SECTION 230923.14 - FLOW INSTRUMENTS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section Includes:

1. Airflow sensors.
2. Airflow switches.
3. Airflow transmitters.
4. Liquid flow meters.
5. Liquid flow sensors.
6. Liquid flow switches.
7. Liquid flow transmitters.

B. Related Requirements:

1. Section 230923 "Direct-Digital Control System for HVAC" for control equipment and software, relays, electrical power devices, uninterruptible power supply units, wire, and cable.
2. Section 230993 "Sequence of Operations for HVAC Controls" for requirements that relate to Section 230923.14.

1.3 DEFINITIONS

A. Ethernet: Local area network based on IEEE 802.3 standards.

B. HART: Highway addressable remote transducer protocol is the global standard for sending and receiving digital information across analog wires between smart devices and control or monitoring systems through bi-directional communication that provides data access between intelligent field instruments and host systems. A host can be any software application from technician's hand-held device or laptop to a plant's process control, asset management, safety, or other system using any control platform.

C. PEEK: polyetheretherketone.

D. PTFE: Polytetrafluoroethylene.

E. PPS: Polyphenylene sulfide.

F. RS-485: A TIA standard for multipoint communications using two twisted pairs.

G. RTD: Resistance temperature detector.

H. TCP/IP: Transport control protocol/Internet protocol incorporated into Microsoft Windows.

1.4 ACTION SUBMITTALS

A. Product Data: For each type of product, including the following:

1. Construction details, material descriptions, dimensions of individual components and profiles, and finishes.
2. Operating characteristics; electrical characteristics; and furnished accessories indicating process operating range, accuracy over range, control signal over range, default control signal with loss of power, calibration data specific to each unique application, electrical power requirements, and limitations of ambient operating environment, including temperature and humidity.
3. Product description with complete technical data, performance curves, and product specification sheets.
4. Installation instructions, including factors affecting performance.

B. LEED Submittals: Product data for flow instruments for use in showing compliance with requirements in ASHRAE 62.1.

C. Shop Drawings:

1. Include plans, elevations, sections, and[**mounting**] details.
2. Include details of product assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
3. Include diagrams for power, signal, and control wiring.
4. Include diagrams for air and process signal tubing.

5. Number-coded identification system for unique identification of wiring, cable, and tubing ends.

D. Delegated-Design Submittal:

1. Schedule and design calculations for flow instruments, including the following.

a. Flow at Project design and minimum flow conditions.
b. Pressure drop at Project design and minimum flow conditions.

1.5 INFORMATIONAL SUBMITTALS

A. Product Certificates: For each product requiring a certificate.

B. Product Test Reports: For each product, for tests performed by [**manufacturer and witnessed by a qualified testing agency**] [**a qualified testing agency**].

1.6 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For instruments to include in operation and maintenance manuals.

1.7 MAINTENANCE MATERIAL SUBMITTALS

A. Furnish extra materials and parts that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

B. Provide parts, as indicated by manufacturer's recommended parts list, for product operation during [**one**] [**two**] **<Insert number>**-year period following warranty period.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

A. Delegated Design: Select and size products to achieve specified performance requirements.

B. Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

2.2 GENERAL REQUIREMENTS FOR FLOW INSTRUMENTS

A. Air sensors and transmitters shall have an extended range of [**10**] [**20**] **<Insert number>** percent above Project design flow and [**10**] [**20**] **<Insert number>** percent below minimum Project flow to signal abnormal flow conditions and to provide flexibility for changes in operation.

B. Liquid and steam sensors, meters, and transmitters shall have an extended range of [**10**] [**20**] **<Insert number>** percent above Project design flow and [**10**] [**20**] **<Insert number>** percent below Project minimum flow to signal abnormal flow conditions and to provide flexibility for changes in operation.

2.3 AIRFLOW SENSORS:

A. Performance Requirements:

1. Adjustable for changes in system operational parameters.
2. Airflow Sensor and Transmitter Range: Extended range of [**10**] [**20**] **<Insert number>** percent above Project design flow and [**10**] [**20**] **<Insert number>** percent below minimum Project flow to signal abnormal flow conditions.
3. Manufacturer shall certify that each flow instrument indicated complies with specified performance requirements and characteristics.

    a. Product certificates are required.

B. Pitot-Tube Airflow Sensor Station:

1. Products: Subject to compliance with requirements, [**provide the following**] [**provide one of the following**] [**available products that may be incorporated into the Work include, but are not limited to, the following**]:

    a. Air Monitor Corporation; Fan Evaluator.
    b. **<Insert manufacturer's name; product name or designation>**.

2. Description: Multiple total- and static-pressure sensors positioned at the center of equal area of the station cross section and interconnected by respective averaging manifolds.

    a. Stations 4 sq. ft. (0.4 sq. m) and Smaller: One total-pressure sensor and one static-pressure sensor for every 16 sq. in. (103 sq. cm) of station area.
    b. Stations Larger than 4 sq. ft. (0.4 sq. m): One total-pressure sensor and one static-pressure sensor for every 36 sq. in. (232 sq. cm) of station area.

3. Casing: Galvanized sheet steel at least 0.079 inch (2.0 mm) thick with coating complying with ASTM A 653/A 653M, G90 (Z275). Casings shall be stainless steel, 0.0781 inch (2.0 mm) thick, when connected to stainless duct and aluminum, 0.063 inch (1.6 mm) thick, when connected to aluminum duct.

    a. Joints and Seams: Continuously weld. Clean galvanized areas damaged by welding and coat with aluminum paint.
    b. Casing Depth: At least 8 inches (200 mm).
    c. Casing Flanges: Outward flange, minimum flange face 1.5 inches (38 mm).
    d. Casing Configuration and Size: Match shape (rectangular, round, flat oval) and same size as adjacent duct unless otherwise indicated.

4. Include an open parallel cell air straightener or air equalizer honeycomb mechanically fastened to casing.

a. Construct straightener or equalizer from Type 3003 aluminum or Type 316 stainless steel, depending on casing material. Use stainless steel for units with stainless-steel casings.

5. Construct pressure sensor array from drawn copper or stainless-steel tubing. Use stainless steel for units with stainless-steel casings. Copper tubing shall comply with ASTM B 75 and ASTM B 280. Minimum tube wall thickness shall be 0.030 inch (0.8 mm). Include internal piping and external pressure transmitter ports.
6. Station Labeling: Identification label on each station casing indicating model number, size, area, and application-specific airflow range.
7. Performance:

a. Pressure Loss: 0.015-inch wg (3.8 Pa) at 1000 fpm (5 m/s), or 0.085-inch wg (22.5 Pa) at 2000 fpm (10 m/s).
b. Accuracy: Within 2 percent of actual airflow.
c. Self-Generated Sound: NC 40 and sound level within the duct shall not be amplified.
d. Performance rated and tested according to AMCA 610. Each station shall bear the AMCA seal.

C. Pitot-Tube Fan Inlet Airflow Traverse Sensor:

1. Products: Subject to compliance with requirements, [**provide the following**] [**provide one of the following**] [**available products that may be incorporated into the Work include, but are not limited to, the following**]:

a. Air Monitor Corporation; Volu-probe/ [**FI**] [**or**] [**FI/SS**].
b. **<Insert manufacturer's name; product name or designation>**.

2. Traverse manifold designed for mounting in fan inlets.
3. Contain multiple total- and static-pressure sensors placed at concentric area centers along the exterior surface of cylindrical manifold and internally connected to their respective averaging manifolds. Sensors shall not protrude beyond the surface of the manifold nor be adversely affected by particle contamination present in airstream.
4. Manifold (two per inlet) shall have dual end support swivel brackets suitable for mounting in the fan inlet bell and symmetrical averaging signal takeoffs and fittings.
5. Sensors shall be capable of producing steady, non-pulsating signals of standard total- and static-pressure without need for flow corrections or factors, with an accuracy of 3 percent of actual flow over a turndown range of 6 to 1.
6. Manifold Materials: [**Copper or anodized aluminum**] [**or**] [**Type 316 stainless steel**].
7. Unless otherwise required by application and without affecting the fan and sensor performance, nominal diameter copper and aluminum manifolds shall be the following:

a. For Fan Inlets Smaller than 20 Inches (500 mm): 0.375 inch (9 mm).
b. For Fan Inlets 20 Inches (500 mm) and Larger: 0.75 inch (19 mm).

8. Unless otherwise required by application and without affecting the fan and sensor performance, nominal diameter stainless-steel manifolds shall be the following:

a. For Fan Inlets Smaller than 20 Inches (500 mm): 0.375 inch (9 mm).
b. For Fan Inlets 20 through 48 Inches (500 through 1200 mm): 0.75 inch (19 mm).

c. For Fan Inlets Larger than 48 Inches (1200 mm): 1.0 inch (25 mm).

D. Piezometer Ring Fan Inlet Airflow Sensor:

1. Products: Subject to compliance with requirements, [**provide the following**] [**provide one of the following**] [**available products that may be incorporated into the Work include, but are not limited to, the following**]:

   a. Twin City Fan & Blower; Piezometer Ring.
   b. **<Insert manufacturer's name; product name or designation>**.

2. In lieu of externally mounted fan inlet airflow sensors, option to provide fans with airflow measurement integral to fan inlet cones for continuous measurement of air volume flow rate.
3. Multiple pressure sensor points strategically placed along the circumference of the inlet cone and internally connected to an averaging ring manifold located behind the inlet cone.
4. Sensor points shall not protrude beyond the surface of the inlet cone nor be adversely affected by particle contamination present in the airstream.
5. Sensor shall produce steady, non-pulsating signals to achieve accuracy within 5 percent of actual airflow.
6. Sensor shall be non-intrusive and not impact fan performance.
7. Product shall be a standard offering of the fan manufacturer and include published literature with supporting test data to validate sensor performance.

E. Thermal Airflow Station:

1. Products: Subject to compliance with requirements, [**provide the following**] [**provide one of the following**] [**available products that may be incorporated into the Work include, but are not limited to, the following**]:

   a. Ebtron, Inc.; Gold Series.
   b. **<Insert manufacturer's name; product name or designation>**.

2. Source Limitations: Obtain airflow and temperature measuring sensors and transmitters from single manufacturer.
3. Description: Airflow station shall consist of one or more sensor probes [**mounted in a casing,**]and a remotely mounted microprocessor-based transmitter.
4. Performance:

   a. Capable of independently processing up to [**16**] **<Insert number>** independently wired sensor assemblies.
   b. Airflow rate of each sensor assembly shall be equally weighted and averaged by transmitter prior to output.
   c. Temperature of each sensor assembly shall be velocity weighted and averaged by transmitter prior to output.
   d. Listed and labeled by an NRTL as successfully tested as an assembly according to UL 873, "Temperature-Indicating and Regulating Equipment."
   e. Components shall be interconnected by exposed NRTL-listed plenum-rated cable or non-listed cable placed in conduit.

f. Each flow station shall be factory calibrated at a minimum of [**16**] <**Insert number**> airflow rates and [**three**] <**Insert number**> temperatures to standards that are traceable to NIST.
g. Airflow Accuracy: Within [**2**] [**3**] [**5**] <**Insert number**> percent of reading over the entire operating airflow range.

1) Devices whose accuracy is combined accuracy of transmitter and sensor probes must demonstrate that total accuracy meets the performance requirements throughout the measurement range.

h. Temperature Accuracy: Within 0.2 deg F (0.11 deg C) over entire operating range of minus 20 to plus 140 deg F (minus 29 to plus 60 deg C).
i. Sensor Ambient Operating Temperature Range: Minus 20 to plus 160 deg F (Minus 29 to plus 71 deg C).
j. Transmitter Ambient Operating Temperature Range: Minus 20 to plus 120 deg F (Minus 29 to plus 49 deg C).
k. Sensor and Transmitter Ambient Operating Humidity Range: Zero to 99 percent, non-condensing.
l. Instrument shall compensate for changes in air temperature and density throughout calibrated velocity range for seasonal extremes at Project location.
m. Pressure Drop: 0.05-inch wg (12.5 Pa) at 2000 fpm (10.2 m/s) across a 24-by-24-inch (600-by-600-mm) area.
n. Instruments mounted in throat or face of fan inlet cone shall not negatively influence fan performance by reducing flow more than [**1**] [**2**] <**Insert number**> percent of Project design flow or negatively impact fan-generated sound. Losses in performance shall be documented with submittal data, and adjustments to compensate for performance impact shall be made to fan in order to deliver Project design airflow indicated.

5. Sensor Assemblies:

a. Each sensor probe shall contain two individually wired, hermetically sealed bead-in-glass thermistors.
b. Mount thermistors in sensor using a marine-grade, waterproof epoxy.
c. Thermistor leads shall be protected and not exposed to the environment.
d. Each sensor assembly shall independently determine airflow rate and temperature at each measurement point.
e. Each sensor probe shall have an integral cable for connection to remotely mounted transmitter.
f. Sensor Probe Material: Gold anodized, extruded 6063 aluminum tube or Type 304 stainless steel.
g. Probe Assembly Mounting Brackets Material: Type 304 stainless steel.

6. Casing:

a. Factory mount sensor probes in an airflow station casing to create a single assembly for field mounting.
b. Material: Galvanized sheet steel at least 0.079 inch (2.0 mm) thick with coating complying with ASTM A 653/A 653M, G90 (Z275). Casings shall be stainless steel, 0.0781 inch (2.0 mm) thick, when connected to stainless duct and aluminum, 0.063 inch (1.6 mm) thick, when connected to aluminum duct.

c. Joints and Seams: Continuously weld. Clean galvanized areas damaged by welding and coat with zinc-rich paint.
d. Casing Depth: At least 8 inches (200 mm).
e. Include casing inlet and discharge connections with a minimum[**1.5-inch (40-mm)**] [**2-inch (50-mm)**] <**Insert dimension**> face flange.

7. Transmitter:

a. Integral digital display capable of simultaneously displaying total airflow and average temperature, individual airflow, and temperature readings of each independent sensor assembly.
b. Capable of field configuration and diagnostics using an onboard push-button interface and digital display.

1) Include an integral power switch to operate on 24-V ac (isolation not required) and include the following:

a) Integral protection from transients and power surges.
b) Circuitry to ensure reset after power disruption, transients, and brownouts.
c) Integral transformer to convert field power source to operating voltage required by instrument.

c. Remote Signal Interface:

1) Linear Analog Signals for Airflow[**and Temperature**]: Fuse protected and isolated, [**field selectable,**] [**zero- to 10-V dc**] [**or**] [**4 to 20 mA**].
2) RS-485: BACnet-ARCNET, BACnet-MS/TP, and Modbus-RTU.
3) 10 Base-T Ethernet: BACnet Ethernet, BACnet-IP, Modbus-TCP, and TCP/IP.
4) LonWorks free topology.

2.4 AIRFLOW SWITCHES

A. Polymer Film Sail Switch:

1. Products: Subject to compliance with requirements, [**provide the following**] [**provide one of the following**] [**available products that may be incorporated into the Work include, but are not limited to, the following**]:

a. Honeywell International Inc., Building Solutions; Model S688A.
b. <**Insert manufacturer's name; product name or designation**>.

2. Performance:

a. Suitable for applications operating at velocities up to 400 fpm (2.0 m/s).
b. Suitable for mounting with air direction in horizontal, vertical up or down.
c. Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
d. Voltage: 24-, 120-, 240-V ac.

e. Normally Open Full Load Current: 2 A at 120-V ac.
f. Normally Closed Full Load Current: 1 A at 120-V ac.
g. Normally open switch actuates at 250 fpm (1.3 m/s) and opens at 75 fpm (0.4 m/s).
h. Normally closed switch actuates at 75 fpm (0.4 m/s) and closes at 250 fpm (1.3 m/s).
i. Maximum Process Temperature: 170 deg F (77 deg C).
j. Maximum Ambient Temperature: 125 deg F (52 deg C).

3. Construction:

a. Polyester film sail encasing a wire frame.
b. Sail actuates a SPDT snap switch.
c. Enclosure Material: Zinc-plated steel.
d. Enclosure with removable cover.
e. NEMA 250, Type 1 enclosure.
f. Removable spring counterbalances sail to allow mounting in either vertical (up or down) or horizontal airflow.
g. Electrical Connections: Screw terminals.
h. Conduit Connections: 1/2-inch (16-mm) trade size conduit knock outs on top and bottom.

B. Stainless-Steel Single Vane Switch:

1. Products: Subject to compliance with requirements, [**provide the following**] [**provide one of the following**] [**available products that may be incorporated into the Work include, but are not limited to, the following**]:

a. Dwyer Instruments, Inc.; Model 530.
b. <**Insert manufacturer's name; product name or designation**>.

2. Description:

a. Velocities up to 2000 fpm (10.2 m/s).
b. Suitable for mounting with air direction in horizontal.

3. Performance:

a. Voltage: 125-, 240-, and 480-V ac.
b. Full Load Current: 9.8 A at 125-V ac.
c. Field-Adjustable Velocity Set Point: 400 to 1600 fpm (2.0 to 8.2 m/s).
d. Maximum Process Temperature: 180 deg F (82 deg C).
e. Maximum Ambient Temperature: 125 deg F (52 deg C).

4. Construction:

a. Stainless-steel vane.
b. Vane actuates a SPDT snap switch.
c. Enclosure Material: Die-cast metal.
d. Enclosure with removable cover.
e. NEMA 250, Type 1 enclosure.
f. Screw set-point adjustment.

g. Electrical Connections: Screw terminals.
h. Conduit Connections: 1-inch (27-mm) trade size conduit knock outs on top and bottom.

2.5 AIRFLOW TRANSMITTERS

A. Airflow Transmitter with 0.10 Percent Accuracy and Auto-Zero Feature:

1. Products: Subject to compliance with requirements, [**provide the following**] [**provide one of the following**] [**available products that may be incorporated into the Work include, but are not limited to, the following**]:

   a. Air Monitor Corporation; Veltron II.
   b. **<Insert manufacturer's name; product name or designation>**.

2. Transmitter shall receive total- and static-pressure signals from a primary element, amplify signals, extract the square root, and scale the signals to produce 4- to 20-mA dc output signals linear to airflow.
3. NEMA 250, Type 1 enclosure.
4. Construct assembly so that shock, vibration, and pressures surges of up to 1 psig (6.9 kPa) will neither harm transmitter, nor affect its accuracy.
5. Transmitter with automatic zeroing circuit capable of automatically readjusting transmitter zero at predetermined time intervals. The automatic zeroing circuit shall re-zero transmitter to within 0.1 percent of true zero.
6. Performance:

   a. Range: As required by application and at least 10 percent below minimum airflow and 10 percent greater than design airflow.
   b. Calibrated Span: Field adjustable, minus 40 percent of the range.
   c. Accuracy: Within 0.10 percent of natural span.
   d. Repeatability: Within 0.15 percent of calibrated span.
   e. Linearity: Within 0.2 percent of calibrated span.
   f. Hysteresis and Deadband (Combined): Less than 0.2 percent of calibrated span.

7. Integral digital LED or digital display for continuous indication of airflow.

B. Airflow Transmitters with 0.25 Percent Accuracy and Auto-Zero Feature:

1. Products: Subject to compliance with requirements, [**provide the following**] [**provide one of the following**] [**available products that may be incorporated into the Work include, but are not limited to, the following**]:

   a. Air Monitor Corporation; DPT 2500 Plus.
   b. **<Insert manufacturer's name; product name or designation>**.

2. Transmitter shall receive total- and static-pressure signals from a flow element, amplify signals, extract the square foot, and scale the signals to produce 4- to 20-mA dc output signals linear to airflow.
3. NEMA 250, Type 1 enclosure.

4. Construct assembly so shock, vibration, and pressures surges of up to 1 psig (6.9 kPa) will neither harm transmitter, nor affect its accuracy.
5. Transmitter with automatic zeroing circuit capable of automatically readjusting transmitter zero at predetermined time intervals. The automatic zeroing circuit shall re-zero the transmitter to within 0.1 percent of true zero.
6. Performance:

    a. Range: As required by application and at least 10 percent below minimum airflow and 10 percent greater than design airflow.
    b. Calibrated Span: Field adjustable, minus 40 percent of the range.
    c. Accuracy: Within 0.25 percent of natural span.
    d. Repeatability: Within 0.15 percent of calibrated span.
    e. Linearity: Within 0.2 percent of calibrated span.
    f. Hysteresis and Deadband (Combined): Less than 0.2 percent of calibrated span.

7. Integral digital display for continuous indication of airflow.

C. Pressure Differential Transmitters for Airflow Measurement:

1. Products: Subject to compliance with requirements, [**provide the following**] [**provide one of the following**] [**available products that may be incorporated into the Work include, but are not limited to, the following**]:

    a. Setra Systems, Inc.; Model 267.
    b. **<Insert manufacturer's name; product name or designation>**.

2. Performance:

    a. Range: As required by application and at least 10 percent below minimum airflow and 10 percent greater than design airflow.
    b. Accuracy: Within [**1**] [**0.5**] [**0.4**] [**0.25**] percent of the full-scale range.
    c. Hysteresis: Within 0.10 percent of full scale.
    d. Repeatability: Within 0.05 percent of full scale.
    e. Stability: Within one percent of span per year.
    f. Overpressure: 10 psig (69 kPa).
    g. Temperature Limits: Zero to 150 deg F (Minus 18 to plus 66 deg C).
    h. Compensate Temperature Limits: 40 to 150 deg F (4 to 66 deg C).
    i. Thermal Effects: 0.033 percent of full scale per degree F.
    j. Shock and vibration shall not harm the transmitter.

3. Output Signals:

    a. Analog Current Signal:

        1) Two-wire, 4- to 20-mA dc current source.
        2) Signal capable of operating into 800-ohm load.

    b. Analog Voltage Signal:

        1) Three wire, zero to [**5**] [**10**] V.
        2) Minimum Load Resistance: 1000 ohms.

4. Display: Four-digit digital with minimum 0.4-inch- (10-mm-) high numeric characters.
5. Operator Interface:

    a. Zero and span adjustments located behind cover.

6. Construction:

    a. Plastic casing with removable plastic cover.
    b. Fittings: Swivel fittings for connection to copper tubing or barbed fittings for connection to polyethylene tubing. Fittings on bottom of instrument case.
    c. Screw terminal block for wire connections.
    d. Vertical plane mounting.
    e. NEMA 250, Type 4.
    f. Mounting Bracket: Appropriate for installation.

D. Pressure Differential Indicating Transmitter, Switch, and Controller for Airflow Measurement:

1. Products: Subject to compliance with requirements, [**provide the following**] [**provide one of the following**] [**available products that may be incorporated into the Work include, but are not limited to, the following**]:

    a. Dwyer Instruments, Inc.; Series DH3 Digihelic.
    b. **<Insert manufacturer's name; product name or designation>**.

2. Description:

    a. Three-in-one instrument, including digital display, control relay switches, and a transmitter with a current output.
    b. Field configurable for pressure, velocity, and volumetric flow applications through user interface.
    c. Select instrument range based on application.

3. Performance:

    a. Accuracy including hysteresis and repeatability:

        1) Ranges Less than 5-Inch wg (1250 Pa): Within 1 percent.
        2) Other Ranges: Within 0.5 percent at 77 deg F (25 deg C).

    b. Stability: Within 1 percent per year.
    c. Response Time: 250 ms.
    d. Overpressure:

        1) Ranges Less than 50-Inch wg (12.5 kPa): 5 psi (34.5 kPa).
        2) Range of 100-Inch wg (25 kPa): 9 psi (62 kPa).

    e. Temperature Limits: 32 to 140 deg F (Zero to 60 deg C).
    f. Thermal Effects: 0.020 percent per deg F (deg C).
    g. Warm-up Period: One hour.

4. Controller: Programming through menu keys to access five menus.

a. Security level.
b. Pressure, velocity, or flow application.
c. Engineering units.
d. K-factor for use with flow application.
e. Set-point control only; set-point and alarm operation; alarm operation as high, low, or high/low with manual; or automatic reset and delay.
f. View high and low readings.
g. Digital dampening for smoothing erratic applications.
h. Scaling of analog output to fit range and field calibration.

5. Display:

a. Four-digit digital, with minimum 0.4-inch- (10-mm-) high alphanumeric characters.
b. Four LED indicators; two LEDs for set point and two LEDs for alarm status.

6. Operator Interface:

a. Set-point adjustment through keypad on face of instrument.
b. Zero and span adjustments accessible through menu.
c. Programming through keypad.

7. Output Analog Signal: Two-wire, 4- to 20-mA dc current source; capable of operating into a 900-ohm load.
8. Output Digital Signal: Two, SPDT relays; each rated for 1 A at 30-V ac or 30-V dc.
9. Construction:

a. Die-cast aluminum casing and bezel.
b. Connections on side and back.
c. Vertical plane mounting.
d. NEMA 250, Type 1 rating.
e. Nominal 4-inch- (100-mm-) diameter face.
f. Mounting Bracket: Appropriate for installation.

2.6 LIQUID FLOW METERS

A. General Requirements for Liquid Flow Meters:

1. Adjustable for changes in system operational parameters.
2. Liquid and Steam Sensors, Meters, and Transmitters: Extended range of [**10**] [**20**] <**Insert number**> percent above Project design flow and [**10**] [**20**] <**Insert number**> percent below Project minimum flow to signal abnormal flow conditions.
3. Manufacturer shall certify that each flow instrument indicated complies with specified performance requirements and characteristics.
4. Product certificates are required.

B. Insertion Paddle Wheel Flow Meter, NPS 2 (DN 50):

1. Products: Subject to compliance with requirements, [**provide the following**] [**provide one of the following**] [**available products that may be incorporated into the Work include, but are not limited to, the following**]:

    a. Data Industrial, Badger Meter, Inc.; Series 200 Sensor with Series 500 Transmitter.
    b. <**Insert manufacturer's name; product name or designation**>.

2. Description: Insertion-type meter with a non-magnetic spinning paddle wheel.
3. Performance:

    a. Range: 0.5 to 30 fps (0.15 to 9.1 mps).
    b. Accuracy: Within 1 percent of full scale over flow range.
    c. Linearity: Within 0.2 percent of full scale over flow range.
    d. Repeatability: Within 0.3 percent of full scale over flow range.
    e. Ambient Temperature: 14 to 150 deg F (Minus 10 to plus 66 deg C).
    f. Maximum Process Temperature: [**221 deg F (105 deg C)**] [**285 deg F (141 deg C)**].
    g. Maximum Pressure: 400 psig at 100 deg F (2758 kPa at 38 deg C).

4. Output Signal: Frequency pulse.
5. Construction:

    a. Wetted Metal Parts, Including Sensor Sleeve, Mounting Adapter, and Isolation Valve: [**Brass**] [**Type 316 stainless steel**].
    b. Shaft: [**Tungsten carbide**] [**Titanium**] [**Hastalloy C**] [**Monel**] [**Type 316 stainless steel**].
    c. Impeller: [**Nylon**] [**Tefzel**].
    d. Process Connection: NPS 2 (DN 50).
    e. Instrument Isolation Valve: [**Gate**] [**Full port ball**] valve for system isolation.
    f. Insertion Depth: Threaded positioning nut for accurate sensor depth in the pipe.
    g. Electronics Enclosure:

        1) Polyphenylene sulfide (PPS) with Viton seal.
        2) Electrical Connection: Cable furnished with sensor.

6. Transmitter:

    a. User-adjustable scale to refine resolution of flow range over 4- to 20-mA signal.
    b. Enclosure Material: Polycarbonate with tongue and groove, with neoprene sealed cover.
    c. NEMA 250, Type 4X enclosure.
    d. Electrical Connection: Screw terminals.
    e. Linearity less than one percent.
    f. Output Response Time: 6 seconds for 10 to 90 percent step.
    g. Load resistance of 650 ohms at 24-V dc.
    h. Operating Temperature: Minus 32 to plus 122 deg F (Minus 36 to plus 50 deg C).
    i. Digital display of flow rate.

C. Insertion Paddle Wheel Flow Meter, NPS 1 (DN 25):

1. Products: Subject to compliance with requirements, [**provide the following**] [**provide one of the following**] [**available products that may be incorporated into the Work include, but are not limited to, the following**]:

    a. Data Industrial, Badger Meter, Inc.; SDI Series.
    b. <**Insert manufacturer's name; product name or designation**>.

2. Description:

    a. Insertion-type meter with a non-magnetic spinning paddle wheel.
    b. Each meter shall be wet calibrated at factory to standards traceable to NIST and provided with a certificate of calibration.
    c. Programming kit including cable connector and Microsoft-Windows-compatible software.
    d. Where indicated, provide meter with bi-directional flow measurement.

3. Performance:

    a. Range: 0.33 to 20 fps (0.1 to 6.1 m/s).
    b. Accuracy: Within [**0.5**] [**1**] percent of flow rate.
    c. Repeatability: Within 0.5 percent.
    d. Ambient Temperature: 14 to 150 deg F (Minus 10 to plus 66 deg C).
    e. Maximum Process Temperature: 300 deg F (149 deg C) with PEEK sensor tip.
    f. Maximum Pressure: 350 psig at 300 deg F (2413 kPa at 149 deg C) with PEEK sensor tip.
    g. Pressure Drop: Up to 0.5 psig at 10 fps (3.5 kPa at 3 m/s) for pipe sizes NPS 1-1/2 (DN 20) and larger.

4. Output Signal:

    a. Unidirectional Flow Meter: Frequency pulse.
    b. Unidirectional Flow Meter: Analog, two wire, loop-powered, 4- to 20-mA signal.
    c. Unidirectional Flow Meter: Scaled pulse.
    d. Bi-directional Flow Meter: Analog 4- to 20-mA signal plus direction.
    e. Bi-directional Flow Meter: Scaled pulse.

5. Operator Interface:

    a. Programming: Instrument programming through computer and programming kit.
    b. Digital Display: Eight-character digital display of flow rate, flow totalization, input, output, and flow direction for bi-directional meters.

6. Construction:

    a. Wetted Metal Parts (Including Sensor Stem, Mounting Adapter, and Isolation Valve): Type 316 stainless steel.
    b. Sensor Tip: PPS or PEEK.
    c. Shaft: Tungsten carbide.
    d. Impeller: Stainless steel.
    e. Process Connection: NPS 1 (DN 25).
    f. Instrument Isolation Valve: Full port ball valve for system isolation.

g. Insertion Depth: Threaded positioning nut for accurate sensor depth in the pipe.
h. Electronics Enclosure:

1) Polypropylene with Viton-sealed acrylic cover.
2) Removable cover.
3) NEMA 250, Type 4X.
4) Electrical Connection: Screw terminals.
5) Conduit Connection: 1/2-inch (16-mm) trade size.

D. Insertion Turbine Flow Meter:

1. Products: Subject to compliance with requirements, [**provide the following**] [**provide one of the following**] [**available products that may be incorporated into the Work include, but are not limited to, the following**]:

a. Onicon Incorporated; F-1100 Series Sensor with D-1200 Series Remote Display Module for pipe sizes NPS 1-1/4 to NPS 2 (DN 32 to DN 50), Onicon F-1200 Series Sensor with D-1200 Series Remote Display Module for pipe sizes NPS 2-1/2 (DN 65) and larger.
b. **<Insert manufacturer's name; product name or designation>**.

2. Description:

a. Operating pressure of 300 psig (2068 kPa) with a temperature of 200 deg F (93 deg C).
b. Meters in hot water systems shall be suitable for maximum system temperatures encountered, but not less than 250 deg F (121 deg C).
c. Pressure drop not to exceed 1 psig (6.9 kPa) at 20-fps (6.1-m/s) flow velocity in a NPS 2 (DN 50) pipe and decreasing in large pipe with lower velocity.
d. Sensor Accuracy:

1) Within 1 percent of actual flow between the flow velocity range of 3 to 30 fps (0.9 to 9.1 m/s).
2) Within 2 percent of actual flow between the flow velocity range of 0.4 to 20 fps (0.1 to 6.1 m/s).
3) Within 0.5 percent of actual reading at the calibrated velocity.

e. Wet calibrate and tag sensors to standards traceable to NIST, and provide each sensor with a certificate of calibration.

3. Sensor:

a. For Pipe Sizes NPS 2 (DN 50) and Smaller: Single turbine sensors.
b. For Pipe Sizes NPS 2-1/2 (DN 65) and Larger: Dual turbine sensors.
c. Piping with Bi-directional Flow: Bi-directional dual turbine sensors.
d. Dual turbine sensors shall have dual, contra-rotating turbine elements, each turbine element with its own rotational sensing system, and an averaging circuit.
e. Rotational sensing of each turbine shall be accomplished electronically by sensing electronic impedance change (non-magnetic and non-photoelectric).

f. Sensor shall have an integral frequency output linear with flow rate. For dual turbine units, with individual top and bottom turbine outputs for diagnostic purposes.
g. Bi-directional sensors shall have isolated solid-state dry contacts with a contact rating of 100 mA at 50 V. The contacts shall close when the flow in direction of arrow is 0.18 fps (0.05 m/s) or more.
h. Flow sensor shall be complete with installation hardware necessary to enable insertion and removal from pipe without system shutdown.
i. Construct turbine elements of polypropylene with sapphire jewel bearings and tungsten carbide shafts. Construct wetted metal components of Type 316 stainless steel, including installation hardware.
j. House sensor electronics in a NEMA 250, Type 4 enclosure.
k. Enclosure shall include connection(s) for field-installed conduit.
l. Sensor shall have cable of length sufficient to connect to display module.
m. Sensor housing shall have full port [**Type 316 stainless-steel**]ball valve for system isolation.

4. Display Module:

a. Remote from sensor.
b. House in a NEMA 250, Type 4X enclosure.
c. Label terminal strip for all wiring connections.
d. 120-V ac power supply with 24-V dc output to power the flow sensor.
e. Remote Interface:

1) Hardwired Analog Outputs for Flow Rate and Totalization: 4 to 20 mA and zero- to 10-V dc.
2) Serial Communication Interface: Compatible with host to share flow rate and totalized flow data.
3) Outputs linear to within 0.1 percent of calibrated span.

f. Digital display for flow rate and totalized flow.

1) At least eight display digits for totalization.
2) Bi-directional units with separate digital display for flow and totalization in each direction.

g. Local reset of flow totalization.
h. Program and data shall be stored in nonvolatile memory in event of power loss.
i. For bi-directional units, with display of flow direction (contacts open or closed).

E. Inline Turbine Flow Meter:

1. Products: Subject to compliance with requirements, [**provide the following**] [**provide one of the following**] [**available products that may be incorporated into the Work include, but are not limited to, the following**]:

a. Onicon Incorporated; F-1300 Series Sensor with D-1200 Series Remote Display Module.
b. <**Insert manufacturer's name; product name or designation**>.

2. Description:

   a. Available in NPS 3/4 and NPS 1 (DN 20 and DN 25).
   b. Operating pressure of 300 psig (2068 kPa) with a temperature of 200 deg F (93 deg C).
   c. Meters in hot water systems shall be suitable for maximum system temperatures encountered, but not less than 250 deg F (121 deg C).
   d. Pressure drop not to exceed 3 psig at 38 gpm (21 kPa at 2.4 L/s).
   e. Sensor Accuracy:

      1) Within 2 percent of actual flow between the flow range of 0.8 to 38 gpm (0.05 to 2.4 L/s).
      2) Within 0.5 percent of actual reading at the calibrated velocity.

   f. Wet calibrate and tag sensors to standards traceable to NIST, and provide each sensor with a certificate of calibration.

3. Sensor:

   a. Rotational sensing of turbine shall be accomplished electronically by sensing electronic impedance change (non-magnetic and non-photoelectric).
   b. Sensor shall have an integral frequency output linear with flow rate.
   c. Sensor shall have threaded union on each end.
   d. Construct turbine elements of polypropylene with sapphire jewel bearings and tungsten carbide shafts.
   e. Construct wetted metal components of brass or stainless steel.
   f. House sensor electronics in a NEMA 250, Type 4 enclosure.
   g. Enclosure shall include connection(s) for field-installed conduit.
   h. Sensor shall have cable of length sufficient to connect to display module.

4. Display Module:

   a. Remote from sensor.
   b. Enclosure: NEMA 250, Type 4X.
   c. Label terminal strip for all wiring connections.
   d. 120-V ac power supply with 24-V dc output to power the flow sensor.
   e. Remote Interface:

      1) Hardwired Analog Outputs for Flow Rate and Totalization: 4 to 20 mA and zero- to 10-V dc.
      2) Serial Communication Interface: Compatible with host to share flow rate and totalized flow data.
      3) Outputs linear to within 0.1 percent of calibrated span.

   f. Digital display of flow rate and totalized flow.
   g. At least eight display digits for totalization.
   h. Local reset of flow totalization.
   i. Program and data shall be stored in nonvolatile memory in the event of power loss.

F. In-line Body Electromagnetic Flow Meter:

1. Products: Subject to compliance with requirements, [**provide the following**] [**provide one of the following**] [**available products that may be incorporated into the Work include, but are not limited to, the following**]:

    a. Onicon Incorporated; F-3200 Series.
    b. **<Insert manufacturer's name; product name or designation>**.

2. Description:

    a. No moving parts.
    b. Suitable for flow measurement of fluids with electrical conductivity more than 5 micro-Seimens per cm.
    c. Inherent bi-directional flow measurement.
    d. Flow measurement with three pipe diameters upstream and two pipe diameters downstream.
    e. Wet calibrate and tag meters to standards traceable to NIST, and provide each meter with a certificate of calibration.
    f. Transmitter [**integral to**] [**remote from**] meter.

3. Performance:

    a. Accuracy for Velocities between 3.3 and 33 fps (1 and 10 m/s): Within 0.2 percent of reading.
    b. Accuracy for Velocities between 1.0 and 3.3 fps (0.3 and 1 m/s): Within 0.75 percent of reading.
    c. Accuracy for Velocities Less than 1.0 fps (0.3 m/s): Within 0.0075 fps (0.0023 m/s).
    d. Ambient Temperature: Minus 4 to plus 140 deg F (Minus 20 to plus 60 deg C).
    e. Process Temperature: Minus 4 to 212 deg F (Minus 20 to plus 100 deg C).
    f. Pressure: [**225 psig (1551 kPa)**] [**580 psig (3999 kPa)**].

4. Analog Output Current Signal:

    a. Two-wire, 4- to 20-mA dc current source.
    b. Signal capable of operating into 1000-ohm load.
    c. Isolated.

5. Digital Output Signal: Two, programmable, digital/pulse outputs configurable for frequency, pulse, or directional flow.
6. Operator Interface:

    a. Keypad.
    b. Digital Display: Multiple-line digital display of alphanumerical characters.
    c. LED for normal and alarm operation.

7. Construction:

    a. Body: [**Epoxy-coated carbon steel**] [**Type 316 stainless steel**].
    b. Body Liner Material: [**PTFE**] [**Ebonite**] [**Polypropylene**].
    c. Flow Tube: Type 304 stainless steel.
    d. Connection: [**150 Class flange**] [**300 Class flange**] [**Threaded**] [**Wafer**].

e. Electrodes: Type 316 stainless steel. Quantity determined by manufacturer based on application.
f. Electronics Enclosure:

1) Painted aluminum.
2) Removable cover.
3) NEMA 250, Type 6.

G. Insertion Electromagnetic Flow Meter:

1. Products: Subject to compliance with requirements, [**provide the following**] [**provide one of the following**] [**available products that may be incorporated into the Work include, but are not limited to, the following**]:

a. Onicon Incorporated; F-3500 Series[**with D/B-1200 Series remote display module**].
b. <**Insert manufacturer's name; product name or designation**>.

2. Description:

a. No moving parts.
b. Suitable for flow measurement of fluids with electrical conductivity between 20 to 60000 micro-Seimens per centimeter.
c. Suitable for pipe sizes NPS 3 through NPS 72 (DN 80 through DN 1800).
d. Wet calibrate and tag meters to standards traceable to NIST, and provide each meter with a certificate of calibration.
e. Continuous auto-zero function.
f. Transmitter integral to meter.

3. Performance:

a. Flow Range: 0.25 to 20 fps (0.08 to 6.1 m/s).
b. Accuracy for Velocities between 2 and 20 fps (0.6 to 6.1 m/s): Within 1 percent of reading.
c. Accuracy for Velocities Less than 2 fps (0.6 m/s): Within 0.02 fps (0.006 m/s).
d. Ambient Temperature: Minus 5 to 150 deg F (Minus 21 to plus 66 deg C).
e. Process Temperature: 15 to 250 deg F (Minus 9 to plus 121 deg C).
f. Pressure: 400 psig (2758 kPa).

4. Output Signals:

a. Field-selectable analog signals.

1) Current Signal (Isolated): 4 to 20 mA.
2) Voltage Signal (Isolated): Zero- to [**5**] [**10**]-V dc.

b. Digital Signal: Dry-contact closure signaling fault condition.
c. Frequency Signal: Zero- to 15-V peak pulse, zero to 500 Hz.
d. Scalable Pulse Output:

1) Isolated solid-state dry contact.

2) Contact Rating: 100 mA at 50-V dc.
3) Pulse Duration: 0.5, 1, 2, or 6 seconds.

5. Construction:

a. Wetted Metal Parts: Type 316 stainless steel.
b. Sensor Head: Polysulfone.
c. Process Connection: 1-inch (25-mm).
d. Instrument Isolation Valve: Full port Type 316 stainless-steel ball valve for system isolation.
e. Electrodes: Type 316 stainless steel.
f. Electronics Enclosure:

1) Painted aluminum.
2) Removable cover.
3) NEMA 250, Type 4.
4) Electrical Connection: PVC-jacketed cable, 10 feet (3 m) long.
5) Conduit Connection: 1/2-inch (16 mm) trade size.

6. Display Module:

a. Remote from meter.
b. House in a NEMA 250, Type 4X enclosure.
c. Label terminal strip for all wiring connections.
d. 120-V ac power supply with 24-V dc output to power the flow sensor.
e. Input Signal from Meter: Zero- to 15-V pulse output.
f. Output Signals: Additional output signals furnished with flow meter connected to display module terminal strip.
g. Auxiliary Output Signals: Analog current output (isolated) shall be 4 to 20 mA.
h. Auxiliary Output Signals: Analog voltage output (isolated) shall be zero to [**5**] [**10**] V.
i. Auxiliary Output Signals: Digital output (isolated) shall be solid-state dry contacts rated for 100 mA at 50 V.
j. Digital Display:

1) Flow rate.
2) Totalized flow.
3) At least six display digits for flow rate and eight display digits for totalization.
4) Bi-directional units with separate digital display for flow and totalization in each direction.

k. Local reset of flow totalization.
l. Program and data shall be stored in nonvolatile memory in the event of power loss.
m. For bi-directional units, provide LED display of flow direction (contacts open or closed).

H. Vortex Shedding Flow Meter with Integral Temperature Measurement:

1. Products: Subject to compliance with requirements, [**provide the following**] [**provide one of the following**] [**available products that may be incorporated into the Work include, but are not limited to, the following**]:

    a. Onicon Incorporated; F-2200 Series[**with D-2100 Series remote display**].
    b. **<Insert manufacturer's name; product name or designation>**.

2. Description:

    a. Flow measurement using vortex shedder body with integral 1000-ohm platinum RTD.
    b. Meter NPS 3/8 through NPS 8 (DN 10 through DN 200).
    c. Each meter shall be factory calibrated at five points from zero to 250 fps (zero to 76 m/s) and tagged accordingly against the manufacturer's flow standards. The manufacturer shall provide a certificate of calibration for meter.
    d. Each meter shall be programmed using project-specific application data.
    e. Meter shall include integral diagnostics to verify installation conditions and proper operation.

3. Performance:

    a. Volumetric Flow Accuracy: Within 1 percent of reading for meter NPS 1 (DN 25) and larger; within 2 percent of reading for smaller sizes.
    b. Mass Flow Accuracy: Within 1.5 percent of reading for NPS 1 (DN 25) and larger; within 2.5 percent of reading for smaller sizes.
    c. Ambient Temperature: Zero to 132 deg F (Minus 18 to plus 56 deg C).
    d. Process Temperature: 25 to 464 deg F (Minus 4 to plus 240 deg C).
    e. Pressure: Equal to flange rating.

4. Output Signals:

    a. Analog Current Signal of Flow Rate:

        1) Two-wire, 4- to 20-mA dc current source.
        2) Signal capable of operating into 1000-ohm load.

    b. Digital Signal: Pulse output for flow totalization. Two wire, scaled pulse, 0.5 Hz, 100 mA at 30-V dc.

5. Operator Interface:

    a. Keypad.
    b. Digital Display: Two-line digital display of alphanumerical characters. The meter shall display flow rate, flow totalization, and temperature and support field programming of all parameters.

6. Construction:

    a. Material: Type 316L stainless steel for sizes through NPS 4 (DN 100); Type 304 stainless steel for larger sizes.
    b. Connection: [**Class 300**] [**Class 600**] flange.

c. Vortex Shedder: Unalloyed titanium.
d. Shedder Seal: Nickel-plated Inconel.
e. Enclosure:

1) Epoxy-painted cast aluminum.
2) Removable screw-on cover.
3) NEMA 250, Type 4X.
4) Electrical Connection: Screw terminals.
5) Conduit Connection: Two, 1/2-inch (16-mm) trade size.

7. Remote Display Module:

a. Remote from meter.
b. House in a NEMA 250, Type 4 enclosure.
c. Label terminal strip for all wiring connections.
d. 120-V ac power supply with 24-V dc output to power the flow meter.
e. Input Signal from Meter: Analog current, 4 to 20 mA.
f. Output Signals:

1) Analog Current Output: Two wire, 4 to 20 mA, maximum loop resistance 275 ohms.
2) Digital Output (Isolated): Solid-state dry contacts rated for 100 mA at 50-V dc.

g. Digital Display:

1) Flow rate.
2) Totalized flow.
3) Display Digits: 3.5 for flow rate and 8 for totalization.

h. Local reset of flow totalization.
i. Program and data shall be stored in nonvolatile memory in the event of power loss.

8. Upstream Flow Straightener:

a. Flow straightener where required by installation.
b. Straightener shall be wafer type, constructed of Type 304 stainless steel, designed to be installed between field-installed flanges.
c. Straightener size shall match meter size.

I. Vortex Shedding Flow Meter with Integral Pressure and Temperature Measurement:

1. Products: Subject to compliance with requirements, [**provide the following**] [**provide one of the following**] [**available products that may be incorporated into the Work include, but are not limited to, the following**]:

a. Onicon Incorporated; F-2500 Series.
b. **<Insert manufacturer's name; product name or designation>**.

2. Description:

a. Mass flow measurement corrected for density using vortex shedder body with integral piezoelectric pressure sensors and 1000-ohm platinum RTD.
b. Meter NPS 1/2 through NPS 12 (DN 15 through DN 300).
c. Each meter shall be factory calibrated at five points from Zero to 250 fps (0 to 76 m/s) and tagged accordingly against the manufacturer's flow standards. The manufacturer shall provide a certificate of calibration for meter.
d. Each meter shall be programmed using project-specific application data.
e. Meter shall include integral diagnostics to verify installation conditions and proper operation.

3. Performance:

a. Volumetric Flow Accuracy for Liquid: Within 0.75 percent of reading for Reynolds numbers 20000 and larger.
b. Volumetric Flow Accuracy for Steam and Gas: Within 1 percent of reading for Reynolds numbers 20000 and larger.
c. Mass Flow Accuracy for Steam and Gas: Within 1.5 percent of reading for Reynolds numbers 20000 and larger.
d. Repeatability: Within 0.1 percent.
e. Long-Term Stability: Within 0.1 percent per year.
f. Ambient Temperature: Minus 40 to plus 185 deg F (Minus 40 to plus 85 deg C).
g. Process Temperature: Minus 40 to plus 464 deg F (Minus 40 to plus 240 deg C).
h. Pressure: Equal to flange rating.

4. Output Signals:

a. Analog Current Signal of Flow Rate:

1) Two-wire, 4- to 20-mA dc current source.
2) Signal capable of operating into 1000-ohm load.

b. Analog Current Signals for Pressure and Temperature: Separate 4- to 20-mA signals for gage pressure and temperature.
c. Digital Signal:

1) Pulse output for flow totalization. Two wire, scaled pulse, 0.5 Hz, 100 mA at 30-V dc.
2) HART, FSK protocol.

5. Operator Interface:

a. Keypad.
b. Digital Display: Two-line digital display of alphanumerical characters. The meter shall display flow rate, flow totalization, pressure, temperature, and support field programming of all parameters.

6. Construction:

a. Material: Type 316L stainless steel.
b. Connection: [**Class 150**] [**Class 300**] [**Class 600**] flange.
c. Enclosure:

1) Epoxy-painted cast aluminum.
2) Removable screw-on cover.
3) NEMA 250, Type 6.
4) Electrical Connection: Screw terminals.
5) Conduit Connection: Two, 1/2-inch (16-mm) trade size.

7. Upstream Flow Straightener:

a. Meter manufacturer shall provide flow straightener where required by installation to comply with manufacturer's installation recommendations.
b. Straightener shall be wafer type, constructed of Type 304 stainless steel, designed to be installed between field-installed flanges.
c. Straightener size shall match meter size.

J. Vortex Shedding Flow Meter for Hazardous Environments:

1. Products: Subject to compliance with requirements, [**provide the following**] [**provide one of the following**] [**available products that may be incorporated into the Work include, but are not limited to, the following**]:

a. Rosemount, Inc., Emerson Electric Co.; 8800C Series.
b. <**Insert manufacturer's name; product name or designation**>.

2. Standard: ASME MFC-6M.
3. Description:

a. FM Approved for hazardous environments.

1) Intrinsically safe for Class I, Division 1, Groups A, B, C, and D; Class II and III, Division 1, Groups E, F, and G.
2) Explosion-Proof for Class I, Division 1, Groups B, C, and D.
3) Dust-Ignition-Proof for Class II and III, Division 1, Groups E, F, and G.

b. Sensor shall be isolated from process and replaceable without breaking process seals.
c. Meter immune to vibration.
d. Clog-free design eliminates gaskets and ports.
e. Meter NPS 1/2 through NPS 12 (DN 15 through DN 300).
f. Each meter shall be factory calibrated and provided with a certificate of calibration.
g. Meter shall be furnished with a permanently attached stainless-steel tag.
h. Meter shall include integral diagnostics to verify proper operation.

4. Performance:

a. Flow Accuracy: Within 0.65 percent of reading plus 0.025 percent of span for Reynolds numbers 20000 and larger.
b. Repeatability: Within 0.1 percent of flow rate.
c. Long-Term Stability: Within 0.1 percent of flow rate per year.
d. Response Time: Greater of three vortex shedding cycles or 0.2 seconds.
e. Dampening: Adjustable between 0.2 to 255 seconds.

f. Ambient Temperature: Minus 58 to plus 250 deg F (Minus 50 to plus 121 deg C).
g. Humidity: Zero to 95 percent noncondensing.
h. Process Temperature: Minus 40 to plus 450 deg F (Minus 40 to plus 232 deg C).
i. Pressure: Equal to flange rating.

5. Output Signals:

a. Analog Current Signal of Flow Rate:

1) Two-wire, 4- to 20-mA dc current source.
2) Signal capable of operating into 1000-ohm load.

b. Digital Signal:

1) Pulse output for flow totalization.
2) HART protocol.

6. Digital Display: Digital display of alphanumerical characters. The meter shall display flow rate, flow totalization, percent of range, and current output.
7. Body and Flanges:

a. Material: Type 316L stainless steel.
b. Connection: ASME B16.5, [**Class 150**] [**Class 300**] [**Class 600**] flange.
c. Enclosure:

1) Polyurethane-painted cast aluminum.
2) Removable screw-on cover.
3) NEMA 250, Type 4X.
4) Electrical Connection: Screw terminals.
5) Conduit Connection: 1/2-inch (16-mm) trade size.

2.7 LIQUID FLOW SENSORS (PRIMARY ELEMENTS)

A. Averaging Pitot Tubes:

1. Products: Subject to compliance with requirements, [**provide the following**] [**provide one of the following**] [**available products that may be incorporated into the Work include, but are not limited to, the following**]:

a. Rosemount, Inc., Emerson Electric Co.; Model 485 Annubar.
b. **<Insert manufacturer's name; product name or designation>**.

2. Standards: ASME MFC-12M.
3. Description:

a. Sensor shall include isolation valves and connections that are suitable for connecting to a remote pressure instrument.
b. Sensor shall consist of high- and low-pressure plenums and be able to accommodate an integral RTD.

c. Sensor's cross-sectional tee shape shall allow flow separation at a fixed point independent of flow rate, pressure, or temperature with a stable flow coefficient maintained over a wide range of Reynolds numbers.
d. Sensor shape shall promote less-turbulent zones on the backside of the sensor. Individual sensing ports shall be located in this less-turbulent region to measure low pressure. Number of sensing ports shall be a function of the pipe size.
e. High pressure shall be measured by a frontal slot design extending full length of sensor. Number of slots shall be a function of pipe size.
f. Manufacturer shall submit on request independent testing documentation (product test reports), demonstrating compliance with specified performance.

4. Performance:[**$ds~Product test reports are required.**]

a. Discharge Coefficient Factor: Within 0.75 percent of flow rate.
b. Repeatability: Within 0.1 percent.
c. Flow Turndown: 10:1.
d. Sensor Size for Pipe Size NPS 2 through NPS 8 (DN 50 through DN 200): Minimum rod Reynolds number of 6000; probe width of 0.59 inch (15 mm).
e. Sensor Size for Pipe Size NPS 6 through NPS 36 (DN 150 through DN 900): Minimum rod Reynolds number of 12500; probe width of 1.060 inch (27 mm).
f. Sensor Size for Pipe Size NPS 12 through NPS 72 (DN 300 through DN 1800): Minimum rod Reynolds number of 25000; probe width of 1.953 inches (50 mm).
g. Process Temperature Limit: 500 deg F (260 deg C).
h. Process Pressure Limit: Equal to flange rating.

5. Construction:

a. Sensor Surface Finish: Front surface textured for high-Reynolds-number applications to create a more turbulent boundary layer on front surface of sensor and produce a more predictable and repeatable separation of flow at edge of sensor.
b. Sensor Material: Type 316 stainless steel.
c. Packing Gland:

1) Wetted Parts: Type 316 stainless steel.
2) Packing Material: Graphite.

d. Isolation Valve: Type 316 stainless-steel full port ball valve configured to remove sensor while isolating process.
e. Flanged In-line Pipe Spool:

1) Mount sensor in a flanged section of pipe.
2) Pipe material to match adjacent pipe.
3) Flanges to match adjacent pipe.

B. Venturis:

1. Basis-of-Design Products: Subject to compliance with requirements, provide Hydronic Components, Inc. (HCi); Terminator MS Series or comparable product by one of the following:

a. Jomar Hydronics.
b. Preso Meters, Division of Racine Federated, Inc.
c. **<Insert manufacturer's name>**.

2. On request, submit independent testing documentation (product test reports), demonstrating compliance with specified performance.
3. Standard: ASME MFC-3M.
4. Performance:

a. Accuracy within 1 percent of measured flow throughout flow range from design to 10 percent of design flow.
b. Accuracy with five pipe diameters of straight pipe upstream and two pipe diameters downstream.
c. Size and beta ratio shall be matched with transmitter to provide accuracy of entire assembly within 1 percent of design flow rate, when the flow rate is allowed to vary between 10 to 100 percent of the design.

5. Construction:

a. One-piece brass construction with removable venture and threaded connections for pipe sizes NPS 1/2 through NPS 3/4 (DN 15 to DN 20).
b. Fabricated steel with flanged connections for pipe sizes NPS 2-1/2 through NPS 12 (DN 65 to DN 300).
c. Sensing Taps: Two, accurately located built-in sensing taps.
d. Identification Tag: Attached to each venturi and label indicating pipe size, venturi series, station identification, and meter reading at flow rate and pressure differential.
e. Use venturi with pressure differential transmitter.

C. Orifice Plates:

1. Products: Subject to compliance with requirements, [**provide the following**] [**provide one of the following**] [**available products that may be incorporated into the Work include, but are not limited to, the following**]:

a. Rosemount, Inc., Emerson Electric Co.; Model 405 Series.
b. **<Insert manufacturer's name; product name or designation>**.

2. Standards: ASME MFC-3M or ASME MFC-14M.
3. Performance:

a. Orifice plates shall be sharp, square-edged concentric type.
b. Shop fabricate and calibrate orifice meter runs through NPS 2 (DN 50).
c. Field fabricate orifice runs NPS 3 (DN 80) and larger.
d. Meter run piping or tubing shall be uniform internal surface, which is free of internal grooves and striations, but is not polished. Out of roundness shall not exceed 0.5 percent. A reduction of the pipe diameter or distortion caused by welding is unacceptable.
e. Size orifice plates for 100-inch wg (24.9-kPa) pressure differential, except that the absolute value of the meter range shall not exceed the absolute value of the flowing pressure.

f. Ratio of orifice diameter to actual internal pipe diameter d/B (beta) shall be between 0.70 and 0.30.
g. Locate orifice plates in horizontal or vertical lines in accordance with good metering practice.
h. Minimum upstream and downstream straight pipe shall comply with ASME Fluid Meters Research Committee Reports.

4. Construction:

a. Fabricate the orifice plate and matching companion flanges of Type 316 stainless steel.
b. Transmitter connection shall be at least NPS 1/2 (DN 15).
c. Stamp the orifice plates with the number and the orifice bore on the handle of the plate.

5. Use orifice plate with pressure differential transmitter.
6. Calibration information and calculations shall comply with either of the referenced standards for each orifice plate.

D. Segmented Wedge Flow Sensor:

1. Products: Subject to compliance with requirements, [**provide the following**] [**provide one of the following**] [**available products that may be incorporated into the Work include, but are not limited to, the following**]:

a. Preso Meters, Division of Racine Federated, Inc.; COIN Series.
b. <**Insert manufacturer's name; product name or designation**>.

2. Description: Pressure differential design using a segmented or segmental wedge installed in a straight section of pipe.
3. Performance: [**Product test reports are required.**]

a. Accuracy within 0.5 percent of the measured flow over flow range from design flow to 10 percent of design flow.
b. Accuracy with 10 pipe diameters of straight pipe upstream and five pipe diameters downstream.
c. Repeatability shall be within 0.2 percent over flow range.
d. Discharge coefficient shall be linear and stable throughout the flow range.
e. Determine H/ID ratios to meet specified performance.
f. Capable of bi-directional flow measurement with no degradation of performance, with flow in either direction.
g. Suitable for working pressure of 200 psig at 200 deg F (1379 kPa at 93 deg C).

4. Construction:

a. Pipe: Type 316 stainless steel with inside diameter to match adjacent pipe. Length determined by manufacturer.
b. Wedge: Type 316 stainless-steel segmented angled wedge equal on both sides.
c. Flanges: Class 150 [**weld neck**] [**raised face**], Type 316 stainless steel.
d. Instrument Connections: NPS 1/2 (DN 15), Class 3000, Type 316 stainless-steel half couplings.

e. Identification Tag: Stamped or engraved stainless steel.

5. Use with a pressure differential transmitter.

E. Portable Meter Package for Liquid Flow Sensors:

1. Metal-reinforced-plastic carrying case.
2. Waterproof meter with nominal 6-inch (150-mm) round dial face.
3. Meter with dual rupture-proof liquid-filled bellows having integral temperature compensation.
4. Meter with external range and zero adjustment.
5. Multiple meters in package, if required to accommodate venturis with a wide range of pressure signals.
6. Two connecting hoses, [**10-feet (3-m)**] <**Insert dimension**> long, with quick connect couplings compatible with venturi couplings.
7. Two brass blowdown valves with Buna-N seals and blowdown hoses.
8. Instruction book with flow versus differential curves.
9. Suitable for working pressure of 200 psig (1380 kPa) at 200 deg F (93.3 deg C).
10. Portable meter package to connect to flow sensor without disturbing connection to pressure differential transmitter. Provide isolation valves at connections.
11. Turn over to Owner at Project completion.

2.8 LIQUID FLOW SWITCHES

A. Liquid Flow Switch (Bellows Type):

1. Products: Subject to compliance with requirements, [**provide the following**] [**provide one of the following**] [**available products that may be incorporated into the Work include, but are not limited to, the following**]:

a. W. E. Anderson, Division of Dwyer Instruments, Inc.; Series FS-2.
b. <**Insert manufacturer's name; product name or designation**>.

2. Description:

a. Field-adjustable four-vane combinations.
b. Field-adjustable set-point adjustment screw.
c. Suitable for pipe sizes NPS 1 through NPS 8 (DN 25 through DN 200).
d. Switch mounted vertically in horizontal pipe.

3. Performance:

a. Flow Rate Actuation and De-actuation: Varies with vane combination and set-point adjustment.
b. Pressure Limit: 145 psig (1000 kPa).
c. Temperature Limit: 230 deg F (110 deg C).
d. Electrical Rating: 10 A resistive, 3 A conductive at 250-V ac.
e. Switch Type: SPDT snap switch.

4. Wetted Parts Construction:

a. Bellows: Tin-bronze.
b. Vanes: Stainless steel.
c. Body: Forged brass.
d. Process Connection: NPS 1 (DN 25).

5. Enclosure:

a. Die-cast aluminum alloy.
b. NEMA 250, Type 4.
c. Electrical Connection: Cable gland with attached wire leads.

B. Liquid Flow Switch (Magnetic Type):

1. Products: Subject to compliance with requirements, [**provide the following**] [**provide one of the following**] [**available products that may be incorporated into the Work include, but are not limited to, the following**]:

a. W. E. Anderson, Division of Dwyer Instruments, Inc.; Series V4.
b. <**Insert manufacturer's name; product name or designation**>.

2. Description:

a. Field-adjustable five-vane combinations.
b. Suitable for pipe sizes NPS 1-1/2 through NPS 20 (DN 40 to DN 500).
c. Mounting Suitable for Application: Switch vertically mounted in horizontal pipe, or switch horizontally mounted in vertical pipe with flow up.
d. Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for hazardous-environment Class I, Groups C and D; Class II, Groups E, F, and G.

3. Performance:

a. Flow Rate Actuation and De-actuation: Varies with vane combination.
b. Pressure Limit: 1000 psig (6895 kPa) for brass body, 2000 psig (13790 kPa) for Type 316 stainless-steel body.
c. Temperature Range: Minus 4 to plus 275 deg F (Minus 20 to plus 135 deg C).
d. Electrical Rating: 10 A at 125/250-V ac.
e. Switch Type: [**SPDT**] [**DPDT**] snap switch.

4. Wetted Parts Construction:

a. Vanes: Type 316 stainless steel.
b. Body: [**Brass**] [**Type 316 stainless steel**].
c. Magnetic Keeper: [**Type 430 stainless steel**] [**Type 316 stainless steel**].
d. Process Connection: NPS 1-1/2 (DN 40).

5. Enclosure:

a. Die-cast aluminum alloy.
b. Threaded cover.
c. NEMA 250, Type 4.

d. Electrical Connection: Terminal block.
e. Conduit Connection: 3/4-inch (21-mm) trade size.

C. Liquid Flow Switch (Magnetic Type) for Small-Diameter Pipe:

1. Products: Subject to compliance with requirements, [**provide the following**] [**provide one of the following**] [**available products that may be incorporated into the Work include, but are not limited to, the following**]:

a. W. E. Anderson, Division of Dwyer Instruments, Inc.; Series V6.
b. <**Insert manufacturer's name; product name or designation**>.

2. Description:

a. Suitable for pipe sizes NPS 1/2 through NPS 2 (DN 15 through DN 50).
b. Mounting Suitable for Application: Switch vertically mounted in horizontal pipe, or switch horizontally mounted in vertical pipe with flow up.
c. Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for hazardous-environment Class I, Groups A, B, C, and D; Class II, Groups E, F, and G.

3. Performance:

a. Flow Rate Actuation and De-actuation: Not adjustable.
b. Pressure Limit of Body: 1000 psig (6895 kPa) for brass, 2000 psig (13790 kPa) for Type 303 stainless-steel body.
c. Pressure Limit of Tee: 250 psig (1724 kPa) for brass, 1000 psig (6895 kPa) for malleable iron, and 2000 psig (13790 kPa) for forged carbon steel and stainless steel.
d. Temperature Range: Minus 4 to plus 220 deg F (Minus 20 to plus 104 deg C).
e. Electrical Rating: 5 A at 125/250-V ac.
f. Switch Type: [**SPDT**] [**DPDT**] snap switch.

4. Wetted Parts Construction (Lower Body):

a. Vanes: Type 301 stainless steel.
b. Body: [**Brass**] [**Type 303 stainless steel**].
c. Magnet: Ceramic.
d. Process Connection: NPS 1/2 (DN 15).

5. Enclosure (Upper Body):

a. [**Brass**] [**Type 303 stainless steel**].
b. NEMA 250, Type 4.
c. Electrical Connection: Terminal block.
d. Conduit Connection: 3/4-inch (21-mm) trade size.

6. Integral Mounting Tee Furnished with Switch:

a. [**Brass**] [**Forged carbon steel**] [**Malleable iron**] [**Stainless steel**].
b. Size: [**Match adjacent pipe**] <**Insert size**>.

c. Connection: Threaded pipe.

2.9 LIQUID FLOW TRANSMITTERS

A. Pressure Differential Transmitter with 0.07 Percent Accuracy for Flow Measurement [**in Hazardous Environment**]:

1. Products: Subject to compliance with requirements, [**provide the following**] [**provide one of the following**] [**available products that may be incorporated into the Work include, but are not limited to, the following**]:

   a. Rosemount, Inc., Emerson Electric Co.; Model 3051CD.
   b. **<Insert manufacturer's name; product name or designation>**.

2. FM Approved for hazardous environments.

   a. Intrinsically safe for Classes I, II, and III, Divisions 1 and 2, Groups A through H.
   b. Explosion-Proof for Class I, Division 1, Groups B, C, and D.
   c. Dust-Ignition-Proof for Class II, Division 1, Groups E, F, and G.
   d. Dust-Ignition-Proof for Class III, Division 1.

3. Performance:

   a. Range: Minus 250- to 250-inch wg (Minus 62.5 to 62.5 kPa).
   b. Span: Field adjustable.
   c. Minimum Span: 2.5-inch wg (500 Pa).
   d. Accuracy: Within 0.07 percent of span or better.
   e. Stability: Within 0.125 percent of upper range limit for 5 years.
   f. Overpressure Limits: 3626 psig (25000 kPa).
   g. Process Temperature Limits: Minus 40 to plus 250 deg F (Minus 40 to plus 121 deg C).
   h. Ambient Temperature Limits: Minus 40 to plus 185 deg F (Minus 40 to plus 85 deg C).
   i. Temperature Effect: Within 0.025 percent of upper range limit plus 0.125 percent of span.
   j. Shock and vibration shall not harm the transmitter.

4. Analog Output Current Signal:

   a. Two-wire, 4- to 20-mA dc current source.
   b. Signal capable of operating into 1000-ohm load.
   c. Digital signal based on HART protocol carried with current signal.
   d. Dampening: Field selectable zero to 30 seconds.

5. Operator Interface: Zero and span adjustments located behind cover.
6. Display: Five-digit, two-line digital display with 0.4 inch (10 mm) high alphanumeric characters.
7. Construction:

   a. Nonwetted parts of transmitter constructed of aluminum or stainless steel.

b. Enclosure with removable cover on each side.
c. Wetted parts of transmitter constructed of Type 316 stainless steel.
d. NPS 1/2 (DN 15) process connections on bottom of instrument.
e. Drain/vent valve on low- and high-pressure connections.
f. Two 1/2-inch (16-mm) trade size conduit connection on side of instrument enclosure.
g. Screw terminal block for wire connections.
h. NEMA 250, Type 4X.
i. Mounting bracket suitable for installation.

8. Five-Valve Manifold:

a. Each transmitter shall have integrally mounted manifold.
b. Construct manifold body of Type 316 stainless steel.
c. Manifold shall have NPS 1/2 (DN 15) process connections.

B. Liquid Pressure Differential Transmitter for Flow Measurement:

1. Products: Subject to compliance with requirements, [**provide the following**] [**provide one of the following**] [**available products that may be incorporated into the Work include, but are not limited to, the following**]:

a. Dwyer Instruments, Inc.; Series 645.
b. <**Insert manufacturer's name; product name or designation**>.

2. Performance:

a. Range: Approximately 2 times the set point.
b. Span: Adjustable plus or minus 1 mA, non-interactive.
c. Accuracy: Within 0.25 percent of full scale.
d. Maximum Operating Pressure: 2.5 times range.
e. Temperature Limits: Zero to 175 deg F (Minus 18 to plus 79 deg C).
f. Compensate Temperature Limits: 30 to 150 deg F (Minus 1 to plus 66 deg C).
g. Thermal Effects: 0.02 percent of full scale per degree F.
h. Response Time: 30 to 50 ms.
i. Shock and vibration shall not harm the transmitter.

3. Analog Output Current Signal:

a. Two wire, 4- to 20-mA dc current source.
b. Signal capable of operating into 1000-ohm load.

4. Operator Interface:

a. Zero and span adjustments located behind cover.
b. Bleed screws on side of body, two screws on low-pressure side and one screw on high-pressure side, for air in line and pressure cavity.

5. Construction:

a. Aluminum and stainless-steel enclosure with removable cover.

b. Wetted parts of transmitter constructed of 17-4 PH or 300 series stainless steel.
c. NPS 1/4 (DN 8) process connections on side of instrument enclosure.
d. Knock out for 1/2-inch (15-mm) trade size conduit connection on side of instrument enclosure.
e. Screw terminal block for wire connections.
f. NEMA 250, Type 4X.
g. Mounting bracket shall be suitable for installation.

6. Transmitter shall have three-valve manifold. Construct manifold of brass, bronze, or stainless steel. Manifold shall have NPS 1/4 (DN 8) process connections.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine substrates and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.

B. Examine roughing-in for instruments installed in piping to verify actual locations of connections before installation.

C. Examine roughing-in for instruments installed in duct systems to verify actual locations of connections before installation.

D. Provide the services of an independent inspection agency to confirm that proposed mounting locations comply with requirements indicated and approved submittals.

1. Indicate dimensioned locations with mounting height for all surface-mounted products to walls and ceilings on shop drawings.
2. Do not begin installation without submittal approval of mounting location.

E. Complete installation rough-in only after confirmation by independent inspection is complete and approval of location is documented for review by Owner and Architect on request.

F. Prepare written report, endorsed by Installer, listing conditions detrimental to performance.

G. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTRUMENT APPLICATIONS

A. Select from instrument types to achieve performance requirements and characteristics indicated while subjected to full range of system operation encountered.

B. Duct-Mounted Airflow Sensors:

1. Measured Velocities [**500 fpm (2.5 m/s)**] **<Insert value>** and Less: Thermal airflow station.

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2. Measured Velocities Greater than [**500 fpm (2.5 m/s)**] <**Insert value**>: [**Pitot-tube airflow sensor station**] [**Thermal airflow station**].

C. Damper-Mounted Airflow Sensors:

1. Measured Velocities [**400 fpm (2.0 m/s)**] <**Insert value**> and Less: Thermal airflow station.
2. Measured Velocities Greater than [**500 fpm (2.5 m/s)**] <**Insert value**>: [**Pitot-tube airflow sensor station**] [**Thermal airflow station**] [**Damper with integral flow measurement**] [**Damper with integral flow control**].

D. Fan-Mounted Airflow Sensors:

1. Measured Velocities [**500 fpm (2.5 m/s)**] <**Insert value**> and Less: Thermal airflow station.
2. Measured Velocities Greater than [**500 fpm (2.5 m/s)**] <**Insert value**>: [**Pitot-tube fan inlet airflow sensor station**] [**Piezometer ring fan inlet airflow sensor**] [**Thermal airflow station**].

E. Airflow Switches:

1. Measured Velocities 400 fpm (2.0 m/s) and Less: Polymer film sail switch.
2. Measured Velocities Greater than 400 fpm (2.0 m/s): Stainless-steel single-vane switch.

F. Airflow Transmitters for Use with Pitot-Tube-Type Sensors:

1. Exhaust Air Airflow: [**Airflow transmitter with 0.10 percent accuracy and auto-zero feature**] [**Airflow transmitter with 0.25 percent accuracy and auto-zero feature**] [**Pressure differential transmitter for airflow measurement**] [**Pressure differential indicating transmitter, switch and controller for airflow measurement**].
2. Outdoor Air Airflow: [**Airflow transmitter with 0.10 percent accuracy and auto-zero feature**] [**Airflow transmitter with 0.25 percent accuracy and auto-zero feature**] [**Pressure differential transmitter for airflow measurement**] [**Pressure differential indicating transmitter, switch and controller for airflow measurement**].
3. Return Air Airflow: [**Airflow transmitter with 0.10 percent accuracy and auto-zero feature**] [**Airflow transmitter with 0.25 percent accuracy and auto-zero feature**] [**Pressure differential transmitter for airflow measurement**] [**Pressure differential indicating transmitter, switch and controller for airflow measurement**].
4. Supply Air Airflow: [**Airflow transmitter with 0.10 percent accuracy and auto-zero feature**] [**Airflow transmitter with 0.25 percent accuracy and auto-zero feature**] [**Pressure differential transmitter for airflow measurement**] [**Pressure differential indicating transmitter, switch and controller for airflow measurement**].

G. Liquid Flow Sensors (Primary Elements):

1. <**Insert system**> System, <**Insert unique application**>: [**Averaging pitot tubes**] [**Venturis**] [**Orifice plates**] [**Segmented wedge**].

H. Liquid Flow Meters:

1. **<Insert system>** System, **<Insert unique application>**: [**Insertion paddle wheel transmitter**] [**Turbine flow meter**] [**Electromagnetic flow meter**] [**Vortex shedding flow meter with integral temperature measurement**] [**Vortex shedding flow meter with integral pressure and temperature measurement**] [**Vortex shedding flow meter for hazardous environments**].

I. Liquid Flow Switches:

1. **<Insert system>** System, **<Insert unique application>**: [**Bellows type**] [**Magnetic type**].

J. Liquid Flow Transmitters:

1. **<Insert system>** System, **<Insert unique application>**: [**Pressure differential transmitter with 0.07 percent accuracy for flow measurement**] [**Liquid pressure differential transmitter**].

3.3 INSTALLATION, GENERAL

A. Furnish and install products required to satisfy more stringent of all requirements indicated.

B. Install products level, plumb, parallel, and perpendicular with building construction.

C. Properly support instruments, tubing, piping wiring, and conduit to comply with requirements indicated. Brace all products to prevent lateral movement and sway or a break in attachment when subjected to a **<Insert value>** force.

D. Install ceiling, floor, roof, and wall openings and sleeves required by installation. Before proceeding with drilling, punching, or cutting, check location first for concealed products that could potentially be damaged. Patch, flash, grout, seal, and refinish openings to match adjacent condition.

E. Install products in locations that are accessible and that will permit calibration and maintenance from floor, equipment platforms, or catwalks. Where ladders are required for Owner's access, confirm unrestricted ladder placement is possible under occupied condition.

F. Corrosive Environments:

1. Use products that are suitable for environment to which they will be subjected.
2. If possible, avoid or limit use of materials in corrosive environments, including, but not limited to, the following:

a. Laboratory exhaust airstreams.
b. Process exhaust airstreams.
c. **<Insert requirement>**.

3. When conduit is in contact with a corrosive environment, use Type 316 stainless-steel conduit and fittings or conduit and fittings with a corrosive-resistant coating that is suitable for environment.

4. Where instruments are located in a corrosive environment and are not corrosive resistant from the manufacturer, field install products in a NEMA 250, Type 4X enclosure constructed of Type 316L stainless steel.

3.4 ELECTRIC POWER

A. Furnish and install electrical power to products requiring electrical connections.

B. Furnish and install circuit breakers. Comply with requirements in Section 262816 "Enclosed Switches and Circuit Breakers."

C. Furnish and install power wiring. Comply with requirements in Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

D. Furnish and install raceways. Comply with requirements in Section 260533 "Raceways and Boxes for Electrical Systems."

3.5 INSTRUMENTS, GENERAL INSTALLATION REQUIREMENTS

A. Mounting Location:

1. Rough-in: Outline instrument-mounting locations before setting instruments and routing cable, wiring, tubing, and conduit to final location.
2. Install switches and transmitters for air and liquid flow associated with individual air-handling units and connected ductwork and piping near air-handlings units co-located in air-handling unit system control panel, to provide service personnel a single and convenient location for inspection and service.
3. Install liquid and steam flow switches and transmitters for indoor applications in mechanical equipment rooms. Do not locate in user-occupied space unless indicated specifically on Drawings.
4. Install airflow switches and transmitters for indoor applications in mechanical equipment rooms. Do not locate in user-occupied space unless indicated specifically on Drawings.
5. Mount switches and transmitters not required to be mounted within system control panels on walls, floor-supported freestanding pipe stands, or floor-supported structural support frames. Use manufacturer mounting brackets to accommodate field mounting. Securely support and brace products to prevent vibration and movement.
6. Install instruments in steam, liquid, and liquid-sealed-piped services below their process connection point. Slope tubing down to instrument with a slope of [**2**] [**3**] **<Insert number>** percent.
7. Install instruments in dry gas and non-condensable-vapor piped services above their process connection point. Slope process connection lines up to instrument with a minimum slope of [**2**] [**3**] **<Insert number>** percent.

B. Mounting Height:

1. Mount instruments in user-occupied space to match mounting height of light switches unless otherwise indicated on Drawings. Mounting height shall comply with codes and accessibility requirements.

2. Mount switches and transmitters, located in mechanical equipment rooms and other similar space not subject to code, state, and federal accessibility requirements, within a range of 42 to 72 inches (1050 to 1800 mm) above the adjacent floor, grade, or service catwalk or platform.

    a. Make every effort to mount at 60 inches (1500 mm).

C. Seal penetrations to ductwork, plenums, and air-moving equipment to comply with duct static-pressure class and leakage and seal classes indicated using neoprene gaskets or grommets.

3.6 FLOW INSTRUMENTS INSTALLATION

A. Airflow Sensors:

1. Install sensors in straight sections of duct with manufacturer-recommended straight duct upstream and downstream of sensor.
2. Installed sensors shall be accessible for visual inspection and service. Install access door(s) in duct or equipment located upstream of sensor, to allow service personnel to hand clean sensors.

B. Liquid and Steam Sensors:

1. Install sensors in straight sections of piping with manufacturer-recommended straight piping upstream and downstream of sensor.
2. Alert manufacturer where installation cannot accommodate recommended clearance, and solicit recommendations for field modifications to installation, such as flow straighteners, to improve condition.
3. Install pipe reducers for in-line sensors smaller than line size. Position reducers at distance from sensor to avoid interference and impact on accuracy.
4. Install in-line sensors with flanges or unions to provide drop-in and -out installation.

C. Liquid Flow Meters:

1. Install meters in straight sections of piping with manufacturer-recommended straight piping upstream and downstream of sensor.
2. Install pipe reducers for in-line meters smaller than line size. Install reducers at distance from meter to avoid interference and impact on accuracy.
3. Install in-line meters with flanges or unions to provide drop-in and -out installation.
4. Insertion Meters:

    a. Install system process connections full size of meter connection, but not less than [**NPS 1 (DN 25)**] [**NPS 1-1/2 (DN 40)**] [**NPS 2 (DN 50)**] <**Insert pipe size**>. Provide [**stainless-steel**]bushing if required to mate to system connection.
    b. Install meter in top dead center of horizontal pipe positioned in an accessible location to allow for inspection and replacement.
    c. In applications where top-dead-center location is not possible due to field constraints, install meter at location along top half of pipe if acceptable by manufacturer for mounting orientation.

D. Liquid Switches:

1. Install system process connection full size of switch connection, but not less than [**NPS 1 (DN 25)**] [**NPS 1-1/2 (DN 40)**] [**NPS 2 (DN 50)**] <**Insert pipe size**>. Install [**stainless-steel**]bushing if required to mate switch to system connection.
2. Install switch in top dead center of horizontal pipe positioned in an accessible location to allow for inspection and replacement.
3. In applications where top-dead-center location is not possible due to field constraints, install switch at location along top half of pipe if switch is acceptable by manufacturer for mounting orientation.

E. Transmitters:

1. Install airflow transmitters serving an air system in a single location adjacent to or within system control panel.
2. Install liquid flow transmitters, not integral to sensors, in vicinity of sensor. Where multiple flow transmitters serving same system are located in same room, co-locate transmitters by system to provide service personnel a single and convenient location for inspection and service.

3.7 IDENTIFICATION

A. Identify system components, wiring, cabling, and terminals. Each piece of wire, cable, and tubing shall have the same designation at each end for operators to determine continuity at points of connection. Comply with requirements for identification specified in Section 260553 "Identification for Electrical Systems."

B. Install engraved phenolic nameplate with instrument identification[**and on face of ceiling directly below instruments concealed above ceilings**].

3.8 CLEANING

A. Remove grease, mastic, adhesives, dust, dirt, stains, fingerprints, labels, and other foreign materials from exposed interior and exterior surfaces.

B. Wash and shine glazing.

C. Polish glossy surfaces to a clean shine.

3.9 CHECKOUT PROCEDURES

A. Description:

1. Check out installed products before continuity tests, leak tests, and calibration.
2. Check instruments for proper location and accessibility.
3. Check instruments for proper installation with respect to direction of flow, elevation, orientation, insertion depth, or other applicable considerations that will impact performance.
4. Check instrument tubing for proper isolation, fittings, slope, dirt legs, drains, material, and support.

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B. Flow Instrument Checkout:

1. Verify that sensors are installed correctly with respect to flow direction.
2. Verify that sensor attachment is properly secured and sealed.
3. Verify that processing tubing attachment is secure and isolation valves have been provided.
4. Inspect instrument tag against approved submittal.
5. Verify that recommended upstream and downstream distances have been maintained.

3.10 ADJUSTMENT, CALIBRATION, AND TESTING

A. Description:

1. Calibrate each instrument installed that is not factory calibrated and provided with calibration documentation.
2. Provide a written description of proposed field procedures and equipment for calibrating each type of instrument. Submit procedures before calibration and adjustment.
3. For each analog instrument, make a three-point test of calibration for both linearity and accuracy.
4. Equipment and procedures used for calibration shall meet instrument manufacturer's recommendations.
5. Provide diagnostic and test equipment for calibration and adjustment.
6. Field instruments and equipment used to test and calibrate installed instruments shall have accuracy at least twice the instrument accuracy being calibrated. For example, an installed instrument with an accuracy of 1 percent shall be checked by an instrument with an accuracy of 0.5 percent.
7. Calibrate each instrument according to instrument instruction manual supplied by manufacturer.
8. If after-calibration-indicated performance cannot be achieved, replace out-of-tolerance instruments.
9. Comply with field-testing requirements and procedures indicated by ASHRAE Guideline 11, "Field Testing of HVAC Control Components," in the absence of specific requirements, and to supplement requirements indicated.

B. Analog Signals:

1. Check analog voltage signals using a precision voltage meter at zero, 50, and 100 percent.
2. Check analog current signals using a precision current meter at zero, 50, and 100 percent.
3. Check resistance signals for temperature sensors at zero, 50, and 100 percent of operating span using a precision-resistant source.

C. Digital Signals:

1. Check digital signals using a jumper wire.
2. Check digital signals using an ohmmeter to test for contact.

D. Sensors: Check sensors at zero, 50, and 100 percent of Project design values.

E. Switches: Calibrate switches to make or break contact at set points indicated.

F. Transmitters:

1. Check and calibrate transmitters at zero, 50, and 100 percent of Project design values.
2. Calibrate resistance temperature transmitters at zero, 50, and 100 percent of span using a precision-resistance source.

3.11 MAINTENANCE SERVICE

A. Maintenance Service: Beginning at Substantial Completion, maintenance service shall include [**three**] [**six**] [**nine**] [**12**] months' full maintenance by [**skilled employees of systems and equipment Installer**] [**manufacturer's authorized service representative**]. Include [**monthly**] [**quarterly**] [**semiannual**] [**annual**] preventive maintenance, repair or replacement of worn or defective components, cleaning, and adjusting as required for proper operation. Parts and supplies shall be manufacturer's authorized replacement parts and supplies.

3.12 DEMONSTRATION

A. [**Engage a factory-authorized service representative to train**] [**Train**] Owner's maintenance personnel to adjust, operate, and maintain instrumentation and control devices.

B. Coordinate video with operation and maintenance manuals and classroom instruction for use by Owner in operating, maintaining, and troubleshooting.

C. Record videos on DVD disks.

D. Owner shall have right to make additional copies of video for internal use without paying royalties.

END OF SECTION 230923.14