused (typically 5-amp at 115V ac) with blown fuse indicator lights. The output modules shall be optically isolated from inductively generated, normal mode and low energy, common mode transients to 1500 volt peak. All output modules shall have LED lights to indicate output has been cycled ON by the controller.

3. Analog Input Modules: Defined as analog inputs for 1 to 5 VDC or 4 to 20 mA dc signals, where an analog to digital conversion is performed and the digital result is entered into the processor. New inputs shall be provided for every scan.

4. Analog Output Modules: Defined as analog output for 1 to 5 VDC or 4 20 mA dc signals, where a digital to analog conversion is performed and the analog result is produced as an output. New outputs shall be produced on every scan.

J. **Data Access Panel:** Where required, a Data Access Panel with LCD display and keypad shall be provided to allow the operator to monitor and make changes in internal registers for set points, timers, and counters in the PLC. Program logic or sequence changes shall not be made from this panel unless a security code or key lock is used to prevent unauthorized changes. Interconnecting cables between the Data Access Panel and the PLC shall be provided.

K. **Communications:** If the PLC is required to interface with the DCS via a datalink, is shall be done so by an RS422 or RS232 serial link. The serial link type used shall be determined by distances. The PLC system shall be provided with all appurtenances to support this requirement. The communications protocol shall be MODBUS with the

PLC configured in a slave mode. The DCS will operate in the master mode.

L. **Programming Laptop:** All programming shall be accomplished with a laptop computer. The laptop shall be capable of being directly plugged into the PLC system without the requirements of additional hardware. All programming, all monitoring, all searching, and all editing shall be accomplished with the laptop. These functions shall be capable of being done both "on line" while the PLC processor is scanning or "off line" while the PLC processor is not scanning. The laptop shall display multiple series and parallel contacts, coils, timers, counters, and calculation functions. The laptop shall also be able to monitor the status of all inputs, all outputs, all timers, all counters, and all coils. It shall have the capability to disable/force all inputs, all outputs, and all coils to simulate system operation. It shall also indicate "power flow" through all elements and include a search function to locate any element and its program location. The PLC processor status information, such as error indication and amount of memory remaining, shall be shown on the laptop screen. The CONTRACTOR shall provide one new laptop complete with manuals to the OWNER to enable future system support. The laptop shall be turned over to the OWNER at START-UP.

M. **PLC Control System Software:** This Section covers the furnishing of standard and customized software, fully installed and fully configured in the control systems specified herein. It is the intent of this specification to have the PLC System Supplier furnish his latest generation, standard, field proven, fully debugged and supported software package for this application with a minimum of additions or changes. Customized or specially written software shall be furnished if required to meet all of the functional requirements specified herein. Any custom applications software required shall be fully integrated into the basic software and shall not require unique command structures. Software specified herein is described in broad, functional categories. The System Supplier shall furnish a complete software package including the functional requirements specified herein along with whatever additional software is required by the supplier for proper and efficient operation of the PLC Control System. No attempt has been made to list all software or list all characteristics of software required by the System Supplier to meet the functional requirements specified herein.

1. General: The software package shall provide a system capable of controlling system level activities and a higher level process control language allowing the operator to monitor and control the process through an interactive human interface. The software environment shall support a multi-programming atmosphere allowing concurrent execution of more than one program in a background/foreground mode or multi-tasking mode.

2. Throughout the execution of all software modules, the operator shall be presented with all of the command or operation choices available at that point in the program using sufficient verbiage or symbols to make the choices self-explanatory and unambiguous. Question and answer or fill-in-the-blank requests shall only be permitted where file names, tag names, or other unique text or numerical information is required.

3. System-level software shall include a real time operating system, a calendar/time

program, a file management program and a system of diagnostic routines in addition to any compilers, editors, loaders, or assemblers required to support the process control software language.

4. All programs shall be self-configuring, such that they obtain the size and configuration of the system from parameters contained in the various files created during system generation. No parameters related to the hardware configuration shall be hard coded into any of the software.

5. System Level Software: System-level software shall include a complete and unmodified operating system furnished by the System Supplier that provides system-level functions as specified herein. Operating system software shall function automatically without operator intervention, except as required to establish file names and similar information.

6. Operating System Software: The real-time operating system software shall be the standard uncorrupted product of the host computer and shall provide the following minimum functions:

    a. Respond to demands from a program request or to demands from an operator.

    b. Dynamic allocation of the resources available in the system. These resources shall include main memory usage, computation time, peripheral usage, and I/O channel usage.

    c. Allotment of system resources on the basis of task priority levels such that a logical allocation of resources and suitable response times are assured.

    d. Queuing of requests in order of priority if one or more requested resources are unavailable.

    e. Resolution of contending requests for the same resource in accordance with priority.

    f. Service requests for execution of one program by another.

    g. Transfer data between programs as requested.

    h. Management of all information transfers to and from peripheral devices.

    i. Control and recovery from all program fault conditions.

    j. Diagnose and report real-time hardware device errors.

7. Program execution shall be scheduled on a priority basis. A multilevel priority interrupt structure is required. A program interrupted by a higher priority program shall be entered into a list of pending programs. Its execution shall be

resumed once it becomes the currently highest priority program. Initiation of programs shall, as a minimum, be activated in the following ways:

a. In response to external interrupts.

b. At a scheduled time of the day.

c. On an elapsed time interval basis.

d. On request by another program.

e. On request from the data access panel.

8. The system shall allow periodic programs to be scheduled. The allocation of resources to a time scheduled program shall be based on its relative priority ad the availability of computer system resources.

9. Start-up and Restart: Software shall be provided which initializes and brings a computer or any microprocessor based hardware unit from an inactive condition to a state of operational readiness.

   Initialization shall include determination of computer system status prior to start-up of initializing operating system software and initializing application software. Initialization shall also include the loading of all memory resident software, initialization of timers, counters, and queues, and initialization of all dynamic database values.

10. Shutdown: The software shall provide an orderly shutdown capability for shutdowns resulting from equipment failure, including computer processor failure, primary power failure, or a manually entered shutdown command. When the loss of primary power is sensed, a high-priority hardware interrupt shall initiate software for an immediate, orderly shutdown. When a shutdown occurs in response to a command or malfunction, the software shall control the affected hardware quickly and automatically to a secure state.

11. Diagnostics: Diagnostic programs shall be furnished with the software package to detect and isolate hardware problems and assist maintenance personnel in discovering the causes for system failures. The system manufacturer's standard diagnostic routines shall be used as much as possible. Diagnostic software and test programs shall be furnished for each significant component in the system.

    Diagnostic routines shall test for power supply, central processing unit, memory, and I/O bus failures as a minimum.

12. Calendar/Time Program: The calendar/time program shall update the second, minute, hour, day, month and year in the operating system and transfer accurate time and date information to all system level and application software. Variations in the number of days in each month and in leap years shall be handled

automatically by the program. The operator shall be able to set or correct the time and date from the data access panel, only at the highest security level.

N. **Operator Interface**: System-level software shall provide for creation and modification of alphanumeric displays, compression of display information for storage, and linking of dynamic files to database variables. Each display screen shall be able to be made up of static and dynamic alphanumeric information. The system shall be furnished with standard displays as specified herein. The system shall be capable of storing and utilizing all standard display formats.

Additionally, all display screens shall include a dedicated area that shall display the current time and date, and at lease one line for system-level messages.

O. **Standard Displays:** The operator interface systems shall include at least the following standard, non-configurable displays.

1. Current Alarm Summary--As specified in the alarm processing section of this document.

2. System Overview--Displaying the current status of major systems hardware components including the input/output hardware.
3. Menu Displays--Indicating the various displays and application level choice available to the operator.

4. Point Displays--Detailed displays in a standard format for all types of points in the system. Any point in the system shall be able to be displayed indicating all parameters associated with the point. Each entry in the display shall be labeled in engineering units.

P. **Algorithms:** System software shall support the implementation of algorithms for the determinations of control actions and special calculations involving analog and discrete inputs. These algorithms shall be capable of outputting positional or incremental control outputs or providing the product of calculations. The algorithms shall include alarm checks where appropriate. As a minimum, the following types of algorithms shall be provided.

1. A calculator algorithm which performs functions such as summing several variables, raising to a power, roots, dividing, multiplying, and subtracting.

2. A switch algorithm which reads the current value from its input address and stored it as the value of its output address. Two types of switches shall be accommodated, 2 outputs with one input and one output with 2 inputs.

3. A 3 mode Proportional-integral-Derivative (PID) controller algorithm, with each of the 3 modes independently adjustable. The algorithm shall support both direct and reverse acting modes.

4. Algorithms for lead, lag, dead time, and ration compensators.

5. Algorithms to perform integration and totalization of analog process variables.

6. Algorithms that drive the set point of a controller shall include provisions for bumpless transfer, which shall be implemented by use of a bias value.

7. Algorithms shall be implemented and modified in the system at any time through the use of interactive software modules in a manner consistent with other interactive modules and shall not required any direct source of code changes.

Q. **Alarm Processing**

1. Alarm processing software shall be provided to recognize and report alarm events and conditions to the Local Control Panel in an organized, unambiguous, clear, and convenient manner. Alarms shall be classified into at least 2 priority levels and at least 2 independent classes.

2. Alarm processing software shall generate alarms for the following conditions:

a. Discrete input or output change of state is defined as an alarm in the control software.
b. Analog value exceeding alarm limits defined in the control software.

c. Analog rate of change exceeding limits defined in the control software.

d. Failure of the PLC processor, mass memory device, process input/output hardware, or other major hardware component.

Alarms shall be generated in each case above at the time of occurrence and at the time the condition returns to normal.

R. **Testing:** The CONSTRUCTION MANAGER shall witness testing of the PLC system. Solid-state logic systems shall be tested as complete assemblies. Testing of individual components or modules shall not be acceptable.

S. **Training:** A manufacturer's representative shall supply two 8-hour days of on-site training for the OWNER'S personnel. The training shall include but not be restricted to, operation of programming unit, trouble shooting of system hardware and software, and program development.

T. **Seven Day Acceptance Test:** After start up has been completed, the System shall undergo a 7-day acceptance test. The System must run continuously for 7 consecutive days. During this period, all System functions shall be exercised. Any System interruption and accompanying component, subsystem, or program failure shall be logged for cause of failure, as well as time of occurrence and duration of each failure. A failure shall cause termination of the 7-day acceptance test. When the cause of a failure has been corrected, a new 7-day acceptance test shall be started.

Each time the CONTRACTOR's technician is required to respond to a System malfunction, he must complete a report which shall include details concerning the nature of the complaint or malfunction and the resulting repair action required and taken.

U. **Operations and Maintenance Manuals:** The CONTRACTOR shall furnish to the OWNER 5 complete sets of operation and maintenance manuals. The manuals shall include date, information drawings, etc., for the system, subsystem, and all components, and shall include names, addresses and telephone numbers of equipment suppliers, representatives and repair facilities.

This shall include a complete description of the recommended operating procedures, maintenance procedures, and spare/replacement parts list for equipment items with catalog data, diagrams, and drawings or cuts describing the equipment. Each set shall include full size assembly and wiring diagrams; drawings showing "as-build" conditions shall be furnished to the OWNER.

PART 3 -- EXECUTION

3.1 INSTALLATION

A. The CONTRACTOR shall employ installers who are skilled and experienced in the installation and connection of all elements, all instruments, all accessories, and all assemblies provided under this Contract.

B. The CONTRACTOR shall install all instruments according to the manufacturer's installation instructions and the following:

1. Perform field engineering as required for mounting and supporting all field mounted components.

2. Prepare any additional schematic and interconnection diagrams required for installation.

3. Assemble and interconnect instrument components disconnected for shipping purposes.

4. Remove all temporary supports, bracing, and padding inserted in instrument control panels and other equipment to prevent damage during shipping, storage, or installation.

5. All piping shall be field measured prior to fabrication and erection. Any significant discrepancies between drawings and field conditions shall be reported to the CONSTRUCTION MANAGER. The OWNER will not be responsible for any costs to the CONTRACTOR for rework because of CONTRACTOR failure to take measurements prior to fabrication.

6. Adequately support and protect capillary tubing. All extra tubing shall be carefully coiled, tied, and protected at the instrument location.

C. The CONTRACTOR shall install pneumatic instrument air systems according to the manufacturer's installation instructions and the following:

1. Install all pneumatic tubing and make all connections at control panels, instruments, and control valves.

2. Perform field engineering as required for instrument air supply headers and individual air supply taps and lines.

3. Check all air supply branch headers by blowing with clean air and checking for tightness.

4. Clean all transmission and control tubing by blowing with dried and filtered air prior to connecting to instrument components.

5. Leak test all pneumatic control circuits in accordance with ISA Recommended Practice RP-7.1.

6. Set all instrument air regulators at manufacturer's recommended supply pressures.

D. It is the intent of the Contract Documents that all wiring external to Control Panels be provided under the requirements of Division 16. Further, it is the general intent that all 4-20 mA signal circuits, process equipment control wiring, signal wiring to field instruments, and Control Panel input and output wiring, be provided under Division 16 and be terminated and identified under Division 13.

E. The CONTRACTOR's attention is directed to the electrical and mechanical schematics and details of this project. Referral to these portions of the Contract Documents shall be required in order to understand the full intent and scope of work required.

F. Monitoring and control system configurations are diagrammatic only. Locations of equipment are approximate unless dimensioned on the drawings. Exact locations and routing of wiring and cables shall be governed by structural conditions, physical interferences, and locations of electrical terminations on equipment.

G. Where job conditions require minor changes in approximated locations and arrangements, the CONTRACTOR shall make such changes without additional cost to the OWNER.

H. All instruments shall be located and installed for ready access by the OWNER'S operation and maintenance staff. The OWNER reserves the right to require minor changes in location of equipment prior to roughing without any additional cost to the OWNER.

I. Meters shall be installed in easily accessible locations and orientated for ease of reading and maintenance, and where shown, for balancing flow. Wherever possible, meters shall be inserted in such a way to comply with the manufacturer's recommendations. Meters, shut-off and balancing valves shall be properly supported. In-line meters shall be installed to ensure full-line flow and not less than the manufacturer's recommended head at all times.

3.2 CONTROL PANEL SIGNAL AND CONTROL CIRCUIT WIRING

A. **Wiring Installation:** All wires shall be in plastic wireways except (1) field wiring, (2) wiring between mating blocks in adjacent sections, (3) wiring from components on a swing-out panel to components on the fixed structure, and (4) wiring to panel-mounted components. Wiring from components on a swing-out panel to other components on fixed panels shall be tied into bundles with nylon wire ties, and shall be secured to panels at both sides of the "hinge loop" so that conductors are not strained at the terminals.

B. Wiring to control devices on the front panels shall be tied together at short intervals with nylon wire ties and secured to the inside face of the panel using adhesive mounts.

C. Wiring to rear terminals on panel-mount instruments shall be in plastic wireways secured to horizontal brackets above or below the instruments in about the same plane as the rear of the instruments.

D. **Wire Marking:** Each signal, control, alarm, and indicating circuit conductor connected to a given electrical point shall be designated by a single unique number which shall be shown on all shop drawings. These numbers shall be marked on all conductors at every terminal using white numbered wire markers which shall be permanently marked heat-shrink plastic.

3.3 INSTRUMENT CABLE TESTS

A. **General:** The following tests shall be performed on each instrumentation and control system cable. All tests shall be end-to-end tests of installed cables with the ends supported in free air, not adjacent to any grounded object. All test data shall be recorded on forms which are available from the CONSTRUCTION MANAGER. Complete records of all tests shall be made and delivered to the CONSTRUCTION MANAGER. Each form shall be signed by the [CONSTRUCTION MANAGER or the CONSTRUCTION MANAGER's Representative] who witnessed the testing.

B. Continuity tests shall be performed by measuring wire/shield loop resistance of each signal cable as the wires, taken one at a time, are shorted to the channel shield. No loop resistance measurement shall vary by more than plus or minus 2 ohms from the calculated average loop resistance value.

C. Insulation resistance tests shall be performed by using a 500 volt megometer to measure the insulation resistance between each channel wire, between each channel wire and the

channel shield, between individual channel shields in a multichannel cable, between each individual channel shield and the overall cable shield in a multi channel cable, between each wire and ground, and between each shield and ground. Values of resistance less than 1 megohms shall be unacceptable.

3.4 INSTALLATION, CALIBRATION, TESTING, PRECOMMISSIONING, STARTUP AND INSTRUCTION

A. **Installation and Connection:** The CONTRACTOR shall install and connect all field-mounted components and assemblies under the following criteria:

1. Process sensing lines and air signal tubing shall be installed to the installation of conduit indicated under Section 16050. Individual tubes shall be run parallel and near the surfaces from which they are supported. Supports shall be used at intervals not longer than 3 feet of tubing.

2. Bends shall be formed with the proper tool and to uniform radii and shall be made without deforming or thinning the walls of the tubing. Plastic clips shall be used to hold individual plastic tubes parallel. Ends of tubing shall be square-cut and cleaned before insertion into fittings. Bulkhead fittings shall be provided at all panels requiring pipe or tubing entries.

3. All flexible cables and all capillary tubing shall be provided in flexible conduits. Lengths shall be sufficient to withdraw the cables and tubing for periodic maintenance.

4. Thermocouple lead wire shall be provided in dedicated conduit or wireway from the thermocouple to the control panel. Conduit or wireway shall be sized in accordance with the capacity of the instrument.

5. All power and all signal wires shall be terminated with spade type lugs.

6. All connectors shall be, as a minimum, water tight.

7. After all installation and connections have been completed, a technical field representative of the CONTRACTOR shall check the WORK for polarity of electric power and signal connections, leaks at all process connections, and conformance with requirements. The technical field representative shall certify in writing to the CONTRACTOR that each loop and system meets requirements.

8. All wire and all cable shall be connected from terminal to terminal without splices, arranged in a neat manner and securely supported in cable groups. All wiring shall be protected from sharp edges and corners.

B. **Calibration:** All analog instrumentation and all control system equipment shall be calibrated and tested after installation to verify that requirements are satisfied. The CONTRACTOR shall provide all necessary labor, tools, and equipment to calibrate and test each instrument in accordance with the manufacturer's instructions. Each

instrument shall be calibrated at a minimum of three points using test equipment to simulate inputs and read outputs. All test equipment and all instruments used to simulate inputs and read outputs shall be suitable for the purpose intended and shall have an accuracy better than the required accuracy of the instrument being calibrated. Test equipment shall have accuracies traceable to the NIST as applicable. All analog instruments shall be calibrated and tested in place without removal. Test data, applicable accuracy requirements, all instrument manufacturer published performance specifications and all permissible tolerances at each point of calibration shall be entered on test forms available from the CONSTRUCTION MANAGER. These test forms shall verify compliance with all. A report shall be delivered to the CONSTRUCTION MANAGER for each instrument, certifying that the instrument has been calibrated in the presence of the [CONSTRUCTION MANAGER or the CONSTRUCTION MANAGER's designated representative] and meets contract and system requirements.

C. **Analog Loop Tests:** The CONTRACTOR shall be responsible for loop checking and testing all instrumentation loops with this project. The CONTRACTOR shall coordinate all loop check functions with the CSP to ensure that a single total loop check is conducted. The intent of the loop checks is to confirm and document each loop's component specification conformance up to and including all field-situated CSP devices. The CSP will have all control room personnel present to witness and confirm loop check results at the CRT level. The CONTRACTOR shall provide all necessary labor, tools, and equipment to field test, inspect and adjust each instrument to its indicated performance requirement in accordance with manufacturer's specifications and instructions. Any instrument which fails to meet any Contract requirement, or any published manufacturer performance specification for functional and operational parameters, whether or not indicated in the Contract Documents, shall be repaired or replaced, at the discretion of the CONSTRUCTION MANAGER at no additional cost to the OWNER.

1. At least [15] [ ] days before installation testing begins, the CONTRACTOR shall submit to the CONSTRUCTION MANAGER a detailed description, in duplicate, of the installation tests to be conducted to demonstrate correct installation of the instrumentation and control system and the anticipated dates the testing will occur.

2. Controllers and electronic function modules, shall be tested and exercised by the CONTRACTOR to demonstrate correct operation, first individually and then collectively as functional analog networks. Each hardwired analog control network shall be tested to verify proper performance within indicated accuracy tolerances. Accuracy tolerances for each analog network are defined as the root-mean-square-summation of individual component accuracy tolerances. Individual component accuracy tolerances shall be as indicated by contract requirements, or by published manufacturer accuracy specifications, whenever contract accuracy tolerances are not indicated.

3. Each analog network shall be tested by applying simulated inputs to the first element(s). Simulated sensor inputs corresponding to 10 percent, 50 percent, and

90 percent of span shall be applied, and the resulting outputs read to verify compliance to network accuracy tolerance requirements. Continuously variable analog inputs shall be applied to verify the proper operation of discrete devices. Temporary settings shall be made on controllers, alarms, etc., during analog loop tests. All analog loop test data shall be recorded on test forms, which include calculated root-mean-square-summation system accuracy tolerance requirements for each output.

4. Air systems shall be tested for leaks in compliance with ISA RP7.1.

5. When installation tests have been successfully completed for all individual instruments and all separate analog control networks, a certified copy of all test forms signed by the [CONSTRUCTION MANAGER or the CONSTRUCTION MANAGER's representative] as a witness, with test data entered, shall be submitted together with a clear and unequivocal statement that all instrumentation has been success fully calibrated, fully inspected, and fully tested.

D. **System Pre-commissioning:** The CONTRACTOR shall responsible for demonstrating the operability of all systems provided under this specification. The City will assist and coordinate the operability assessment with the CONTRACTOR. Pre-commissioning shall commence after acceptance of all wire, all calibrating and loop tests, and all inspections have been conducted. Pre-commissioning shall demonstrate proper operation of all systems with process equipment operating over full operating ranges under actual operating conditions.

1. The CONTRACTOR shall develop and submit to the CONSTRUCTION MANAGER for approval a Pre-Commissioning Plan which describes detailed test procedures, checklists, blank forms and data to be recorded, test equipment to be used and calculated tolerance limits.

2. System pre-commissioning activities shall include the use of water to establish service conditions that simulate, to the greatest extent possible, normal final control element operating conditions in terms of applied process loads, operating ranges and environmental conditions. Final control elements, control panels, and ancillary equipment shall be tested under start-up and steady-state operating conditions to verify that proper and stable control is achieved using motor control center and local field mounted control circuits. All hardwired and software control circuit interlocks and alarms shall be operational. The control of final control elements and ancillary equipment shall be tested using both manual and automatic (where provided) control circuits. The stable steady-state operation of final control elements running under the control of field mounted automatic analog controllers or software based controllers shall be assured by adjusting the controllers, as required, to eliminate oscillatory final control element operation. The transient stability of final control elements operating under the control of field mounted, and software based automatic analog controllers shall be verified by applying control signal disturbances, monitoring the amplitude and decay rate of control parameter oscillations (if any) and making necessary controller adjustments, as required, to eliminate excessive oscillatory amplitudes

and decay rates.

3. All electronic control stations incorporating proportional, integral or differential control circuits shall be optimally tuned, experimentally, by applying control signal disturbances and adjusting the gain, reset or rate setting(s) as required to achieve a proper response. Measured final control element variable position/speed setpoint settings shall be compared to measured final control element position/speed values at 10 percent, 50 percent and 90 percent of span and the results checked against indicated accuracy tolerances. Accuracy tolerances are defined as the root-mean-square summation of individual component accuracy tolerances.

   Individual component accuracy tolerances shall be as indicated in the Contract Documents or as specified by published manufacturer accuracy specifications whenever not indicated.

4. The CONTRACTOR shall submit an instrumentation and control system pre-commissioning completion report which shall state that all Contract requirements have been met and which shall include a listing of all instrumentation and all control system maintenance and repair activities conducted during the pre-commissioning testing. The CONSTRUCTION MANAGER must accept the instrumentation and control system pre-commissioning testing before the seven day operational testing may begin. Final acceptance of the control system shall coincide with final acceptance of the WORK.

E. **7-Day Operational Testing:** The CONTRACTOR shall furnish his own personnel, electrical personnel, and any instrument manufacturers representatives as required during the testing period required in Section 01660 to produce a fully operational system.

F. **Instruction:** The CONTRACTOR shall train the OWNER'S maintenance personnel in the maintenance, calibration and repair of all instruments provided under this contract.

1. The training shall be scheduled a minimum of [3] [ ] weeks in advance of the first session. The training shall be performed concurrent with the pre-commissioning in subparagraph D.

2. The training shall be performed by qualified representatives of the instrument manufacturers and shall be specific to each instrument model provided. Instructors shall have at least 2 years of training experience.

3. Each training class shall be a minimum of [8] [ ] hours in duration and shall cover Operational Theory, Maintenance, Trouble Shooting/Repair, and Calibration of the instrument.

4. Proposed training material, including resumes for the proposed instructors and a detailed outline of each lesson shall be submitted to the CONSTRUCTION

MANAGER at least 30 days in advance of when the lesson is to be given. The CONSTRUCTION MANAGER shall review the submitted data for suitability and provide comments which shall be incorporated into the course.

5. Within 10 days after the completion of each lesson the CONTRACTOR shall present to the CONSTRUCTION MANAGER the following:

   a. A list of all OWNER personnel that attended the lesson.

   b. An evaluation of OWNER personnel knowledge through written testing or equivalent.

   c. A copy of text utilized during the lesson with all notes, diagrams, and comments.

3.5 PROCESS CONTROL STRATEGIES

A. The control strategies shown in Appendix A complement the Process and Instrumentation Diagrams (P&IDs). All materials and components shall be furnished, whether explicitly indicated or not, to effect the functional requirements defined on the P&IDs and in the process control strategy descriptions. The CONTRACTOR shall utilize the control strategies as a resource in generating control narratives to be included in the analog hardware submittal.

B. Common functions that are generally applicable to all strategies or to similar strategies are described under the heading “General Functions”. These functions are not repeated in the descriptions for each strategy.

C. Each strategy is described as follows:

1. **Overview**: A brief description of the mission of the related strategy including the roles of logic, monitoring and control stations located/associated with MCCs, field situated, and , DCS -based.

2. **Detailed Strategy Functions**: A detailed description of each and every monitoring and control function associated with the associated strategy. This description addresses the strategies reaction to sensor failures, process equipment failures, control device failures, DCS malfunctions, and power interruptions. All control modes (MCC, local hand station, local control panel, DCS keyboard) are fully described. These descriptions are augmented by a listing of all instruments, valves, control devices, process equipment, and DCS equipment associated with the noted strategy. All control sequences associated with equipment activation, deactivation, process startup and process shutdown are defined along with all required time delays.

3. **Preface to Control Strategy Section**:

   Tag numbering system

Definitions and terms
Controls and control functions provided for all equipment, unless otherwise noted
Local control station at equipment
Local/DCS switch
Alarms logic - open contact for alarms (fail-safe)

4. Format for Each Strategy

a. General Description

(1) An overall description of the process
(2) Major control components (PCM, PLC, annunciator, panels)
(3) General function of each major control component
(4) P & ID references for this strategy
(5) Reference to I/O listing

b. Related Equipment:

c. Overview of Strategy

d. Non-DCS Control

(1) Local Manual Control: Description of monitoring and control from each equipment item. If this is covered by the general statement in the Preface, describe any deviations. Example: "Because of inaccessibility location of this valve in the sump, a local control station is not provided."

(2) Remote Manual Control: Description of control from any local or area control panels. Other Control: Package system, PLC, etc.

e. DCS alarm, monitoring and control functions

(1) DCS Manual Control

(2) DCS Automatic Control

(3) Alarms - define alarms and alarm priorities. Define level (1, 2, 3, or 4) for each alarm

f. Failure Modes

g. Communications Interfaces

h. In-Service/Out of Service Algorithm: Description of devices which determine in/out of service status for each piece of equipment. (In-service (I/S)/out of service (OOS) algorithms mask or block out all or selected alarms associated with the OOS device (i.e., if a wetwell is

declared OSS, low level alarms shall be inhibited). Additionally, if a device has been designated OOS, all control routines shall declare the equipment as being unavailable for service.

See Appendix A for detailed descriptions of the process control strategies.

3.6 INSTRUMENT SUMMARY

A. **General**: The Instrument Summary (IS) shown in Appendix C itemizes the instrumentation devices, including control panels, to be furnished under this contract. Specific device requirements for the instrumentation referenced in Part 2 shall be included in the instrument summary such as meter size, ranges, scales, set points, NEMA ratings, flange sizes, pipe connection sizes, material types, probe types, etc.

B. Each column on the Instrument Summary is defined as follows:

1. Tag Number: The identifier assigned to a device which performs a function in the control system. The CONTRACTOR shall use this identifier in tagging devices in the field.

2. Loop Number: The number assigned to the control loop associated with the device.

3. Description: A process-oriented functional description which defines the measured/monitored/controlled parameter and the associated process/process equipment.

4. P&ID Drawing Number: The Process and Instrumentation drawing upon which the device appears.

5. Technical Specification Number: The number associated with the technical specification which describes the requirements associated with the device.

6. Specification Section Number: The specification section under which the device shall be provided.

7. Control Panel Number: The designation of the control panel where the device resides.

8. Control Panel Reference Number: The drawing or schedule number associated with the control panel's face-plate representation.

9. Mechanical Drawing Number: The mechanical drawing upon which the device appears.

10. Electrical Drawing Number: The electrical drawing upon which the device appears.

11. Installation Detail Number: The designation of the installation detail defining the installation requirements associated with the device.

3.7 DCS INPUT/OUTPUT (I/O) SUMMARY

A. **General:** The I/O list contained in Appendix B itemizes all inputs and outputs to and from the DCS, both hardwired and data linked, which are furnished by the Contractor.

B. Each column on the I/O List is defined as follows:

1. Tag Number: The ISA identifier assigned to a device which performs a function in the control system. The Contractor shall use this identifier in tagging devices in the DCS.

2. Loop Number: The number assigned to the control loop associated with the I/O.

3. Description: A 30-character process-oriented functional description which defines the measured/monitored/controlled parameter and the associated process/process equipment.

4. Alarm Priority: A 0-3 designation that determines the severity of the alarm triggered with 3 being the highest (most severe) and 0 the lowest.

5. Scale: The top value and bottom value of the analog process variable to be displayed or controlled by the DCS.

6. Set: The status to be displayed on the alarm summary when a digital point is activated.

7. Reset: The status to be displayed on the alarm summary when a digital point is not activated or returns to its normal state.

8. P&ID Drawing Number: The Process and Instrumentation drawing upon which the device appears.

9. I/O Type: The type of I/O required for current and future monitoring and control activities (spare I/O is not included).

a. Analog Input (AI): If the tag number generates an AI, the quantity of AIs are listed here.

b. Analog Output (AO): If the tag number generates an AO, the quantity of AOs are listed here.

c. Discrete Input (DI): If the tag number generates a DI, the quantity of DIs are listed here.

d. Discrete Output (DO): If the tag number generates a DO, the quantity of DOs are listed here.

10. Data link No.: The name of the data link the soft I/O point is associated with.

11. PCM /RIO/PLC Number: The designation of the PCM, RIO, or PLC where the I/O resides.

12. Fail-safe: (Yes or No) : For digital inputs, whether the field device is to be wired as “open contact on alarm”.

13. Remarks: Any clarifying remarks are made in this area such as pulse inputs, cross references to mechanical and electrical drawings on which the PCM appears.

14. Totals: A summary row shown at the bottom of the I/O list which indicates the total amount of each type of I/O associated with a PCM. I/O associated with future shall be separately tabulated.

** END OF SECTION **

APPENDIX A - CONTROL STRATEGIES

SECTION 13300 - INSTRUMENTATION AND CONTROL

LEGEND

PCM - Process Control Module (Transmits process data to and from the field and provides plant automation)

DCS – Distributed Control System (Plant Computer Control System)

UPS – Uninterruptable Power System (Provides battery back-up power to the PCM)

DH – Data Highway (Plant process network where PCM, workstation, and historian communications take place)

DIN – District Information Network (Fiber Optic Transmission to COMC)

LCP – Local Control Panels

PID – Proportional-Integral-Derivative

PLC – Programmable Logic Controller

PROJECT OVERALL CONTROL SYSTEM STRATEGY OVERVIEW

[Provide a brief overall project control strategy overview]

GENERAL CONTROL AND MONITORING

These control strategies are not intended to be all-inclusive operational procedures for the operation of the complete facility. In general, control and monitoring functionality is as follows:

1. Alarm monitoring and generation, process sequencing, automatic control of auxiliary systems and equipment interlocking control strategies are resident within the DCS.

2. Fault tolerant PCM(s) communicate with the DH and contain enhanced DCS automatic control algorithms for process sequencing control based on level, pressure, flow, or other conditions.

3. The DCS workstations shall serve as the operation staff's "window" into the process, enabling operations to locally monitor, interrogate, and manipulate plant processes.

4. The DCS shall provide reporting, historian, diagnostic, client access and other file server functions.

5. The DCS provides information to the District Information Network (DIN) via the communication link between DCS and DIN

6. All alarms shall be fail safe and activate upon loss of power.

COMMON DCS/PLC FUNCTIONS

Common functions and terms for basic monitoring and control operations are provided as a standard of implementation for the control system. These terms and functions address items that are typical for process control loops and most operator initiated actions. These functions are not necessarily repeated in each individual control strategy. Unless otherwise stated they are considered a part of each implemented control strategy.

Provision shall be made to include certain control functions that apply to all analog inputs, virtual variables, analog controllers and discrete control whether or not shown on the P&IDs, even though one or more of the functions may be disabled by the user for a given data base point:

1. **Verification of Digital Outputs**: In Semi-Auto and Auto mode each command will be monitored for the desired results before proceeding to the next step and if the sired results are not achieved in a certain predetermined time an alarm will be generated. The operator will have the ability to override and move to the next stage.

2. **Analog Data Scaling**: This control function shall scale all analog inputs to a common span and shall normalize the digital representation of each analog input to a percent of the operating span. The processed value shall be expressed as a binary number that specifies the analog input's position on a straight line lying between zero and full scale as defined for a given input by the zero span values in the data base.

3. **Amplitude Limit Check**: This control function shall perform dual level, high/low amplitude limit checking and shall identify a limit violation every time a measured or virtual variable goes out-of-limits and returns back into limits. The control unction shall determine the time at which each limit excursion occurred. A dead-band shall be provided on each limit and shall be expressed as a percentage of span or in engineering units.

4. **Engineering Unit Conversion**: This control function shall convert scaled analog data to engineering units by means of the following equation:

$$Y = (H - L)\,(D/DH) + L$$

where:

Y = value in engineering units

H = high value of span, expressed in engineering units

L = low value of span, expressed in engineering units

D = digitized scale input value in counts

DH = full scale digitized value in counts

5. **Discrete Event Monitor**: This control function shall monitor an alarm (where appropriate) all discrete status changes.

6. **Manual Control**: It shall be possible for the operator or plant engineer to interrupt any sequence, loop or automatic operation and operate the same manually from remote.

The following terms are used in the descriptions of DCS/PLC functions:

1. **Operator Settings (Set points)**: Operator set or entered values that are adjustable or set from operator displays. Examples of operator set or entered values are controller set points, batch set points, timers, counters, mode selection, etc. Specific values that are required to be operator settable are noted (bracketed [ ]) in the process control strategy descriptions. Unless otherwise stated to be tunable or fixed, a set point value is operator settable.

2. **Tunable Values**: Tunable values are set points that are adjustable at password protected engineer level displays without requiring any PLC or DCS software reconfiguration. Examples of tunable values are tunable time settings, tunable alarm set points, PID tuning constants, etc. These values are not adjustable from operator level displays. Tunable values are also identified and their preliminary values are shown in brackets [xxx].

3. **Fixed Values**: Fixed values are constants that are contained within the PLC or DCS control logic normally inaccessible by the DCS system. Modification of fixed values requires a modification to the control logic via the PLC programming, configuration and diagnostics software package.

4. **Displayed Values**: The term “displayed” means that the value, or information referred to, is displayed in an easily read and understood format on the DCS workstation. Values are identified by their device tag reference and associated equipment number. For analog variables the value is tagged and its associated engineering units are displayed.

5. **Hardware Interlocks**: Hardware interlocks refer to interlocks directly wired within the electrical control circuits of equipment that, when activated, shall cause the equipment to shutdown or otherwise prevent operation of the equipment. Hardware interlocks do not necessarily pass through or depend on the PLC or DCS to be operable.

   Hardware interlocks may also be derived by local control panels or switches wired directly to the PLC or DCS to provide direct hardwired alarm status to the PLC or DCS for processing.

6. **Software Interlocks**: Software interlocks refer to interlocks that are generated by the PLC or DCS logic or otherwise pass through the PLC or DCS. Software interlocks are not operable when the PLC is not operable or if for some reason equipment is operated while by-passing the PLC logic.

7. **Hardware Generated Alarms**: Hardware generated alarms are alarms that are generated external to the PLC by equipment such as local control panels, analytical devices and process switches.

    a. Direct wired alarms that do not depend on the PLC or DCS to be operable. An example would be a High H2S level signal from the H2S monitor and wired directly to an alarm light or horn.

    b. Direct PLC wired alarms such as a High-High pressure switch that interfaces directly with the PLC.

8. **Software Generated Alarms**: Alarms that are processed or generated by PLC or DCS logic are referred as software generated. Software generated alarms are displayed on the DCS workstation alarm screens and are available for archiving.

9. **Local Automatic Control Mode**: Local automatic control refers to control logic performed in a local control panel independent of the PLC or DCS. An example is a standalone blower package that, when in the local automatic control mode, automatically controls the blower to maintained air pressure within a fixed dead band.

10. **Local Manual Control Mode**: Local manual control refers to the mode where operators control equipment from the equipment location. Examples are hoist and trolley that may be stopped or started from the compressor's local control panel (LCP), or a gate that may be opened or closed from the gate operator.

11. **DCS Automatic Control Mode**: In DCS automatic mode equipment is controlled automatically per predetermined control schemes residing in the DCS usually without operator intervention. However, in some cases the operators may be required to initiate certain automatic functions, or enter set points.

12. **DCS Manual Control Mode**: DCS manual control refers to the remote manual control of equipment from the DCS workstation. In this mode, the operators override the DCS automatic control logic but, usually, DCS safety interlock logic remains in effect.

13. **DCS Override Control**: DCS override control refers to the ability to override specific software interlocks and initiate control actions. Software interlocks or permissives that can be overridden are identified within the individual control strategies. Override control is an abnormal control operation and a "SAFETY INTERLOCK OVERRIDE ALARM" shall be initiated for the specific override condition whenever an override command is in effect.

COMMON DCS/PLC SOFTWARE FUNCTIONS

To provide for a standard of implementation, various software control and monitoring functions are defined. The standard functions may not be fully delineated within each control strategy, however, unless otherwise stated the standard function shall be utilized to provide the defined alarm, action, display or control action.

DCS is configured as the primary control system for all alarm monitoring, start/stop sequencing, shutdown and interlock and basic process control functions.

When delineated within individual control strategies as DCS controlled or DCS logic, the control program is resident within the DCS system. Complex control algorithms and historical data calculations are normally performed by the DCS system.

The following provides for common PLC and DCS software functions:

1. All equipment status items monitored by the DCS/PLC and generated within the DCS/PLC control strategies are displayed at the DCS. Unless otherwise specified the following is displayed for each equipment item:

    a. Equipment READY status

    b. Equipment RUNNING or ON status

    c. Equipment OFF status

    d. Equipment FAILURE alarm

    e. Equipment FAIL-TO-OPERATE alarm

    f. Equipment OUT-OF-SERVICE

2. All analog inputs transmitted to the DCS shall have instrument bad/failure indications or alarms when the input is below 0 percent or above 100 percent.

3. All discrete alarm and failure inputs are alarmed by the DCS application software and displayed at the DCS. Each discrete alarm input shall have an associated alarm delay that prevents nuisance tripping. A discrete alarm shall be generated based on a tunable set point of 10 seconds after the discrete event is initiated.

4. Where alarms are specified in the control strategy descriptions, those alarms are initiated by the DCS control logic based on the applicable analog input signals. User tunable trip points shall be provided for each analog input to establish High- High, High, Low, Low-Low, and Rate-Of-Change events. Each trip point shall be provided with a user tunable dead band for set and reset operations. Individual signal trip points shall be provided with a tunable delay to alarm activation.

5. DCS alarm activation and annunciation shall adhere to a priority hierarchy that is established and maintained at the DCS system. Each alarm shall have an associated priority level defined as:

    Level 1 - Life Threatening or Danger Conditions

    Level 2 - Critical process alarms that shall create a plant shutdown condition, cause a critical process failure or severely hinder plant operation.

    Level 3 - Minor process alarms associated with warning conditions and minor equipment failures.

Level 4 - Informational alarms shall not hinder operation or cause equipment failure.

6. All process related analog inputs are trended at the discretion of the operator.

7. All flow inputs and equipment run times are totalized, recorded and displayed at the DCS. Totalizers are resettable at the engineer level only.

8. **Displays**: DCS system shall have adequate number of displays for each system to enable the operator to effectively monitor and control the system. Displays are grouped functionally for ease of operation. Both analog and discrete functions associated with an item of equipment or a group of equipment shall be provided on the same display. Displays shall show process graphics, alarms, equipment status, system mode of operation, control strategy implementation, etc.

9. Most interlocks, permissives and start sequences are provided at the DCS level. Unless otherwise stated or shown, all discrete outputs shall be provided as follows:

    a. For equipment START functions, the PLC or DCS shall issue a maintained START command until a RUNNING state is detected or the START command is removed.

    b. When a momentary command is required, the PLC or DCS shall issue the command for a minimum 2 seconds, then remove the signal.

10. For equipment that the DCS/PLC is allowed to control, the DCS/PLC shall provide a FAIL-TO-OPERATE alarm if the equipment fails to comply with a DCS/PLC command signal. The (START, STOP, OPEN, CLOSE) shall has been present for more than a tunable time period. In this event, the command shall be removed subsequent to the expiration of the tunable time period.

11. In the event of a DCS system failure the system shall retain the last command from the DCS system for all equipment that is in service. All interlocks are enabled during a DCS communications or systems failure.

12. All PID control functions (P, PI, and PID) are provided with standard analog controller functions and operator interfaces including, but not limited to, the following:

    a. AUTO/MANUAL mode selection: In AUTO, the output of controller shall be based on the PID control calculation. In MANUAL, the output of the controller shall be operator adjustable. Transfer between operational modes shall be bumpless.

    b. LOCAL/REMOTE set point selection: In LOCAL, the set point shall be operator adjustable from the equipment. In REMOTE, the set point shall be adjustable from a REMOTE set point input.

    c. Set point, process variable, and controller output shall be displayed. Provisions shall be included to prevent reset windup.

d. Dead band limits shall be placed on PID control algorithms to avoid hunting and continuous change actions. Dead band limits shall maintain a constant control until the process variable exceeds the dead band boundaries. A dead band value of zero shall disable the dead band.

e. Bumpless transition shall be provided when PID is invoked after a transition from manual to PID control or when pump start logic utilizes minimum speed controls for starting applications. The transition from current speed to calculated speed shall be provided as a user tunable set point percentage per second value.

13. When main equipment is tagged OUT-OF-SERVICE, a DCS function, all associated equipment and devices are automatically placed in OUT-OF-SERVICE status and their alarms inhibited until the tagged equipment is tagged IN SERVICE. Associated equipment for each piece of main equipment shall be determined on a case by case basis.

14. **Verification of Result**: Whenever a command is issued, DCS/PLC shall verify that its command is implemented before proceeding to the next step, e.g., a valve open command is issued, the DCS/PLC software shall verify that the valve open limit switch is activated after a preset time, before proceeding to the next step in the program. If no verification is received an alarm will be generated and operator intervention will be necessary to resume the automatic operation.

NTS: Detailed Control Strategies to be inserted here. For large projects, the Design Engineer may include an index for all of the Control Strategies.

APPENDIX B – DCS I/O List

NTS: Begin Appendix B on another page and include the project database.

APPENDIX C – Instrument List

NTS: Begin Appendix C on another page and include the project database. Other appendices (D, E, F, etc,) can follow in sequence.